





# SUSTAINABLE LAND MANAGEMENT PRACTICES

VOLUME II-CENTRE OF EXCELLENCE ON SUSTAINABLE LAND MANAGEMENT | INDIAN COUNCIL OF FORESTRY RESEARCH AND EDUCATION, DEHRADUN, INDIA





**VOLUME - II** 

CENTRE OF EXCELLENCE ON SUSTAINABLE LAND MANAGEMENT
INDIAN COUNCIL OF FORESTRY RESEARCH AND EDUCATION
DEHRADUN, INDIA



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Government of India

मंत्री पर्यावरण, वन एवं जलवायु परिवर्तन भारत सरकार



भूपेन्द्र यादव BHUPENDER YADAV



Climate change, biodiversity loss, and land degradation are the most challenging issues before mankind today. The last four decades have witnessed constantly rising temperatures because of anthropogenic causes, especially the release of greenhouse gases. This has greatly impacted life on Earth and could mark these times as Anthropocene, a crucial epoch in history.

In light of these crucial events, it is imperative to focus on the restoration of ecosystems and the sustainable management of land. Adopting strategies that reduce the impacts of climate change, not only enhances living standards but also secures the environment, food, and water resources.

The Government of India's initiatives such as the Green India Mission focus on expanding forest cover to mitigate climate impacts and secure rural livelihoods. India has aligned with the global climate targets through the National Determined Contribution (NDC) to increase forest and tree cover to sequester 2.5-3 billion tonnes of carbon dioxide by 2030. These efforts underline India's leadership in sustainable development and conservation of biodiversity worldwide.

The second volume of the "Compendium on Sustainable Land Management Practices", developed by the CoE-SLM, ICRE showcases such exemplary practices in India. It highlights India's best SLM practices, which will help policymakers and stakeholders in adopting and implementing the same to achieve Land Degradation Neutrality.

Date: 23.07.2024

(Bhupender Yadav)



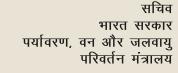












SECRETARY GOVERNMENT OF INDIA MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE





Land degradation is a critical issue affecting the food security, livelihood and well-being of humans. Worldwide, it is among the major environmental challenges. In India, approximately 97.85 million hectares land is under degradation, witnessing an increase of about 3.32 million hectares from 2003-05 to 2018-19.

Achieving Land Degradation Neutrality (LDN) is an essential objective for safeguarding the natural eco-systems. Sustainable Land Management (SLM), which focuses on enhancement of ecosystem services across all land-use systems is an effective tool for achieving LDN. By adopting SLM practices, it is possible to restore degraded lands, enhance productivity and build resilience against climate change.

The Centre of Excellence for Sustainable Land Management (CoE-SLM) at the Indian Council of Forestry Research and Education aims to scale up SLM practices through research, innovation, and knowledge sharing. The "Compendium of Best Sustainable Land Management Practices." prepared by CoE-SLM highlights the SLM practices from across India.

The country's diverse ecosystems and agricultural landscapes require locally relevant management strategies. The practices documented in this compendium showcase the ingenuity and dedication of the researchers and practitioners, who have developed and implemented these solutions. Their efforts serve as an inspiration and offer replicable models for sustainable development.

I congratulate the team of CoE-SLM for bringing out this publication. Their collaborative efforts have made it possible to share invaluable insights and lessons with a broader audience. I am confident that the Compendium will be a valuable resource for all the policymakers, researchers and practitioners involved in sustainable land management. Adoption of these best practices at a larger scale would certainly go a long way in securing a sustainable and prosperous future for all.

New Delhi, June 27, 2024

(Leena Nandan)













वन महानिदेशक एवं विशेष सचिव भारत सरकार पर्यावरण, वन और जलवायु परिवर्तन मंत्रालय DIRECTOR GENERAL OF FORESTS & SPL. SECY. GOVERNMENT OF INDIA MINISTRY OF ENVIRONMENT FOREST AND CLIMATE CHANGE





Land degradation is an important issue affecting not only land productivity but also water quality, human health and the fundamentals of ecosystems which support life. Additionally, land degradation causes reduction in carbon sink capacity leading to adverse effect on the environmental cleanliness. It is required to prevent land degradation and also, restore degraded land ecologically.

Land Degradation Neutrality will contribute significantly in achieving various goals of climate change mitigation and adaptation and also the Sustainable Development Goals. In this direction, Sustainable Land Management (SLM) practices will be useful for delivery of the expected ecosystem services.

To facilitate exchange of information and raise awareness on SLM, the "Centre of Excellence on Sustainable Land Management" has prepared the second volume of "Compendium of SLM Practices". It is an excellent compilation of the thirty-one different types of SLM Practices.

I appreciate the work done by the team of "Centre of Excellence on Sustainable Land Management" and believe that this compendium will be useful for the policy makers, researchers and other stakeholders in Sustainable Land Management.

Place: New Delhi Date: 9<sup>th</sup> July 2024

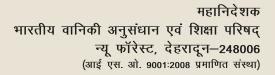
(Jitendra Kumar)

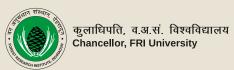






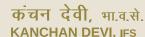








Director General Indian Council of Forestry Research and Education Government of India Ministry of Environment Forest and Climate Change (An ISO 9001:2008 Certified Organisation)





Land degradation is a significant global challenge adversely affecting land productivity, water quality, human health and the vital ecosystems that sustain life. Land degradation significantly drives climate change by increasing greenhouse gas (GHG) emissions. The loss of productivity of land also has a detrimental impact on the biodiversity. These interconnected issues present substantial challenges to the sustainability of natural resources and human livelihoods.

According to the Space Application Centre's (SAC) Desertification and Land Degradation Atlas of India 2018-19 indicates that 97.85 million hectares of land, comprising 29.76% of our total geographical area, is degraded. This pervasive land degradation poses a fundamental challenge affecting global food security, livelihoods and human well-being. Achieving Land Degradation Neutrality (LDN) is crucial in meeting the goals of the Convention on Biological Diversity (CBD), the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Convention to Combat Desertification (UNCCD) and the Sustainable Development Goals (SDGs). Sustainable Land Management (SLM) practices offer effective solutions to preserve and enhance ecosystem services across diverse land-use systems while fostering resilience and adaptation to local conditions.

The Centre of Excellence for Sustainable Land Management (CoE-SLM), established at Indian Council of Forestry Research and Education (ICFRE), Dehradun aims to foster South-South Cooperation to address land degradation issues. One of the objectives of the centre is to disseminate knowledge on the SLM practices through capacity enhancement programmes, research, innovation and knowledge products. In this context, the centre has prepared the second volume of the "Compendium of SLM Practices". This comprehensive compilation showcases various SLM practices being implemented in India.

I extend my greetings to the editors for their efforts in bringing out this publication. I am confident that this compendium will be a valuable resource for policymakers, researchers, practitioners, stakeholders and others in adopting SLM practices. Let us continue to work together to achieve Land Degradation Neutrality. ensuring a sustainable and prosperous future.

Message

(Kanchan Devi)

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# **PREFACE**

Land degradation, desertification and climate change are the issues of global concern, affecting not only land productivity but also water quality, human health and ecosystem and its services. As a result, a variety of ecological and socio-economic consequences have been noticed in the recent past, such as soil erosion, unusual floods, depletion of natural resources, drying of natural springs/streams, human-wildlife conflict, limited livelihood opportunities and migration of the population to urban areas, Additionally, land degradation is also considered as a driver of climate change through greenhouse gas (GHG) emissions and reduction in carbon sink capacity. This in turn is further exacerbating land degradation processes through scattered rainfall, floods, increase in temperature, frequency as well as severity of drought, dry spells and rise in sea-level. According to the SAC-ISRO, 2021 report, 27,000 biological species and 24 billion tons of fertile soil are being lost every year globally affecting 3.2 billion people around the globe.

The impact of land degradation can also be seen in India, wherein, 97.85 Mha land, equivalent to 29.77% of the total geographical area of the country, has been degraded or turned into desert. Wind, vegetation and water erosion are the three major causes of land degradation in India. The SAC-ISRO, 2021 report further states that, more than 50% of the land is degraded or desertified in the states of Jharkhand, Rajasthan, Delhi, Gujarat and Goa compared to less than 10% in Kerala,

Assam, Mizoram, Haryana, Bihar, Uttar Pradesh, Punjab and Arunachal Pradesh. Therefore, urgent efforts are required at national and international level to minimize and reverse the land degradation trends.

Aiming to save humanity from the interconnected issues of land degradation/desertification, climate change, biodiversity loss, poverty and inequality, the United Nations declared 2021-2030 to be a "Decade on Ecosystem Restoration", Numerous international initiatives have been launched to address these problems, including the Convention on Biological Diversity (CBD), the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Convention to Combat Desertification (UNCCD) and Disaster Risk Reduction (DRR). In the similar line, Govt. of India, has stared variety of initiatives to contribute to national and international obligations. The Bonn Challenge, for instance, pledges to restore 21 million hectares of degraded and deforested land by 2030; the Green India Mission seeks to protect. restore and enhance India's diminishing forest cover and respond to climate change and India's Nationally Determined Contribution (NDC) aims to improve forest and tree cover and sequester an additional 2.5 to 3 billion tons of CO, equivalent by 2030.

Recognizing the significance and need of achieving land degradation neutrality and sustainable management of land resources, the Centre of

Excellence on Sustainable Land Management (CoE-SLM, ICFRE) was inaugurated on 20<sup>th</sup> May 2023, by the Hon'ble Union Forest Minister Shri Bhupender Yadav with a vision to provide technical support at the national and sub-national levels in India. The centre aims to facilitate sustainable land management practices and foster global south-south cooperation for achieving Land Degradation Neutrality (LDN).

The Centre has mandate of capacity building and provides technical support to different stakeholders at national and international levels on SLM, developing transformative projects, networking of national and international institutions working on sustainable land and ecosystem management for knowledge sharing, awareness generation for implementing sustainable land and ecosystem management projects.

To facilitate exchange of information and raise awareness, the Centre released a "Compendium of SLM Practices" in the year 2023 and in continuation of efforts, prepared "Compendium of SLM Practices Volume II" which has compilation of the thirty-one different types of Sustainable Land Management Practices mainly focusing on the land restoration, water conservation, traditional farming practices. We hope that, this volume will be very useful in successful implementation of SLM practices to achieve the LDN in the country.





# SUSTAINABLE LAND MANAGEMENT

AN OVERVIEW

#### INTRODUCTION

Sustainable Land Management (SLM) is a critical component of environmental stewardship, balancing human needs with the preservation and responsible utilization of natural resources. It involves using land-based natural resources, such as soils, water, animals, and plants, to produce goods and services while ensuring their long-term productivity and the maintenance of their environmental functions. The United Nations defines SLM as "the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions". TerrAfrica partnership held in 2005, defines Sustainable Land Management as "the adoption of land-use systems that, through appropriate management practices enable land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources" (FAO, 2023).

SLM encompasses established approaches such as soil and water conservation, natural resource management, and integrated landscape management (ILM). It involves a holistic approach to achieving productive and healthy ecosystems by integrating social, economic, physical and biological needs and values and it contributes to sustainable and rural development (Alemu, 2016). Under the current climate change scenario, where land degradation and desertification threaten the food security and livelihoods of millions of people, especially in drylands, SLM is becoming increasingly important. By adopting SLM practices, land users can increase agricultural productivity and resilience, enhance ecosystem services, reduce land degradation, improve livelihoods and adapt to and mitigate the impacts of climate change. The objectives of SLM include: (i) Maintaining and improving soil health and fertility; (ii) Ensuring efficient and sustainable use of water resources; (iii) Conserving biodiversity and maintaining ecosystem services; (iv) Preventing and reversing land degradation processes; (v) Adapting to and mitigating the impacts of climate change; (vi) Promoting stakeholder participation and integrated land management; (vii) Enhancing food security and improving rural livelihoods (FAO, 2023; Alemu, 2016)

# **SLM** COMPENDIUM OF SUSTAINBLE LAND MANAGEMENT

# **Evolution and integration** of Sustainable Land Management practices

The concept of Sustainable Land Management (SLM) has evolved significantly over time, reflecting changing societal needs and a growing awareness of the importance of managing land resources sustainably. Historically, communities throughout the world developed traditional land management practices, which aimed at efficiently utilizing local resources and were thus inherently sustainable and tailored to local ecosystems. Based on indigenous knowledge, these practices aimed to maintain soil fertility, conserve water resources and preserve biodiversity.

In the late 20th century, increased environmental awareness highlighted land degradation as a significant global issue. This awareness laid the foundation for the development of sustainable land management practices. The concept of SLM was formalized at a workshop in Chiang Rai, Thailand, in 1991. This workshop recommended forming an international working group to refine the idea, develop a definition and establish procedures to monitor progress towards sustainable land use systems. The following workshop in Lethbridge, Canada (1993) emphasized developing indicators of Sustainable Land Management for monitoring and evaluation. The results were presented at the XVth Congress of Soil Science in Acapulco in 1994.

From 1995 to 1997, a series of international workshops took place in Cali, Colombia (1995), Nairobi, Kenya (1995), Washington, D.C. (1996) and Naurod, Germany (1997), focusing on land quality indicators as part of the necessary SLM indicators. Another significant workshop in Enschede in 1997 set the stage for the next steps in developing and implementing SLM (CIESIN, 2019).

In 2013 and 2014, Jordan updated its Rangeland Strategy to legally enshrine 'Hima', contributing to Sustainable Development Goal 15, Target 3. In 2015, the Economics of Land Degradation (ELD) study provided policy-relevant information linking the biophysical aspects of land degradation with economic drivers and societal implications (UNEP, 2017). The study found that the benefits of action against land degradation through sustainable management are seven times higher than the costs over the coming 15 years (CIESIN, 2019).

Over time, SLM evolved from focusing on specific practices to adopting a holistic approach that integrates the management of land, water and other resources to meet human needs while ensuring sustainability, ecosystem services, biodiversity, and livelihoods. It balances economic, social and environmental considerations and increasingly emphasizes participatory, land-user-driven approaches, involving stakeholders at multiple levels. This collaboration values local knowledge and addresses complex challenges.

The shift from traditional to modern SLM practices also reflects the evolution in land management approaches, moving towards a more comprehensive and holistic understanding of sustainable land use. Traditional SLM practices are rooted in indigenous knowledge and local customs. These practices focused on soil fertility, water conservation and biodiversity preservation using natural resources, and traditional tools. Modern SLM practices use scientific methods, advanced technology and modern equipment to achieve higher productivity (Motavalli et al., 2013). They address climate change adaptation, biodiversity conservation and ecosystem services, emphasizing stakeholder participation, integrated land management and evidence-based decision-making to balance economic, social, and environmental considerations (Kumar, 2019). Thus, both traditional and modern SLM practices are crucial for promoting sustainable land management and ensuring the well-being of ecosystems and communities. While traditional practices offer valuable insights into sustainable resource management, modern practices integrate scientific knowledge and technology to address contemporary challenges and ensure long-term sustainability.

# **SLM** COMPENDIUM OF SUSTAINBLE LAND MANAGEMENT

# Role of SLM in addressing the global challenges

SLM practices such as conservation tillage, cover cropping, crop rotation, agroforestry and sustainable forest management can improve soil health, increase biodiversity, sequester carbon, enhance food security and reduce environmental degradation. These practices are essential for maintaining land productivity while protecting and improving natural resources. SLM is crucial for addressing global challenges like land degradation, desertification, climate change impacts, biodiversity loss and food security issues (Haregeweyn et al., 2023). By maintaining soil health, promoting water use efficiency and enhancing vegetation cover, SLM helps prevent and reverse land degradation processes like soil erosion, salinization and desertification. Practices like agroforestry and conservation agriculture sequester carbon, reduce greenhouse gas emissions and enhance agricultural resilience to climate variability and extreme events, incorporating strategies to adapt to and mitigate climate change impacts

Maintaining diverse plant and animal species and their habitats ensures ecosystem resilience and functioning, a key emphasis of SLM (Motavalli et al., 2013). Landscape-level approaches for sustainable land management minimize ecosystem impact. Sustainable intensification of agriculture, diversification and using drought-resistant crops help meet the growing demand for food while ensuring long-term sustainability. Increasing agricultural productivity and resilience through these methods improves food security and nutrition (Henry et al., 2018).

SLM provides economic and social benefits by improving livelihoods, creating employment opportunities and reducing poverty (Kumar, 2019). By diversifying income sources and reducing vulnerability to environmental and economic shocks, SLM contributes to sustainable development and the achievement of the Sustainable Development Goals (SDGs). Promoting efficient water use, conserving biodiversity and minimizing land degradation contribute to the overall environmental sustainability of land-based systems, maintaining long-term productivity and environmental functions of land resources. The economic benefits of SLM, such as increased crop yields and reduced costs of land degradation, can outweigh the cost of implementation (Giger et al., 2015).

Emphasizing the involvement of all stakeholders, including land users, policymakers and researchers, ensures that the planning and implementation of sustainable land management practices address the needs and concerns of different social groups, promoting social equity and community ownership of SLM initiatives (Kumar, 2019). The environmental, social and economic benefits of SLM demonstrate its potential to address a wide range of sustainability challenges and promote the long-term viability of land-based systems.

Promoting evidence-based decision-making, integrating scientific research and local knowledge and ensuring stakeholder participation in planning and implementing sustainable land management practices are essential to fully realizing SLM's potential in addressing these global challenges (Haregeweyn, et al., 2023). With concerted efforts and targeted investments, SLM can play a crucial role in building a more sustainable and resilient future for all.

# SLM COMPENDIUM OF SUSTAINBLE LAND MANAGEMENT

## Principles of Sustainable Land Management

The foundation of sustainable land management lies in understanding and integrating its core principles. At its essence, SLM involves the responsible and careful use of land resources to achieve long-term sustainability. The application of sustainable land management is guided by several key principles, including:

**Ecosystem-based Approach (EbA):** An ecosystem-based approach aims to safeguard or restore equilibrium within ecosystems and acknowledges the interconnectedness of diverse ecological components. By considering the interactions between land, water, plants, animals and humans, SLM ensures that biodiversity is preserved and ecosystem services are provided.

**Participatory Decision-making:** Participatory decision-making involves including local communities, landowners, governments and NGOs in land management policies. This approach leverages traditional knowledge passed down through generations, promoting local ownership and more sustainable outcomes.

**Adaptive Management:** Adaptive management is a reiterative process that permits the modification of a land management plan based on monitoring, assessment and observation. This approach allows land managers to achieve long-term sustainability and make informed decisions based on their experiences.

**Integrated Approach:** An integrated approach addresses complex land use issues by combining different sectors and specialties. This method considers social, economic and environmental factors in decision-making.

**Knowledge-based Decision-making:** SLM decision-making combines traditional knowledge with scientific research and local expertise. Emphasizing evidence-based approaches ensures that SLM practices are practical and adaptable, continuously improving planning and implementation strategies.

These principles highlight the dynamic nature of SLM, ensuring that land use practices meet current needs while preserving resources and ecosystem functions for future generations.

# **Key components of Sustainable Land Management practices**

Different repositories classify SLM practices according to their components, JRC-WAD (Cherlet, et al., 2018) classifies the SLM measures from the WOCAT (nd.) databased as agronomic, vegetative, structural and management measures and then there a combination of these measures. However, the essence of Sustainable Land Management (SLM) lies in its key components. These components are soil conservation techniques, water management strategies, agroecological approaches and integrated landscape management (FAO, 2023).

Soil conservation techniques, such as contour ploughing, terracing, cover cropping and reduced tillage, safeguard soil health and fertility while preventing erosion. Water management strategies, including water harvesting, efficient irrigation methods and groundwater recharge, optimize water use efficiency and availability for agriculture while preventing pollution. Agroecological approaches integrate ecological

principles into farming practices, promoting biodiversity, enhancing soil health and reducing reliance on chemical inputs. Techniques like crop rotation, agroforestry and integrated pest management contribute to resilient and sustainable agricultural systems.

Integrated landscape management takes a holistic approach to land use planning and conservation, considering biodiversity conservation, water resource management and sustainable agriculture (FAO, 2023). Integrating various land uses and engaging stakeholders fosters collaboration to effectively address environmental and social challenges. Collectively, these components work synergistically to promote sustainable land use, conserve natural resources, enhance agricultural productivity and support ecosystem health. They ensure that land resources remain productive and viable for future generations, embodying the principles of environmental sustainability and responsible land stewardship.

### Global resources on Sustainable Land Management

WOCAT Global Database on Sustainable Land Management, endorsed by the United Nations Convention to Combat Desertification (UNCCD), is one of the prominent global resources for SLM data. The database offers free access to documented field-tested SLM practices worldwide, providing practitioners with valuable insights and tools for evidence-based decision-making (WOCAT, n.d.). As of May 2023, of the 2434 SLM practices from 36 countries enlisted in WOCAT database, 81 practices from India are registered in WOCAT database, which are further classified into SLM technology (34), UNCCD PRAIS practice (31) and SLM approach (16).

WOCAT has developed a robust framework and standardized tools for documenting, monitoring, evaluating and disseminating SLM knowledge, facilitating its widespread adoption. The objective is to share valuable land management knowledge, support evidence-based decision-making and scale up successful practices to combat land degradation and restore degraded land.

Recognized as a global resource for SLM best practices, the WOCAT database is interconnected with initiatives like the Land Potential Knowledge System and the Carbon Benefits Project, further enhancing its impact and reach. Overall, it serves as a primary repository for accessing and sharing information on field-tested SLM practices, fostering evidence-based decision-making and global scalability of successful SLM initiatives (UNEP 2021a).

FAO also provides a rich repository of databases and scientific references vital for Sustainable Land Management (SLM). Accessible via its website, these resources cover various aspects, including agricultural, land-related, water-related and forest-related information. Essential tools like the Land Resource Information and Decision Support System (LriS), Global Terrestrial Observing System (gtOS), FAO/UNESCO Digital Soil Map of the World (DSMW), and FAO/IIASA Global Agro-ecological Zones Study (GAEZ) are available.

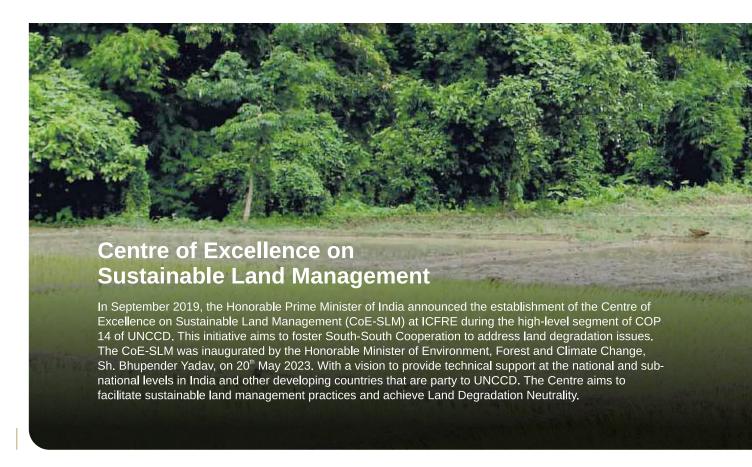
Additionally, FAO offers access to standards and regulatory norms for water administration (FAOLeX) and livestock management (LeAd). Programs like Africover and the Land Degradation Assessment in Drylands (LADA) contribute valuable insights into land management practices (FAO, 2023).

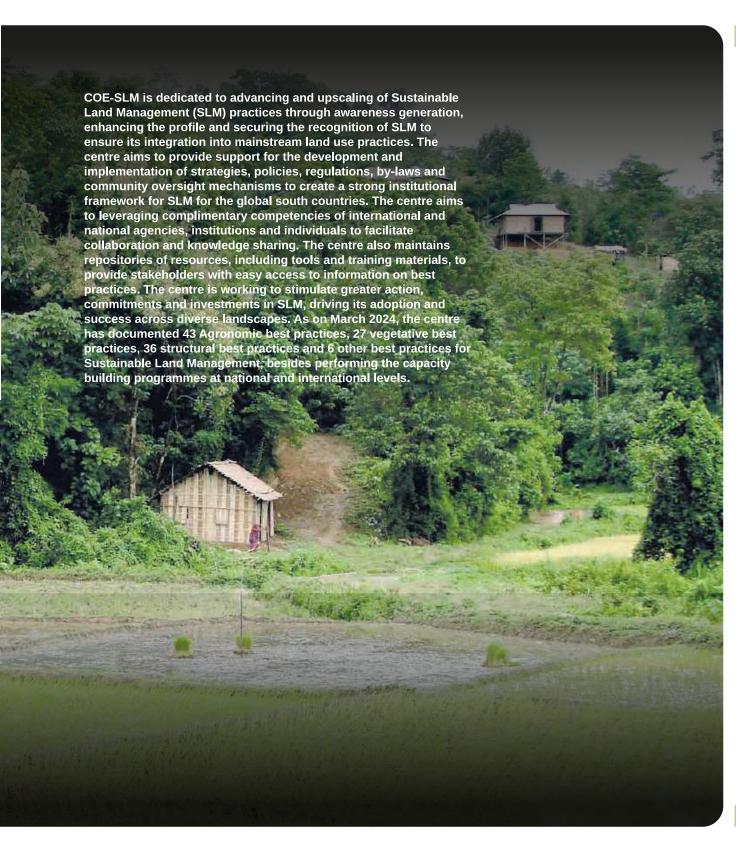
Furthermore, FAO actively engages in international initiatives such as the World Overview of Conservation Approaches and Technologies (WOCAT), Asia-Pacific Agroforestry Network (APAN), Participatory Watershed Management in Asia Network (WATMANet) and Network for the Integrated Management of Salt-Affected Soils (SPuSh), enhancing the global understanding and implementation of SLM practices (FAO, 2023).

# Policy and institutional frameworks for SLM

Robust policy and governance structures are vital for the successful implementation of Sustainable Land Management practices. National policies provide guidance and incentives at the local level. Facilitative policies and an institutional framework ensure the effective implementation of SLM practices, thereby ensuring a balance between economic development and environmental conservation. At the national level, policies play a crucial role in promoting Sustainable Land Management practices. They offer guidance for land-use planning, taking into account the country's distinct natural resources, cultural heritage and socioeconomic conditions (Nkonya et al., 2023). These policies create frameworks for decision-making processes and define pathways toward sustainable practices. National policies provide financial mechanisms and support programs to encourage the adoption of SLM practices. These mechanisms include subsidies and incentives for promoting land stewardship and resource conservation. National policies also empower landholders by addressing issues related to land tenure and rights, aiming to ensure equitable access to land resources.

International policies complement national efforts through collaboration and support across borders, ensuring a holistic approach to the management of land resources (UNEP, 2021b). Agreements such as the United Nations Convention to Combat Desertification (UNCCD) and the Convention on Biological Diversity (CBD) promote collaboration among country parties to achieve Land Degradation Neutrality. These agreements encourage knowledge-sharing and capacity-building initiatives to strengthen institutional and technical capabilities (Nkonya, et al., 2023).





# COMPENDIUM OF SUSTAINBLE LAND MANAGEMENT

### Constraints and challenges for implementation of **SLM** practices

The implementation of SLM practices have varied challenges and constraints across countries, states and geographical areas. These constraints may include economic constraints, institutional governance issues, technical knowledge gaps and social and cultural

Lack of suitable incentives and compensation mechanism to encourage adoption of sustainable land management is often considered to be the major challenge for upscaling the SLM practices. Limited access to financial resources and credit further impedes land users from investing in SLM, compounded by competing short-term economic interests prioritizing immediate gains over long-term sustainability (Henry et al., 2018). Absence of institutional framework and policies to support upscaling of SLM is also one of the major challenges (Haregeweyn et al., 2023). Insufficient coordination among government agencies and stakeholders involved in land management exacerbates these issues. Moreover, unclear land tenure rights discourage long-term investments in SLM.

Land users also lack awareness of SLM's benefits and methodologies. Research is required to conduct a costbenefit analysis of SLM practices compared to prevalent practices (Haregeweyn et al., 2023). Lack of research on the efficacy of SLM practices in diverse contexts, along with the inadequate provision of extension services and capacity-building programs, may be one of the reasons for the less awareness on SLM practices. Also, social and cultural resistance to change stemming from entrenched cultural norms and traditional land use systems hinders SLM adoption. Insufficient community participation and ownership in SLM initiatives, coupled with gender inequalities and social disparities, further exacerbate these challenges.

A multifaceted approach encompassing economic incentives, policy reinforcement, research investment, extension service enhancement and active community engagement ensuring gender equity is required for popularising and upscaling SLM practices (Henry et al., 2018; Haregeweyn et al., 2023)

## Innovations and future directions for implementation of **SLM** practices

The future of SLM lies in embracing innovative technologies, adopting ecosystem-based approaches and fostering collaboration among diverse stakeholders. These efforts will help address the evolving challenges of land degradation, climate change and biodiversity loss, ensuring sustainable and resilient land management.

Emerging trends, technological innovations and strategies are shaping the future of scaling up the successful practices of SLM, Integrating Climate-smart agriculture in SLM can be an effective adaptive mechanism for climate change. This will enhance the resilience of the agriculture system against climate change and reduce greenhouse gas emissions. Similarly, Ecosystem-based approaches focus on restoring and conserving ecosystems to support sustainable land use and biodiversity conservation. Precision agriculture utilizes technology for precise and efficient resource management, optimizing inputs and reducing environmental impacts.

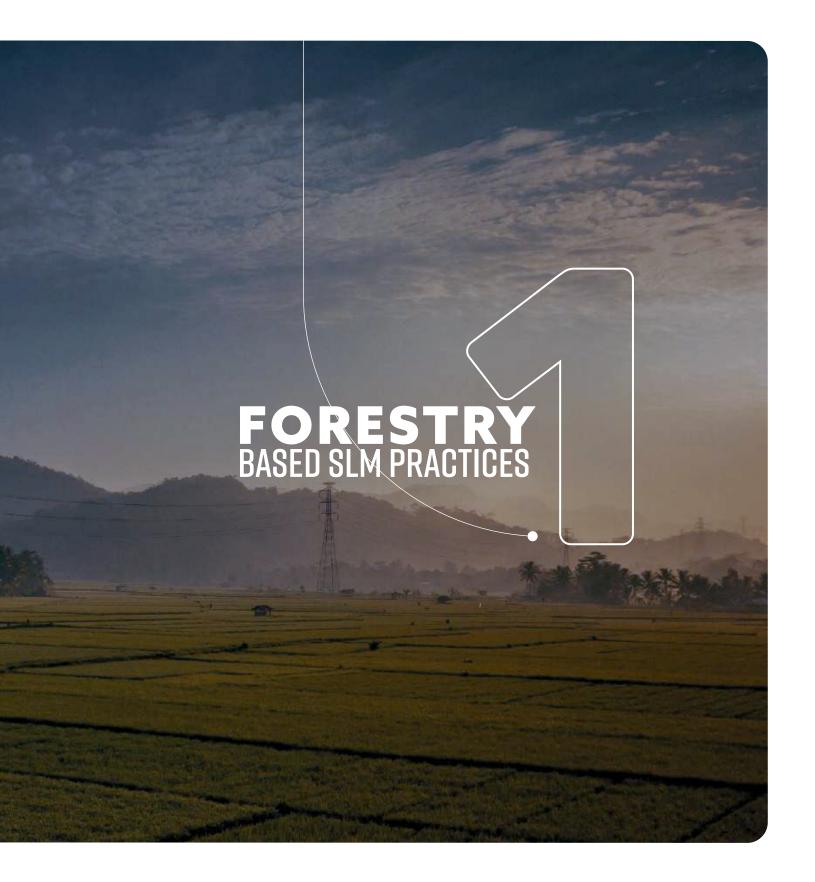
Technological advancements in Sustainable Land Management provide tools for monitoring, assessment and informed decision-making. Remote sensing and Geographic Information Systems (GIS) are leveraged for monitoring land use changes, soil health assessment and precision agriculture. Digital tools, including mobile applications, facilitate data collection, monitoring and decision-making in land management practices. Agroecological innovations, such as agroforestry. conservation agriculture and integrated pest management, are implemented for sustainable and productive land use.

Knowledge sharing and capacity building of stakeholders are essential for scaling up successful SLM practices (Haregeweyn et al., 2023). Developing supportive policies, incentives and regulations encourages the adoption of sustainable land management initiatives. Public-private partnerships involving the private sector, NGOs, and research institutions are crucial for scaling up SLM practices and innovations. Community engagement ensures local participation and ownership in decision-making processes, fostering the successful implementation of SLM practices.

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A traditional method for reforestation of native forest by native trees

The Miyawaki plantation technique restores forests using native species based on Japanese principles and ecological science. Developed by Dr. Akira Miyawaki, it involves planting dense clusters of native trees to rapidly establish mature forests. This method sequesters carbon, regulates microclimates and enhances biodiversity, making it ideal for urban and rural areas.

Rapid land restoration



**Ecological** benefits



Cost-effective solution for both urban and rural areas



Miyawaki plantation technique, or "Native Forest by Native Trees," is derived from traditional Japanese "Chinju-No-Mori" principles and ecological science. Dr. Akira Miyawaki developed this method to restore and recreate forests using native species adapted to the local habitat, based on comprehensive field assessments and ecological theories. This technique involves selecting primary tree species and their associated species from the region's potential natural vegetation. Seeds are collected, cultivated in pots until their root systems are fully established and then planted in close proximity to replicate natural forest density. Trees play a pivotal role in reducing atmospheric carbon dioxide by sequestering carbon through photosynthesis and converting it into oxygen. Each tree species exhibits different capacities for carbon sequestration. Additionally, tree canopies contribute to microclimate regulation by providing shade and through transpiration processes. The Miyawaki plantation technique facilitates the rapid development of mature natural forests through the careful selection of species most









Fig. 1: Preparation of pits in Miyawaki plantation (Source: ICFRE-TFRI, 2023)



**Fig. 2:** Tree Saplings for Miyawaki plantation (Source: Green Yatra)

suitable for the local environment. This method is particularly advantageous for rapidly urbanizing areas, as it establishes a permanent canopy of climax tree species without undergoing successional stages. Applicable to areas of various sizes, this technique creates mini-forests that deliver multiple ecological and social benefits to both urban and rural populations (ICFRE-TFRI, 2023). Natural restoration is closely linked to improved sustainability, encompassing the rehabilitation of ecosystem functions, the expansion of specific ecosystems and the enhancement of biodiversity. Thus, Miyawaki method is one of the promising techniques for forest and ecological restoration (Miyawaki., 1999).



#### **Brief description of practice**

**Selection of site:** Choosing the right site is a crucial step in the plantation program, leading to the successful establishment of forest tree plantations. A well-chosen site facilitates the following decisions:

- Selection of species for site-specific planting.
- Determination of necessary ground preparations.
- Planning of internal layouts for roads, rides, firebreaks and water points.

**Soil condition:** Soil meets three essential needs for tree growth: moisture supply, nutrient provision, and mechanical support. The primary

considerations include good soil fertility, favourable physical condition, and adequate rootable depth.

**Cleaning of site:** Clearing the site by removing weeds, grasses and stones from the selected sites.

**Layout of site:** Layout design based on area availability and site conditions. Generally, in urban areas, land available for plantation purposes ranges from 100 to 1000  $\text{m}^2$  plot. For successful establishment, a minimum spacing of 60 cm  $\times$  60 cm should be adopted to ensure good growth of the plantation. This spacing helps to avoid or reduce plant mortality over time due to competition for nutrients and space. When deciding the spacing, it is important to consider the canopy growth, height and root spread of both the main and associate species.

#### Addition of fertilizer

**Organic:** Farm yard manure, oil cakes (Groundnut cake, coconut cake, castor cake, neem cake, mahua cake) etc can be used as a organic fertilizer.

Inorganic: Urea, DAP (Di-ammonium Phosphate).

**Selection of plants:** Select the one-year-old seedling, which is free from disease and healthy root system and shoot development.

**Irrigation:** Effective irrigation with high-quality water is essential for the establishment, growth and development of plants.

**Fencing of site:** The selection of fencing depends on the terrain type, soil depth, soil characteristics and the level of protection needed to deter grazing and browsing animals.



Fig. 3: Miyawaki Forest (Source: K. Murali Kumar)

**Pruning operation:** Pruning operations are necessary in the second and third years of the plantation to enhance plant growth and development. This process helps reduce light competition and promotes the straight growth of plants.

Selection of tree species: The selection of tree species for the Miyawaki plantation is crucial. To restore multi-stratal natural or quasi-natural forests, tree species should be chosen from the region's forest communities. In later stages, the growth and development of individual trees are directly related to the canopy development of the planted species. The tree canopy influences many factors, such as light penetration, moisture, humidity, temperature and rainfall, which directly affect the growth of tree species in different canopy layers. Incorrectly choosing the main tree species can hinder the successful regeneration of native forests (ICFRE-TFRI, 2023).



Fig. 4: An aerial view of Miyawaki forest (Source: acaciaeco)



#### **Benefits**

In this system, gardening is conducted on vertical surfaces rather than horizontal ones. It offers several advantages, such as requiring less space and being easier to harvest and maintain. Plants in this method are more accessible for fertilizing, watering and harvesting and the vertical configuration enhances air circulation. Additionally, it protects plants from damage caused by pets or wild animals by keeping them out of reach. Vertical gardens are well-suited for congested areas and traffic intersections. Other benefits include temperature regulation, providing shade and improving air quality by absorbing pollutants, including volatile organic compounds (Gulcinay and Arzu, 2016).

Miyawaki forests, which support the growth of native vegetation with minimal maintenance, present a promising solution. The benefits of Miyawaki forests include rapid land restoration, the development of a complete ecosystem rather than just plant growth, faster greenery development compared to traditional forests, minimal maintenance and care and lower costs. (Singh and Saini, 2019).

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1.2



# PINE NEEDLE AS A SOURCE OF BIOFUEL BRIQUETTES IN HIMALAYAN STATES

A sustainable solution to reduce forest fires and boost local livelihoods

Pine needles contributes to frequent forest fires and associated environmental issues such as habitat loss, soil erosion and greenhouse gas emissions in the Himalayan states. Utilizing pine needles as biofuel through briquetting technology presents a sustainable solution by transforming this waste into valuable energy resources. This process involves collecting, drying and compressing pine needles into dense briquettes. Pine needle briquettes, with high combustion efficiency and lower smoke emissions, serve as a renewable energy source, reducing reliance on fossil fuels and decreasing indoor air pollution. The establishment of small-scale briquetting units fosters local entrepreneurship, providing livelihoods and promoting sustainable forest management.

The highly flammable dry pine needles lead to frequent forest fires, destroying thousands of hectares of forest each year.



Utilizing pine needles as biofuel through briquetting technology transforms waste into a valuable energy resource.



Briquetting offers a renewable energy source with high combustion efficiency and lower smoke emissions.



Pine needle briquettes due to high calorific value and efficient combustion make it a great alternative for cooking and heating



The Himalayan subtropical pine forest ecoregion is primarily characterized by the prevalence of *Pinus roxburgii*, commonly called Chir pine. This ecoregion constitutes the largest subtropical pine forest ecosystem in the Indo-Pacific region. Extensive area of Uttarakhand, Himachal Pradesh and Jammu & Kashmir in the Himalayan states are enveloped by these pine forest. These forests face a significant threat from forest fire, often exacerbated by the accumulation of dry pine needles. Every year, thousands of hectares of forest are destroyed due to forest fires, causing habitat loss for indigenous species, soil erosion and greenhouse gas emissions. A main driver of increasing fire incidences is the widespread monocultures of Chir pine, an aggressive tree species that has overpopulated its native zone and sheds its leaves, resulting in highly inflammable pine needles. The pine forest of Uttarakhand alone produces about 2 million tonnes dry pine needle annually (Bisht and Thakur, 2021).

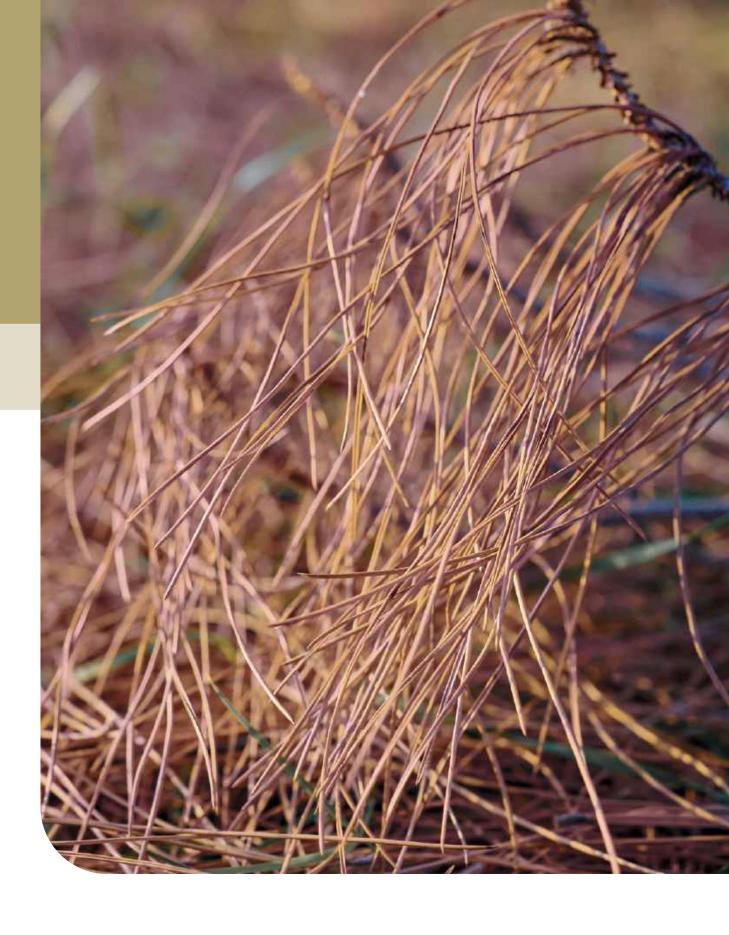


Fig. 5: Pine needle briquettes (Source: The Kashmir Monitor)



The pine needles consist of lignocellulosic biomass, which is unsuitable for use as fodder and does not decompose easily. Dry pine foliage also causes depletion of groundwater and inhibits the growth of grasses by acting like a carpet on the forest bed (Ghosh and Kimothi, 2008), Pine needles are hardly collected by the locals; even if collected, they are mostly used as bedding material for livestock during winter and sometimes as fuel by rural households. In past years, the forest departments have tried various ways to collect and dispose of pine needles to avoid the forest fires caused by it. Despite such efforts bearing great social value, these have not yielded significant results so far but have surely highlighted the gravity of the situation and motivated numerous organizations to look into solving the problem. In the meantime, forest departments have taken the safer route of burning pine needles in a controlled manner.

The government spends a significant amount of money every year to prevent forest fires while to make something constructive from pine needles remains unsolved. An innovative solution to these issues is the use of pine needle briquettes as biofuel. This practice not only provides a sustainable source of energy but also contributes to land management and forest conservation. These bio-briquettes are a biofuel substitute for coal and charcoal, mostly made of green waste.



#### **Brief description of practice**

The forests in Himalayan states produce a substantial quantity of pine needles, which

accumulate on the forest floor. The presence of these needles poses several environmental risks. Notably, dry pine needles are highly flammable, making them a major contributor to forest fires, which can devastate large swathes of forestland, disrupt biodiversity and threaten human settlements. Additionally, the thick layer of needles can inhibit the growth of understory vegetation, leading to increased soil erosion and reduced soil fertility. Utilizing pine needle as bio-fuel represent an innovative approach to addressing the environmental and socio-economic challenges in the Himalayan states.

Converting pine needle to biofuel technology involves the collection, drying and compression of pine needles into dense, energy-rich briquettes. This process transforms a naturally occurring waste product into a valuable resource, providing both ecological and economic benefits. Pine needles being a lignocellulosic biomass, has huge potential as an energy source, which can be transformed into energy products by several ways, like high pressure briquetting, gasification for producer gas, fermentation for ethanol, anaerobic digestion for biogas production, and thermochemical conversion for bio-oil and biochar production (Mandal et al., 2018). There are several ways to convert pine biomass into other forms of energy like steam, briquettes, pellets, biogas, producer gas, bio-oil, biochar, hydrogen and ethanol. Among the available technologies briquetting is highest energy conversion efficiency and cost effective (Singh et al., 2021). Briquetting is a process of binding together pulverized carbonaceous matter, often with aid of binder. The production of pine needle briquettes involves a series of methodical steps designed to maximize efficiency and energy output. However, Joshi and Sharma (2021) came up with an innovative approach to make pine needle briquettes using pure hydraulic pressure of about 1500 to 2000 psi to compact the pine needles without the use of any additives. 100 grams of crushed pine needles makes 80g of briquettes and the whole process takes 80 sec. This method is not only easily to operate but produces zero-carbon footprint. This methodology has been adopted by forest department of Jammu & Kashmir and Uttarakhand Government to combat forest fire and generate livelihood for locals.

Initially, pine needles are collected from forest floors, an activity that not only reduces fire hazards but also generates livelihood for the locals. The collected needles are then dried to reduce moisture content, which is crucial for efficient combustion. Following drying, the needles are shredded to

enhance compactness. The shredded material is then compressed under high pressure in briquetting machines to form dense briquettes. These briquettes are subsequently utilized as a renewable energy source, capable of replacing traditional fossil fuels. The pine needle briquettes have a combustion characteristic of 5230 kcal/kg very similar to firewood (Pandey and Dhakal, 2013). The pine needle briquettes have better combustion and fuel characteristics with higher combustion gas temperature and lower amount of smoke emissions (Roy and Kundu, 2023). The biomass cookstove works with Pine Needles briquettes at an energy efficiency of 35% and reduces household pollution by 70%. Lower amount of smoke emission, higher calorific values, ability to burn longer with stable and uniform temperatures than fuelwood make pine needle briquettes better bio-fuel. Furthermore, the establishment of small-scale briquetting units can stimulate local economies by fostering entrepreneurship and creating new market opportunities.

Several initiatives have been already been taken by the state forest departments. The Forest Department of J&K in collaboration with IIT Roorkee has initiated making fuel briquettes from Chir pine needles in Nowshera Forest Division and established five bio-briquetting machines to be utilized by women SHGs for production of fuel briquettes which have high demand in market. These briquettes used for cooking and heating purpose and can be easily sell out at the rate of Rs 12-15/kg. While in Uttarakhand, CSIR-Indian Institute of Petroleum, Dehradun, has collaborated with the Uttarakhand State Council for Science and Technology (UCOST) to introduce innovative pine needle-based fuel-making technology in Uttarakhand's Champawat district. This will not only provide a sustainable source of energy and livelihood to local but also contributes to land management and forest conservation. Organizations like Avani Bio Energy in Pithoragarh, Uttarakhand have provided technical training and support to local communities, enabling them to produce and sell briquettes effectively.



#### **Benefits**

Pine needle briquettes offer a range of environmental, economic and social benefits, making them a sustainable alternative to traditional fuels in the Himalayan states:

- Regular collection of pine needles reduces the fuel load on the forest floor, mitigating the risk of forest fires.
- Allows understory vegetation to flourish, preventing soil erosion, enhancing soil fertility, and promoting overall ecosystem health.
- Collection, processing and production of pine needle briquettes livelihood opportunities.
- Small-scale briquetting units encourages entrepreneurship and local ownership, fostering economic resilience and community empowerment.
- Pine needle briquettes produces cleaner combustion compared to traditional fuels reduces indoor air pollution.
- Promoting the use of pine needle briquettes encourages environmental stewardship and sustainable land management practices among local communities.
- By reducing forest fire risks and promoting sustainable forest management, pine needle briquettes contribute to climate resilience in vulnerable Himalayan ecosystems.

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1.3

# JOINT FOREST MANAGEMENT (JFM): THE CASE OF ARABARI FOREST RANGE, WEST BENGAL

Community-led conservation efforts for forest restoration

Community involvement in forest restoration efforts has played a crucial role in the Arabari Reserve Forest of West Bengal. Local communities have actively participated in various initiatives aimed at restoring and preserving this important forest ecosystem. Through collaborative efforts with government authorities and non-profit organizations, community members have engaged in activities such as tree planting, fire prevention measures and sustainable harvesting practices. This involvement not only helps in conserving biodiversity and combating deforestation but also empowers local residents by providing livelihood opportunities and fostering a sense of ownership and stewardship towards their natural surroundings. Thus, community participation has been instrumental in promoting the health and resilience of the Arabari Reserve Forest.

Collaboration of local communities, government and NGOs for active restoration efforts



Promoting sustainable practices supporting responsible resource management



Providing economic opportunities through conservation



Cultural preservation by integrating traditional knowledge in conservation efforts



Joint Forest Management (JFM) is a concept of developing partnerships between fringe forest user groups and the Forest Department (FD) on the basis of mutual trust and jointly defined roles and responsibilities with regard to forest protection and development. In JFM, the user (local communities) and the owner (Government) manage the resource and share the cost equally, however it is difficult to generalise the JFM concept and approach in the light of variations across the nation with respect to geography, resource base, socioeconomic status, cultural diversity and pressures on forests. Although it is too early to assess its significance conclusively' the Joint Forest Management programme is being viewed by some observers as a historic policy shift towards a democratic decentralization of forest management in India. It has to be viewed in the historical context of 14 decades of custodial forest management which progressively eroded forest dwellers' rights over their lands and forests. The resulting







Fig. 6: Arabari forest area and Research centre (Source: . Tirthatanay)

disempowerment and displacement of indigenous tribal and hill communities as well as the devaluation and disintegration of their communitybased resource management traditions have been well documented (Gadgil and Guha, 1992).

The Arabari forest range is a prominent forest area situated in the West Midnapore district of West Bengal, India. It is the first community forest of India and a good example of forest and land conservation. The Arabari Forest is bordered by the Subarnarekha River to the south and is part of the larger Bengal Sub-Himalayan region. The Arabari Forest Range predominantly consists of tropical dry deciduous forests. This type of forest is characterized by a mix of deciduous trees, which shed their leaves seasonally, and evergreen species that maintain their foliage year-round. The region is home to a variety of tree species, including Sal (Shorea robusta), which is the dominant species, as well as Teak (Tectona grandis), Eucalyptus and many bamboo species. The undergrowth comprises shrubs, grasses and climbers, which contribute to the forest's rich biodiversity. The Arabari Forest Range has rich biodiversity, supporting a wide range of flora and fauna. The forest plays a critical role in soil and water conservation in the region. The dense vegetation helps in preventing soil erosion. especially during the monsoon season when heavy rains are prevalent. The root systems of the trees and undergrowth bind the soil, reducing runoff and maintaining soil fertility. Additionally, the forest acts as a natural water reservoir, enhancing groundwater recharge and maintaining the hydrological balance in the area.

As a tropical dry deciduous forest, the Arabari forest range is significant in terms of carbon sequestration. The forest absorbs a substantial amount of carbon dioxide from the atmosphere, helping mitigate the effects of climate change. This process not only reduces greenhouse gas concentrations but also contributes to the overall health of the global environment. The Arabari Forest Range is notable for its successful

implementation of JFM practices. This approach involves local communities in the conservation and sustainable management of forest resources. The initiative has led to improved forest cover, better resource management, and enhanced livelihoods for the local population. The successful implementation of JFM practices highlights the importance of community involvement in sustainable forest management. The Arabari forest range not only preserves the ecological balance of the region but also serves as a model for forest conservation and sustainable resource management (Sarin, 1993; Biswas and Rai, 2021).



# Brief description of practice

Joint Forest Management, in the Arabari Forest Range, originated in 1971 as a pilot project with the Forest Department collaborating closely with local communities. The goal was to regenerate degraded forests through effective protection. shared forest produce, and improved livelihood opportunities for forest-dependent communities. Local villagers actively participated in greening the forest, forming JFM committees. These committees facilitated community involvement in conservation efforts, transforming the initially worthless forest into an economic boon for the community. Villagers were engaged in silviculture, harvesting and received 25% of profits from forest produce. Arabari forest range remains an inspiring example of successful joint efforts in sustainable forest management and livelihood improvement (Bisui et al., 2023).

The development of the Arabari Community Forest in India is a fascinating case study in communitybased natural resource management. Here's a detailed methodology of how such initiatives are typically developed:

## 1. Initial Assessment and Feasibility Study:

Experts and community leaders identify suitable forest areas based on ecological significance, biodiversity, and potential for sustainable management. They assess the legal, environmental and socio-economic feasibility of establishing a community forest. This involves understanding local laws, land tenure systems and community willingness.

2. Community Consultation and Mobilization: Organize meetings with local residents, stakeholders, and leaders to discuss the concept of community forestry, its benefits, and potential

challenges. Facilitate discussions to build consensus on the objectives, boundaries, and management rules for the community forest.

- 3. Legal and Institutional Framework: Secure legal rights over the forest area through government recognition of community forest rights or lease agreements. Establish community forest management committees or similar bodies to oversee decision-making, implementation, and monitoring.
- **4. Resource Mapping and Planning:** Conduct a detailed inventory of flora, fauna, water resources, and other ecological aspects of the forest. Develop a management plan outlining sustainable practices for timber extraction, non-timber forest products (NTFPs), grazing, and other uses, ensuring biodiversity conservation and ecological balance.
- **5.** Capacity Building and Training: Provide training to community members on sustainable forest management practices, biodiversity conservation, fire prevention, and monitoring techniques. Build capacity within the community forest management committees to handle administrative, financial, and operational responsibilities effectively.
- **6. Implementation and Monitoring:** Execute activities outlined in the management plan, such as controlled harvesting, reforestation, fire prevention measures, and habitat restoration.

Establish monitoring protocols to assess the impact of management activities on biodiversity, forest health, and socio-economic outcomes. Regular evaluations help in adaptive management.

- 7. Integration with Livelihoods and Socioeconomic Development Explore opportunities for 
  sustainable livelihoods linked to the forest, such as 
  eco-tourism, handicrafts, and sustainable 
  agriculture. Ensure equitable distribution of benefits 
  from the community forest, addressing gender 
  dynamics and marginalized groups.
- 8. Networking and Advocacy: Engage with government agencies, NGOs, research institutions and other stakeholders for technical support, advocacy and resource mobilization. Advocate for supportive policies at local, regional and national levels to strengthen community forest management and secure long-term sustainability.
- **9. Review and Adaptation:** Conduct regular reviews of the management plan and implementation progress, adjusting strategies based on lessons learned and changing socioeconomic or environmental conditions. Embrace adaptive management principles to respond to emerging challenges and opportunities.
- **10. Celebration and Recognition:** Celebrate achievements and recognize

contributions of community members, fostering a sense of pride and ownership in the sustainable management of their forest.

The development of the Arabari Community Forest followed these general steps, customized to the local context and needs, demonstrating the potential for communities to effectively manage and conserve natural resources while improving their livelihoods.



# **Benefits**

The Arabari community forest management system, has demonstrated several benefits for both the local community and the environment. The program involves local communities in forest management, providing employment opportunities in silviculture and harvesting. Villagers share profits from forest produce, which contributes to their livelihoods (Bisui et al., 2023). Forest dwellers in the Arabari range receive benefits such as NTFPs, which play a crucial role in their daily lives and local economies. Around 85% of respondents express high satisfaction with the implementation of the Joint Forest Management (JFM) project in Arabari (Bisui et al., 2023). The standard of living index (SLI) in villages under the JFM project has significantly improved over recent years. The JFM project positively affects ecosystem services, including food production, raw materials, genetic resources, climatic regulation, and soil erosion control. Arabari JFM model serves as a successful example of sustainable forest resource conservation and livelihood improvement for forest dwellers. It's a model that could be applied effectively in other vulnerable forest regions worldwide.

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# **SILVIPASTORAL SYSTEM IN INDIA**

A practice to regenerate and sustainably manage degraded lands

Regenerating degraded hillside areas requires structural, vegetative and managerial interventions. India's growing human and livestock populations strain land resources, leading to degradation. The silvipastoral system emerges as a viable solution, integrating forage production, fuelwood and timber while enhancing soil and microclimate. Research shows that silvipastoral system have positive impact on biomass and livestock productivity compared to conventional grazing, but further study is required for sustainable outcomes. Silvipastoral systems offer promise in meeting resource demands while combating land degradation, with ongoing research aiming for sustainability.

Silvipastoral systems integrate trees, forage crops and livestock grazing on degraded hillside



Aim to sustainably regenerate degraded lands, meeting food, fodder, fuelwood and timber demands



**Trees enhance forage** production, provide shade and fuelwood, benefiting livestock and improving soil quality



sustainability.

This practice consolidates research findings from literature on silvipastoral systems, covering aspects such as forage production from the understory, leaf fodder and fuelwood obtained through tree pruning,

To combat the degradation of hillside areas due to rising human and livestock populations in India, structural, vegetative, and managerial actions are necessary. The escalating demand for food, fodder,

fuelwood and timber exacerbates pressure on land resources, resulting

in degradation. In response, the silvipastoral system offers a viable

solution by integrating trees, forage crops, and livestock grazing, meeting resource needs while promoting land regeneration and



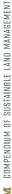




Fig. 7: Almond based hortipastoral system at IĞFRI Regional Research Station Srinagar (Source: Suheel Ahmad)

total system productivity, livestock output, soil enhancement, microclimate modification and economic implications. Studies indicate significant increases in biomass and livestock productivity per unit area and time compared to conventional grazing lands. Furthermore,

silvipastoral systems contribute to improving soil physical and chemical properties. However, identified research gaps highlight the need for further investigation to ensure sustainable production outcomes (WOCAT, n.d.).



# **Brief description of practice**

The described practice involves implementing silvipastoral systems, which integrate trees, forage crops/and livestock grazing on degraded hillside areas. This approach aims to restore and sustainably manage degraded lands while addressing the growing demand for food, fodder, fuelwood, and timber in India. Silvipastoral systems include planting trees, establishing vegetative cover and implementing effective land use and resource management strategies. By integrating







# **Benefits**

The integration of silvipastoral systems presents a multifaceted approach to land management, offering a range of benefits across environmental, social and economic domains. By combining trees with pasture, these systems increase fodder availability, elevate water levels and enhance soil moisture in foothill crop lands. Over the long term, they foster environmental regeneration, reduce land degradation and conserve ecosystems, while also protecting watersheds and downstream areas. Silvipastoral systems mitigate the risk of disasters, adapt to climate change impacts and contribute to climate change mitigation through carbon sequestration. Economically, they create income streams through increased livestock productivity and timber production, while socially, they enhance community resilience and food security. Overall, silvipastoral systems offer a holistic solution for sustainable land management, promoting environmental sustainability, social well-being and economic prosperity.

trees into pasturelands, this system offers numerous benefits. Trees contribute to forage production by providing shade and nutrient-rich leaf fodder, and can be managed to yield fuelwood through pruning. Livestock graze on the pasture, benefiting from the shade and forage provided by the trees. Furthermore, the presence of trees helps enhance soil quality by reducing erosion, increasing organic matter content, and improving water retention (Rai et al., 2020)

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# **KORANGADU**

# Traditional dryland grass farming system in Tamil Nadu

The Korangadu system has deep connections with semiarid and arid zones in Tamil Nadu. Over time, communities in these regions are heavily depended on raising livestock for sustenance, which mandated the cultivation of fodder crops to support the nutritional requirements of cattle, sheep and goats. Due to challenging environmental circumstances and water shortages, farmers ingeniously developed this system to ensure sustainable fodder production and effective range management.

Korangadu is a traditional dryland grass farming system



This practice has supported rural livelihoods by providing fodder for livestock rearing, crucial in regions characterized by low rainfall and sparse vegetation



Tamil Nadu, located in the southern part of India, boasts a rich agricultural heritage shaped by centuries of traditional wisdom and innovative farming practices. One such unique agro-ecological system prevalent in the region is known as "Korangadu." Derived from the Tamil words "korai" meaning dryland grass and "adu" meaning grazing land, Korangadu refers to a traditional dryland grass farming system that has sustained rural livelihoods and ecosystem health for generations. The Korangadu system is intricately linked to the semi-arid and arid regions of Tamil Nadu, characterized by low and erratic rainfall, sandy soils and sparse vegetation. Historically, communities in these dryland areas relied on livestock rearing as a primary source of livelihood, necessitating the cultivation of fodder crops to meet the nutritional needs of cattle, sheep and goats. In response to the harsh environmental conditions and water scarcity, farmers devised the Korangadu system as a sustainable solution to fodder production and range management.





# **Brief description of practice**

The preservation of pasture lands, exemplified by the traditional dryland grass farming system known as "Korangadu," serves as a vital source of income for farmers in the semi-arid regions of Tamil Nadu. In these areas, agriculture is inherently intertwined with livestock rearing, with farmers raising cattle, buffaloes, sheep and goats. The rural populace predominantly relies on livestock as their primary livelihood, adopting settled agro-pastoralist lifestyles where animals graze within their own grassland paddocks spanning 2 to 4 hectares in size

Korangadu pasturelands play a pivotal role in sustaining the day-to-day grazing needs of livestock, especially in regions frequently affected by drought. Characterized by an arid climate with annual rainfall averaging less than 700 mm, these areas pose significant challenges for agricultural productivity. Despite these constraints, farmers rely on the established fences surrounding their paddocks to preserve native vegetation and ensure an adequate forage supply for their animals throughout the year.

To supplement natural forage availability, farmers practice selective cutting of *Commiphora berryii* and other suitable plants only during the months of Ani-Adi (June-July). This strategic timing minimizes disturbance to the ecosystem while allowing for sustainable forage regeneration. Additionally, farmers take proactive measures to ensure access to clean drinking water for their animals by constructing water troughs within individual plots.

In the Korangadu system, animals are typically granted free access to graze within the paddocks, reflecting the harmonious relationship between traditional farming practices and natural resource management. By adhering to time-tested methods of pastureland conservation and utilization, farmers in Tamil Nadu not only safeguard their livelihoods



Fig. 8: Korangadu pasture land (Source: TANUVAS)

but also contribute to the preservation of local biodiversity and ecosystem services (FAO, 2007).

Selection of species: In Korangadu, there are primarily three main types of flora arranged in three spatial tiers. The lower tier consists of the grass species *Cenchrus ciliaris*, while the middle tier comprises tree species such as *Acacia leucophloea*, locally known as Velvel. Surrounding the land is a live fence made of thorny shrubs, locally referred to as Kiluvai (*Commiphora berryii*). They are commonly grown due to their ability to thrive in low-input environments and provide high-quality fodder for livestock. The list of different tree and grass species grown in Korangadu system is given below:

Velamaram Tree (Acacia leucophloea), Kolukottai Grass (Cenchrus ciliaris), Vennampul (Trachys muricata), Ottanpul (Seltaria Vericulata), Kurutupul (Cholris barbata), Cholapul (Chrysopogon montanus), Naripayathankodi (Phaseolus trilobus), Seppunerinji (Indigofera enneaphylla), Savarikodi (Merremia tridentate), Poonapudukukodi (Crotalaria globose), Dadara (Borreria hispida), Hariali (Cynodon dactylon) and Hadupudukanam (Rhynchosia rufescens).

The flora of paddock can be classified under the following heads (Table 1):

Table 1:
Types of
vegetation
and selective
species
cultivated in
Korangadu
system

Туре	Species	
Trees	Acacia leucophloea (Predominant), Albizia amara, Azadirachta indica	
Grass	Cenchrus ciliaris (Predominant), Vennampul, Ottanpul, Kurutupul, Cholapul, Cynodon dactylon, Moongil pul, Seegampul	
Legume	Phaseolus trilobus, Trychosanthes tricuspidata, Seppunerinji	
Shrub	Commiphora berryii (Predominant Live fence), Agave americana	



Fig. 9: Cattle grazing in Korangadu pasture (Source: TANUVAS)

### **Grazing System**

The paddock offers grazing grounds for animals for a minimum of five months annually. Grass growth is observed shortly after rainfall is received. Rainfall typically occurs during three distinct seasons, as commonly observed in these areas (Table 2).

Table 2: Rainy season and respective period

Rainy season	Period	
South west monsoon	June - September	
North east monsoon	October - December	
Summer showers	February - March	

and sustainability of traditional agro-pastoral practices. The Korangadu system provides income security for local livestock keepers while contributing to the conservation of animal genetic diversity and the ecological balance of the region.

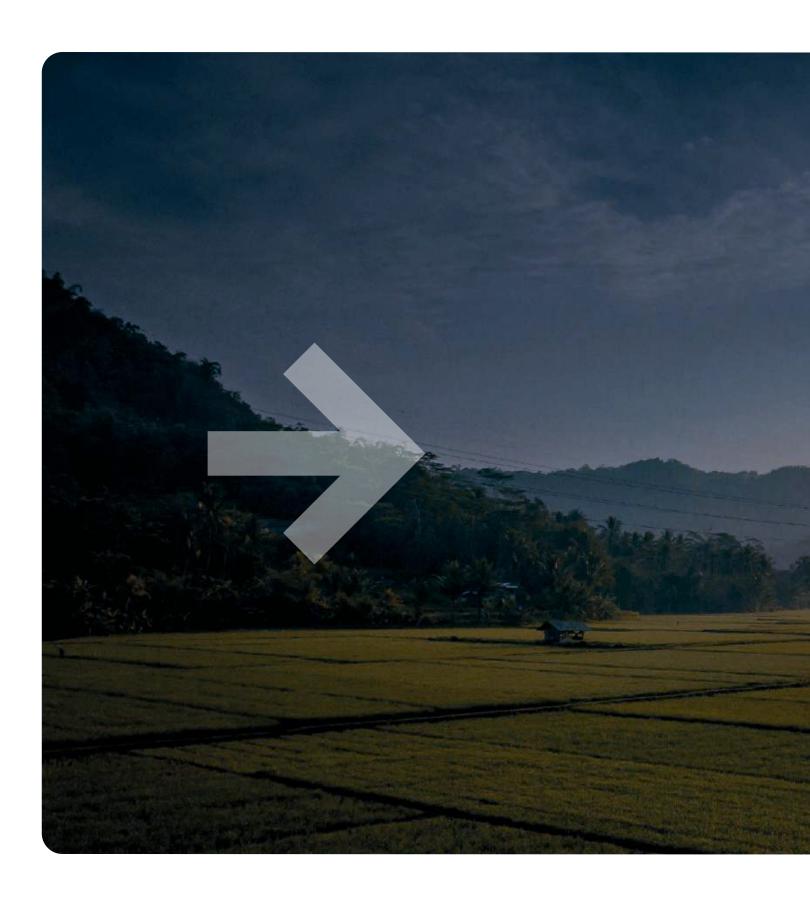
Animals are not permitted to graze in first year after sowing, but are allowed in the second year of establishment. Approximately one month is allotted for the grass to germinate and achieve the necessary growth before animals are introduced into the paddock for grazing. Grazing takes place throughout the day, from morning till evening. Drinking water is provided in stone or cement troughs within the paddock to ensure that animals have access to water as needed. Water is sourced from the village and transported to the paddocks either by carrying it manually or by using bicycles or bullock carts. The animals are not provided with any supplementary feed. The excess fodder is harvested and stored as hay for feeding the animals during off-season. Farmers construct water troughs (long narrow channels) in the individual plots for providing drinking water for the animals. Recycling of nutrients through animal droppings occurs; external application of fertilizer on the grassland is unheard of. The growth of different local fodder species also spread in such a manner that it is likely to support the partial grazing of animals at least during 8 -10 months in a year (Bharathy et al., 2018).

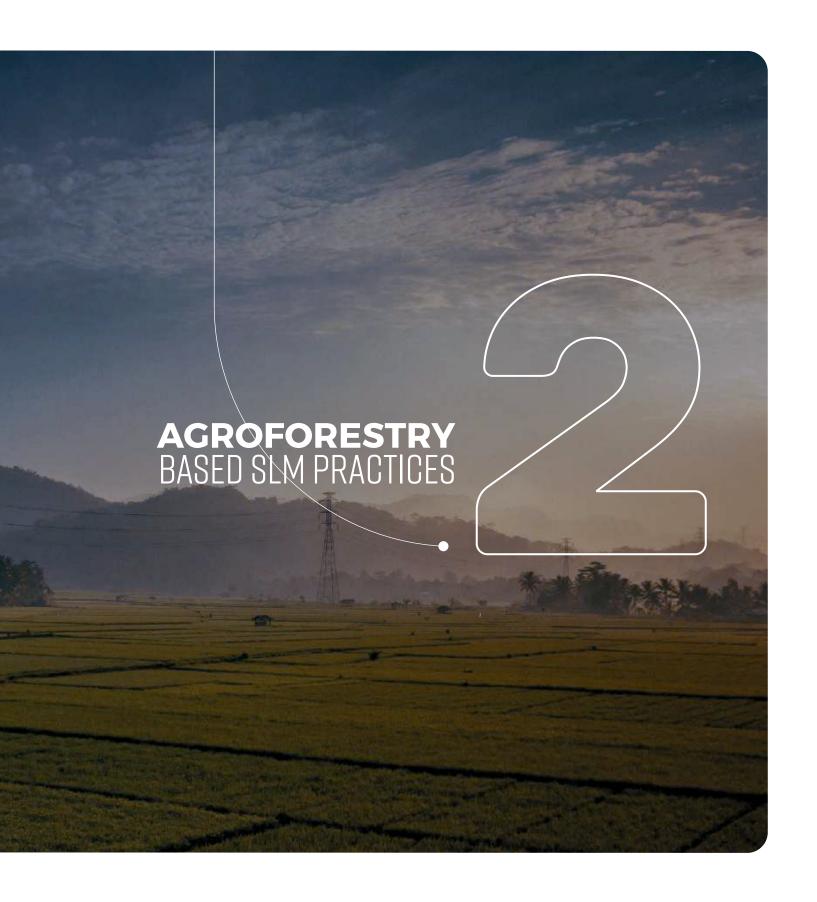


# **Benefits**

Grazing strategies within the Korangadu system contribute to disaster and risk reduction in land degradation due to over grazing. Establishment of Korangadu pasturelands involves forage availability and sharing grazing land practices. These pasturelands typically feature a diverse mix of grasses, legumes and tree species, ensuring continuous forage availability. Indigenous coping mechanisms adopted by livestock keepers reduce cattle mortality rates and improve fodder development. Traditional practices within the Korangadu system effectively prevent disease outbreaks in both animals and humans. Economic viability of this system is demonstrated by a farmer managing a 2-hectare pastureland with a diverse livestock population. Over 10 years, a farmer can generate high incomes, showcasing the profitability

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# 2.1

# ZABO FARMING SYSTEM

# An age-old farming system of Chakhesang tribes of Nagaland

The Zabo farming system, indigenous to Kikruma region, particularly practiced by the Chakhesang tribe in Nagaland, integrates forest management, water conservation, and terrace farming. This sustainable agricultural method involves creating water catchment areas on hilltops to capture and store rainwater, which is then channelled to irrigate terraced fields below. By combining traditional knowledge with ecological principles, Zabo farming enhances agricultural productivity and environmental sustainability.

Sustainable farming practiced by the Chakhesang tribes in Nagaland



Farming system that combines forestry, horticulture, agriculture, fishery and animal husbandry with wellfounded soil and water conservation



The rainwater is collected from the hilltop catchments and channelled to irrigate terraced fields, integrating livestock and agroforestry for sustainable agriculture



Zabo is an age-old farming system practiced by the Chakhesang tribes in Kikruma village of the Phek district of Nagaland. Also known as the "Dzüdü" or "Ruza" system, "Zabo" refers to impounding runoff water into ponds. This indigenous method captures rainwater from forest hilltops and channels it into ponds constructed within paddy fields. The Zabo system integrates forestry, horticulture, agriculture, fishery and animal husbandry with robust soil and water conservation practices. Farming is the main occupation of the Chakhesang tribes. Although this region receives sufficient rainfall, surface runoff leads to water scarcity. This challenge prompted the development of the Zabo system, an elaborate water management arrangement (Singh et al., 2018). The system includes water harvesting and recycling with conservation practices to control soil erosion and manage soil fertility and water availability. It is a sustainable practice for resource management and maintaining ecological balance (Pulamte, 2008).



Fig. 10: Zabo farming system in Kikruma village, Phek, Nagaland (Source: Dr Krishna Giri)





# **Brief Description of practice**

The Zabo system is a three-tier system divided into the (i) Top Section: Protected village forest land at the hilltop, serving as the catchment area for rainwater. Strict rules govern foraging and timber harvesting, which are usually permitted during the dry winter season; (ii) Mid-Hill Section: The village resides here, maintaining water-harvesting ponds approximately 0.2 ha in area and 1.5 to 2.5 m in depth, equipped with suitable silt traps. This area also includes permanent vegetation; (iii) Lower Section: This section contains rice paddy fields and fishery ponds. The system is typically practiced on land holdings of 2.0 to 2.5 ha. This structure ensures efficient water management and sustainable agricultural practices.

Upper Section or the top most section comprised of communities conserved forest area. Strict rules are enforced regarding foraging and collecting of wild foods (leaves, berries, fruits, seeds, roots and barks), and harvesting of the forest timber. Such activities are normally taken up during the dry seasons of winter. These forests act as catchment for the rain water.

The mid-hill section includes water-harvesting ponds, residential areas and cattle yards.

Community members dig ponds to harvest rainwater during the monsoon through natural flows and man-made channels. The bottom surface of the pond is thoroughly puddled (mixed) and the sides of the ponds are rammed and compressed to minimize the loss of water through seepage. Often, multiple ponds are constructed to manage surplus water. Water channels are maintained at suitable locations, with bamboo check dams to control soil erosion. Silt retention tanks or small ponds are constructed to collect runoff before it reaches the main ponds. Water from the ponds is released for irrigation through an outlet at the base, using open channels or bamboo pipes. This water, passes through animal yards, carries dung and urine, enhancing soil fertility (Singh et al., 2018). Livestock like cattle, goat, sheep, pig and poultry are raised besides the pond. The cattle enclosures are fenced with bamboo and wooden branches. Enclosure and houses for livestock are constructed on a little lower side of the water-harvesting pond.

The lower section includes vegetable and fruit growing areas, paddy terraces and fish ponds. Runoff rainwater carries soil nutrients from the forest, increasing soil fertility. Vegetables and fruits like squash, Colocasia, Cucumber, Chow-chow, Banana, Papaya, Oranges and other Citrus crops are cultivated on the pond banks, seasonal vegetables are also grown below livestock enclosures. Paddy fields, located at lower

elevations, have embankments rammed with wooden sticks and paddy husk to reduce water seepage. Farmers typically grow a local long-duration paddy variety called "Tanyekemüga." Paddy-cum-fish culture is common, with farmers raising mud fish in wet rice terraces. A small pit in the rice field allows fish fingerlings to be released in July. By the end of October, paddy matures and fields dry out or excess water is drained before harvesting. As ponds dry, fish move to the pit, from where they are harvested. Some farmers also introduce snails as an additional source of income.

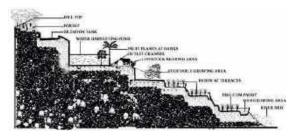


Fig. 11: Land management in Zabo farming system (Source: Singh et al., 2012)



# **Benefits**

The Zabo farming system is a viable sustainable land management (SLM) practice that effectively addresses several agricultural and environmental challenges. By strategically situating forests at the hilltops and implementing ponds with bamboo check dams in the mid-section, the Zabo system mitigates soil erosion, thereby preserving the integrity of the land. Zabo system excels in water management, offering a dependable irrigation source year-round. This aspect is particularly crucial in regions susceptible to seasonal water scarcity. By harnessing rainwater through ponds



Fig. 12: An aerial view of Zabo farming system (Source: scroll.in)

and carefully constructed water channels, the farming system ensures consistent water access for agricultural purposes, contributing significantly to enhanced crop yields and overall food security. Additionally, by prioritizing the preservation of natural forests, the Zabo system actively contributes to biodiversity conservation, safeguarding the delicate ecosystem.

The farming system exemplifies an approach to land management that prioritizes sustainability, ecological balance, and conservation. Organic matter from forest litter and animal waste enriches the soil fertility in the lower agricultural fields, promoting robust crop growth thus require limited chemical fertilizer.

By integrating different agricultural practices such as forestry, horticulture, agriculture, fisheries and animal husbandry, Zabo maximizes land use efficiency, leading to higher overall productivity and income potential for farmers. Compared to traditional slash-and-burn methods, Zabo achieves superior crop yields while simultaneously promoting long-term soil health and ecological resilience. Traditionally overseen by the village community, Zabo encourages collaboration and knowledge sharing among farmers, facilitating the adoption of best practices and the collective pursuit of sustainable agricultural outcomes. This communitydriven ethos not only strengthens social cohesion but also enhances the system's adaptability and resilience in the face of evolving environmental challenges.

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# 2.2.

# ALDER BASED FARMING SYSTEM

A traditional farming practices for enrichment of Jhum land

Alder based indigenous farming system of Nagaland, hold good promises for amelioration of Jhum land. In this system, crops are grown along with Alder tree (*Alnus nepalensis*) where, regular pruning of the tree is being done to enrich the soil nutrients. This indigenous intervention is showing good effect in increasing the yield of Jhum crops.

Sustainable indigenous farming model practiced in Nagaland, India



Farming approach based on farming integration and conservation of natural resources

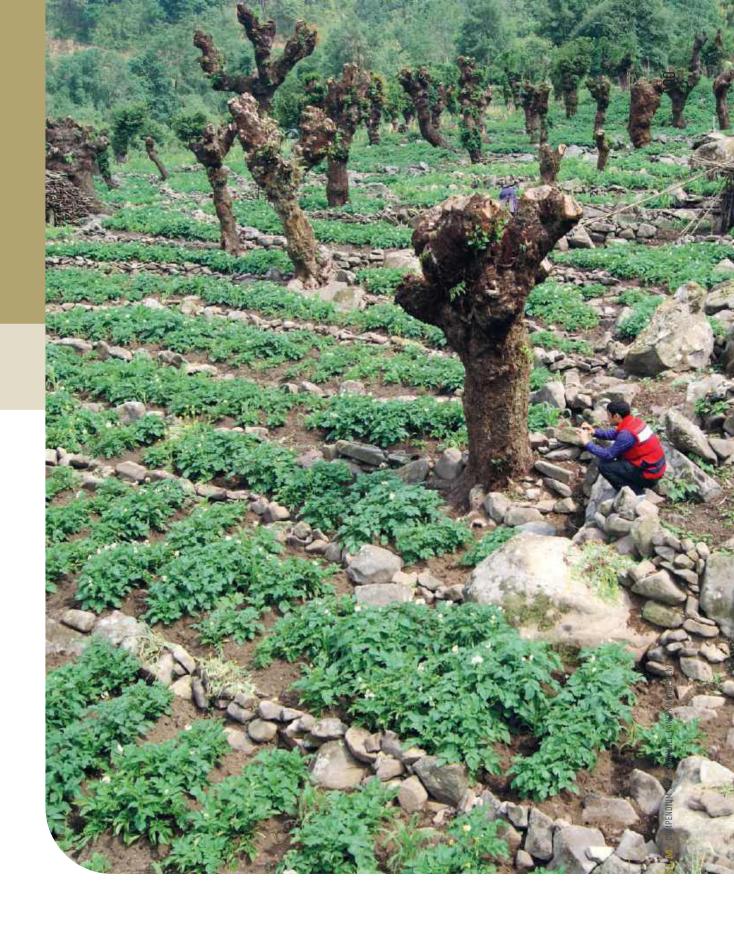


Alder tree gown along with agriculture crops and pruned during off season for soil enrichment



Nagaland is one of the seven sister states, located in north-eastern region of India. More than half of the state population lives in rural areas and agriculture is the main occupation for more than 70% of the population. Shifting/Jhum cultivation which is an old traditional system of farming, is widely practiced in the state. It is believed that the age old practice of shifting cultivation dates back to the Neolithic period around 7000 BC. However, shifting cultivations leads to deforestation, loss of biodiversity, fire etc. and is not considered as a sustainable approach for farming and land management practice. Over the years tribal farmer through their ingenious skill and experiences has developed a different alternative farming system of shifting cultivation and one of such systems is alder-based farming system (Sharma and Singh, 1994).

This Alder (*Alnus nepalensis*) based traditional farming system, known for its nitrogen-fixing properties and rapid growth, has been practised for generations by indigenous tribes such as the Angami, Chakhesang, Chang, Yimchunger and Konyak in Nagaland (Kehie et al., 2017).



SLM



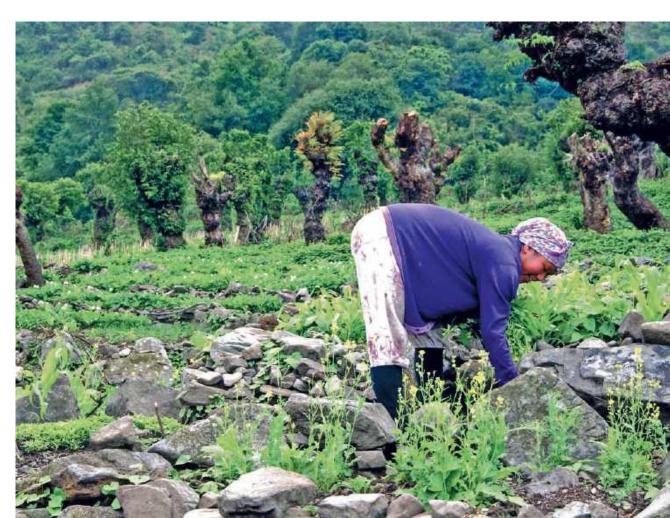
# **Brief description of practice**

Tribal farmers have long recognized the importance of Alder (Alnus nepalensis) which is a non-leguminous nitrogen faxing tree species. Morphologically, it is a deciduous or semideciduous tree, with a straight trunk reaching heights of up to 30 meters and diameters of 60 cm, commonly found at higher altitudes. The climate in Nagaland is very suitable for this tree species. This tree thrives well in sunlight but can also be grow in shaded areas. In this practice, agriculture crops are cultivated alongside of Alnus trees and regular pruning of the tree leaf biomass being carried out for enriching the soil fertility. When combined with crops, the tree creates an Agro-forestry system that is highly suitable for the sloping lands. Besides, adding nitrogen to the soil, the fallen leaves and branches after decompose add phosphorus, potassium, calcium and other nutrients to the soil.

Farmers in Kohima and Phek districts are adopting

an agroforestry approach, integrating Alder trees into their paddy cultivation. The rapid growth of Alder provides ample biomass, enriching the soil with nutrients. It also serves as an effective crop for intercropping, Additionally, Alder is utilized as a shade crop for certain horitcultural crops such as turmeric, *Cinchona*, and *Eletaria subulatum*. On terraced slopes, Alder trees are commonly pruned for poles and planted alongside crops like paddy, maize, barley, chili and pumpkin. In the central Himalayas, it's a common practice to cultivate large cardamom (*Amomum subulatum*) or *Cinchona* alongside Alder trees.

Fig. 13: Alder based farming system (Source: Dr Krishna Giri)



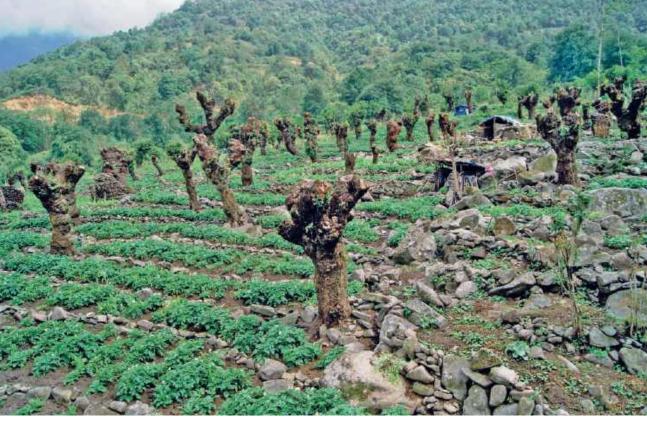


Fig. 14: Potato cultivation with Alder in Kohima, Nagaland (Source: Dr Krishna Giri)



# **Benefits**

Alnus species play a crucial role in environmental conservation and rehabilitation efforts. Cultivation of Alnus trees aids in stabilizing soil on slopes vulnerable to erosion and mitigating land degradation resulting from surface runoff. Additionally, Alnus trees facilitate nutrient cycling through the decomposition of their litter, enriching soil fertility and supporting ecosystem productivity. The litter produced by Alnus trees, constitutes a significant source of organic matter and nutrients. Annual litter production ranges from 3 to 6 tons per hectare, which is source of different essential nutrients like, nitrogen, phosphorus, potassium and calcium. This nutrient-rich litter not only enhances soil fertility but also fosters vegetative growth, thereby contributing to ecosystem resilience and sustainability.

This indigenous practice has shown positive impact by enhancing the yield of jhum crops. There is a urgent need for systematic identification and validation of such practices in specific areas, followed by their widespread adoption in other jhum regions to facilitate their improvement and sustainability.

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2.3

# LAC CULTIVATION FOR LIVELIHOOD GENERATION

Lac cultivation as lifeline for rural and forest communities

Lac cultivation is a lifeline for rural and forest communities across India, especially in states like Jharkhand, Chhattisgarh and Madhya Pradesh. Despite its immense potential, lac production faces hurdles—from climate change impacts to overexploitation of forest resources. The absence of scientific methods and marketing strategies compounds the challenge. However, embracing scientific techniques can significantly boost lac production. Its versatility—used in food, cosmetics, textiles, and industry—offers lucrative opportunities.

Lac cultivation serves as a vital source of income for rural and forest dwellers, particularly in states like Jharkhand, Chhattisgarh and Madhya Pradesh



Lac production involves cultivating lac insects on specific host trees, follows steps like host plant preparation, inoculation, resin secretion, harvesting, and processing to produce various lac products



Lac cultivation is a vital source of income for rural and forest dwellers in India, particularly for millions of tribal people in the country's central and eastern regions. Major lac-producing states include Jharkhand, Chhattisgarh, Madhya Pradesh, West Bengal, Odisha, Andhra Pradesh, Maharashtra and Uttar Pradesh, Despite India's vast potential for lac production, it faces challenges such as climate change, pollution and overexploitation. Production is also affected by seasonality and varying atmospheric conditions, especially postwinter (Mohanasundaram et al., 2014). The Chota-Nagpur plateau, home to principal lac host plants like Butea monosperma, Schleichera oleosa and Ziziphus mauritiana, still holds significant potential for improved lac cultivation through scientific techniques (Patel and Ashwini, 2022). Natural lac derivatives, including resin, dye and wax, are used in various commercial applications such as food items, cosmetics, medications, textiles, adhesives, paints and varnishes. Enhanced lac cultivation techniques are straight forward and require minimal labour, time and financial investment, offering higher income compared to other agricultural products. Lac is secreted by lac insects, primarily Kerria lacca (Kerr), to protect the mother and her young. These insects feed on the sap of host plants and are found in two strains, Rangeeni and Kusmi, each producing two crops annually. Lac production is sustainable and eco-friendly, providing valuable natural resin for various industrial products such as varnishes, polishes and adhesives.





# **Brief description of practice**

Lac production involves cultivating lac insects on specific host trees through the following steps:

**Host Plant Preparation:** Select and prepare host plants like Palas, Kusum and Ber, which provide food and shelter for lac insects. Farmers prune the branches to encourage new growth preferred by the insects.

**Inoculation:** Introduce lac insects to the prepared host plants either naturally or artificially:

**Natural Inoculation:** Lac insects from nearby trees crawl onto the prepared branches.

**Artificial Inoculation:** Farmers collect twigs with lac insect eggs (broodlac) from mature trees and

tie them to the branches of new host plants. The insects hatch and spread onto the new branches.

**Resin Secretion:** Lac insects feed on the sap of the host plant and secrete a resinous substance as a protective covering. This resin accumulates over time, encrusting the branches and forming sticklac, the raw material for lac production.

**Harvesting:** Sticklac is harvested when the lac insect colony matures, typically after 3 to 6 months. The timing depends on the specific type of lac being produced.

**Processing:** The harvested sticklac is processed to remove impurities like bark, twigs, and insect debris. The cleaned lac is then crushed, ground and refined into different grades and forms, such as seedlac, shellac and button lac.





Fig. 16: Lac insects on a Babybonnet branch (Source: Wikimedia commons)



# **Benefits**

Lac cultivation offers rural communities a host of benefits within an eco-friendly framework. Even small farmers can boost their income with minimal investment. Unlike many crops, lac can be cultivated on the vegetation growing in degraded or rocky lands. Lac coexists harmoniously with other crops and farmers can cultivate beneath lachosting trees. Women and children can participate,

as tasks are not physically demanding. Importantly, lac production doesn't harm host trees and may enhance soil fertility. This eco-friendly practice aligns perfectly with sustainability goals. Beyond the environment, lac provides year-round income, empowering rural communities and reducing reliance on unpredictable yields. In summary, lac cultivation is a powerful tool for brighter rural futures.

Fig. 17: A farmer preparing host for lac cultivation by pruning (Source: Wikimedia commons)



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2.4



An approach for sustaining agriculture and environment

Agroforestry based sustainable biochar production technology presents a viable strategy for environmental stewardship and sustainable agriculture. This technique protects watershed areas, maintains ecological integrity and improves soil fertility, structure and prevent land degradation. Furthermore, the utilization of biochar technology results in favorable economic and social consequences for communities by reducing the likelihood of disasters and lessening the effects of climate change.

Intensive cropping practices, monoculture and heavy use of synthetic fertilizers although increased the agriculture production and farmers income but degraded the soils and ecosystem. Farmers in Odisha's Balangir district face the similar challenges. To combat these issues and promote sustainable farming methods, a biochar production initiative was introduced. Utilizing crop residues and forest waste, biochar a carbon rich material was produced to enhance soil fertility and structure. This initiative is part of the Pro-Soil Project by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), India and implemented by the International Centre for Research in Agroforestry (ICRAF). The technology and technical support for biochar production were provided by the Indian Institute of Soil Science, Bhopal. Biochar, derived from biomass through pyrolysis, can improve soil structure, water retention, nutrient retention and crop yields. It also helps reduce greenhouse gas emissions by sequestering carbon in the soil. In the project area, farmers used crop residues like rice and wheat straw, along with forest waste such as branches and leaves, for pyrolysis. With abundant forest resources, availability of waste is not an issue. The produced biochar is applied to crop fields and agroforestry

Agroforestry based biochar production technology



**Enhancing soil fertility** and sequestering carbon



Promote gender equality and awareness among stakeholders





Process of Biochar production (Source: Wikimedia commons)

Fig. 18:



systems. The project also promoted agroforestry by integrating trees and shrubs into existing agricultural practices, offering benefits like improved soil health, biodiversity and carbon sequestration. By integrating sustainable biochar production into these systems, agricultural waste is converted into biochar, enhancing soil fertility and sequestering carbon. The project actively engaged women farmers, young entrepreneurs and farmer groups in biochar collection, production and application, promoting community participation and raising awareness about biochar benefits. The use of biochar is gaining success in India due to its promise to improve soil quality and fertility, increase crop yield and sequester carbon in the soil. In India, knowledge and resources can be leveraged to bring agroforestry-based biochar solutions to scale in support of sustainable food systems and climate resilience (Singh et al., 2024).



# **Brief description of practice**

The biochar kiln technology, sourced from the Indian Institute of Soil Science in Bhopal, is utilized for the conversion of biomass into biochar via pyrolysis. Within the biochar kiln, the collected biomass undergoes a meticulously controlled pyrolysis process in an oxygen-deprived environment. Technical expertise is applied throughout production, encompassing kiln temperature regulation, feedstock preparation and management of pyrolysis gases to ensure optimal biochar production efficiency. This process results in the transformation of biomass into biochar, while also yielding bioenergy-rich gases. Stringent quality control measures are enforced to produce biochar with superior attributes, including high carbon content, porosity and stability. The design of the biochar kiln prioritizes temperature optimization and efficient biomass conversion. An effective loading mechanism facilitates smooth and controlled biomass input into the kiln, ensuring consistent material flow during pyrolysis. Despite the absence of certain features typically found in commercial kilns, local kilns are nevertheless proficient in biochar production.





Fig. 19: Household production of biochar using diverse feedstock (Source: WOCAT, 2024)



# **Benefits**

Biochar acts as a soil enhancer, improving water retention, nutrient availability and microbial activity, thereby enhancing soil fertility and reducing nutrient leaching, leading to increased crop yields and resilience to climate variations. Additionally, carbon sequestration through biochar helps mitigate greenhouse gas emissions, aligning with global climate change mitigation efforts. Utilizing agricultural residues for biochar production reduces air pollution from open burning and offers a sustainable solution for organic waste disposal. Land users appreciate the enhanced soil productivity and environmental benefits of biochar. In nutshell, sustainable biochar production technology offers a promising approach for sustainable agriculture and environmental stewardship, particularly when integrated into agroforestry systems. This integration not only enhances soil fertility and structure but also combats land degradation, preserves ecosystem integrity and safeguards watershed areas. Moreover, by minimizing disaster risks and mitigating climate change impacts, biochar technology contributes to positive economic and social outcomes within communities.

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2.5

# SAND DUNE **STABILIZATION** AND SAND DRIFT **CONTROL USING** SURFACE **VEGETATION**

# A scientific intervention in Rajasthan

In the desert regions of Rajasthan, communities face shortages of fodder and fuelwood which is worsened by growing human and livestock populations, leading to mismanagement of sandy terrain, sand dune reactivation and land degradation. Drifting sands threaten agricultural fields, settlements, infrastructure and water bodies, posing substantial challenges to livelihoods and infrastructure. Surface vegetation significantly aids in enabling tree seedling roots to penetrate deeper soil layers by engaging in root competition, thus protecting trees from root exposure and uprooting amidst strong winds.

**Efforts to stabilize and control** sand drift involve mitigating wind velocity and curtailing sand erosion



The success of biological sand dune fixation hinges on the delicate equilibrium between soil nutrients/moisture availability and their utilization for biomass production



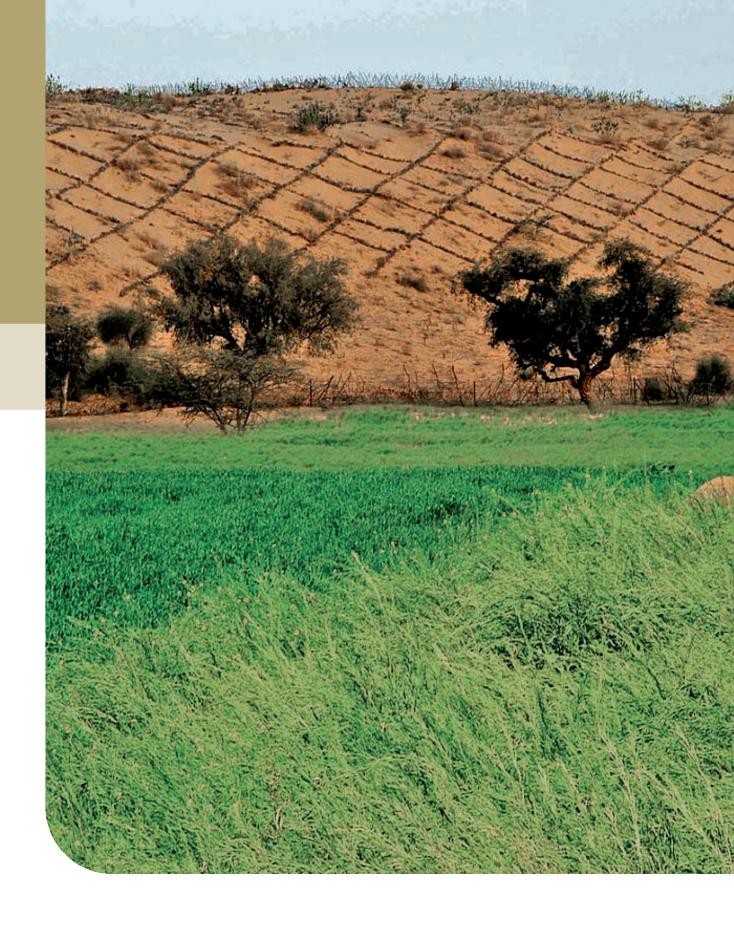
Planting under shrubs and grasses alongside tree species has positive effects on sand drift control. This is particularly beneficial as the planted seedlings grow into mature trees, facilitating unrestricted airflow beneath the canopy



found in various regions including Africa, the coasts of Chile, France, Belgium, the Netherlands, Australia, the Middle East and the Thar desert in India. Covering an extensive area, the Sahara desert spans 3.5 million square miles. Besides their striking formations, sand dunes harbor diverse life forms superbly adapted to their unique environment. The formation of sand dunes is intricate, with three fundamental requirements: an abundant supply of loose sand, sufficient wind energy to mobilize sand grains and topographical features conducive to sand settlement. Various objects such as shrubs, rocks or fence posts can impede wind force, leading to sand accumulation and the eventual formation of large dunes. Wind direction, velocity and local sand availability contribute to the diversity of dune shapes and sizes. The soils of Western Rajasthan are nutrient-deficient and vulnerable to soil and water erosion of varying degrees. Communities in the region grapple with shortages of fodder and fuelwood, while burgeoning human and livestock populations exacerbate mismanagement of the

Sand dunes are ubiquitous across the globe and are prominent features





sandy terrain, resulting in sand dune reactivation and land degradation. Drifting sands encroach upon productive agricultural fields, human settlements, canals, roads, railway tracks and water bodies, posing significant challenges to livelihoods and infrastructure.

Efforts to stabilize and control sand drift involve mitigating wind velocity and curtailing sand erosion. Over the past six decades, a range of physical, chemical and biological methods have been explored, with careful plantation of trees, shrubs and grasses emerging as the most effective approach. The success of biological sand dune fixation hinges on the delicate equilibrium between soil nutrients/moisture availability and their utilization for biomass production. Introducing under shrubs and grasses alongside tree species yields positive outcomes in sand drift control, especially as planted seedlings mature into trees, allowing for unimpeded air movement beneath the canopy.

Sowing leguminous and non-leguminous under shrubs or grasses enhances nitrogen and organic matter levels in arid zone dunes, effectively curbing sand drift while providing fodder for livestock. The introduction of Cassia angustifolia (Sonamukhi or Senna) offers economic opportunities for desert dwellers, with its perennial nature providing a regular crop for several years, making it an ideal candidate for restoring barren and infertile lands. Cenchrus ciliaris, a crucial grass species in Indian dry zones, serves as fodder for milch animals. Surface vegetation plays a pivotal role in facilitating tree seedling root penetration into deeper soil layers through root competition, thereby safeguarding trees from root exposure and uprooting during high winds.

Fig. 20: Wind breaks and shelter belts to stabilize sand dunes (Source: Ebin Benny Abraham)





**Fig. 21:** Surface Vegetation to stabilize sand dunes (Source: Ebin Benny Abraham)



# **Brief description of practice**

Following extensive experimentation with various species and combinations, Indian Council of Forestry Research and Education-Arid Forest Research Institute, Jodhpur identified the most suitable surface vegetative species for sand dune stabilization and sand drift control. Calligonum polygonoides emerged as the optimal species, fostering a conducive microenvironment and effectively establishing surface vegetation to mitigate sand drift. The combination of C. polygonoides with Cassia angustifolia proved to be particularly effective in sand drift control while enhancing biodiversity and ecology in arid regions. Moreover, the introduction of under shrubs like Cassia angustifolia and grasses such as Cenchrus ciliaris alongside tree species yielded beneficial outcomes in managing sand reactivation and drift, especially as planted seedlings matured into trees, facilitating unimpeded air movement under the canopy and subsequent sand drift control. Additionally, sand dunes typically exhibit deficiencies in soil organic matter and nutrients, notably nitrogen. It was suggested that microwindbreaks consisting of C. angustifolia could be established prior to or concurrently with plantation during the onset of the monsoon season to bolster effective surface vegetation (Singh, 2003).

Similarly, Indian Council of Agricultural Research-Central Arid Zone Research Institute (CAZRI) in Jodhpur, has devised a technology for sand dune stabilization. This technology entails the following procedures (ICAR, 2004):

- Shielding against biotic interference,
- Implementing micro-wind breaks (mulching) on the surface of the dunes to minimize sand displacement and
- Afforesting treated dunes

Shielding against biotic interference: Because of the dense human and livestock populations, any vegetation that emerges on the dunes is either harvested by locals or consumed by grazing animals, resulting in desolate dunes. These areas require protection from biotic pressures. The most effective method for safeguarding dunes is the installation of angle-iron-barbed wire fencing.

Implementation of micro-wind breaks: The indigenous brushwood materials found in the area should be efficiently utilized to build windbreaks. These materials should be placed upside down on the dunes, arranged in parallel rows or in a chessboard pattern, with a height of one foot above the dune surface. The brushwood from the following bushes can be employed: Senia (Crotolaria burhea), Bui (Aerva persica), Kheep (Leptadenia pyrotechnica), Thorns of Bordi (Ziziphus nummularia) and Khejri (Prosopis cineraria)

Afforesting treated dunes: Following the establishment of micro-wind breaks, it is imperative to re-vegetate these dunes with appropriate grasses, creepers, trees or shrubs, planted on the protected side of the micro-wind breaks. Some of the grasses, creepers and trees suitable for afforesting dunes are depicted in Table 3:

# **Table 3:** Vegetative species suitable for afforesting sand dunes

**Grasses:** Sewan (*Lasiurus sindicus*), Anjan (*Cenchrus ciliaris*), Murat (*Panicum turgidum*)

**Creepers:** Tumba (*Citrullus colosynthes*), Kachri (*Cucumus* sp.)

Trees/shrubs: Israeli babul (Acacia tortilis), Nubica (Acacia nubica), Kumat (Acacia senegal), Bhubavali (A. jaquimontii), Bavenosa (A. bavenosa), Angrezi babul (Prosopis juliflora), Phog (Calligonum polygonoides), Bordi (Ziziphus nummularia), Ami (Clerodendrum phlomoidis)

**Guidelines for revegetation:** Directly sow grass and creeper seeds. For trees/shrubs, transplant nursery-raised seedlings that are five months old. Plant trees at a spacing of 5x5 meters. It is crucial to carry out all these activities within specified

timeframes. It is advised to complete fencing work by the end of June, establish micro-wind breaks before July, prior to the onset of the monsoon. Raise tree-shrub nurseries in February or March and transplant trees/shrubs at the start of the monsoon. By diligently implementing these steps, it is feasible to efficiently stabilize the dunes.

This technology has garnered widespread acceptance from the State Government Forest Department for community participatory management and the stabilization of sand dunes.

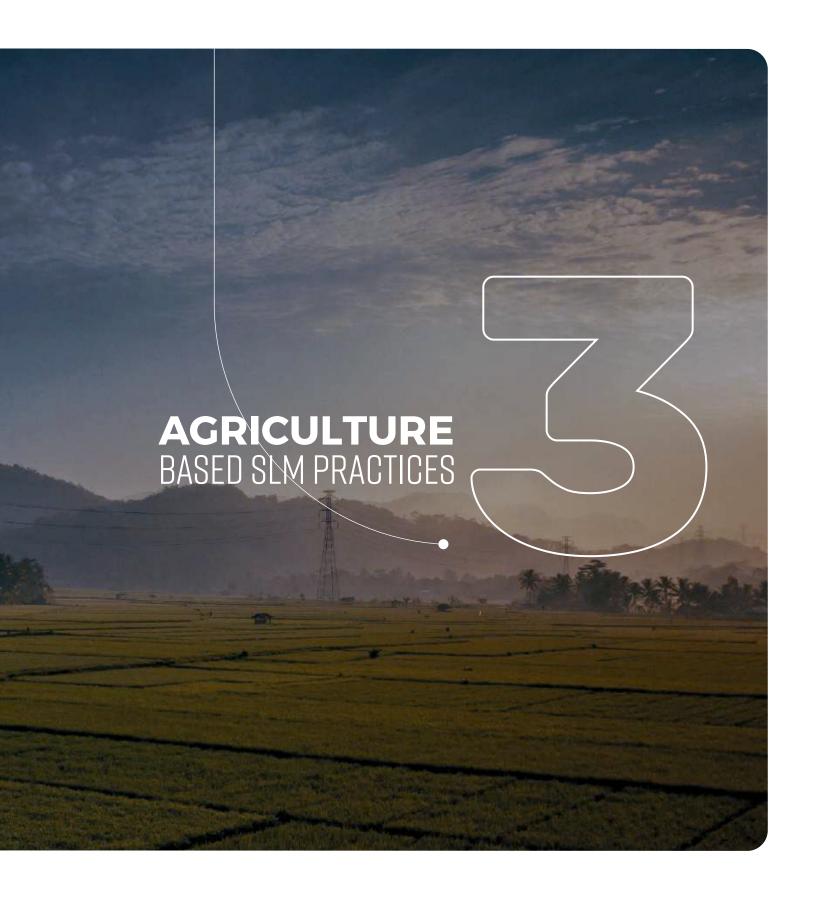


## **Benefits**

Sand dune stabilization using surface vegetation offers several environmental, ecological, and socioeconomic benefits. The vegetation helps to bind the sand, reducing the risk of wind and water erosion. The roots of the plants hold the sand in place, preventing it from shifting and forming moving dunes thus helps in soil stabilization. Plants grown in this system contribute organic matter to the soil, enhancing its fertility and structure over time. Further, vegetation can lead to a more stable local climate. Stabilized dunes can support a variety of plant and animal species, creating diverse habitats. Vegetation provides food and shelter for wildlife, contributing to the overall health of the ecosystem. Vegetation helps in capturing and holding rainwater, which can recharge groundwater reserves and support surrounding flora and fauna. Stabilized dunes act as natural barriers against wind and sand, protecting roads, buildings, and other infrastructure. Vegetated dunes can improve the visual appeal of an area, boosting tourism and recreational opportunities. Stabilized land can be converted to agricultural use, providing a source of income and food for local communities. Using vegetation for dune stabilization is often less expensive and more sustainable than engineering solutions like seawalls or groynes.

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# SANDA/KALAM PRACTICE

Double transplanting of rice in eastern Uttar Pradesh

In prominent rice-growing areas of eastern Uttar Pradesh, the single nursery raising becomes challenging due to issues such as overcrowding, nutrient deficiency and the occurrence of diseases like brown spot and leaf blast. To address these issues, farmers commonly adhere to a traditional practice known as the Sanda/Kalam method.

Sanda/Kalam technique involves double transplanting of rice as a favorable contingency measure in floodprone lowlands



This method is a viable option in situations of delayed rain, providing an effective strategy to mitigate the effects of early-stage drought during crop growth



Rice constitutes the primary agricultural output in Uttar Pradesh, covering approximately 5.90 million hectares of land, which represents 13.5% of India's total rice cultivation (Ansari et al., 2022). In eastern Uttar Pradesh, agriculture is mainly rainfed and the recent fluctuations in monsoon patterns have exacerbated the situation. Analysis of long-term rainfall data indicates consistent deficiencies in both annual and seasonal precipitation levels, particularly with a noticeable decrease in September rainfall over the past two decades. The transplanting period often extends significantly, ranging from early July to late August, due to unfavorable moisture/water levels in the fields during the early season. In situations of delayed planting, maintaining seedling health for 2-3 months in the same nursery becomes challenging due to issues such as overcrowding, nutrient deficiency and the occurrence of diseases like brown spot and leaf blast. To address these issues, farmers in eastern Uttar Pradesh commonly adhere to a traditional practice known



as the Sanda/Kalam method. This technique involves double transplanting as a favorable contingency measure in flood-prone lowlands of eastern India. Initially, 21 to 25-day-old seedlings are transplanted at a rate of 8 to 10 seedlings per hill, placed closely together (5-8 cm apart) in a small area. Subsequently, a second transplanting occurs 30 to 35 days after the first, utilizing normal spacing. The Sanda method presents itself as a viable option in situations of delayed rain, providing an effective strategy to mitigate the effects of early-stage drought during crop development stage. Additionally, it conserves groundwater, lowers cultivation costs and ensures higher profits.

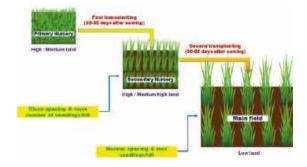


Fig. 22: Double transplanting of rice aka Sanda/Kalam practice in eastern UP (Source: Biswas and Das, 2023)



### **Brief description of practice**

In the Sanda method, the preparation of seed beds for raising seedlings follows the same procedure as followed for traditionally transplanted rice. Approximately 4 kg of thoroughly cleaned seeds are sown in a nursery area of 40 square meters, which is adequate for transplanting an area of 1 hectare. The seedlings, aged between 21 and 25 days, are carefully uprooted and transplanted at a rate of 8-10 seedlings per hill, with close spacing covering an area of 400 square meters. The initial close transplanting of rice in a small area allows for easy maintenance through field irrigation, particularly during periods of early-stage drought stress. After 30-35 days, the initially transplanted rice is lifted and its roots are cleaned in water. The seedlings and tillers are then separated and the seedlings are re-transplanted using the recommended spacing for transplanted rice, typically at a rate of 1 seedling per hill in 1 ha area. The second transplanting of rice is managed in the same manner as traditionally transplanted rice (Singh et al., 2015).

Researchers have outlined several potential benefits of this method over conventional transplanting, including seed conservation, staggered labor utilization, lodging prevention, increased grain count per panicle, larger panicles and approximately ten days earlier maturity. This

practice fosters the growth of robust, taller seedlings capable of withstanding adverse conditions, such as high-water depths during transplanting. In certain flood-prone regions, farmers adopt double transplanting (and sometimes triple transplanting) techniques to cultivate taller seedlings suitable for transplanting into standing water early in the season or to

rejuvenate seedlings while awaiting flood waters to recede to levels conducive for transplanting in the main field. Effective management of seedlings in nurseries or post-transplanting in the field is crucial. It is noted that double-transplanted rice often yields more than conventionally transplanted rice with seedlings of the same age. In India, the practice of double transplanting or two-step transplanting prevails in eastern regions of Uttar Pradesh as well as in Central Bihar and Chhattisgarh. In Assam, it is popularly known as Ballan system, in Meghalaya as Changgini geani and in Bihar as Kharonha. In regions such as Ballia, Gazipur, Azamgarh, Mau, Jounpur and Varanasi, where double transplanting, known locally as "Sunda planting", it is recommended that the nursery period for seedlings do not exceed 7 weeks. Ideally, it should be either 3 + 3 weeks or 3 + 4 weeks. All instances of double transplanting have shown superior performance compared to single transplanting methods. Though, not all rice varieties are compatible with double transplanting.

Short-duration, photosensitive cultivars are unsuitable for this method, whereas, long-duration (150 days), photoperiod-sensitive rice varieties are well-suited for double transplanting. Some common cultivars grown under Sanda method are given inn Table 4 (Kumar et al., 2019).

Table 4: Cultivars grown under Sanda Method

State	Cultivars
UP, Bihar, Assam,	Swarna, Ranjit, Swarna sub-1,
Garo hills district	Monoharsali, Kehol, Resu, Barut,
(Meghalaya)	Tipi, Jabilin and Kochugisim





Fig. 23: Second Transplanting of Rice after 55-65 days of sowing (Source: Suprijono Suharjoto/Dreamstime)

vegetative to maturity stages, while transplanted rice necessitates 5 to 6 irrigations throughout its lifecycle. Thus, this method aids in conserving underground water for future use. It enables farmers to cultivate rice even during initial period of droughts by managing small Sanda plots with minimal water and their own resources, leading to expanded rice cultivation, thereby boosting total farm yield, employment and income. It also lowers susceptibility to false-smut and bacterial blight due to robust growth of the paddy crop. It prevents lodging, whereas transplanted rice in lowland conditions tends to develop nodal tillers, increasing the risk of lodging and yield loss. This technique of rice cultivation requires less nitrogen fertilizer. It also produces a greater number of tillers per hill, with all tillers bearing panicles. The panicles are heavier, grains are fully filled and test weight is higher, resulting in increased yield.



### **Benefits**

The sanda method provides a number of benefits. It requires a smaller quantity of seeds (4 kg/ha) compared to transplanted rice (40 kg/ha), resulting in a net saving of approximately Rs. 1,000/ha. It avoids early-stage drought stress during seedling and vegetative growth phases (up to 50-55 days of crop duration). Rice cultivated using Sanda technique can be easily maintained in a compact area with minimal irrigation water, conserving groundwater, diesel for pump operation and labour. It provides increased employment opportunities for farming families through double transplanting. The paddy in Sanda method requires fewer life-saving irrigations (1-2) in case of drought during

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### Sustaining agriculture in Chhattisgarh

The Utera cropping system is an innovative system which involves the cultivation of short-duration crops, predominantly pulses and oilseeds, during the brief interval between the harvest of the primary kharif (monsoon) crop and the subsequent rabi (winter) crop.

Derived from the local dialect, "Utera" translates to "the second crop," signifying its unique position in the agricultural calendar

6

Utera cropping evolved as a response to the region's erratic rainfall patterns and the need to optimize land utilization throughout the year



The state of Chhattisgarh in central India, has a rich agricultural history that has been influenced by its varied topography and climate. One of the traditional cropping systems deeply rooted in the agrarian landscape of Chhattisgarh is the Utera cropping system. Derived from the local dialect, "Utera" translates to "the second crop," signifying its unique position in the agricultural calendar. In this system, short-duration crops such as oilseeds & pulses are planted in between the harvest of the main monsoon crop (Kharif) and the winter crop (Rabi).

Chhattisgarh's agro-ecological diversity, characterized by fertile plains, upland plateaus and forested hills, provides an ideal setting for the Utera cropping system to thrive. Historically, this cropping pattern evolved as a response to the region's erratic rainfall patterns and the need to optimize land utilization throughout the year. By harnessing the residual soil moisture post-monsoon and leveraging favorable climatic conditions, farmers in Chhattisgarh have successfully integrated Utera crops into their agricultural practices, enhancing farm productivity and resilience.

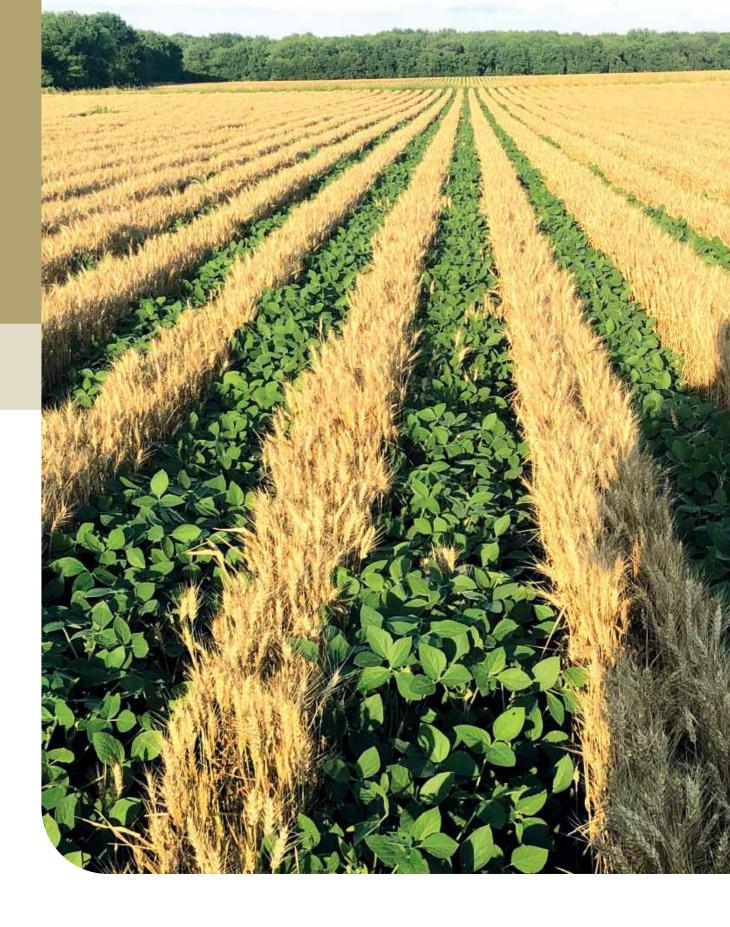
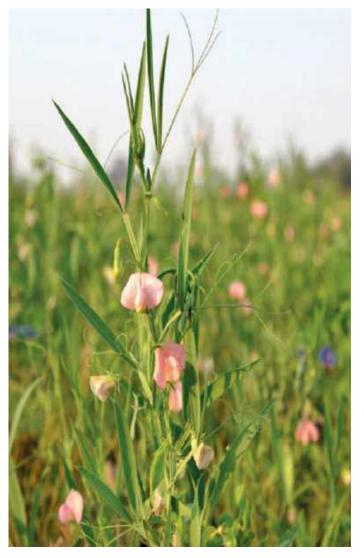


Fig. 24: Lathyrus: from seed to field as Utera crop (Mooventha n et al., 2019)







### **Brief description of practice**

The Utera cropping system is characterized by its distinctive crop selection and timing, which complement the traditional kharif-rabi cropping cycle prevalent in the region, mainly featuring paddy.

The key components of the Utera cropping system can be summarized as follows:

Crop selection: The choice of crops in the Utera cropping system is tailored to local agro-climatic conditions and market demand. Pulse crops such as lentils (masoor), chickpeas (chana) and pigeon peas (tur) are popular choices due to their ability to fix atmospheric nitrogen and improve soil fertility. Additionally, oilseed crops like mustard and sesame are favored for their high nutritive value and economic viability. These crops not only diversify the farm income but also contribute to crop rotation, pest management and soil health improvement.

**Timing:** Utera crops are sown immediately after the harvest of the primary kharif crop, typically in late September or early October. This timing capitalizes on the residual soil moisture accumulated during the monsoon season, providing a conducive environment for seed

germination and early crop establishment. The short duration of Utera crops ensures that they mature before the onset of winter, allowing for timely harvesting and subsequent preparation of land for the rabi crop. Under the Utera system, which involves relay cropping of *Lathyrus sativus*, there is no need for tillage. However, when planting after the rice harvest, it is essential to conduct one deep ploughing followed by cross harrowing and planking (Singh and Sureja, 2008).

Cultural practices: Utera crops are cultivated using traditional farming techniques adapted to local conditions. Land preparation involves ploughing and harrowing to create a fine seedbed conducive to germination and root growth. Seeds are sown either manually or using seed drills, ensuring uniform spacing and optimal plant density. Depending on soil fertility and moisture availability, farmers may apply organic manures or fertilizers to enhance crop productivity. Weed management, pests control and diseases prevention are addressed through a combination of cultural, mechanical and biological measures, minimizing reliance on chemicals.

### Harvesting and post-harvest management:

Utera crops are typically harvested within 60 to 90 days of sowing, depending on the crop variety and local growing conditions. Hand tools such as sickles or mechanized implements like harvesters may be used for efficient crop removal. Postharvest operations include threshing, winnowing and drying to remove excess moisture and ensure proper storage. Grading and packaging of harvested produce enhance marketability and value realization for farmers. In some cases, surplus Utera crops may be stored for household consumption or sold in local markets, contributing to food security and rural livelihoods.

Chhattisgarh. The sale of surplus produce generates supplementary income for farmers, enabling investment in agricultural inputs, education, healthcare and other essential needs. Furthermore, the cultivation of high-value crops like pulses and oilseeds enhances market access and price realization, improving the socio-economic status of farming communities. The Utera cropping system promotes environmentally sustainable agriculture by reducing reliance on synthetic inputs and minimizing negative environmental impacts. Practices such as crop rotation, intercropping and organic farming enhance soil health, biodiversity and ecosystem services. Additionally, the conservation of water resources and promotion of agro-ecological resilience contribute to climate change mitigation and adaptation efforts at the local and regional levels.



### **Benefits**

The Utera cropping system offers a lot of benefits to farmers, ecosystems and communities, contributing to sustainable agriculture and rural development in Chhattisgarh. By harnessing residual soil moisture and temporal gaps between kharif and rabi crops, the Utera cropping system optimizes land utilization throughout the agricultural calendar. This enables farmers to derive multiple harvests from the same piece of land, thereby enhancing farm productivity and income potential. The cultivation of diverse Utera crops diversifies farm income and mitigates risks associated with mono-cropping. Pulse and oilseed crops enrich soil fertility, break pest and disease cycles and improve overall agro-ecosystem resilience. Moreover, the integration of legumes in the cropping system enhances nitrogen fixation, reducing the need for chemical fertilizers and promoting sustainable nutrient management practices. The Utera cropping system is inherently resilient to climatic variability, particularly erratic rainfall patterns and temperature fluctuations. Short-duration crops are less vulnerable to weather extremes, allowing farmers to adapt quickly to changing conditions and minimize crop losses. Additionally, the conservation of soil moisture and organic matter through Utera crops enhances soil water retention capacity and drought tolerance, ensuring crop stability in water-stressed environments. Utera crops contribute significantly to rural livelihoods and economic development in

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# An indigenous practice followed by Apatani tribe in Ziro valley of Arunachal Pradesh

The rice-fish farming system established in the Ziro valley of Arunachal Pradesh, embodies an integrated ecosystem designed to suit the area's cultural, environmental and economic characteristics. Consisting of interrelated subagricultural ecosystems, this system serves as a vital provider of services including the preservation of genetic diversity, soil stabilization and regulation of soil fertility and nutrient cycling.

Agriculture forms the backbone of livelihoods in Arunachal Pradesh, with approximately 80 per cent of rural populations relying heavily on indigenous farming practices such as shifting cultivation, rotational fallow systems, wet-rice cultivation and traditional home gardens agroforestry methods. Over centuries, agriculture in Arunachal Pradesh has thrived on local resources including land and water, leveraging indigenous varieties and traditional knowledge. The rice-fish farming system in the Ziro valley of Arunachal Pradesh, represents an integrated ecosystem tailored to local cultural, environmental and economic conditions. Comprising complementary sub-agricultural ecosystems, this system plays a crucial role in provisioning services such as genetic diversity preservation, soil retention and regulation of soil fertility and nutrient cycling.

It involves cultivation of two rice crops annually while concurrently rearing fish in paddy fields during the primary rainy season



This innovative farming system exemplifies mutualistic biotic interactions, benefiting both rice and fish



In contrast to prevalent shifting cultivation practices in the region, Ziro valley farmers from the Apatani tribe capitalize on abundant water resources, sourced from rainfall supplemented by natural flow from surrounding hills. They cultivate two rice crops annually while concurrently rearing fish in paddy fields during the primary rainy season.



The symbiotic relationship between rice and fish optimizes ecosystem functioning, with each subsystem enhancing the productivity of the other. Fish play a vital role in controlling aquatic weeds and algae, which can harbor diseases and pests that compete with rice for nutrients. Additionally, the shading provided by rice plants helps maintain favorable water temperatures for fish during summer. The decomposition of rice leaves creates favorable conditions for microbial growth, serving as the primary food source for fish. Conversely, fish activity aerates the soil. increasing soil permeability



### **Brief description of practice**

Initially, rice seedlings are nurtured in a nursery (known as Miding) covering approximately 48 square meters, which is subdivided into three to four nursery beds (Hohe) measuring 4 × 3 meters each. Each indigenous rice landrace is meticulously maintained separately to prevent any potential mixing of seedlings. Preparation of the nursery beds commences shortly after the conclusion of the Murung festival in February, utilizing traditional implements (referred to as Hiita). Seeds are sown at a rate of approximately 80 kg per hectare. The seedlings (referred to as Andee) are attentively cared for over a period of about 75 days until they reach a height of approximately 15 cm and are ready for transplantation.

Remarkably, finger millet seedlings (*Eleusine coracana*), destined for planting in the field bunds, are typically raised in nursery beds within home gardens. Rice, alongside four local varieties of finger millet, is planted on elevated partitioned bunds situated between the rice plots. The size, timing and preparation techniques of the nursery beds closely resemble those employed for rice cultivation. Once the finger millet seedlings attain a height of around 15 cm, they are transplanted using traditional implements (locally referred as Dum), following the completion of rice seedling transplantation from the nursery beds, which typically commences in April and concludes by the end of May.

The Apatani tribe in the Ziro valley cultivates at least sixteen indigenous rice varieties. However, the selection of varieties is influenced by household preferences, with the most favoured and oxygen content, thereby promoting microbial vitality and accelerating nutrient decomposition for



Fig. 25: Rice-fish farming by Apatani tribe in Ziro valley of Arunachal Pradesh (Source: CPREEC-ENVIS)

enhanced rice absorption. This reciprocal exchange of energy and matter within the rice field ecosystem ultimately benefits both fish and rice production, enriching the livelihoods of farmers.

local rice varieties being Ampu ahare, Eylang eamo and Ampu Hatte, primarily due to their high productivity and socio-religious significance, collectively accounting for approximately 70 % of total wet rice fields. The indigenous landraces of rice grown in this rice-fish system is given in Table 5:

Table 5: Indigenous varieties of rice

**Early varieties:** Ampu ahare, Tepe pyaying, Kogii pyate, Mithu mipye, Pyare mipye, Eylang mipye, Kogii paying, Mishang mipye, Pyapu paying, Pyate pyapu, Zeehe paying, Zeehe pyate

Late varieties: Eylang eamo, Ampu hatte, Radhe eamo

Apatani farmers introduce fish fingerlings into their rice-fish fields, selecting cyprinids such as Common carp (Cyprinus carpio), Grass carp (Ctenopharyngodon idella), Silver carp (Hypophthalmichthys molitrix), Rohu (Labeo rohita), Catla (Catla catla) and Mrigal (Cirrhinus mrigala) in April, with harvest typically taking place in July, coinciding with the early rice cropping phase, Approximately 2.500 fingerlings are utilized per hectare by local farmers. Trenches, approximately 50 cm deep, are excavated in the field to provide shelter for the fish. As water recedes in the field, fish seek refuge in these trenches where water remains. The deeper trenches offer a cooler environment for the fish during hot weather. Fish are easily captured, even during harvest, from these trenches using indigenous traps crafted from bamboo, strategically positioned at the outlets.



**Fig. 26:** Harvesting of fishes from integrated rice + fish farming in Ziro valley (Tangjang and Nair, 2015)



### **Benefits**

Practices such as rice-fish farming, as employed by the Apatani tribe in the Ziro valley of Arunachal Pradesh, exemplify the ecological wisdom inherent in traditional small-scale agriculture, serving as enduring models of successful community-based land-use systems. Based on the collective knowledge of local farmers, integrated rice-fish farming is deemed sustainable, self-reliant and efficient. This multifaceted approach to rice and fish cultivation is not only viable but also environmentally sound, economically appealing and cost-effective, with numerous advantages including enhanced income, increased availability of fish for household consumption, heightened biodiversity and reduced reliance on fertilizers and pesticides. This indigenous farming technique holds significant potential in addressing food security, income generation, nutritional enhancement and livelihood improvement for rural communities. Fish, especially small varieties, are abundant in micronutrients and vitamins, thereby offering considerable benefits to human nutrition through consumption. Furthermore, surplus rice and fish are sold to generate additional cash income, thus, contributing to the economic stability of households.

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3.4

# BADI CROPPING SYSTEM OF BAIGA TRIBES OF MADHYA PRADESH

A traditional farming practices that maximize land use efficiency

Since centuries, Baiga tribes of Madhya Pradesh has practiced a Badi agricultural system suited to their mountains, forested environment and to their limited resources. This seems to be a holistic approach for land management and sustainable utilization of resource. This practice involves slash-and-burn techniques and mixed cropping with indigenous drought-tolerant varieties before the monsoon season.

The Badi cropping system, involves growing diverse cereals, vegetables and fruits in both Rabi and Kharif seasons



Indigenous and droughttolerant crop varieties are used, reducing crop failure risk and ensuring food security



Utilizing natural water sources for irrigation and domestic wastewater for crops, the system is designed to be sustainable, compatible with local culture and reduces reliance on external inputs



Nestled in the hilly terrains of Madhya Pradesh, India, the Baiga tribes have practiced a unique agricultural system for centuries known as the "Badi," This ingenious method, developed to adapt to their hilly, forested environment and limited resources, represents a holistic approach of land management and resource utilization. Traditionally inhabiting hilly regions with poor soil fertility and unpredictable rainfall, the Baiga tribes have developed the Badi cropping model with indigenous and droughttolerant varieties. The Badi system, believed to have evolved over generations, is characterized by shifting cultivation techniques. Baiga tribes burn dried bushes and branches on slopes to leave behind nutrient-rich ash for upcoming crops. Multiple crops are sown in these fields before the onset of monsoon. Villages of the Baiga tribe are strategically situated near natural water sources, enabling traditional irrigation practices, while directing domestic wastewater to the Badi cropping system, which supports vegetable cultivation and boosts environmental and economic sustainability (Yadav and Devi, 2020).



Despite being classified as shifting cultivation, deemed harmful to forests under the Indian Forest Rules of 1927, the Baiga tribe preserved their traditional Badi system. Recent years have seen growing recognition of the Badi system as a sustainable land management practice, valued for its contributions to sustainability, resilience and indigenous knowledge. Efforts are underway to ensure its legacy, including documentation and preservation of indigenous knowledge, integration into modern agricultural systems and advocacy for policies that recognize the value of traditional knowledge and support tribal communities.





## **Brief description of practice**

Prior to the monsoon season, the Baiga tribes employ the slash and burn technique. Bushes and branches are cut and dried on chosen slopes, then burned, leaving behind nutrient-rich ash for upcoming crops. They plant a diverse mix of seeds, often up to 16 varieties, a week before the rains arrive, which include coarse cereals like kodon, pulses and various vegetables. The Badi cropping system, a traditional agricultural practice among tribal communities, involves cultivating a variety of cereal foods, vegetables and fruits throughout the rabi and kharif seasons. During kharif, maize is sown in lines using a local implement called chadi, alongside vegetables like red-amaranth, lady-finger, cucurbits and elephantfoot-yam, as well as various fruit crops. In the rabi season, crops such as rai (mustard) and radish are grown, alongside indigenous and drought-tolerant vegetables, fruit trees like papaya, guava, zizyphus and banana are strategically planted along field peripheries, serving as living fences, windbreaks and erosion preventers during heavy rains. This system optimizes the fertile land in home surroundings, ensuring a diverse range of food crops and fruits.

The Badi cropping system guarantees a variety of cereal-foods, vegetables and fruits, thereby ensuring food security and balanced nutrition for tribal communities. Most crops involved in this system are indigenous and drought-tolerant, well-suited to the local environment and reducing the risk of crop failure. Utilizing natural water resources for irrigation through traditional implements and domestic wastewater for irrigating vegetable crops minimizes reliance on external inputs and chemicals. Designed to align with local culture, socio-economic conditions and biophysical factors, the Badi cropping system ensures long-term sustainability.

Dryland farmers create favourable microenvironments for crop diversification, such as using artificial and natural trenches for crop growth, showcasing an innovative approach to sustainable agriculture in challenging agro-ecosystems. Additionally, community leaders enforce regulations on hunting and resource extraction, ensuring the protection of native flora and fauna within their territory.





Fig. 27: Badi farming system: Mixed cropping in slope practiced by the Baiga tribe (Source: D G Nyogi, 2021)



### **Benefits**

The Badi cropping system offers a myriad of environmental, economic, and social advantages to tribal communities. By leveraging indigenous and drought-tolerant crop varieties and employing methods to conserve soil moisture, such as utilizing domestic wastewater for irrigation, the system significantly contributes to environmental sustainability. Practicing Multiple Cropping System, with diverse array of crops, vegetables, and fruits ensures maximum resource utilization, while providing resilience to the crop failure ensuring food security for tribal communities.

Economically, the Badi system fosters sustainability through the exchange of crops, facilitating practices like trading red gram seeds, thereby enhancing economic stability within these communities. Moreover, the system's efficient utilization of natural water resources for irrigation, coupled with techniques like "Utera cropping" which optimize moisture in dry land areas, further supports economic sustainability.

Furthermore, the Badi system minimizes the risk of pest and disease infestation through crop rotation, while the mix of crops also enriches the soil by incorporating organic matter, thus promoting soil health. Additionally, the system aids in controlling erosion of fertile surface soil, conserving water, and enhancing soil fertility by incorporating litters and organic matter from forest hilltops. Overall, the

Badi cropping system represents a holistic approach to agriculture, offering numerous benefits that extend beyond mere food production.

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- Yadav, M. and Devi, R. (2020). Indigenous technical knowledge documentation for sustainable use in rainfed agriculture. The Pharma Innovation Journal, 9(11):

# KAIPAD RICE **FARMING** SYSTEM, **KERALA**

A traditional way of rice and fish cultivation in sea water along the coast

Kaipad rice farming system is a traditional method of cultivating rice in the coastal wetlands of Kerala, Named after "kayal" (saltwater lake) and "padam" (paddy field) in Malayalam, it produces purely organic rice in naturally brackish environments. This farming system integrates rice cultivation with fish and shrimp farming, benefiting from mutual symbiosis and ancestral knowledge passed down through generations.

The Kaipad rice farming system is a unique and traditional method of

cultivating rice in the coastal wetlands of Kerala, India, particularly in

the northern districts of Kozhikode, Kannur and Kasaragod. The rice

naturally brackish due to the tidal influence of seawater mixing with

freshwater sources. Over centuries, a complex and ecologically responsive rice-fish farming system has evolved in these coastal

produced in this ecosystem is purely organic. These coastal areas are

Kaipad rice farming relies on specific conditions like brackish water and tidal patterns, cultivating salt-resistant rice varieties with minimal disturbance to natural soil



Alongside rice cultivation, it incorporates fish and shrimp aquaculture, fostering a symbiotic relationship where aquatic organisms benefit from rice plant nutrients, promoting biodiversity and reducing external inputs



wetland regions of India (Vanaja, 2013).

Kaipad rice farming promotes biodiversity, groundwater recharge and acts as a natural carbon sink



The Kaipad rice farming system has a rich history, deeply intertwined with the cultural and environmental context of Kerala's northern coastal regions. This system likely emerged from the need to utilize the unique coastal wetlands for agriculture while adapting to the challenges of salinity (Chandramohanan and Mohanan, 2011). Fish and shrimp are farmed alongside rice, further benefitting the paddy crop through addition of the organic matter to the soil. The development and refinement of Kaipad techniques have been passed down through generations of local farmers, representing a deep understanding of the local ecosystem and the ability to work with, rather than against, natural processes.



Fig. 28: Kaipad rice cultivation (Source: Kaipad farmers)



The Kaipad rice cultivation methodology emphasizes harmonizing with the natural ecosystem. It is a low-input, sustainable system that produces high-quality rice while promoting biodiversity, making it both unique and eco-friendly. This system promotes biodiversity, recharges groundwater aquifers and acts as a natural carbon sink. In 2013, Kaipad rice was awarded a Geographical Indication (GI) tag, recognizing its special characteristics and link to its origin.



## **Brief description of practice**

The Kaipad rice farming system is uniquely adapted to the conditions found in the northern coastal districts of Kerala, India, specifically Kozhikode, Kannur and Kasaragod, These areas possess distinct conditions such as brackish water, specific tidal patterns, coastal wetland soil and the availability of salt-resistant rice varieties, which contribute to the success of Kaipad farming.

Rice farming in Kaipad is conducted in a natural manner, relying solely on the monsoon and sea tides. A single crop of rice is cultivated on mounds during the low to medium saline phase of the production cycle, which spans from June to October. Existing Kaipad fields with proper bunds

and water control mechanisms are selected. The land is minimally disturbed, relying on the natural fertility of the wetland soil, without the use of external fertilizers or tilling. Rice cultivation is integrated with fish and shrimp aguaculture, creating a symbiotic relationship between the plants and animals. The fish and shrimp benefit from the nutrients released by the rice plants and organic matter, while their activity aerates the water and helps control weeds. No chemical fertilizers or pesticides are used. Traditionally, salt-resistant rice varieties like "Orkayma" and "Kuthiri" are cultivated on mounds within the paddy fields, with the newer variety "Ezhome" developed specifically for the Kaipad environment (Chandramohanan and Mohanan, 2012).

Within the paddy field, small mounds of earth, approximately 30-45 cm high and spaced about 60 cm apart, are created. Seeding typically occurs at the beginning of the monsoon season, around June. Seeds are either broadcasted or sown in rows on top of the mounds. Farmers rely on the natural rise and fall of the tides to regulate salinity levels. During high tide, saltwater enters the fields, bringing essential nutrients for the rice, fish and shrimp. Low tide allows for drainage, preventing the rice from being exposed to excessively salty water. Additional water management may involve small canals and gates within the field. Weeding is performed manually using traditional tools, with the integrated fish and shrimp helping to control weeds to some extent.





Fig. 29: Kaipad farm in Kerala (Source: Kaipad farmers)

Due to the dependence on the monsoons and the tidal cycle, Kaipad is a single-crop system. Harvesting occurs around October and is done by hand using traditional techniques such as sickles. This approach minimizes environmental impact and grain loss. During harvest, panicles along with a small portion of the culm are harvested, leaving a larger part of the stubble in the field. The vield of traditional Kaipad cultivars ranges from 1.0 to 1.5 t/ha, while that of high-yielding varieties ranges from 3.2 to 3.5 t/ha. After the rice harvest, the Kaipad field is left for aquaculture, particularly shrimp farming. This farming system has significant potential to contribute to food security, nutritional security, livelihood security, water security, biodiversity, and environmental protection, despite facing various challenges.



### **Benefits**

The Kaipad rice farming system boasts a range of benefits and positive outcomes, making it a unique and valuable agricultural practice. Kaipad relies on natural fertility and avoids chemical fertilizers and pesticides, promoting a healthy ecosystem. The integrated fish and shrimp farming creates a habitat for diverse aquatic life, fostering biodiversity within the paddy fields and provides additional income for farmers beyond the rice harvest. The

reliance on natural resources minimizes the need for external inputs like fertilizers and pesticides, reducing overall farming costs. Kaipad contributes to local food security by providing a source of nutritious rice and seafood for communities. The system represents a rich cultural heritage passed down through generations, fostering a sense of identity and community. Kaipad provides a sustainable livelihood for coastal communities, promoting economic stability and well-being.

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Agronomic measure for water conservation in paddy growing regions

The System of Rice Intensification (SRI) presents a cultivation method aimed at boosting rice yields while minimizing the need for seeds and water. SRI entails cultivating rice with a focus on organic manure, planting young seedlings individually in wider spaces arranged in a square pattern.

Ideal conditions for SRI include well-drained loamy to clayey fertile soils with a pH range between 5.5 to 7



Saves up to 40% of irrigation water and increases productivity of land by around 45%



Rice cultivation in India demands substantial amounts of water, with one kilogram of rice requiring approximately 3000-5000 litres of water (Kumar et al., 2018). The System of Rice Intensification (SRI) presents a cultivation method aimed at boosting rice yields while minimizing the need for seeds and water. SRI entails cultivating rice with a focus on organic manure, planting young seedlings individually in wider spaces arranged in a square pattern. This method also involves intermittent irrigation to maintain soil moisture without excessive waterlogging, along with frequent soil aeration through inter-cultivation using a weeder. In regions like Chhattisgarh and Madhya Pradesh, where water resources are limited, traditional paddy growers can benefit from adopting SRI practices, tapping into its significant potential. The idea of SRI is becoming increasingly popular in India, with approximately 100,000 farmers across states such as Assam, Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Karnataka, Maharashtra, Manipur, Odisha, Uttar Pradesh and Uttarakhand having already embraced this approach (Kumar et al., 2018).





### **Brief description of Practice**

In India, the regions where rice is cultivated and receiving around 1000 mm annual rainfall with irrigation facilities, are considered suitable for implementing SRI. Ideal conditions for SRI include well-drained loamy to clayey fertile soils with a pH range between 5.5 to 7.0 Moreover, the land should be leveled, easily accessible for irrigation and drainage and free from salinity or alkalinity issues. The Directorate of Rice Development, Patna (2013) gave the following steps involved in SRI method of rice cultivation.

### Steps involved in SRI

Pre-treatment of seeds for germination: The process begins by immersing healthy seeds of improved rice varieties in water for 12 to 24 hours. Subsequently, these soaked seeds are placed under moist gunny bags for 24 to 48 hours, with regular watering to aid in sprouting. To acquire suitable improved rice varieties tailored to the region, individuals can reach out to the nearest Krishi Vigyan Kendra, Agriculture Department, or Kisan Sewa Kendra. Before sowing the selected seeds in the nursery, they undergo pretreatment with biopesticides or a combination of Carbendazim (1 gram), Mancozeb (2 grams) and Thiomethoxam (2 grams) per kilogram of seed.

Nursery preparation and management: A standard garden nursery serves as the perfect setting for implementing SRI. In this approach, 5 kilograms of seeds per hectare are necessary. For every 5 kilograms of seeds, a nursery area spanning 100 square meters is required. The topsoil (0 to 15 cm depth) is thoroughly pulverized and blended with finely decomposed organic manure. To prepare a nursery bed covering 100 square meters, 50 Kg of compost or farmyard manure, or 25 Kg of vermicompost, is recommended.

Raised beds, typically measuring 6 to 12 inches in height, are prepared to accommodate the root growth of seedlings aged 8 to 12 days, which extend up to 3 inches. These beds are ideally 4 feet wide and can be adjusted to a convenient length. Depending on preference, either a single large bed or multiple smaller ones can be arranged for planting on one hectare of land. The soil within the beds is enriched with an ample quantity of farmyard manure and irrigated. Seeds are then sown either in rows spaced 10 cm apart or broadcasted evenly. Subsequently, the seeds are

covered with a mixture of fine soil and farmyard manure in equal proportions, creating a layer approximately 2 cm thick. This layer is watered and a protective covering of rice husk is applied for three days. A drainage channel is established surrounding the nursery bed to manage water flow. For stability, raised beds can be reinforced with wooden planks, bamboo or other locally available materials.

Field preparation: In well-drained loamy to clayey soil, it is recommended to apply 15 cartloads or the equivalent of 3 tractor trolley loads of farmyard manure or compost per acre. This should be followed by 1 to 2 ploughings and 2 to 3 harrowings. For SRI implementation, achieving precise leveling and raking is essential to ensure uniform water distribution. To facilitate drainage, 30 cm wide channels are prepared at two-meter intervals across the field.

**Seedling transplanting:** SRI requires a careful approach to minimize disturbance and shock during the transplanting of seedlings. Typically, seedlings at the two-leaf stage (8 to 12 days old) are delicately removed from the nursery, ensuring the seed and soil remain intact during transportation. To accomplish this, a metal sheet is inserted approximately 4 to 5 inches below the seed bed, allowing the seedlings, along with the soil, to be lifted with minimal disruption to the roots. Each seedling is then gently planted at a depth of 1 to 2 cm using the thumb and index finger at the pre-marked intersections spaced at 25x25cm. These intersections are conveniently marked to ensure quick and uniform establishment of the seedlings.



**Fig. 30:** Transplanting at 25 x 25 cm distance (Source: Isha Outreach)





Fig. 31: Mechanical Weeding in SRI (Source: Biksham Gujja)

Irrigation and water management: SRI demands no inundation. Purpose of irrigation is to wet and saturate the soil with moisture. Subsequent irrigation is again required to keep the soil moist when it starts developing cracks. After panicle initiation, irrigation is given to a depth of 2.5 cm a day after the previously ponded water disappears. Watering is necessary at the timing of panicle initiation, booting, heading and flowering.

Weed control: The lack of standing water in SRI can result in increased weed growth. The initial weeding session, conducted around 10 days after transplantation, holds significant importance. Utilizing a weeder is advantageous for reaping the benefits of SRI. Weeding can be accomplished using tools such as conoweeder or by manual labor, employing a criss-cross pattern to effectively control weeds. Alternatively, weeds can be manually uprooted and buried in the soil to enhance soil fertility. Notably, chemical herbicides are not employed in SRI practices.



### **Benefits**

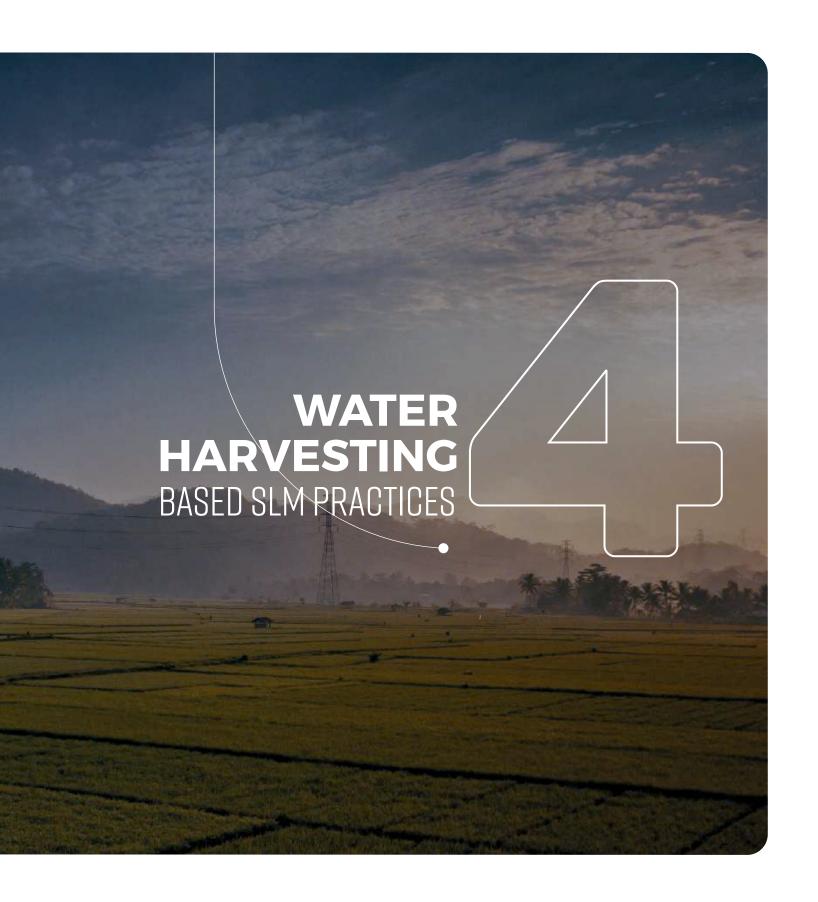
The System of Rice Intensification technique increases savings of the farmers as it reduces the cost of cultivation by 23 percent. It significantly diminishes the duration of the rice crop. Researches have reported that SRI saves up to 40 percent of irrigation water and increases productivity of land by around 45 percent. Further, the cost of nursery raising is reduced significantly in SRI. Subsequently, it increases overall production of rice (ICFRE, 2020).

Harvesting: It is recommended to harvest the rice crop when the stem is still green and the panicles have ripened to prevent shattering. With SRI, the duration of the rice crop is shortened by approximately 10 days. This provides farmers with extra time to prepare for the rabi crop.

Minimum and maximum area under SRI: The size of land allocated for SRI ranges from 0.4 to 1.0 hectares. Implementing this method over larger expanses of land will decrease water percolation osses.

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4.1

# VIRDA TECHNIQUE OF MALDHARI TRIBE OF GUJARAT

A traditional rain water harvesting system in Great Rann of Kachchh

Virdas are shallow wells dug in low depressions called lakes (tanks). These are prevalent in the Banni grasslands, a part of the Great Rann of Kachchh in Gujarat. The Virdas are built by nomadic cattlemen tribe 'Maldhari' who used to roamed these grasslands but now settled there. These structures harvest rainwater in salty desert. By studying the flow of water during the monsoon, the Maldharis identify the depressions and make Virdas there. Through this technique Maldharis people separate potable freshwater from unpotable salt water.

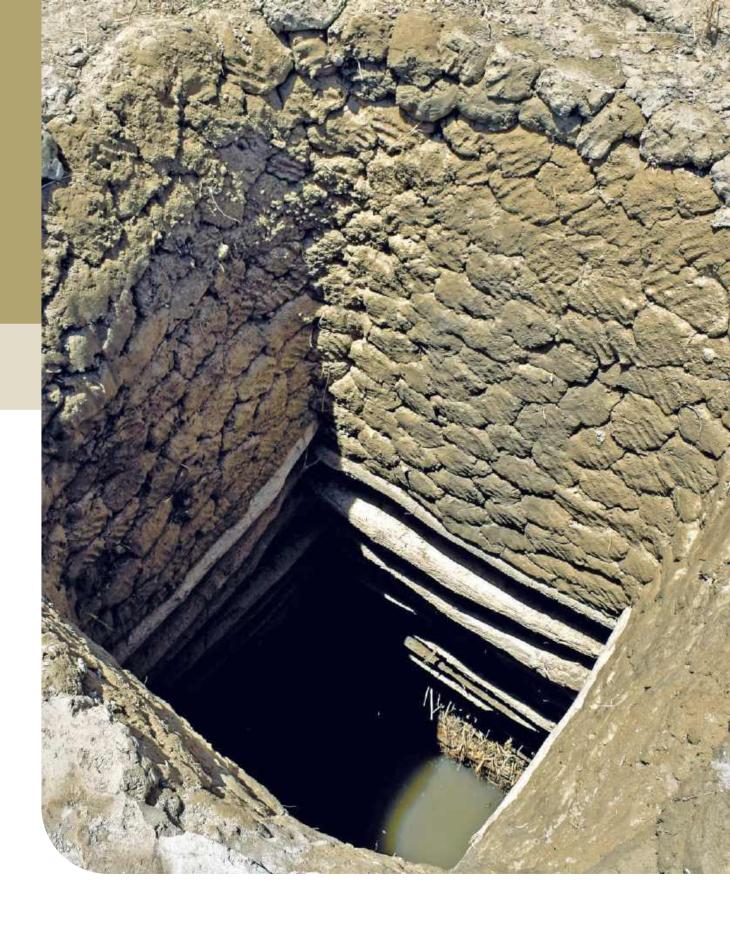
Water scarcity challenges in arid regions have long been addressed through the practice of water harvesting, a tradition dating back centuries. One of the best traditional indigenous rain water harvesting system called Virda, originating from the Banni grasslands of Kachchh, Guiarat, India, The Banni grassland, covering an area of 3847 sg, km. is now a vast mudflat located near the Great Rann of Kachchh in the northern region of the Kachchh district in Gujarat, India (Machiwal et al., 2018). In this region, the agriculture is not feasible due to minimal rainfall and the inherent soil and water salinity and the primary occupation is animal husbandry, carried out by the local community known as Maldharis. The indigenous water harvesting technique, rooted in traditional wisdom, has proven highly effective in sustaining both human livelihoods and the well-being of animals. The enduring success of Virdas over the centuries attests to its efficacy and resilience. The practices developed by the Maldharis through generations of learning and experience, not only serves as a practical solution but also holds deep cultural significance within the community. The water collected through Virda practice is suitable for drinking purposes, making it an integral part of the Maldharis' way of life in

Traditional rain water harvesting technique suitable for saline soil



Cost effective technique to separate potable freshwater from unpotable salt water





SLM

Fig. 33:

fetching water from a

(Source:

Wordpress)

Virda

Maldharis





Banni. This system consists of interconnected wells strategically placed within shallow depressions known as jheels. As these jheels dry up, deeper wells are dug to access subsurface water through the ingeniously designed Virdas structures. These Virdas represent the sole internal source of fresh water within the Banni grasslands (Machiwal et al., 2018).

The water stored in Virdas meets the World Health Organisation (WHO) standards for livestock consumption. Implementing measures like silt-traps and grass barriers can enhance its functionality and its adaptable nature makes it suitable for similar environments worldwide. There is an urgent need for improving this traditional practice through the integration of scientific advancements.





### **Brief description of practice**

The entire indigenous rainwater harvesting system in the area is built using locally sourced materials, making it cost-effective. Typically, constructing the Virda involves three main materials: wooden sticks, grass and soil, all abundantly available in the area. A Virda typically takes two days to construct with the help of 4-5 workers. First, a suitable spot inside the jheel is chosen and a circular pit about 6-7 feet in diameter and 10-15 feet deep is manually dug. Wooden sticks or tree twigs are then arranged in a square frame up to 1 meter depth to prevent soil collapse. The upper part of the Virda is made of plastered soil, slightly wider than the wooden frame, allowing water to be lifted out easily using ropes and baskets. Locally available grasses mixed with moist soil are used to seal the macropores in the wooden frame, acting as a filter to slow down water flow and prevent erosion. For more durability in Virdas, now-a-days, masonry or cement concrete tops are also used. The water collected in Virdas is not old underground water but recently recharged surface water, likely from the previous rainy season, making it an effective means of groundwater recharge.





Fig. 34: Maldharis extracting water from Virda (Source: Wordpress)



### **Benefits**

Virda proves to be an effective tool for addressing water scarcity in arid and saline environments like the Banni grassland. The technology is developed by local communities based on generations of wisdom and experience, Virda demonstrates sustainability, resilience and is deeply rooted in the

cultural practices of the local pastoralist community, showcasing the integration of traditional knowledge with practical solutions. The Virda technology's adaptable nature suggests its potential for adoption in similar climatic and salinity conditions, especially in developing nations, offering a scalable solution to water scarcity challenges.



Fig. 35: Water being extracted from a Virda (Source: Wordpress)

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4.2

# SURANGAM RAINWATER HARVESTING TECHNIQUE

A traditional practice of water management in Kasaragod district, northern Malabar region, Kerala

The Surangam technique of water management ensures consistent access to water for drinking and irrigation, essential for small-scale farms located in foothills of the Western Ghats. This method utilizes the natural pressure gradient from surrounding slopes to facilitate various irrigation systems like spray irrigation, foggers and drip networks on the hillsides.

The Surangam technique, deeply rooted in the traditional knowledge of water management, represents a remarkable example of sustainable engineering practices developed by communities inhabiting the foothills of the Western Ghats in India, particularly within the districts of Kasaragod in Kerala. Originating from the necessity to harness and utilize near-surface phreatic groundwaters for drinking and irrigation in areas with laterite soils, Surangam embodies a sophisticated system of manmade horizontal adits or tunnel networks. These tunnels are meticulously constructed to access and extract water from phreatic water tables safely. Laterite, the predominant soil type in these regions, plays a crucial role in the functionality of Surangam. Initially porous, laterite gradually accumulates rainwater, which percolates through its layers, interacting with organic matter and dissolving calcium deposits. This process results in the formation of voids, effectively creating underground reservoirs within the laterite soil matrix. Over the years, Surangam systems have demonstrated both resilience and vulnerability. Instances of partial wall collapses and catastrophic failures, leading to permanent abandonment, underscore the challenges associated with their construction and maintenance. Known

Sustainable water management practice



Empowers local communities with a reliable and sustainable water supply



Contributing to agricultural productivity and livelihoods in the region





Fig. 36: Multiple Surangam in Kerala (Source: Subin P. Thomas)



by various names reflective of local dialects and traditions, Surangam exemplifies the ingenuity and adaptive capacity of communities in managing their water resources sustainably.

As Surangam continues to attract attention for its potential in water conservation and agricultural sustainability, further research and technological innovations are required with aim to enhance its efficiency and resilience. By integrating traditional knowledge with modern advancements, the Surangam technique offers valuable insights into addressing contemporary challenges in water management and environmental sustainability.







### **Brief description of practice**

Surangam is typically constructed on short, steep slopes commonly found in the foothills of the Western Ghats of India. They are often associated with small farm units, typically around 1.8 hectares in size, although sizes can vary widely, ranging from much larger to smaller plots, sometimes as small as 0.3 hectares. Farm dwellings are usually built on levelled terraces, which can be as small as 1.5 meters by 4.5 meters, especially in areas where arboriculture and intercropping are practiced. In some locations, larger levelled terraces, measuring around 30 meters by 30 meters, are used for paddy cultivation and growing vegetable crops. Water harvesting structures, such as small farm ponds (kere), are typically located on these terraces, fed by either nearby Suranga or ones at higher altitudes. Usually, at least one Surangam is constructed close to the family home and is dedicated exclusively for drinking water. Water from Suranga is typically channelled through small pipes under gravitational force, although in the past, small open channels were also used for distribution. This setup allows for the utilization of natural pressure gradients from adjacent slopes to

support irrigation systems such as spray irrigation, foggers and drip irrigation networks on the slopes.

Water allocation for different crops is calculated based on their growth cycles and fruiting patterns, with the majority of water typically allocated to areca plantations, and for coconut and banana cultivation. The selection of sites for constructing Surangam is determined by various factors, including ecological indicators such as termite mounds and hydrophilic plant species in the catchment recharge area and the structural properties of the laterite soil. The laterite must have sufficient strength to prevent tunnel collapse, usually indicated by its lateral layering patterns and rock substrate. Surangam dimensions vary, with lengths ranging from 3 to 300 meters. The average length is approximately 33.08 meters, with widths ranging from 0.45 to 0.7 meters and heights ranging from 1.6 to 2 meters, typically matching the dimensions of the laborers who use to dig it. Extension of tunnel length is a common strategy to enhance water supply, sometimes necessitating the bifurcation of the main conveyance channel to reach more reliable water sources or bypass hard rock formations. (Crook et al., 2015).



### **Benefits**

The Surangam technique offers numerous benefits in sustainable agriculture and water management. By tapping into near-surface phreatic groundwater sources, Surangam provides reliable access to water for drinking and irrigation, crucial for small farm units typically found in the foothills of the Western Ghats. The construction of Surangam on short, steep slopes optimizes water utilization. particularly in areas with limited land space. The utilization of levelled terraces for farm dwellings and water harvesting structures enhances land productivity and promotes water conservation. Furthermore, the integration of Surangam with gravity-fed irrigation systems enables efficient water distribution, supporting diverse cropping patterns including areca plantations, coconut and bananas. The selection of construction sites based on ecological indicators ensures sustainability and resilience to environmental factors. Overall, Surangam technology empowers local communities with a reliable and sustainable water supply, contributing to agricultural productivity and livelihoods in the region.





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  (accessed on 1<sup>st</sup>
  June 2024)

4.3

# HAVELI BUNDIES CULTIVATION OF BUNDELKHAND REGION

### A traditional rainwater management technique

The haveli system, an ancient rainwater management technique in Central India's Bundelkhand region, historically addressed water scarcity and soil degradation. Negligence and environmental changes caused its decline. Efforts by organizations such as ICRISAT have revived it, incorporating modern features like masonry core walls. This revitalized system blends traditional knowledge with technology, enhancing water management and agricultural yields. Monitoring indicates positive outcomes, highlighting the significance of such initiatives for sustainable resource management in fragile ecosystems like Bundelkhand.

Centuries old haveli system vital for water management in Bundelkhand



Monitoring shows success in addressing water scarcity, boosting agriculture and improving livelihoods, highlighting the importance of sustainable management



The traditional haveli system, deeply embedded in Central India's Bundelkhand region for over three centuries, plays a vital role in managing rainwater and restoring degraded landscapes. Bundelkhand, known for its semi-arid climate and unpredictable rainfall, grapples with enduring issues like water scarcity, soil degradation and agricultural productivity. Historically, the haveli system emerged as a response to these challenges, evolving into a lifeline for the region's agricultural communities. Over time, however, the traditional haveli system faced various challenges, including negligence, poor maintenance and its inability to adapt to changing environmental conditions. Modernization and altered rainfall patterns further strained its functionality, leading to a decline in its effectiveness and relevance. Recognizing the need for revitalization, stakeholders sought innovative solutions to rejuvenate the haveli system, leveraging advancements in technology and expertise from research institutions and consortium partners. In response to





Fig. 39: Land restored by Haveli system in Bundelkhand region (Source: CGIAR)

these challenges, initiatives led by organizations like the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and collaborative efforts with local communities were undertaken to modernize the haveli system. Innovative approaches, such as the construction of masonry core walls with outlets, were introduced to enhance the system's efficiency and resilience to changing climatic conditions. These efforts were aimed not only to restore the functionality of the haveli system but also to improve its integration with modern agricultural practices and sustainable water management strategies. The revitalization of the haveli system has demonstrated promising results, showcasing its potential to address water scarcity, enhance agricultural productivity and uplift rural livelihoods in the Bundelkhand region. Through comprehensive monitoring and evaluation, the impacts of these interventions on landscape hydrology, land use dynamics, crop productivity, and household income have been documented. providing valuable insights for informed decisionmaking and sustainable natural resource management. Overall, the resurgence of the haveli system represents a convergence of traditional wisdom, technological innovation and collaborative efforts aimed at addressing the water and

agricultural challenges faced by fragile ecosystems like Bundelkhand (Singh et al., 2022).



## **Brief description of practice**

Historically, the haveli cultivation system emerged as a solution to harness rainwater effectively. Farmers constructed earthen embankments equipped with spillways, spanning lengths of 100-300 meters, across sloped terrain. These structures, strategically positioned to capture surface runoff during the monsoon, facilitated the recharge of shallow dug wells and borehole wells, ensuring water availability for agricultural activities during dry spells. During the post-monsoon period, impounded water was drained from the haveli structures, allowing for the cultivation of rabi crops using residual soil moisture. This innovative system not only preserved land from inundation during the monsoon but also significantly enhanced crop productivity, attributed to the enriched soil conditions resulting from decomposed organic matter and excess humus.



Fig. 40: Building a masonry core wall and spillway (top left); Capturing rainwater in haveli structures during the monsoon (top right); Removal of water from the haveli before planting post-monsoon crops (bottom left); Cultivating wheat crops on the haveli bed during the post-monsoon season (bottom right) (Source: Singh et al., 2022).



### **Benefits**

Revitalizing the haveli cultivation system in the Betwa catchment provides numerous benefits. By effectively managing rainwater through masonry core walls and spillways, the system ensures consistent irrigation, enhancing crop yields and food security while reducing water scarcity. Moreover, it combats soil erosion, preserving land productivity and promotes groundwater recharge vital for domestic and agricultural needs during dry periods. Cultivating rabi crops on haveli beds diversifies agriculture, reducing reliance on erratic rainfall. Enhanced crop productivity and reduced input costs lead to increased incomes for farmers. Additionally, communal management fosters social cohesion and empowers communities. Overall, the revitalized haveli system offers a sustainable solution to water scarcity, poverty and environmental degradation, fostering resilience and prosperity in the region.

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# 4.4

# **JOHADS**

# **Restoring water security in Haryana**

Johads are traditional earthen dams found in Haryana, India, primarily used for rainwater harvesting and groundwater recharge. These structures date back centuries and are crucial for sustaining agriculture in arid regions. Johads collect rainwater during the monsoon season, helping to replenish local water sources and support farming communities throughout the year. Johads represent an ancient yet effective method of water conservation and management in the region.

Johads are small
earthen dams
constructed along land
contours to store
rainwater during the
monsoon season



They are integral components of local water management strategies, helping to sustain agriculture and communities throughout the year



Haryana, a state nestled in the heart of northern India, has long grappled with water scarcity issues. The arid climate and erratic rainfall patterns exacerbate the challenge, leaving communities vulnerable to drought and water shortages. A traditional method of gathering water called Johad has come to light as a ray of hope in the midst of this hardship. The Raiasthani word "Johar", which means "to collect", is where the name "Johad" comes from. These structures are essentially small earthen dams built along the contours of the land to capture and store rainwater during the monsoon season. Johads date back centuries, with their origins traced to ancient India where communities relied on them to sustain agriculture and livestock through dry spells. In Haryana, Johads have become a vital component of water management strategies, particularly in rural areas where access to potable water is scarce. Traditionally, the responsibility of building and maintaining Johads rested with the local communities, fostering a sense of ownership and collective responsibility.







# **Brief description of practice**

Johads are simple yet ingenious structures designed to harness rainwater effectively. Constructed using locally available materials such as mud, stones and vegetation, Johads are low-cost and environmentally sustainable solutions to water scarcity. Building a Johad involves a meticulous process that draws upon local knowledge and expertise. Identifying suitable locations for Johads is critical for its effectiveness. Typically, areas with gentle slopes and natural depressions are chosen to maximize rainwater capture. Community consultations and participatory mapping exercises help determine optimal sites that align with local hydrological conditions. Skilled

laborers, often drawn from the local community. undertake the excavation process. Using simple tools such as shovels and pickaxes, they dig shallow depressions in the earth, carefully contouring the land to channel rainwater runoff towards the center of the structure. The excavated soil is then utilized to build embankments or bunds along the periphery of the depression. These embankments serve as barriers to contain the collected rainwater, preventing it from flowing out and facilitating percolation into the soil. The embankments are meticulously compacted to ensure structural integrity and minimize seepages. Johad structures exhibit variability in their shape, size and less depth, reaching approximately six meters. The landscapes adorned with numerous Johads, are usually interconnected via a network of channels, either situated underground or above ground level. Below-ground channels, locally termed as "Nullahas", serve as vital conduits, facilitating the seamless flow of rainwater from one Johad to another by gravitational force. This interconnectedness ensures efficient rainwater collection and redistribution, as excess water from elevated Johads cascades into those situated in lower-lying areas, eventually finding its way into the local streams. Consequently, this systematic drainage mechanism not only mitigates the risk of monsoon floods but also optimizes groundwater replenishment by maximizing rainwater retention within the landscape.

Fig 42: A distant view of Johad (Source: Indian Water Portal)



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In some cases, additional measures may be taken to reinforce the Johad and enhance its longevity. This may involve incorporating stones, boulders or vegetative materials into the embankments to stabilize the structure and prevent erosion. Traditional knowledge passed down through generations informs these reinforcement techniques, ensuring their effectiveness in local contexts. Vegetation plays a crucial role in Johad construction and maintenance. Native plant species with deep root systems are often planted along the embankments to prevent soil erosion and enhance water infiltration. These plants not only stabilize the soil but also contribute to groundwater recharge and biodiversity conservation. Once constructed, Johads require regular maintenance to ensure optimal performance. This may include desilting to remove accumulated sediment, repairing embankments damaged by erosion or wildlife and clearing vegetation to prevent obstruction of water flow. The annual ritual of desilting plays a pivotal role in preserving the functionality and significance of Johads within the community. This practice entails the removal of accumulated sediment from the Johads, thereby maintaining their storage capacity and effectiveness. By adhering to this tradition, communities safeguard these ancient waterharvesting structures, ensuring their continued utility and societal value. Furthermore, the regulation of monsoon floodwaters through Johads not only prevents potential damage to infrastructure and crops but also fosters groundwater recharge, contributing to the sustainable management of water resources in the region.

Johads represent a time-honored tradition of water conservation and management, deeply embedded in the cultural fabric of the region. Their intricate design and interconnectedness exemplify the ingenuity of traditional water-harvesting practices, offering a sustainable solution to water scarcity and flooding woes. As communities continue to uphold the legacy of Johads through practices like desilting, they not only preserve their rich heritage but also ensure water security for future generations.



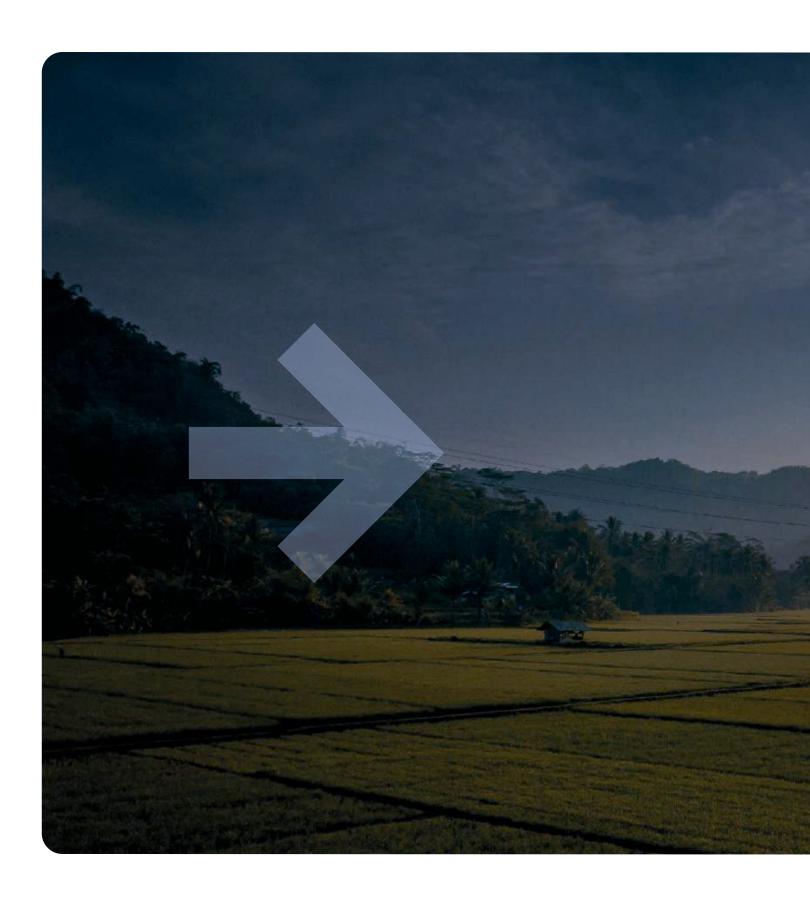
## **Benefits**

The resurgence of Johads in Haryana might yield a plethora of benefits, ranging from improved water availability to socio-economic empowerment. By

capturing and storing rainwater. Johads mitigate the impact of droughts and erratic rainfall, ensuring a steady supply of water for drinking, irrigation and livestock. This resilience is particularly crucial for agrarian communities reliant on rain-fed agriculture for their livelihoods. The percolation of rainwater into the soil recharges groundwater aguifers, replenishing depleted reserves and enhancing the sustainability of water sources. This, in turn, supports the long-term viability of farming activities and reduces dependence on unsustainable groundwater extraction.

Johads act as micro-watersheds, creating conducive environments for native flora and fauna to thrive. The presence of water attracts wildlife. fostering biodiversity conservation and ecological balance. Additionally, the vegetation surrounding Johads helps prevent soil erosion and desertification, preserving fragile ecosystems. The revival of Johads is a testament to the power of community-led initiatives in addressing water scarcity. By actively participating in the construction and maintenance of Johads, local residents reclaim agency over their water resources, fostering a sense of ownership and collective stewardship. In the face of climate change-induced uncertainties, Johads offer a sustainable adaptation strategy for vulnerable communities. By harnessing naturebased solutions, such as rainwater harvesting. Haryana can build resilience against extreme weather events and ensure the well-being of its populace.

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# An indigenous irrigation method of South Bihar

The Ahar Pyne system is a traditional water management technique from Bihar, India. It consists of interconnected ponds (ahars) and channels (pynes) that capture and distribute rainwater for irrigation. This ancient system helps to recharge groundwater, mitigate droughts and support agriculture in the region.

Ahar Pyne System showcasing the indigenous knowledge of sustainable water management



Supports agricultural productivity by ensuring reliable water supply for irrigation, crucial for the region's economy



Contributes to groundwater recharge, helps in flood control/ and sustains ecosystems in the area



Bihar, characterized by a continental monsoon climate and a predominantly agrarian economy, showcases a blend of rural and semiurban landscapes. Traditional farming practices play a pivotal role, yielding diverse crops such as rice, wheat, pulses, vegetables and fruits. In the southern region of Bihar, however, water management poses significant challenges due to the terrain and soil characteristics, marked by poor water retention and low groundwater levels. The Ahar Pyne system, an indigenous irrigation method, addresses these challenges by harnessing floodwater for cultivation, primarily benefiting paddy farming in the region.

The Ahar Pyne system, deeply rooted in historical agricultural practices dating back to the Magadhan kingdom era, has evolved as a response to the unique agroclimatic conditions of the region. Comprising two key components – the 'pyne' channels and 'ahar' retention ponds – this system employs raised embankments and catchment basins to harvest and store water for irrigation purposes. Unlike conventional tanks, Ahars feature embanked structures that facilitate water retention, aiding both Kharif and Rabi crop cultivation.



Fig. 43: Ahar Pyne, traditional irrigation management method of South Bihar (Source: India Climate Dialogue)





# **Brief description of practice**

Currently, the Ahar Pyne system is being revitalized in drought-prone areas of Bihar to support landless farmers under the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA). The system's intricate design, with raised embankments and natural gradient-based catchment basins, allows for efficient water utilization during both rainy and dry seasons. Pynes, artificial channels originating from rivers and streams, play a crucial role in diverting floodwater to ahars for storage, ensuring continuous water supply for agriculture.

Ahar Pyne networks are strategically structured to optimize water distribution across farming communities. Utilizing a series of embankments, channels and reservoirs, the system efficiently manages flood discharges, especially during high river spates. Traditional governance mechanisms, such as the Parabandi System used to regulate water allocation among villages, ensuring equitable access and timely irrigation throughout the agricultural calendar.

The Ahar Pyne system boasted meticulously devised institutional mechanisms for equitable water distribution among farmers. Agricultural activities were synchronized throughout the year by allocating specific 14-day periods according to the lunar cycle for various farming operations as

detailed in Table 6. Traditionally, landlords designated individuals to oversee water allocation among tenants. The Parabandi System, employed for water distribution from a communal source. typically a Pyne, derived its name from "Para" (turn) and "Bandi" (fixation), signifying the fixation of turn. Each village adhered to predetermined schedules, stipulating the number of days and hours allotted for water usage, established through mutual agreements or ancient customs. In certain systems, a detailed register known as the "Lal Bahi" (red register) delineated the irrigation rights of each village. Parabandi arrangements typically commenced in Aswin (mid-September), coinciding with heightened demand and limited supply. During other periods, all branches of Pynes remained open. The reliability and punctuality of Ahar irrigation stemmed from reservoir storage, ensuring water availability when Pynes were depleted and rainfall was scarce, particularly crucial during the hathia period when paddy cultivation required ample water (Pant, 1998). While water equity was not guaranteed, it was inherently ingrained in the system. The fragmented nature of landholdings within each command area meant that major landholders with influence over allocation had vested interests both upstream and downstream of the distributary. Insufficient water supply reaching the tail end left portions of the command area unirrigated, affecting all stakeholders. Pynes supplied multiple Ahars, with several distributaries originating from each Ahar, contributing to the intricate water distribution network.

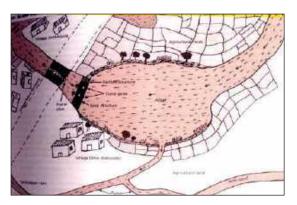


Fig. 44: Structure of Ahar-Pyne (Source: Sharma and Kumar, 2013)

Table 6: Timing of agriculture operations in Ahar Pyne system

S. No	Period	Operation
1	June 20 to July 5	Seed bed sowing
2	July 18 to August 15	Transplantation
3	September 12 to September 25	Field water drained out
4	September 26 to October 7	Fields filled again
5	October 8 to October 20	Standing water in Fields
6	October 21 to November 3	Field water Drained out
7	November 4 to November 15	Harvesting

(Source: Aggarwal and Narain, 1997)



## **Benefits**

A notable trend observed in the Ahar Pyne regions, as well as in south Bihar and adjacent areas, is the prevalence of small, fragmented and dispersed land holdings among farmers. Consequently, every landowner within a Pyne's command area possesses plots situated at various points along the irrigation channel, encompassing advantageous positions at the head, middle and disadvantaged locations at the tail. Thus, farmers are compelled to actively engage across all circumstances to optimize their irrigation practices.

Historically, the Ahar-pyne system served as the most economical and accessible means of irrigation in the region, requiring collective efforts from villagers. Under this system, major repairs are undertaken by the government, alleviating cultivators from bearing any water-related expenses. Consequently, farmers readily participate in collective maintenance activities or respond to emergencies such as breaches in pyne or embankments without hesitation.

In this farming practice, uniformity prevails in crop selection, primarily rice cultivation, throughout the irrigation command, with farmers synchronizing their planting and harvesting activities. Given the collective utilization of Ahars and Pynes, agricultural operations undertaken by cultivators remain consistent across the entire irrigation command.

Communal engagement in irrigation operations and maintenance. known as "Goam." involves large groups working collectively. The construction of Ahar Pynes exemplifies the extraordinary joint efforts of individuals against the challenges posed by nature. Despite the existence of a rigid caste hierarchy in South Bihar, similar to other regions of India, various caste groups, including scheduled castes, unite for the collective welfare and shared concerns. Cultivators drawing water from the same Pyne or Ahar, irrespective of their village locations or castes, join forces for collective action whenever their irrigation activities face disruptions or potential threats.

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# **ARTIFICIAL GLACIERS** (ICE STUPA) OF LADAKH

An innovative initiative addressing water shortage in cold desert of Northern India

Ladakh, a frigid desert region in northern India, relies on glacial streams for agriculture, facing water scarcity in April to May and excess water in mid-June. Chewang Norphel, known as the 'Ice Man,' pioneered artificial glaciers, addressing water shortages. Sonam Wangchuk's innovative "Ice Stupa" project, aided by crowdfunding and government support, creates ice structures storing water for spring irrigation, now expanding across Ladakh, easing water scarcity and boosting tourism.

Ladakh, a cold desert, faces acute water scarcity due to minimal rainfall and melting snow, exacerbated by disappearing Himalayan alaciers



**Chewang Norphel and Sonam** Wangchuk pioneered solutions like artificial glaciers and ice stupas, harnessing freezing temperatures to create reservoirs that provide water for crops during crucial months, sustaining farming communities



These inventive solutions not only address water scarcity but also attract tourism, with plans to expand the number of ice stupas, highlighting the success of combining traditional wisdom with modern engineering to combat environmental challenges



Ladakh is a Trans-Himalayan Mountain desert in the extreme north of India with villages located at 2,700m to 4,000m altitudes. It is a cold desert with winter temperatures touching -30° C and an average annual rain/snow fall of only 100 mm. Human settlements are almost always located around glacial streams which feed into the Indus and other rivers as tributaries. The key to human settlement in this cold desert is the art of diverting water from the streams through meticulously built canals toward deserts to grow crops like barley, wheat, vegetables and trees like apricots, apples, willow and poplar. Most villages face acute water shortage, particularly during the two crucial months of April and May when there is little water in the streams and all the villagers compete to water their newly planted crops. By mid-June there is an excess of water and even flash flooding due to the fast melting of the snow and glaciers in the mountains. By mid-September all farming activities end, and yet a smaller stream flow throughout the winter steadily but wastefully going into the Indus River without being of use to anybody. The problem is getting worse with time as Himalayan glaciers are disappearing due to global warming and local pollution.



COMPENDIUM OF SUSTAINBLE LAND MANAGEMENT

Fig. 45: A traditional stone stupa in the Phyang valley in Ladakh (Source: Sonam Wangchuk)



Padma Shri awardee Er. Chewang Norphel is popularly known as the 'Ice Man of Ladakh' is the first person who worked on creating artificial glaciers in Ladakh. He has built over 17 artificial glaciers in the region. An artificial glacier holds the melt-water that flows down the mountains into streams and ultimately rivers. It is stored within the bunds, freezes in layers and used when it melts in the springtime, just when the fields need watering. Artificial glacier is built with traditional wisdom and introduces and combines modern engineering techniques. In 2015, Sonam Wangchuk managed to raise some funds through crowdfunding and created a 64 feet ice stupa. The water freezes into a cone, which resembles a Buddhist shrine. The intelligent stupa is designed in a way that it remains frozen until the sun warms the fields during the springs, making irrigation and cultivation manageable for farmers in the village. The government has also joined the project and with the combined efforts of the Ministry of Tribal Affairs and Wangchuk, the number of ice stupas in Ladakh are increasing. In the year 2013, the stupa was just in one village; today, there are 26 such ice stupas across Ladakh (after the government joined in 2019-20). As of now, the inventor is preparing to create 50 more ice stupas that will provide 10 million liters of water a year. Besides solving the water crisis in the region and reinhabiting several ghost villages, these inventive stupas have also become an important tourist attraction in Ladakh (The Times of India, 2020).



# **Brief description of practice**

The idea is very simple and needs no pumps or power because water maintains its level. Therefore, water piped from 60m upstream would easily rise close to 60m up from ground when it reaches the village. The water flowing through pipe were exposed to -30 to -50°C temperature during winter nights and freezes to form ice. After the water freeze at the ground level the pipe is mounted higher, meter by meter as the thickness of the ice grows, finally reaching the height of the source from where the water is piped.

The idea is also to conserve this tower of ice for longer duration in the summer as much as possible to feeds the fields until the real glacial melt waters starts flowing in June. Since these ice cones extend vertically upwards towards the sun, they receive fewer sun's rays per unit volume of water stored; hence, will take much longer time to melt compared to an artificial glacier of the same volume formed horizontally on a flat surface.

Ladakh's ice stupas melt down in late spring when the need for water is greatest. The prototypical stupa erected in the winter of 2013 contained 150,000 liters of frozen water and lasted until May 18, 2014 according to a report published in 2023.



Fig. 46: Ice Stupa in Ladakh (Source: NATGEO)



### **Benefits**

The Ice Stupa in Ladakh offers several benefits. It maintains regular water supply for the local people. Ice stupas serve as a reliable water source during the dry months when glacial streams run low. By storing excess winter water in the form of ice, they provide irrigation for crops and sustain livelihoods. It also helps in climate change mitigation as Himalayan glaciers recede due to global warming; ice stupas help offset water scarcity caused by glacier melt. They also contribute to local adaptation strategies against climate change. The concept of creating artificial glaciers has captured global attention. Ice stupas demonstrate human ingenuity and creativity in addressing environmental challenges. It also promotes tourism and awareness. Ice stupas have become tourist attractions, drawing visitors who are fascinated by these man-made glaciers. Through tourism, awareness about water conservation and climate change spreads. Finally, the ice stupas play a crucial role in ensuring water availability, combating climate change and inspiring sustainable solutions in Ladakh.

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Community-driven water management in mountainous regions of Himachal Pradesh

The Kulh irrigation system in Himachal Pradesh, India serves as a remarkable example of community-driven water management in mountainous regions. For over 300 years, local farmers have sustained agriculture through interconnected canals known as Kulhs. These ancient water channels facilitate the distribution of water for crop cultivation. Despite facing challenges such as erratic rainfall patterns and disappearing springs, the community collaborates to revitalize watersheds and renovate the Kulhs. By doing so, they address contemporary environmental issues, including climate change impacts and water disputes. This traditional system underscores the importance of community participation and traditional knowledge in achieving sustainable water resource management.

The Kulh irrigation system in Himachal Pradesh showcases a community-centric approach to water management, utilizing interconnected canals known as Kulhs to sustain agriculture in mountainous terrains

Kulhs are shallow surface channels diverting water from streams or springs to cultivated fields, showcasing a traditional Babylonian technique adapted for the region's hilly topography



The Kulh irrigation system is a traditional and ingenious method of water management practiced in the mountainous regions of Himachal Pradesh, India. Originating from the need to sustain agriculture in hilly terrains where water sources are not always readily accessible, this system exemplifies a community-driven approach to resource management. The term "Kulh" is derived from the local dialect and signifies the interconnected nature of the canals in this irrigation system. The Kulhs have a history dating back 300 years and play a crucial role in supporting agriculture in the region. Kulh management was often a hereditary post, falling under the purview of a family appointed by the ruler. Kulhs are water channels found in precipitous mountain areas. Kulhs are shallow surface channels diverting water from naturally flowing streams or springs, to cultivated fields, and mainly used for flood irrigation. These channels carry water from glaciers to villages of Himachal Pradesh. Kulhs are one of the best





COMPENDIUM OF SUSTAINBLE LAND MANAGEMENT





examples of community managed water governance systems built on the principle of natural gravity-flow hydraulics. A retaining wall diverts the flow of the stream to the channel taken along the natural gravity path to distribute to the land owners downstream. The channel is built using locally available stones and gravel, needing annual repairs.

Agricultural farms in the state are largely reliant on rain which has become erratic. About 70 % of the population living in the mountainous regions of Himachal Pradesh is dependent on agriculture for their livelihood (Nitu and Singh, 2016). Constraints around climate, geography and the socio-economic landscape have limited the agricultural productivity of the region. The people who live there often depend on natural water springs for drinking water supply, household activities and irrigation. But in recent times, most of the springs have either become seasonal or have been extinct, largely due to ecological imbalances. As a result, farmers face a dual problem - availability of water and access to that water to irrigate their fields. Working together in groups, with support from developmental agencies, farmers are revitalising watersheds and springs, and renovating ancient Kulhs to channel that water directly to their fields to provide direct access.

The Kulh irrigation system not only supports agriculture but also fosters a strong sense of cooperation and community responsibility (Sharma

et al., 2015). However, it faces challenges such as reduced water flow due to climate change, increased demand for water, and sometimes, disputes over water sharing. The Kulh system of Himachal Pradesh is a remarkable example of sustainable water resource management adapted to the specific ecological and social conditions of the region. It underscores the importance of traditional knowledge and community participation in addressing contemporary environmental challenges.



# **Brief description of practice**

In Himachal Pradesh, Kulhs are built along the hill gradient for maintaining proper gravity for irrigation. Kuhls are commonly found in West Himalayas cold deserts. The technique for the preparation of Kulhs for irrigation purposes seems to have originated since Babylonian times, it is still one of the commonest ways of bringing water to the crops. If the river has a steep gradient, water is diverted into a canal some distance upstream and led along a contour so that it can flow to fields by gravity. Kulhs are sometimes made by making notches at the natural water sources and the water is diverted to the fields for irrigation to different terraces, using the natural gravitational flow of water. Since the

topography of the area consists of very high slopes and rocky terrain's, wooden water channels are used at many places as water passes from one place to another. In the lower areas of Himachal Pradesh, bamboo pipes are commonly used as irrigation channels on depressions/small nala. In west Himalayan cold deserts for the optimum harnessing of water for irrigation, water channels are constructed along the natural gradients. The irrigation channels (Kulhs) are diverted from river tributaries by making use of the natural gradients thus the level of water is higher than that of the cultivated fields. In upper Kinnaur, the channels (Kulhs) are simply dug in the ground to regulate the flow of water. However, where the digging of channels is difficult or the channel has to pass through a village path, underground channels covered with stone slates are constructed. However, in some parts the wooden channels are also used which are put like a bridge over the path. These channels are made by making a deep grove in the tree trunk or a thick branch.



#### **Benefits**

In adopting traditional irrigation systems like the Kulh in Himachal Pradesh, farmers are transitioning from subsistence to commercial agriculture, favouring the cultivation of high-value crops such as vegetables and fruit trees over traditional maize. This shift has led to the conversion of wasteland into productive agricultural land, expanding cultivation areas and increasing incomes. By providing a dependable irrigation source, Kulhs facilitate multiple crop cycles per year, bolstering agricultural output and food security in rugged terrains. Equitable water distribution through rotational sharing schemes fosters harmony and cooperation within communities. Compared to modern large-scale irrigation infrastructures, Kulhs have minimal environmental impact, utilizing existing water flows and requiring modest alterations to the landscape. Cost-effective and adaptable, Kulhs embody traditional knowledge and practices, contributing to cultural heritage preservation and imparting valuable lessons in resource management and cooperation among villagers, especially the youth (Baker, 2005).

The Kulh irrigation system, intrinsic to Himachal Pradesh's heritage, offers numerous benefits, particularly in promoting sustainable agriculture



Fig. 48: Traditional system of irrigation Kulh in Dashal Village, Kullu, Himachal Pradesh (Source: Dr Hans Raj)

and community cohesion in mountainous regions. Designed to channel water efficiently, Kulhs minimize wastage due to runoff. Managed collectively by local communities, Kulhs foster a sense of ownership and responsibility towards natural resources, ensuring that the system adapts to the needs of all users.

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5.4

# BAMBOO DRIP IRRIGATION SYSTEM OF MEGHALAYA

Tribal technology of the Khasi and Jaintia hills for efficient irrigation

In Meghalaya, where rainfall is abundant but irrigation is challenging due to hilly terrain, traditional farmers utilize a Bamboo drip irrigation system, dating back 200 years, to irrigate crops on steep slopes. This ingenious gravity-based system employs bamboo pipes to transport water from distant sources, reducing water flow to a precise 20-80 drops per minute at the plantation site. Predominantly used by tribal farmers in Khasi and Jaintia hills, this system optimizes locally available materials and gravity, allowing for efficient irrigation in areas with inaccessible ground channels.

Bamboo drip irrigation system overcome challenges posed by hilly terrain and poor water retention capacity, facilitating precise water distribution to plantation sites



Highlighting the importance of bamboo forests in sustaining indigenous irrigation practices



Meghalaya is renowned for having the highest annual rainfall of about 11,500 mm. Despite the abundance of rain during the monsoon season, the state requires a well-managed irrigation system during the dry spell. Hill farming in Meghalaya faces significant challenges due to its undulating topography, steep slopes and poor, shallow soils prone to erosion. Most agricultural fields are situated on hilly slopes, leading to poor water retention capacity. Transporting water from distant sources to these fields poses a considerable challenge for rural farmers. Ground channeling is impractical due to the undulating landscape. To overcome these adverse conditions, the traditional farmers of Meghalaya have innovated the bamboo drip irrigation system. This system, based on gravity and facilitated by the steep slopes, captures water from uphill sources and transports it to plantations through a main bamboo channel, which can run for several kilometers. The water is then distributed via a complex network of secondary and tertiary bamboo channels to all parts of the field or plantation.



Fig. 49:
Bamboo drip
irrigation - A
marvel to
Meghalaya's
native
farmers
(Source:
Zizira
Agricultural
Service)





# **Brief description of practice**

The bamboo drip irrigation system is an ingenious system for tapping stream and spring water using bamboo pipes to irrigate plantations. It is highly efficient, capable of transporting about 18-20 liters of water per minute over several hundred meters, reducing to 20-80 drops per minute at the plant site. This system, perfected over 200 years, is primarily used by the tribal farmers of the Khasi and Jaintia hills to irrigate crops such as betel-leaf and black-pepper in areca-nut or mixed orchards. Bamboo pipes divert perennial springs from hilltops to lower reaches by gravity. The channel sections, made of bamboo, divert and convey water to the plot site, distributing it without leakage into branches made from different forms of bamboo pipes. Manipulating the intake pipe positions controls the water flow into the lateral pipes. The final channel section ensures water is dropped near the plant roots.

This system is prevalent in the 'war' areas of Meghalaya, particularly in the 'war' Jaintia hills and the Muktapur region bordering Bangladesh. The steep slopes and rocky terrain make ground channels impractical. Cultivation land is owned by the clan and allocated by clan elders on payment of a one-time rent, with leases lasting as long as

the plants survive. Once the plants die, the land reverts to the clan for reallocation.

Meghalaya has approximately 3,108 square kilometers of bamboo forests. In 1990, the total bamboo yield was estimated at 2.09 tons per hectare per year (MSME, 2016). The region hosts 38 bamboo species, harvested and managed by the Autonomous District Councils (ADC). Bamboo supplies face threats from rodent populations, gregarious flowering, disease and large-scale extraction. Conservation efforts are underway in northeastern states to protect over 50% of India's bamboo supply. Despite attempts to introduce modern pipe systems, farmers prefer their indigenous bamboo irrigation methods.

Modified bamboo drip irrigation: The modified bamboo drip irrigation system involves laying bamboo from the water source as the mainline, with lateral bamboo lines connected above properly spaced crop plants. Holes in the bamboo allow water to drip directly onto each plant. The bamboo height is maintained in such a way that it permits the farmers to move underneath for inter cultural operations like hoeing, weeding, etc. The mainline ends are closed, and holes are made to convey water to the laterals, which also have holes above individual plants for drip irrigation. For efficient water use, woolen threads tied to caps in the lateral holes manage drip speed and target specific crop areas. If irrigation is complete, the flow can be stopped by pulling down the threads.

This system saves about 25-30% of water compared to traditional methods and is cost-effective for cash crops like potato, capsicum, tomato and strawberry, grown with definite spacing. Bamboo pipes of varying diameters are used for channels, support structures, diversion pipes and strips, held above ground by bamboo or wooden Y-shaped sticks. The outer casing and internodes of bamboo pieces are partially removed, and sections are lashed together with thin bamboo strips. Indigenous tools like a dao (a local axe) and chisels are used to build the network.

The bamboo pipes divert spring water from hilltops to lower areas by gravity. Water is distributed without leakage into branches made from bamboo. Manipulating intake pipe positions controls flow into lateral pipes. The final channel section delivers water near plant roots. The bamboo channel is smoothed using a dao and round chisel. Small pipes and channels of varying sizes divert and distribute water from the main channel through four to five stages from diversion to application (Swami, 2021).

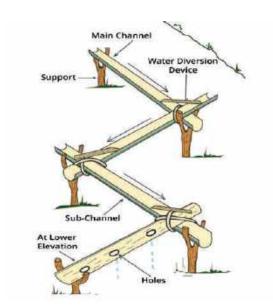


Fig. 50: Technique of bamboo drip irrigation (Source: Zizira agricultural service)



#### **Benefits**

The bamboo drip irrigation system in Meghalaya harnesses the natural landscape and locally available materials, primarily bamboo, to transport

water from springs and streams to the fields below. This sustainable irrigation method offers numerous benefits. Environmentally, it has a low impact due to the use of renewable bamboo and it conserves water by minimizing evaporation and runoff, delivering water directly to plant roots. Economically, it is cost-effective because it utilizes local materials and traditional knowledge, reducing the need for expensive resources and technology. Once set up, it requires minimal maintenance, thereby lowering labor costs. Culturally, this system preserves traditional knowledge passed down through generations and promotes community collaboration, strengthening social bonds and collective responsibility. Agriculturally, bamboo drip irrigation enhances crop yields by providing a steady, controlled water supply, crucial in drought-prone areas and supports crop diversification, improving food security and income for farming households. Additionally, the system is highly adaptable and resilient, customizable to specific farm topographies and scalable with minimal effort and cost. It offers a climate-resilient solution to varying water availabilities without complex technology. The system also holds educational value, serving as a platform for learning sustainable practices and agricultural innovation. Overall, bamboo drip irrigation in Meghalaya exemplifies sophisticated, sustainable indigenous engineering, providing a model of ecofriendly development that could inspire similar practices in other mountainous or resource-limited regions globally.

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# 5.5

# KHADIN CULTIVATION OF JAISALMER, RAJASTHAN

# Sustainable farming in arid Rajasthan

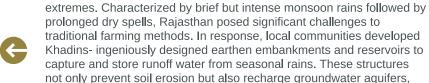
Ancient Khadin cultivation techniques in the arid Jaisalmer district of western Rajasthan have been crucial for maintaining consistent agricultural yields despite minimal and unpredictable rainfall since the 15th century. These systems utilize runoff water to cultivate fertile soils, providing a sustainable solution for desert communities to produce food without environmental harm. Embedded in local tradition, Khadin cultivation has historically supported populations by storing surplus food during favorable rainy seasons.

Runoff farming is crucial in arid and semi-arid regions where droughts lead to unstable food production and malnutrition. Various runoff farming systems are practiced globally to combat these challenges



Khadins are long earthen embankments built across lower hill slopes, designed to harvest rainwater and utilize residual moisture for crop production. This system leads to progressive increases in crop yields by accumulating fresh silt and clay in the Khadin bed, making it a promising solution for enhancing crop production in hyper-arid regions like Jaisalmer

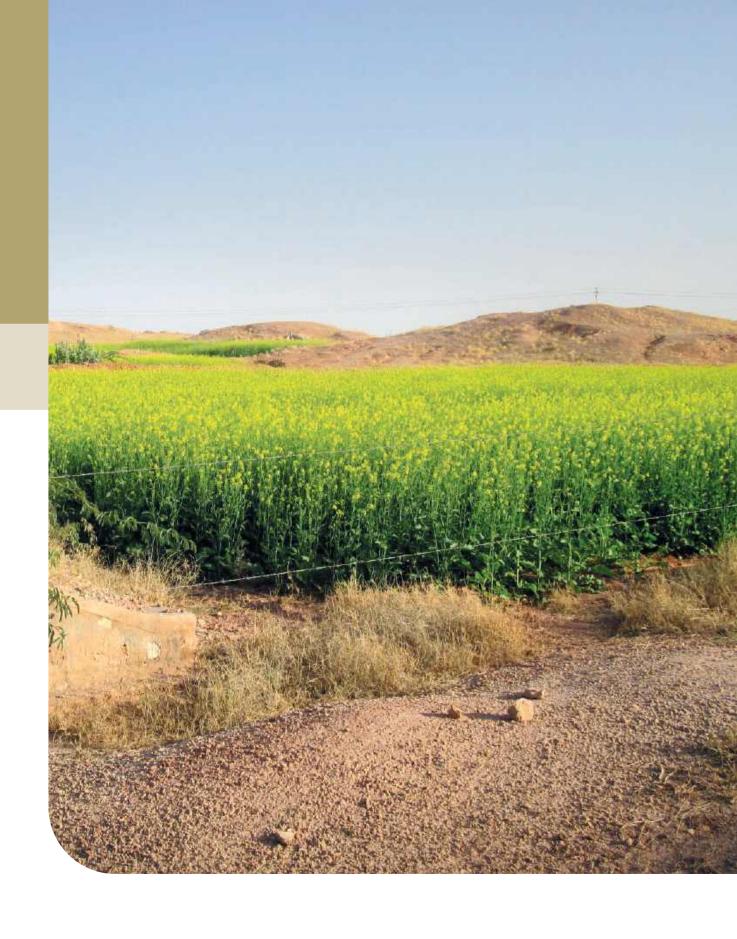
In the arid landscapes of Western Rajasthan, where the scorching sun in unpredictable rainfall define the climate, Khadin cultivation stands a testament to human ingenuity and resilience. This ancient farming practice, dating back to the 15th century, or earlier, has enabled communities to thrive amidst challenging environmental conditions, transforming barren expanses into fertile agricultural lands.



providing a reliable water source for crops throughout the year.

Khadin cultivation emerged as a response to the region's climatic

The essence of Khadin cultivation lies in its integrated approach to water management and agriculture. During the monsoon season,



Khadins collect runoff water, allowing it to percolate into the soil and replenish moisture levels. This stored water supports a diverse range of crops, from hardy cereals like millet and barley to pulses and vegetables, ensuring food security and livelihoods for local farmers. (Prasad et al., 2004).

Beyond its practical benefits, Khadin cultivation holds profound cultural and social significance for

communities in Rajasthan. It is deeply intertwined with local traditions, rituals and communal practices, reflecting a harmonious relationship between humans and their natural surroundings. The knowledge of constructing and maintaining Khadins is passed down through generations, reinforcing community bonds and preserving ancestral wisdom.



# **Brief description of practice**

The main feature of Khadin is a very long (100 to 300 m) earthen embankment built across the lower hill slopes lying below gravelly uplands. Sluices and spillways allow excess water to drain off. The Khadin system is based on the principle of harvesting rainwater on farmland, and use residual moisture for crops production. The ratio of the catchment area to the storage area for a Khadin depends on both catchment characteristics and rainfall patterns. The ratio between cultivated and catchment areas varies from 1:15 to 1:56. The relationship between rainfall-runoff for Khadin was developed, which can be used for prediction of runoff and crop planning in the Khadin. The total energy input of rainwater, sand-silt-clay accumulation and cultivators' own activities are inter-woven into a complete production system of temperate crops. There is progressive increase in

crop yields every year as more and more fresh silt and clay accumulate in the Khadin bed. The ratio of farmland and catchment areas is maintained so that a suitable moisture supply is uniformly maintained. The water holding capacity and water infiltration rate are balanced by the shallow depth of soils in the beds. The basement of Khadin is invariably a hard surface upon which sand-silt clay is made to accumulate just to a depth of few meters. This maintains a convenient supply of natural moisture and nutrients within the crop's root zone. Few wells are generally kept on down side of earthen bund: they are recharged from water in Khadin and the water is used during summer when Khadin bed dries. Research on Khadin soils indicated that these are more fertile than other desert soils. The Khadin has great promise for enhancing crop production in hyper-arid region like Jaisalmer (Goyal et al., 2018).

Fig. 51: Techniques of Khadin (Source:Gee ks for geeks)

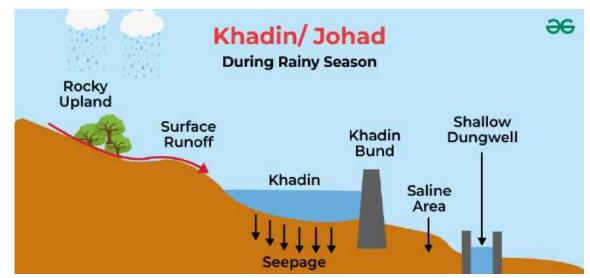






Fig.52: Khadin, filled with rain water (Source: Bhaskar)



#### **Benefits**

Water Management: Khadins are designed to capture and store rainwater during the brief but intense monsoon season. This stored water is then used to irrigate crops during the dry periods.

**Soil Fertility:** The runoff water collected in Khadins carries sediments, enriching the soil with nutrients and improving its fertility.

Sustainability: This method allows for sustainable agriculture in arid environments, reducing dependence on unpredictable rainfall and mitigating risks of crop failure.

**Community Support:** Khadin systems are deeply embedded in local traditions and have historically supported desert communities by providing a reliable source of food and livelihood.

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# ERITECHNIQUE OF KANCHIPURAM, TAMIL NADU

# Tank irrigation in south India: Tradition of sustainability

In Tamil Nadu, an ancient engineering marvel diverted river water into cascading tanks through earthen channels. These tanks efficiently irrigated villages, aided in water conservation, and controlled floods. Historically, tank irrigation played a crucial role in South India. However, its usage declined significantly over the years—from 92% in the 1970s to a mere 5.18% by 2001. Despite tank irrigation's continued dominance in places like Kanchipuram, the rise of individual sources like borewells and tubewells gained prominence and poses a challenge to this traditional water management method.

Tamil Nadu's Eri system, utilizing man-made tanks, plays a vital role in irrigation, flood control and groundwater recharge



The interconnected Eris in Kanchipuram demonstrate ancient engineering and cultural significance, serving as essential communitymanaged water resources for sustainable agriculture and ecological balance



South India has a rich tradition of tanks with the three southern states of Tamil Nadu, Karnataka and Andhra Pradesh contributing to close to 92% of the total irrigation by tanks in the 1970s. Two decades later, this number dwindled to close to 53%. A decade after that, in 2001, the total contribution of tank irrigation in all of India was estimated to be just around 5.18% only. In stark contrast, other sources of irrigation such as borewells and tubewells have clocked consistent increase in percentage use (GoI, 1985-86; 1989-90).

Tamil Nadu has no perennial rivers; they are all fed by the monsoons. These rivers have to cross state boundaries before they irrigate the fields downstream. Several hundred years ago, a system was devised to utilize the water flowing in the rivers to the fullest before it reached the sea. It was a simple act of engineering that diverted the river water into tanks through dug out earthen channels, which in turn took care of the irrigation needs of neighbouring villages. While it was easy to divert water to nearby villages, it wasn't that simple to connect those that were



far away from the source. Engineers devised a simple solution- a series of cascading tanks. The outflow from one tank would serve as the inflow for the next one in the series since the tanks were designed to allow the excess water to flow out after it has reached its capacity. The thought and effort put into designing these massive chains of receptacles and over-flow channels hundreds of years back is awe-inspiring. An Eri or tank system is one of the oldest forms of water conservation systems in India. Many Eris are still in use in Tamil Nadu and play an active role in irrigation. They act as water reservoirs and flood control systems. They prevent soil erosion, recharge groundwater, and prevent wastage of runoff water during heavy rainfall.

Eris are of two types - system and non-system Eris. System Eris are those which are fed by streams of rivers through a channel, while the nonsystem ones are stand-alone isolated tanks fed by rain. Most of the tanks in Tamil Nadu are system Eris. Kanchipuram has a total of 1942 tanks irrigating over 60,000 hectares of farmland in the district.





# **Brief description of practice**

The Eri system of Kanchipuram in Tamil Nadu is a traditional water management system that utilizes man-made lakes or tanks. These tanks are crucial for irrigation, groundwater recharge, and flood management in the region. Historically, Eris were interconnected through a network of canals that allowed for the transfer of water from one tank to another, thus optimizing water use across different areas and agricultural fields.

In Kanchipuram, these tanks are not only vital for supporting the agriculture that predominates the region but also hold significant cultural and religious importance. Many Eris are associated with local temples and are part of the spiritual and communal life of the people. The system

exemplifies ancient engineering wisdom where community-managed water resources helped sustainably manage the hydrology of the region, even in times of scarce rainfall. Today, efforts are ongoing to restore and maintain these Eris, recognizing their value in sustainable water resource management and the ecological balance of the area.





Fig. 53: Eri technique practiced in Tamil Nadu (Source: Ìndian Water Portal)



#### **Benefits**

The Eri system of Tamil Nadu provides numerous ecological, economic and social benefits. It ensures a reliable water source for irrigation, supporting the agriculture-dependent economy and enabling multiple cropping cycles and crop diversification, particularly crucial during the dry season. Eris aid in groundwater recharge by facilitating water percolation, maintaining groundwater levels for wells and borewells. They also act as flood buffers during monsoons, reducing flood damage to crops, property and infrastructure. Biodiversity conservation is another key benefit, as Eris support various species of fish, birds and aquatic plants, enhancing local biodiversity. By mitigating droughts and floods, the Eri system builds climate resilience, helping communities cope with increasingly unpredictable weather patterns. Additionally, Eris hold sociocultural significance, being integral to local cultural

practices and community gatherings. Economically, they support fisheries and lotus farming, providing livelihood opportunities for local families. The scenic beauty and cultural significance of Eris also have tourism potential, promoting eco-tourism and educational tours. Overall, the Eri system exemplifies the wisdom of traditional ecological knowledge and its relevance in contemporary environmental management.

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5.7

# SYSTEM OF WATER FOR **AGRICULTURE** REJUVENATION (SWAR) IN **HYDERABAD**

A low water consuming sub-surface drip irrigation system for drought-prone areas

The System of Water for Agriculture Rejuvenation (SWAR) addresses India's water scarcity in agriculture with an innovative sub-surface drip irrigation system developed by the Centre for Environment Concerns (CEC). SWAR delivers moisture directly to plant roots, enhancing soil nutrients and transforming the livelihoods of farmers in droughtprone areas. SWAR approach earned the Global Champion **Innovation Prize for Water and Forestry at the 2015 Paris** International Agricultural show.

**SWAR** introduces the world's first sub-surface drip irrigation system, delivering moisture directly to plant roots and reducing water requirements significantly



**SWAR follows five key** principles-Moisture delivery. measurement, microbe fostering, mycorrhizae application and management tools-to improve water efficiency, soil health and crop vields



**SWAR promotes water-saving** techniques and soil fertility, making agriculture in India more sustainable and improving farmers' livelihoods without heavy reliance on rainfall

The System of Water for Agriculture Rejuvenation (SWAR) represents a holistic initiative aimed at addressing water scarcity in Indian agriculture while transforming farming practices. More than half of India's agricultural land grapples with low rainfall and recurrent droughts, posing significant risks such as debt and mental distress among farmers, tragically leading to suicides. Traditional irrigation methods heavily reliant on groundwater have proven insufficient, particularly for horticultural crops. The depletion of water resources from canals and groundwater further compounds the challenge. Current irrigation practices in India are under immense pressure due to limited availability of natural resources, resulting in suboptimal yields across thousands of acres of agricultural and horticultural land, leading to substantial economic losses.

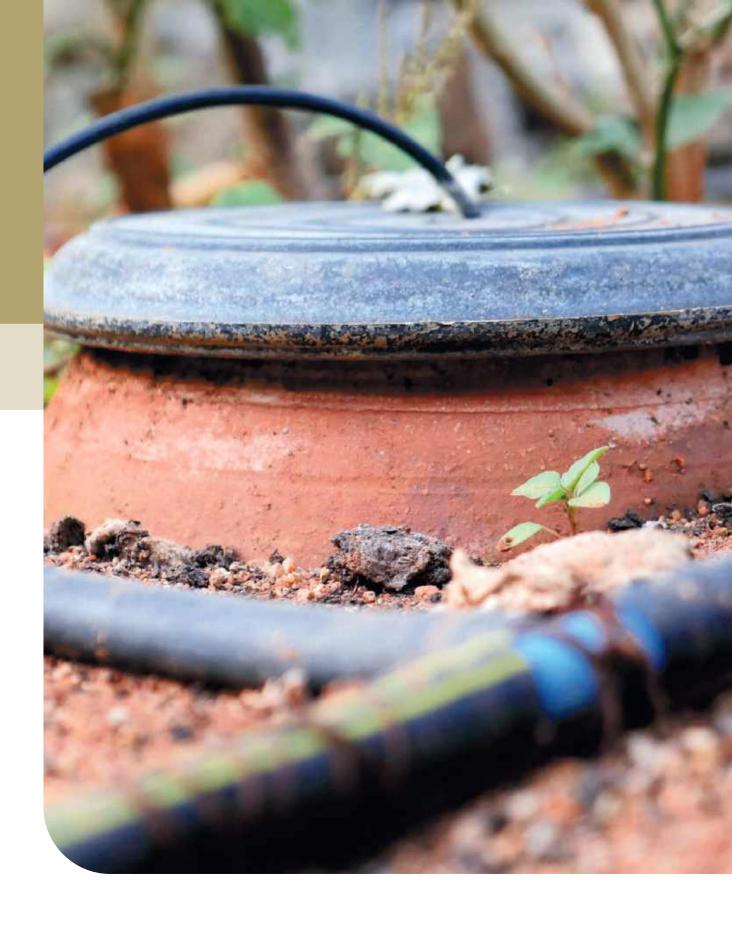


Fig. 54:
Components
of SWAR
Technology
(Source:
Centre for
Environment
Concerns)





The Hyderabad-based Centre for Environment Concerns (CEC), a non-governmental organisation, has been implementing a unique irrigation technology SWAR. It is the one of its kind, sub-surface drip irrigation system that release moisture. This underground, gravity-based irrigation system provides moisture to plants at the root level. SWAR enhances soil nutrients, uses harvested or stored water, provides irrigation to low rainfall areas, and in turn, transforms the livelihoods of poor farmers to help them grow more food. This technique is useful in drought-prone, semi-arid regions marked by poor irrigation availability (SWAR, 2016). In this system, the water requirements are one-quarter to one-fifth of those prescribed for drip irrigation. SWAR has received the Global Champion Innovation Prize for Water and Forestry at the 2015 Paris International Agricultural Show.



# **Brief description of practice**

SWAR technology consists of low-pressure drip irrigation components like overhead tanks and drip lines, but is extended with adapted and permeable clay pots. This technique involves rainwater harvesting in tank. Pots are placed at the root zone and connected to drip lines. Water oozes out of the pots and wets the soil and then 'sweats' to maintain a favourable soil moisture condition. This method assures the uniform water distribution at the plant's

root zone to cultivate vegetables, flowers, fruit and forestry trees using only one fifth of the water as compared to the other drip irrigation systems in India. SWAR is automated, it doesn't require electricity and saves water.

There are five important M's of SWAR

- Moisture: Deliver moisture at the root zone instead of on top of the soil. This is done by using drip irrigation to deliver water directly to the roots.
- Measured: Measure the ideal moisture that is required in the root zone. SWAR helps determine the right amount of moisture needed for each crop, in each season, and in each type of soil.
- Microbes: Foster microbes into the soil to improve soil health. Microbes convert nutrients into a form that can be absorbed by plants and improve aeration and drainage in the soil.
- Mycorrhizae: Apply a locally-made inoculum containing mycorrhizae, which are fungi that form a symbiotic relationship with plant roots and help them absorb nutrients and water.
- Manage: Make farm management easy by providing farmers with a portable sensor to measure soil moisture levels and create an irrigation schedule. This helps bridge the gap between scientific recommendations and farmers practices.

By following these five M's, SWAR can help farmers to improve water efficiency, soil quality, and crop yields. Optimum use of water, combined





SWAR: Irrigation at the roots (Source: thewaterchan nel)

with healthy farming practices such as soil improvements, will make agriculture in India more sustainable and offer improved incomes to smallholder farmers.



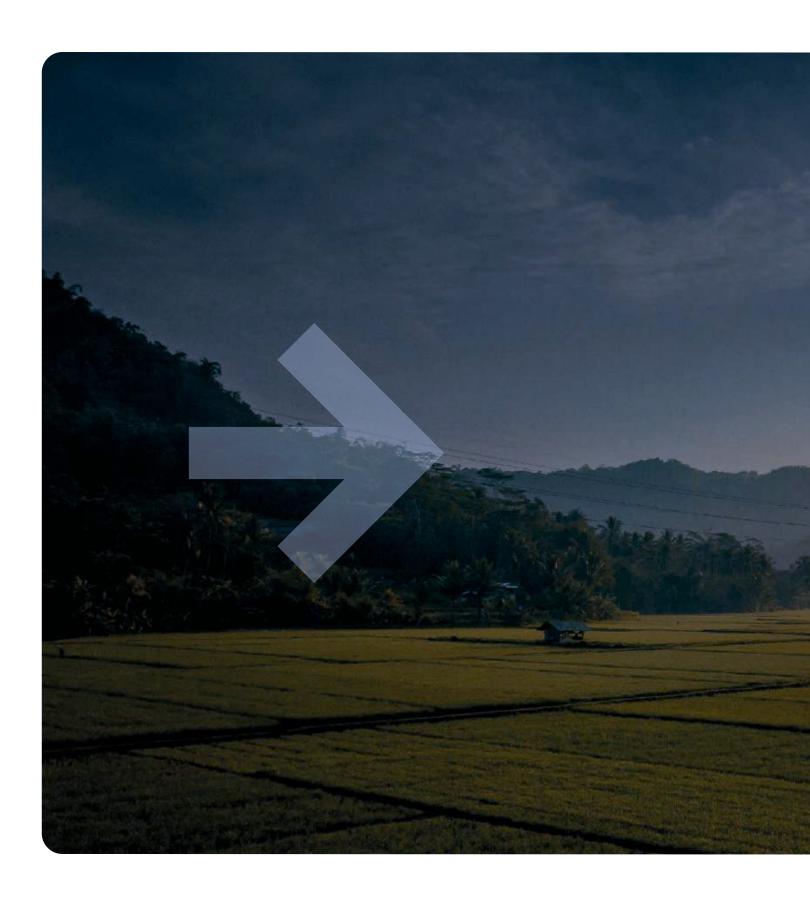
#### **Benefits**

Implementing a System of Water for Agriculture Rejuvenation (SWAR) can bring about numerous benefits. SWAR systems optimize water usage in agriculture by efficiently distributing water resources, reducing wastage, and ensuring that water reaches crops effectively. With better water management and distribution, SWAR systems can lead to increased crop yields. Adequate water supply ensures that crops receive the necessary hydration for healthy growth, leading to improved productivity and higher-quality produce. SWAR systems can help agriculture withstand periods of drought or water scarcity by conserving and utilizing water resources more effectively. Techniques like rainwater harvesting and drip irrigation can mitigate the impact of drought on agricultural production. Proper water management through SWAR systems can prevent soil erosion and degradation. Adequate moisture levels in the soil promote microbial activity, enhance nutrient availability, and maintain soil structure, thus contributing to overall soil health and fertility. By promoting efficient water use and conservation practices, SWAR systems support sustainable agriculture. Sustainable farming practices reduce the environmental footprint of agriculture, conserve natural resources, and minimize negative impacts on ecosystems and biodiversity. SWAR systems

can lead to economic benefits for farmers and rural communities. Increased crop vields and improved product quality can result in higher incomes for farmers. Additionally, the adoption of sustainable agricultural practices can open up opportunities for value addition and market diversification, further boosting economic growth in rural areas. SWAR systems contribute to water security by ensuring reliable access to water for agricultural purposes. By diversifying water sources, implementing efficient irrigation techniques, and reducing reliance on unsustainable water extraction methods, SWAR systems help safeguard water availability for current and future agricultural needs. As climate change leads to more frequent and intense weather events, SWAR systems play a crucial role in helping agriculture adapt to changing climatic conditions. Strategies such as water conservation, soil moisture management, and crop diversification can enhance resilience to climate-related challenges. Overall, implementing a System of Water for Agriculture Rejuvenation offers a holistic approach to water management in agriculture, delivering benefits that extend beyond increased crop production to encompass environmental sustainability, economic prosperity. and resilience to climate change.

#### Reference

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# DAYARA BUGYAL **RESTORATION** MODEL

A cost effective and eco-friendly approach for restoration of soil erosion affected pasture lands

**Dayara Bugyal restoration** model successfully revived degraded alpine meadows, combatting soil erosion and biodiversity loss caused by human activities and natural events



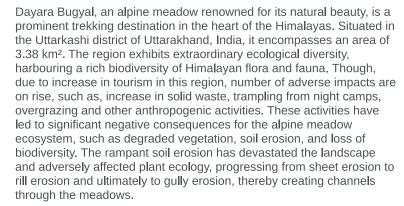
The Dayara Bugyal restoration model, initiated by the Uttarakhand Forest Department, successfully rejuvenated the degraded meadows using eco-friendly methods, improving plant density, reducing soil erosion and enhancing nutrient and water retention. This affordable and replicable approach utilises eco-friendly, low-cost techniques with local involvements to ensure long-term sustainability.

**Employing eco-friendly** techniques like biodegradable coir geo-textile and locally sourced materials, the restoration minimizes environmental impact and ensures long-term sustainability



Local engagement through the Dayara Bugyal conservation committee played a vital role in implementing and sustaining restoration efforts, ensuring continued preservation and

beauty of the ecosystem



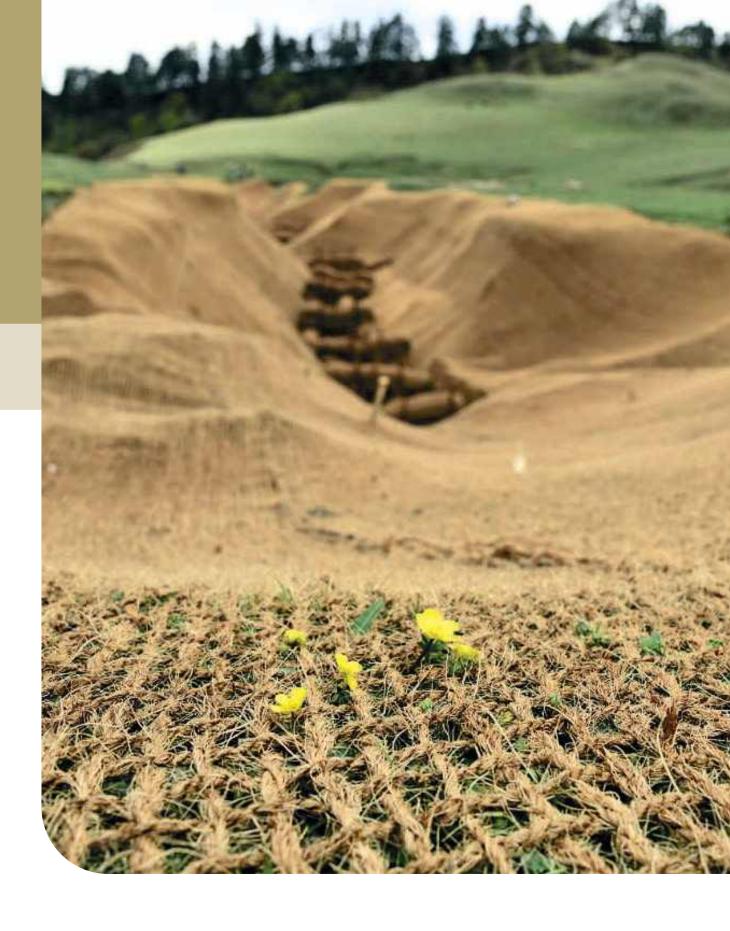




Fig. 56: Eroded gully segment of Dayara Bugyal due to biotic and abotic factors (Source: Kuniyal et al., 2021)



The Dayara Bugyal restoration model, initiated by the Department of Forest, Government of Uttarakhand, has successfully restored the degraded Dayara alpine meadows. In light of the fragile nature of Dayara Bugyal, an eco-friendly approach was adopted to control soil erosion and rejuvenate its natural ecosystem. This restoration model has improved the density and health of plant life in the restored areas and has significantly reduced soil erosion, thereby enhancing the nutrient and water holding capacity of the soil (Joshi, 2020). The Dayara Bugyal model is considered successful due to its cost-effectiveness and ease of replication in other degraded mountain ecosystems. This restoration approach holds significant promise for application in other highaltitude regions facing similar ecological challenges.



## **Brief description of practice**

The Dayara Bugyal restoration model tackles degradation in high-altitude pastures caused by both natural events and human activities. Excessive grazing and a surge in tourism

threatened the ecosystem. The solution involved managing livestock grazing through designated areas, seasonal restrictions and relocating grazing camps. Tourist influx was also limited. To prevent overgrazing, the grazing camps were relocated away from Dayara Bugyal. Similar to grazing, tourist influx was monitored and limited 200 tourists per day to avoid overwhelming the ecosystem as per the orders of Hon'ble High Court Uttarakhand, Nainital, in WPPIL No.123 of 2014, Local communities played a crucial role through the Dayara Bugyal Conservation Committee, fostering collaboration and ensuring project continuity (Kuniyal et al., 2021).

Beyond simply preventing further damage, the Dayara Bugyal restoration model actively addressed existing gully formation all through the middle of the bugyal, scarring the meadows and threatening plant life. Eco-friendly bio-degradable coir geo-textile and locally available pine needle along with bamboo were roped in, to create a series of check dams and channels to control soil erosion, gully formation and vegetation loss. The open degraded sites in different patches of the bugyal, the eroded lateral sites of the gullies were then covered with geo-textile to control soil erosion (Wangchuk, 2020). Local communities play a crucial role in implementing and maintaining the restoration efforts. This fosters a sense of ownership and ensures long-term sustainability. The first step involved laying eco-friendly coir geo-



Fig 57: Dayara Bugyal site after restoration (Source: Joshi, 2020)

textile mats over the gully formation. Geo-matting the areas degraded by massive soil erosion coupled with the embankment of channels made up of coir-pirul (pine needles) logs not only prevents soil erosion but also controls lateral bank cutting all along the gully and provides stability to the soil. The bamboo supported coir-pirul checkdams fitted across at defined intervals all along the channel decrease the speed of water flowing through it and also filter the soil content, thereby reduces debris load in the downstream areas. Finally, local species like Iris kumaonensis and Rosa Sericea were planted to rejuvenate the area to its original beauty. This model not only combat soil erosion, promote natural regeneration and restore the beauty of the ecosystem.

grazing practices protects the pastures from overgrazing and allows for long-term use by local communities. Limiting tourist influx helps prevent overcrowding and its associated negative impacts on the ecosystem. Collaboration between the local communities and the State Forest department promotes a sense of ownership among locals and also ensures the project's long-term sustainability. The Dayara Bugyal restoration model combines community involvement with low-cost, local materials to effectively combat erosion and revive degraded meadows, making it a sustainable land management best practice for alpine and subalpine region in the Himalayas.



### **Benefits**

The Dayara Bugyal restoration model demonstrates a successful approach to environmental restoration in high altitude alpine meadow. It offers a blueprint for managing fragile ecosystems by balancing human needs with ecological well-being. The coir geo-textile mats, channels and check dams made with pine needles significantly reduced soil erosion and prevented further gully formation. By controlling grazing and human exploitation promotes improved plant cover leading to healthier soil with better water retention and nutrient content. Managed and controlled

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6.2



## ECOSYSTEM-BASED ADAPTATION IN MAHARASHTRA, INDIA- BHOJDARI

A comprehensive approach to tackle the complexities posed by climate change

Watershed Organisation Trust (WOTR) has introduced ecosytem-based adaptation (EbA) strategies in Bhojdari village, located in the rain-shadow region of the Western Ghats, to bolster water and food security and enhance resilience against drought

Bhojdari village showcases successful Ecosystems-based Adaptation (EbA) interventions to ensure water and food security



Through EbA strategies like tree planting, soil revitalization and construction of check dams, Bhojdari improved water security, increased groundwater levels and enhanced crop yields, despite facing challenges of a hard land and lack of groundwater recharge



Bhojdari, located in the Ahmednagar district of Maharashtra, is a village in the rain-shadow region of the Western Ghats. Despite being in the upper catchment area with no nearby river, dam or canal, it has sufficient water even during dry months (Kurtkoti, 2020). Bhojdari was one of the first villages where the Indo-German Watershed Development Programme (IGWDP) was successfully implemented by the Sangamner Bhag Sahakari Sakhar Karkhana and the Watershed Organisation Trust (WOTR) in 1996.

The success of the Bhojdari project highlights the effectiveness of EbA in helping communities adapt to climate change by promoting sustainable water management practices, ultimately improving overall well-being and resilience



Maharashtra faced a severe drought in 2002-03, which led to the initiation of the Climate Change Adaptation project. Recognizing the need for a sustainable solution, the project leveraged the philosophy of ecosystem-based adaptation (EbA), which focuses on utilizing the power of nature for sustainable development. This project was implemented in 33 villages, with Bhojdari being a prime example of successful EbA interventions (De Condappa et al., 2021).



Fig. 58: Bhojdari before and after EbA interventions (Source: WOTR)



Bhoidari provides essential ecosystem services that ensure water and food security, even during instances of reverse migration. Since the early 2000s, when the benefits of EbA were first realized, the village has not faced acute water shortages. Despite the land being hard and the geology of the village not supporting groundwater recharge, Bhojdari's water self-reliance was confirmed by the WOTR Centre for Resilience Studies (W-CReS). The village's resilience was further demonstrated during the COVID-19 pandemic and lockdown when returning migrants were supported with sufficient water and food resources (Dadas and Alvares, 2021). This success highlights that villages employing an EbA approach to agricultural policy are better positioned to provide food security and livelihoods to returning migrant workers. EbA interventions help people to adapt to climate change through the sustainable use of ecosystem services and biodiversity, while also promoting participatory governance.



### **Brief description of practice**

Ecosystem-based adaptation (EbA) is a comprehensive approach that leverages the power of healthy ecosystems to help us to adapt to the challenges of climate change. Bhojdari project successfully improves water security and resilience to combat drought in the region. WOTR, in collaboration with the local community, implemented a series of EbA strategies tailored to Bhojdari's specific needs. Degraded lands were revitalized by planting trees. This not only improved soil quality but also increased rainwater infiltration (Kurtkoti, 2020).

The project also involved construction of strategic structures like check dams and trenches. These slowed down rainwater runoff, allowing more time for it to percolate into the ground and replenish groundwater reserves. WOTR promoted watersaving techniques like drip irrigation and rainwater harvesting. This ensured more efficient water use and reduced overall demand.

These EbA strategies have had a significant impact on Bhojdari. The village has seen an increase in groundwater levels, which has led to a more reliable water supply for drinking and irrigation. The improved soil quality has also led to increased crop yields. The success of the Bhojdari project demonstrates the potential of EbA to help communities to adapt to climate change. By working with nature, communities can build resilience to the effects of climate change and improve their overall well-being (WOTR, 2021).



Fig. 59: The EbA framework adopted in Bhojdari project (Source: WOTR)



### **Benefits**

The EbA approach in Bhojdari proved to be a resounding success. The implemented strategies led to a significant rise in groundwater levels. This translated into a more reliable water supply, not just for drinking but also for irrigation. With improved water availability, crop yields increased, leading to better food security and economic opportunities for the villagers. EbA offers multiple benefits besides climate change adaptation, such as improved biodiversity and livelihoods The project's success hinged on the active participation of the Bhojdari community. This fostered a sense of ownership and empowered them to manage their water resources more effectively. Bhojdari's project addressed various aspects of the water cycle, creating a comprehensive solution. Reliable access to water for irrigation proved to be a game-changer for agriculture. Farmers were able to cultivate their lands more effectively, leading to increased crop yields. Better crop yields translated into improved food security for the villagers and potentially created a surplus for selling in the market. This increased income and economic opportunities within the community. Reforestation efforts played a crucial role in improving soil quality. Stronger tree root systems helped hold the soil together, reducing erosion caused by wind and rain. Planting trees and creating a healthier ecosystem could have potentially led to a more diverse range of

plant and animal life in the area. Such costeffective adaptation strategies can be implemented at a local level and scaled up to larger areas.

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6.3

# COMMUNITY-BASED SOIL REHABILITATION FOR GRASSLAND

## A land rehabilitation practice after eradication of the invasive *Lantana* camara

Community-led initiatives in Mandla district, Madhya Pradesh to tackle the invasive *Lantana camara* (commonly known as lantana), restoring degraded grasslands. Through the 'Cut Rootstock' method, women's groups and Village Environment Committees drive Lantana eradication and grassland rejuvenation. Ongoing monitoring and strategic actions ensure sustained ecosystem resilience. This approach highlights innovative, locally-driven solutions to invasive species encroachment and underscores the importance of community engagement in rural landscape management.

Community-driven initiative in Mandla District restores grasslands, emphasizing local participation in conservation



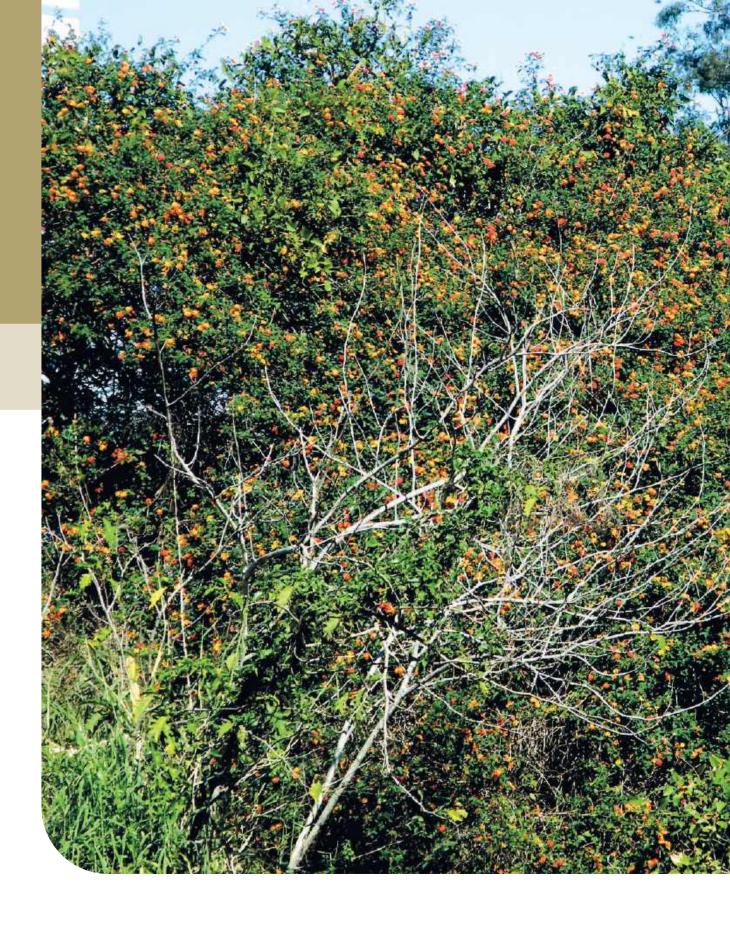
Cut Rootstock technique successfully eliminates invasive Lantana camara, showcasing innovative restoration methods



Ongoing monitoring ensures ecosystem resilience, highlighting the significance of community-led environmental management



The invasive species has been recognized globally for its detrimental impact on ecosystems, including the reduction of plant diversity and disruption of lands for grazing, agriculture and land degradation. In response, the Foundation for Ecological Security (FES) initiated a project aimed at restoring degraded grasslands through community engagement and innovative soil rehabilitation techniques. The utilization of the Cut Rootstock method for community-based soil rehabilitation, particularly in the context of eradicating the invasive plant Lantana camara, represents a significant advancement in sustainable land management practices. This approach has gained prominence for its effectiveness, cost-efficiency and ability to restore grasslands on common lands, notably within the Mandla district of Madhya Pradesh, India. This structure involves the formation of informal women's groups at the hamlet level, Village Environment Committees (VECs) at the village level, and Executive Committees at the cluster level. Through collaboration and consultation, these committees develop and implement strategies for lantana eradication and grassland restoration.



Continual monitoring, follow-up actions and community engagement are integral components of this technology. Strategies such as ongoing mapping, targeted planting of indigenous grass species and revegetation with selected tree varieties further contribute to the long-term sustainability of land management practices. Overall, the adoption of the 'Cut Rootstock' method for community-based soil rehabilitation represents a pioneering approach to addressing invasive species encroachment and promoting ecosystem resilience in rural landscapes (Gupta, 2024).



### **Brief description of practice**

The Cut Rootstock method, employed as part of this technology, has emerged as a cornerstone of soil rehabilitation efforts. By cutting Lantana roots three inches below ground and inverting the plant, this technique prevents seed dispersal and facilitates the removal of the invasive species without the need for chemical herbicides or heavy machinery. Implemented between July and September to coincide with optimal soil moisture conditions, this method has demonstrated significant success in controlling Lantana spread and restoring grassland ecosystems. At the heart of this technology lies a three-tier institutional structure, facilitating community involvement and ownership. This structure includes the formation of informal women's groups at the hamlet level, Village Environment Committees (VECs) at the village level and Executive Committees at the cluster level. Through collaboration and consultation, these committees coordinate efforts to eradicate Lantana and restore grassland ecosystems. The community institution plays a pivotal role in overseeing the procurement of indigenous grass species, which are subsequently encapsulated into seed balls and sown prior to the arrival of the monsoon season. This strategic timing facilitates the germination and proliferation of these grass seeds during the ensuing rainy period, thereby creating an environment less conducive to the germination of Lantana seeds. Furthermore, reforestation initiatives entail the meticulous selection and cultivation of resilient tree species, including bamboo, khameer, java plum, karanj (pongame oil tree), aonla, harar and other non-timber forest product-yielding species. These



Fig. 60: Preparation of seedballs of indigenous grassland seeds and restored grassland after eradication of *Lantana camara* (WOCAT, 2024)

species are purposefully chosen to establish a multi-layered forest ecosystem, aimed at sustainably provisioning essential resources such as food, fuelwood and fodder. Once established, these arboreal constituents serve as effective competitors against Lantana, effectively impeding its proliferation.





problematic plant species, minimizing ecological disruption and avoiding reliance on chemical interventions or heavy machinery. Through inclusive community engagement, with particular emphasis on the involvement of women's groups, stakeholders collaboratively determine the application of this method. By eliminating invasive species and reintroducing indigenous vegetation, ecosystem health can be sustained, facilitating biodiversity and habitat quality. Furthermore, the method yields socio-economic benefits by providing fodder and non-timber forest products, thereby supporting local livelihoods.

The Cut Rootstock method represents a ground breaking approach to community-based soil rehabilitation, addressing the ecological and socioeconomic challenges posed by invasive species encroachment. Through innovative techniques and collaborative governance structures, this technology offers a promising pathway towards restoring degraded landscapes and fostering sustainable land management practices.



### **Benefits**

The Cut Rootstock method represents a sustainable approach to land restoration, particularly effective in mitigating the ecological impacts of invasive species like *Lantana camara*. This method focuses on targeted removal of the

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   based soil rehabilitation for
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## A way to heal the chemically degraded soils

Subhash Palekar Natural Farming (SPNF) presents a holistic approach to agriculture, aiming to rejuvenate soil health and promote sustainability. By prioritizing soil health through techniques like mulching and microbial cultures, SPNF enhances soil fertility and water retention while reducing reliance on external inputs. This eco-friendly method not only improves crop yields and quality but also conserves resources, mitigates environmental pollution and

empowers farmers economically and socially. Embracing

degradation, fostering resilience and regeneration in

agricultural ecosystems for future generations.

SPNF offers a viable solution to the challenges of chemical

Intensive agriculture globally deteriorates soil health, raises environmental concerns and threatens sustainability, prompting the need for alternative farming methods



Subhash Palekar Natural Farming stands out as a holistic approach, emphasizing soil health restoration, biodiversity enhancement and minimal

reliance on external inputs



SPNF benefits farmers, ecosystems and consumers by improving soil fertility, reducing input costs, promoting ecofriendly practices and building resilience to climate change



Subhash Palekar's natural farming, also known as Zero Budget Natural Farming (ZBNF), is a revolutionary agricultural practice that aims to restore the health of the soil, reduce input costs and promote sustainable farming methods. It is based on the principles of traditional Indian farming practices combined with modern scientific understanding of soil health and biodiversity. Natural farming advocates like Subhash Palekar emphasize the importance of working in harmony with nature rather than against it. This approach involves minimal external inputs such as chemical fertilizers, pesticides and herbicides. Instead, it focuses on enhancing soil fertility through natural means like cow dung, cow urine, crop residues and other locally available organic materials.

One of the key principles of Subhash Palekar's natural farming is maintaining soil fertility through the practice of mulching. Mulching



involves covering the soil with organic materials like crop residues or straw, which helps retain moisture, suppress weeds and gradually decompose to enrich the soil with nutrients. This not only improves soil structure but also reduces water requirement and prevents soil erosion.

Another important aspect of ZBNF is the use of traditional seed varieties adapted to local conditions. Palekar advocates for the preservation and promotion of indigenous seeds that are resilient to pests, diseases and adverse weather conditions. This not only reduces farmers' dependency on expensive hybrid seeds but also contributes to preserving agricultural biodiversity.

In addition to soil health and seed diversity, Subhash Palekar emphasizes the role of cowbased agriculture in natural farming. He promotes the use of cow dung and cow urine as natural fertilizers and pesticides. Cow dung, when mixed with urine and water in specific proportions, forms potent compost known as 'Jeevamrutha' or 'Amruthpani' which enriches the soil with beneficial microorganisms and nutrients. Furthermore, natural farming encourages crop diversification and intercropping to enhance biodiversity and reduce the risk of crop failure. By planting a variety of crops together, farmers can improve soil health, suppress pests and diseases and achieve better overall yields without relying on chemical inputs.



## **Brief description of practice**

Subhash Palekar Natural Farming offers a comprehensive and systematic approach to rejuvenating chemically degraded soils while promoting sustainable agriculture. The methodology encompasses several key practices aimed at restoring soil health, enhancing biodiversity and minimizing reliance on external inputs. SPNF is the concept of Zero Budget Natural Farming (Anand and Kumar, 2020), which emphasizes the elimination of external inputs such as synthetic fertilizers, pesticides and herbicides. Instead, farmers rely on locally available resources and indigenous techniques to nurture soil fertility and crop growth. Mulching plays a crucial role in SPNF by conserving soil moisture, suppressing weed growth and providing organic matter to the soil. Farmers utilize crop residues, straw, leaves or any other locally available materials to cover the soil surface around plants, creating a protective

layer that shields the soil from erosion and evaporation.

Jeevamrutha is a fermented microbial culture prepared using cow dung, cow urine, jaggery, pulses flour and water. This potent mixture is rich in beneficial microorganisms and nutrients, which help improve soil fertility, promote nutrient cycling and suppress harmful pathogens. Farmers apply Jeevamrutha to both soil and plants to enhance microbial activity and overall soil health. Similar to Jeevamrutha, Bijamrita is a microbial culture prepared using cow dung, cow urine and local seeds. It contains beneficial microorganisms that facilitate seed germination, enhance root development and improve plant vigor. Farmers soak seeds in Bijamrita before sowing to inoculate them with beneficial microbes, increasing their resilience and productivity.

SPNF encourages farmers to cultivate a diverse range of crops and rotate them seasonally to improve soil structure, fertility and pest management. Crop rotation helps break pest and disease cycles, reduces nutrient depletion and enhances soil biodiversity. Additionally. intercropping and mixed cropping techniques are employed to maximize space utilization and optimize resource use. Livestock integration is a fundamental aspect of SPNF, as it facilitates nutrient recycling, enhances soil fertility and provides additional income streams for farmers. Livestock, such as cows and poultry, contribute valuable manure and organic matter to the soil through their waste. Additionally, their presence on the farm supports natural pest control and weed management. Incorporating trees and perennial crops into farming systems is advocated in SPNF to further enhance soil health, biodiversity and resilience. Agroforestry systems not only provide shade, shelter and fodder but also contribute to carbon sequestration, water retention and ecosystem stability. Trees like legumes fix nitrogen, while deep-rooted species improve soil structure and nutrient cycling. SPNF promotes natural methods of pest and disease management, such as biopesticides, botanical extracts and beneficial insect conservation. By maintaining a balanced ecosystem and healthy soil, farmers can minimize the incidence of pests and diseases while reducing reliance on chemical interventions. By adopting these holistic practices, Subhash Palekar Natural Farming offers a viable solution for healing chemically degraded soils, promoting ecological resilience, and ensuring long-term sustainability in agriculture (Anshu and Chaddha, 2021).



**Fig 61:** Seed Treatment in SPNF (Source: spnfhp)



### **Benefits**

Subhash Palekar Natural Farming offers a myriad of benefits, not only for farmers and agricultural ecosystems but also for consumers and the environment as a whole. SPNF prioritizes soil health through practices like mulching, use of microbial cultures and crop diversity. These techniques improve soil structure, fertility and water retention capacity, ultimately leading to healthier and more resilient soils. By eliminating or significantly reducing the need for external inputs such as synthetic fertilizers, pesticides and herbicides, SPNF helps farmers save on input costs. This makes farming more economically viable, particularly for smallholder farmers with limited resources. SPNF promotes eco-friendly farming practices that minimize chemical usage. soil erosion and environmental pollution. By fostering biodiversity, conserving water and reducing greenhouse gas emissions, SPNF contributes to the preservation of ecosystems and mitigates the impacts of climate change.

Contrary to conventional belief, SPNF has been shown to achieve comparable or even higher crop yields than conventional farming methods, especially over the long term. Additionally, crops grown using natural farming techniques often exhibit better taste, nutritional content and resistance to pests and diseases. Mulching and soil-improvement practices in SPNF help conserve soil moisture and reduce water requirements for irrigation. This is particularly beneficial in regions prone to drought or water scarcity, where sustainable water management is essential for



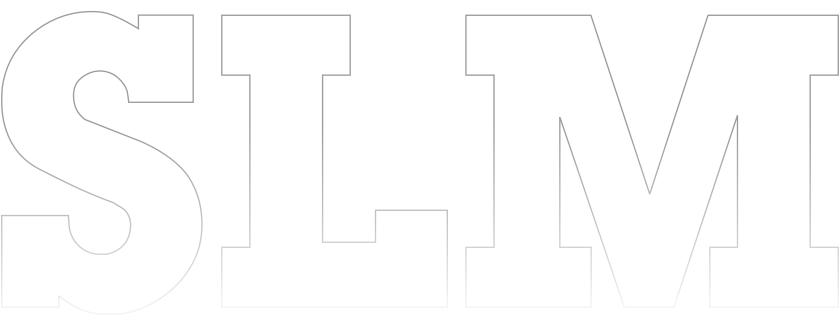
**Fig 62:** A vegetable field raised through SPNF (Source: spnfhp)

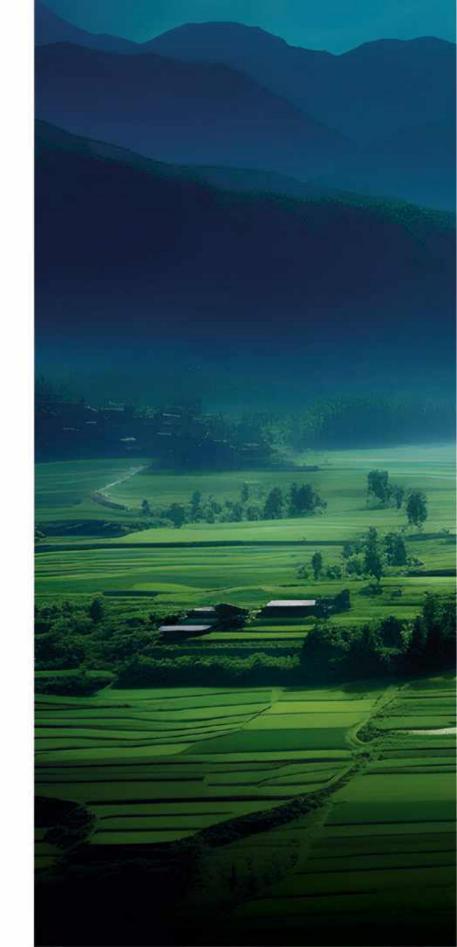
agricultural productivity and resilience. SPNF empowers farmers, especially smallholders, by equipping them with knowledge and skills to practice sustainable agriculture. By reducing dependency on external inputs and improving farm productivity, SPNF enhances the livelihoods and food security of rural communities.

The emphasis on soil health, biodiversity and natural ecosystem processes in SPNF builds resilience to climate change impacts such as erratic weather patterns, extreme temperatures and pest outbreaks. Healthy soils and diversified cropping systems are better equipped to adapt to changing environmental conditions. SPNF incorporates traditional knowledge and indigenous practices, preserving cultural heritage and fostering community cohesion. Through knowledge-sharing and collective learning, SPNF promotes social empowerment and strengthens community bonds among farmers. Subhash Palekar Natural Farming offers a holistic approach to agriculture that not only addresses the challenges of chemical degradation but also promotes sustainable, resilient and regenerative farming systems for the benefit of present and future generations.

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