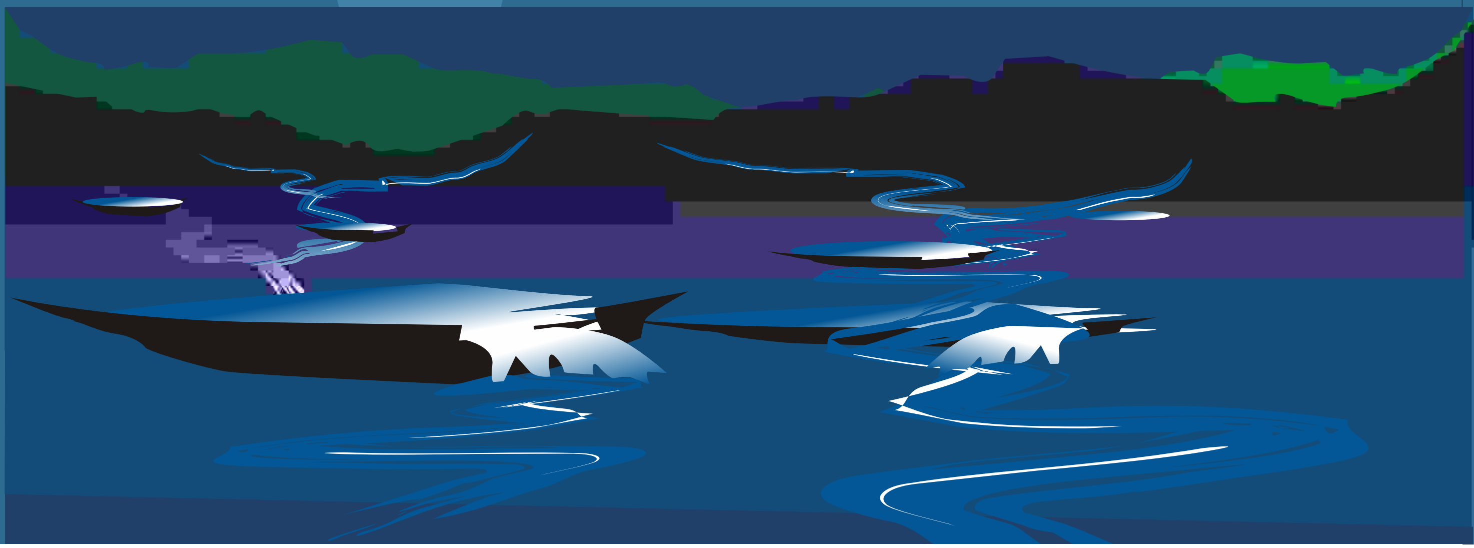
Climate Change

Vulnerability & Adaptation Experiences from Rajasthan & Andhra Pradesh

WRM Water Resource Management

Case Study

INDIA



intercooperation
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Rural Economy
Local Governance and Civil Society

MSSRF

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Action For Food Production

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Swiss Agency for Development and Cooperation SDC

The `Vulnerability Assessment and Enhancing Adaptive Capacity to Climate Change in Semi Arid Regions in India' (V&A) programme in brief

The Swiss Agency for Development and Cooperation (SDC), recognising the risks that climate variability and change pose to livelihoods of rural communities in semi-arid regions of India, supported a process-oriented pilot programme on '*Vulnerability Assessment and Enhancing Adaptive Capacity to Climate Change in Semi Arid Regions in India' (V&A).* The programme was implemented in the period from 2005 to 2009 in two semi-arid regions in India, namely Udaipur district in Rajasthan, and Mahbubnagar district in Andhra Pradesh. The overall goal of the V&A Programme was to secure the livelihoods of rural poor and vulnerable communities by promoting adaptation measures that enhance their capacity to better cope with adverse impacts of climate change and by improving their disaster preparedness.

The programme had **three specific inter-linked objectives:**

- **Objective 1:** To build community level capacities with regard to best practices and technologies in the agriculture, water and energy sectors.
- **Objective 2:** To optimise the service delivery system and services at selected sites in semi-arid areas in India.
- **Objective 3:** To promote policy dialogue and advocacy at different levels.

A range of field activities, some of them building on and aligned to traditional local adaptation practices, were tested in the particularly climate sensitive sectors of water, agriculture, rural energy and livestock. The field interventions helped identify measures and mechanisms for reducing the vulnerability to climate hazards of the poorest social groups in these regions. The emerging lessons were analysed with a view to informing policy processes at state, national and international levels by demonstrating a way forward for integrating development strategies with climate change adaptation.

The programme built on the collaboration between various actors with complementary strengths. A National Consortium, for overall management of the programme, comprised three partners, namely **M.S. Swaminathan Research Foundation (MSSRF), Action For Food Production (AFPRO),** and the **National Institute of Agriculture Extension Management (MANAGE).** An International Consortium for backstopping, quality assurance and facilitation of continuous exchange with ongoing international policy processes was constituted by **INFRAS** and **Intercooperation (IC).**

Mahabubnagar district in Andhra Pradesh and Udaipur district in Rajasthan were selected for implementation of the programme, as rural communities in these districts are among those most vulnerable to climate variability and are likely to be highly impacted by climate change. A multi-stakeholder process and a set of pre-defined criteria, including manifestation of climate hazards and evidence of social organization at village level, helped identify two villages for programme implementation in each district, namely **Kothur** and **Srirangapur** in Mahbubnagar district of Andhra Pradesh and **Amda** and **Kundai** in Udaipur district of Rajasthan.

For further details on the V&A pilot programme and a detailed analysis of the vulnerability of the communities selected for implementation of the programme, see the '*Introduction*' or visit the V&A programme website www.climateadapt.net.

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Vulnerability reduction and adaptation to climate change in semi-arid India - Water Resource Management

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CONTENTS

ACRONYMS

APCBTMP	Andhra Pradesh Community Based Tank Management Project
APFAMGS	Andhra Pradesh Farmer Managed Ground Water Systems Project
APMIP	Andhra Pradesh Micro Irrigation Project
APWALTA	Andhra Pradesh, Water Land and Trees Act
APWELL	Andhra Pradesh Ground Water Borewell Irrigation Scheme
CWB	Crop Water Budget
DWMA	District Water Management Agency
ICAR	Indian Council of Agricultural Research
NREGA	National Rural Employment Gurantee Act
PRECIS	Providing Regional Climates for Impacts Studies
RWSR	Rajasthan Water Sector Restructuring
TSG	Technical Support Group

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This case study could not have been prepared without the committed collaboration of all partners in the Vulnerability Assessment and Enhancing Adaptive Capacity to Climate Change in Semi Arid Regions in India (V&A) programme. In particular, we gratefully acknowledge the time and efforts invested by the local communities of Amda and Kundai villages, Udaipur district, Rajasthan, and Srirangapur and Kothur villages, Mahbubnagar district, Andhra Pradesh, to share their views and provide valuable feedback on the programme throughout the preparation of this documentation.

We owe special thanks to the AFPRO field units of Udaipur and Hyderabad, as well as to the local NGO partners ECO-CLUB (Mahbubnagar district, AP), Sahyog Sansthan and Vikas Sansthan (Udaipur district, RAJ), for all their support in data collection, for facilitating numerous field visits and ensuring that field realities are well understood by all partners and reflected in the documentation.

We are also grateful to Mr. Vishnu Sharma, who has helped to make field visits in Rajasthan extremely fruitful and who has supported the preparation of this documentation.

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Executive Summary

A range of measures were piloted under the SDC supported *Vulnerability Assessment and Enhancing Adaptive Capacities to Climate Change in Semi-Arid India (V&A)* programme, implemented from 2005 to 2009, in 4 villages in Rajasthan and Andhra Pradesh, to address the water related challenges the communities are facing due to climate variability and change. Increased precipitation variability, more concentrated rainfalls over shorter periods of time, excessive run-off, and a higher frequency of dry spells during the rainy season will all reduce groundwater recharge and the availability of surface water, resulting in severe additional risks for the agriculture-based livelihood systems of the communities. The pilot programme took a three-fold approach to make the communities' agricultural systems more resilient to emerging climate risks: It included measures (i) to increase the amount of surface and ground water available for livelihood activities; (ii) to improve water management in order to increase the water use efficiency; and (iii) to reduce water demand in the production system.

The programme has found that rehabilitation of tanks, including de-siltation of tank beds and restoration of bunds, treatment of hillside lands through construction of contour trenches, loose stone check dams, field stone bunds and planting of vegetation along trenches, and the renovation and upgrading of small water harvesting structures were all effective in controlling rainfall run-off and increasing surface water and ground water availability for productive use in agriculture. Water management was improved and the water use efficiency increased through installation of more efficient irrigation technology, a system of closed pipes in a tank irrigation system to minimize seepage losses and optimize water flows, renovation and upgrading of a traditional harren system in Rajasthan (i.e. a system of open diversion channels), and the installation of a water bank (i.e. water tanks at an elevated position, charged from a low-lying well through a system of closed pipes), all in combination with the formation of community-based management committees to ensure equitable distribution of water and adequate maintenance of the facilities. To help reduce the water requirements of the production systems, effective interventions were the application of silt excavated from tank beds to fields, and conducting a participatory crop water budgeting exercise to enhance awareness among communities of limited groundwater resources.

In particular, the pilot programme has demonstrated that traditional water management strategies and technologies provide a valuable entry point for making communities' agricultural systems more resilient to emerging climate change as they have been developed over decades or centuries in response to adverse climate conditions like scarce and erratic rainfall.

It was a key aspect of the V&A programme approach that communities assumed responsibility for maintenance and repair of the structures created under the V&A pilot programme, which helped to enhance their capacities to independently plan and implement similar measures in the future. The community-based groups for managing irrigation and water harvesting structures have put communities in a better position (i) to seek information on existing government programmes and schemes for improving infrastructure around agricultural water use, and (ii) to leverage funding from these sources. These processes of social mobilisation have helped strengthen the capacities of communities to deal with increasing stresses on water resources.

1. Introduction

Of the various effects that climate change is likely to have on ecological, social and economic systems, many are in some way or the other related to changes in water cycles. Increasing temperatures will affect hydrological systems, alter rainfall, magnitude and timing of run-off, moisture levels in air and soils, and groundwater levels. These changes will be felt most distinctly by farmers whose livelihood activities are directly dependent on rainfall and availability of surface and groundwater resources.

The semi-arid areas in Rajasthan and Andhra Pradesh selected for implementation of the *Vulnerability Assessment and Enhancing Adaptive Capacities to Climate Change (V&A)* pilot programme will likely face the difficulty of yet more concentrated and variable rainfalls, and a higher frequency of dry spells occurring even during the rainy season (Kumar et al., 2006). In semi-arid areas in Rajasthan, such dry spells tend to drastically reduce the productivity of the mainly rainfed agricultural systems. Even if they may not cause complete crop failure, they have significant negative impacts on crop yields and productivity, and ultimately on people's livelihoods. Similarly, agricultural systems that depend mainly on groundwater irrigation will come under increasing stress through the projected climate change impacts. Groundwater recharge potentials will be reduced through more concentrated rainfall over shorter periods of time resulting in more excessive run-off. Farmers in semi-arid areas in India have already expressed concerns about observed changes in precipitation patterns and shifts in crop cycles.

The vulnerability to climate variability and change of the rural communities in the semi-arid areas in Andhra Pradesh and Rajasthan is largely centered around the issue of water for drinking, agriculture and livestock rearing. The V&A programme therefore piloted a range of activities around water and irrigation systems to identify ways to make the communities more resilient against climate risks. The interventions covered three broad categories of approaches, aiming at

a) increasing the amount of water available (e.g. reducing run-off through water harvesting structures);

b) improving water management in order to increase the water use efficiency (e.g. increasing water distribution capacity); and

c) reducing agricultural water demand.

Categories (b) and (c) may also be described as working towards "more crop per drop of water".

This case study analyses ways in which the agricultural systems in semi-arid areas in India are at risk from climate variability and change, takes a detailed look at the situation in the villages selected for implementation of the V&A pilot programme, and illustrates the measures that were taken to enhance adaptive capacities of the systems to climate risks. A number of conclusions are drawn with regard to the piloted measures and options for upscaling the successful approaches.

2. Increased stress on water resources due to climate change

There are various ways in which global climate change is expected to manifest itself in impacts on hydrological cycles in South Asia. Water resources in India, which are already under pressure through continuous population growth, increasing water demand for industrial use and more water intensive lifestyles even in remote areas, will experience additional stress due to the impacts of climate change.

Global warming will have an impact on hydrological cycles in the Himalayan mountain regions. The Himalayan glaciers, by providing glacial melt waters, keep the main rivers flowing through the northern plains of India perennial and thus underpin irrigation water availability in the vast and densely populated river basins. With increasing surface temperatures, glacial melt is expected to increase, leading to increased summer flows in some river systems for a few decades, followed by a reduction in flows as the glaciers shrink over the longer run. Some of the major rivers running through the northern plains fed by the Himalayan glaciers are at risk of turning to seasonal rivers by the end of the 21st century (Cruz et al. 2007).

Rainfall patterns are expected to undergo significant changes with global warming over the coming century. The monsoon rainfalls make a major contribution to the flows in all Indian rivers, and constitute the principal source for groundwater recharge. Utility of rainfall in general depends on its spatial and temporal distribution. Obviously, uniform precipitation over longer periods of time and larger areas of land is more useful, while highly erratic and concentrated rainfalls lead to high levels of surface run-off. In India, precipitation has always been extremely variable, with the number of annual rainy days varying from 12 to 100 in certain regions in India, and incidences of up to 60 per cent of the total annual rainfall pouring down within a few hours. With climate change, the inter-annual variability of the monsoon is expected to increase further. Similarly, projections indicate more concentrated rainfall over shorter periods of time within monsoon seasons, while dry spells are also expected to increase in frequency and intensity. Monsoons are thus likely to be even less reliable and run-off even more excessive, thereby reducing groundwater recharge potentials (Mall et al., 2006). In addition, the risk of flooding is expected to rise and pose increased risks to physical and natural resources of communities in many areas.

Figure 1: Groundwater resources in many parts of Rajasthan have decreased to “overexploited” levels.

Another facet of climate change impacts on water availability for agriculture in India is the expected increase in evaporation from soils and surface water reservoirs associated with rising temperatures. It is projected that soil moisture will increase by 15-20 per cent over parts of southern India during the months of monsoon, but decline throughout the rest of the year (Lal and Singh 2001).

At the same time, water requirements of plants are expected to increase with rising temperatures. A study on climate change implications for arid regions of Rajasthan projected an increase in evapotranspiration by 14.8 per cent due to the expected temperate rise (Goyal, 2004).

Figure 2: Water availability is crucial for sustaining livelihoods in semi-arid rural areas in India.

To date, high-resolution scenarios to predict climate change impacts at the scale of sub-national regions constitute a major gap in the basis for climate-related decision-making at the local level. There is high uncertainty in down-scaled projections regarding the precise changes in rainfall, particularly in variability and extremes. The Indian Institute of Tropical Meteorology has applied the regional climate modeling system PRECIS (Providing Regional Climates for Impacts Studies), developed by the Hadley Centre for Climate Prediction and Research, for India (Kumar et al., 2006), and the results suggest that in the semi-arid areas where the V&A pilot programme was implemented, the expected challenges associated with climate change reflect the above scenarios at the national level. For Andhra Pradesh, the total annual precipitation is projected to increase, with a rise in summer monsoon precipitation of between 15 per cent and 20 per cent towards the end of the 21st century compared to present. However, rainfall will be more erratic. In particular, a marked increase in severe rainfall activities is expected for this part of the subcontinent. In Rajasthan, a slight decrease in precipitation is expected, with an increase in extreme events. The risk of droughts and dry spells even during rainy seasons is likely to rise in both V&A programme areas (Kumar et al., 2006).

3. National and State level policies shaping the irrigation infrastructure in Rajasthan and Andhra Pradesh

Agriculture is a key sector of the Indian economy. In combination with allied sectors such as forestry, logging and fishing, it accounted for 16.6 per cent of India's total GDP in 2007, and provided employment for 60 per cent of the total workforce. India is the world's second largest producer of wheat, rice, sugar and groundnut.

3.1 Large and minor irrigation systems in India

At the time of independence, India was a predominantly agrarian economy, with agriculture contributing about a fourth of the country's GDP. However, the fragmentation of agricultural land and traditional cultivation practices set limitations to growth of agricultural output. The systematic development of large irrigation schemes and the introduction of high yielding crop varieties in the course of the Green Revolution brought about the increase in agricultural productivity needed to feed the steadily growing population. The upgrading of agricultural production processes made India nearly food self-sufficient with improved per capita food availability.

However, it is a major challenge for India to maintain the momentum in food production increase so that it can keep pace with population growth. While the first four decades post independence focused on the construction of major irrigation schemes, there is now growing concern about adverse environmental impacts often associated with huge dams. Many large-scale irrigation projects have contributed to soil degradation and salinity. Water logging, formation of hardpan (sub-soil compaction), soil-nutrient imbalance and increased incidence of pests have also emerged from intensive rice-wheat monoculture systems that have spread widely in the course of the Green Revolution, all contributing to stagnation of agricultural productivity. In addition, very high siltation rates of many large dams, much more than anticipated, and poor maintenance of structures have led to a decline in irrigation water availability in many areas. Another concern that has emerged in relation to large-scale dams is that upstream farmers started to grow highly water intensive crops, thereby limiting irrigation water available for tail-end farmers. More recently, diversion of large quantities of irrigation water for industrial and urban use, as in the case of the Sardar Sarovar Project in Gujarat and the Nagarjuna Sagar Project in Andhra Pradesh, is further reducing water availability for agriculture.

Traditionally, a large share of drinking and irrigation water requirements was met through open wells and tanks, particularly in the states of Andhra Pradesh, Karnataka, Tamil Nadu, Orissa and West Bengal. However, the value of these tanks was increasingly neglected in the course of large-scale irrigation infrastructure development, and many tanks have become defunct due to poor maintenance. Recognizing the limitations of large dams for meeting the ever growing irrigation water requirement, the Government of India has chalked out a plan to rehabilitate traditional water harvesting and irrigation systems such as tanks, and to put in place sustainable management systems. Andhra Pradesh has been a pioneering state in initiating restoration of traditional water bodies and setting up Water User Associations for their sustainable community-led management.

Nearly two thirds of cultivated lands in India are still rainfed and highly sensitive to vagaries of monsoon and extreme weather events. Considerable investment in agriculture and rural infrastructure is required to moderate fluctuations in production due to erratic weather conditions. Investment in major, medium and minor irrigation projects as well as in the development of watersheds in rainfed areas assumes primary importance in agricultural investment. Apart from increasing productivity and production, these investments also help provide employment to the rural population and increase their income.

3.2 Public and private investment in irrigation systems

In the first three decades after independence the public sector contributed almost 50 per cent of the total investment in agricultural infrastructure due to the major irrigation development activities undertaken by the government. Since 1981, the public sector share has declined significantly and the contribution of the private sector keeps increasing. Notably, the need for higher public investment in irrigation and infrastructure development has been emphasized recently in the National Agricultural Policy and the approach to the Tenth Five-Year Plan. More than half (Rs 120,700 crores) of the Rs 230,000 crores of public investment in irrigation projects proposed for the next decade in India, is to be made in Andhra Pradesh. Rajasthan's share of the same pie is less than one percent (about Rs 1610 crores).

Traditionally, private investment in irrigation in India was mainly for construction of open wells. However, with the arrival of the Mark II pump and deep drilling equipment in the 1970s, groundwater based irrigation spread rapidly in all parts of the country. Almost all the investment in borewell construction is funded privately by farmers, while the government provides free or subsidized power in many states, including in Andhra Pradesh.

Groundwater is the most important common property resource used for agriculture. Land and water management practices, including soil conservation, water harvesting and agro-forestry, benefit not only the landowner who adopts these practices, but also enhance groundwater recharge potential. However, groundwater levels in many watersheds are declining due to unregulated over-exploitation through groundwater irrigation. As a result, groundwater extraction costs rise and open wells dry up. Studies indicate that upto 50 per cent of wells in many parts of India have dried up, including in southern Rajasthan, northern Gujarat, coastal Tamil Nadu and parts of Haryana and Punjab.

Agricultural productivity with groundwater irrigation is about four times higher than with surface water irrigation. Borewell irrigation has brought prosperity to many rural communities, but uncontrolled exploitation of groundwater has reached unsustainable levels in large parts of the country. In light of the urgent need for more judicious use of groundwater and conservation of non-replenishable aquifers, increasing attention is now given to "demand side" management of groundwater.

3.3 Irrigation and groundwater development in Andhra Pradesh

In 1993, groundwater draft in Andhra Pradesh varied from 7 per cent to 43 per cent in various districts, with an overall rate of 25 per cent. However in 5 full mandals and in parts of 63 mandals, groundwater development had reached more than 85 per cent. By 2002, the overall rate of groundwater development had reached 43 per cent. Due to droughts during 2001-04, groundwater development reached 22 per cent in command areas and 65 per cent in non-command areas according to 2005 estimates. Of the 1229 watersheds into which Andhra Pradesh is divided, 187 watersheds have reached an "over-exploited" stage, 82 "critical" stage and 203 "semi-critical" stage.

In response to this development, the state has initiated a number of community-based groundwater management projects, mostly supported through bilateral and multilateral donors, e.g. the Andhra Pradesh Ground Water Borewell Irrigation Scheme (APWELL) project, or the Andhra Pradesh Farmer Managed

Groundwater Systems Project (APFAMGS). The experience of these projects in participatory groundwater management is being mainstreamed into government projects such as the Andhra Pradesh Community Based Tank Management Project, which is currently being implemented in all districts of the state. The project aims to organize groundwater users, mostly private farmers, in informal groups to facilitate capacity building and promotion of social regulation and judicious water and energy use. Discussions are ongoing to extend the concept of participatory groundwater management to all semi-critical, critical and over-exploited villages, taking a watershed as the planning unit.

3.4 Irrigation and groundwater development in Rajasthan

Two thirds of Rajasthan's population depend on agriculture, with 70 per cent of the total area being primarily rain fed. Irrigation claims over 80 per cent of the available water supply in Rajasthan, with highly inefficient irrigation systems and large water losses. Over 90 per cent of the state's drinking water needs and 60 per cent of the irrigation requirements are met from groundwater extraction. The total groundwater draft of 11.6 billion cubic meters (BCM) in 2004 exceeded the overall recharge of 11.1 BCM. The number of mandals in Rajasthan whose groundwater resources are marked as "over-exploited" has risen drastically from only 23 in 1984 to 207 in 2007, which is a share of 88 per cent of all Mandals in the state. According to the latest NASA satellite data, groundwater levels in northern Indian states - Haryana, Punjab, Rajasthan, and Delhi have been declining at the rate of 33 cm per year over the past decade. The quality of groundwater has also progressively deteriorated.

The Rajasthan Water Sector Restructuring (RWSR) project, started in 2002 and implemented with World Bank assistance, seeks to address the major problems faced by the water sector through improving strategic planning and sustainable development and management of surface and ground water resources in Rajasthan. Elements of the projects are to provide inputs to the development of groundwater legislation and regulations and to promote further investments in the sector. The project also aims to increase the productivity of irrigated agriculture by supporting a "commercialization of irrigation services" pilot in a distributory command of about 6000 Ha, which would develop direct farmer involvement in management of a larger command area on a commercial basis.

Low electricity charges and unreliable supply are a major factor for unsustainable levels of groundwater use. Rural electricity pricing reform was an integral part of the state's overall pricing reform under the Rajasthan Power Sector project. Rural electricity tariffs for groundwater pumping were raised by 40 per cent in 1999. However, in recognition of the important role of electricity policies and regulations in the management of groundwater, there has been close collaboration and coordination between the project teams of RWSR and power sector projects. The teams have started exploring options for linking power tariff adjustments to service improvement. These tariff adjustments are intended as a mechanism to influence farmer use of electricity for ground water pumping.

In addition, the Rajasthan Irrigation Department is being restructured to a more service oriented department; elements of the reforms are (i) the formation and fostering of up to 620 water user associations (WUAs) for the operation and management of surface irrigation systems in a project area covering about one third of the state's irrigation area; (ii) participatory rehabilitation of about 90 (major, medium and minor) schemes covering about 620,000 ha; (iii) strengthening of agricultural extension services in the project area through the introduction of multidisciplinary (irrigation, agriculture, horticulture, animal husbandry, etc) technical support groups (TSGs), and public-private sector coordination for technology transfer to farmers; and, (iv) enhancing the safety of 16 dams supplying water to the project area through rehabilitation.

Figure 3: Drilling of a borewell in Amda, Udaipur district, Rajasthan.

4. Options for better water management along the water cycle

The aggravated stresses on water resources resulting from climate change in India pose special challenges to agricultural systems. More frequent and intense dry spells are a great concern for rainfed agriculture, as deficit of water at the sensitive stages of crop growth significantly reduces potential crop yields (Sharma 2006). In irrigated areas, shortages of surface water and reduction of groundwater recharge potentials may make existing irrigation practices unsustainable over the medium term. Increased water requirements of crops are a concern for both irrigated and rainfed systems. Mahabubnagar district in Andhra Pradesh and Udaipur district in Rajasthan, which were selected for implementation of pilot adaptation activities under the V&A programme, are typical examples of regions where the vulnerability of the rural livelihoods is largely centered around the issue of water for agriculture.

Solutions are needed to sustain agricultural production systems in the face of altered water availability resulting through climate change. The search for such solutions must take into account all stages of the water cycle from precipitation to actual use for agricultural production. There are in principle three ways to approach the challenge, namely

a) increasing the amount of water available (e.g. reducing run-off through water harvesting structures);

b) improving water management in order to increase the water use efficiency (e.g. renovating irrigation channels to reduce seepage losses); and

c) reducing agricultural water demand.

Under the V&A pilot programme, a range of activities was initiated to make communities' agricultural systems more resilient to water scarcity related to climate variability and change. The interventions covered all three categories of approaches above, however with different emphasis considering the distinct situations in the two areas.

In Udaipur district in Rajasthan, the situation analysis indicated that the main entry points for interventions were to control the loss of monsoon precipitation through surface run-off, particularly in light of increased deforestation through droughts in recent years, and water management systems, given that even under an optimal rainwater harvesting scenario, available water resources will declining with decreasing amounts of rainfall. Accordingly, interventions were focused on approaches (a) and (b) above. In Andhra Pradesh, a main concern was the currently practiced utilization of groundwater at unsustainable levels which suggested an additional emphasis on approach (c) above.

Figure 4 illustrates elements of the water cycle that were considered for the design of V&A pilot programme activities.

Interventions to reduce rainwater run-off and increase water available for multiple uses, including irrigation, comprised:

- increasing water storage capacity of tanks through desilting and restoration of bunds (Kothur and Srirangapur, Andhra Pradesh);
- reducing run-off, enhancing soil moisture and groundwater recharge through land treatment on hillsides (Amda, Rajasthan); and

- enhancing rainwater storage capacity and groundwater recharge through renovation and upgrading of small water harvesting structures (Amda and Kundai, Rajasthan).

Interventions for better water management and increased water use efficiency included:

- improving water distribution efficiency between tank and fields through construction of a well engineered pipes system with water chambers (Kundai, Rajasthan);
- improving water distribution efficiency through upgrading of harren system (Amda, Rajasthan);
- enhancing irrigation efficiency through better irrigation technology, i.e. sprinklers and drip-irrigation (Kothur, Andhra Pradesh);
- increasing water distribution efficiency through the installation of a water bank (Kundai, Rajasthan); and
- enhancing water management capacity of the communities through formation of water management committees and water user groups for tanks, harren system and water bank (all 4 programme villages).

Interventions to reduce the water requirements of the production system included:

- enhancing soil water retention capacity through application of silt to fields, with co-benefits for soil fertility (Kothur and Srirangapur, Andhra Pradesh); and
- enhancing awareness on groundwater overuse through participatory crop water budgeting with a view to changing cropping patterns towards less water intensive crops (Kothur and Srirangapur, Andhra Pradesh).

Figure 4: Schematic Diagram of Water Cycle and Programme Interventions

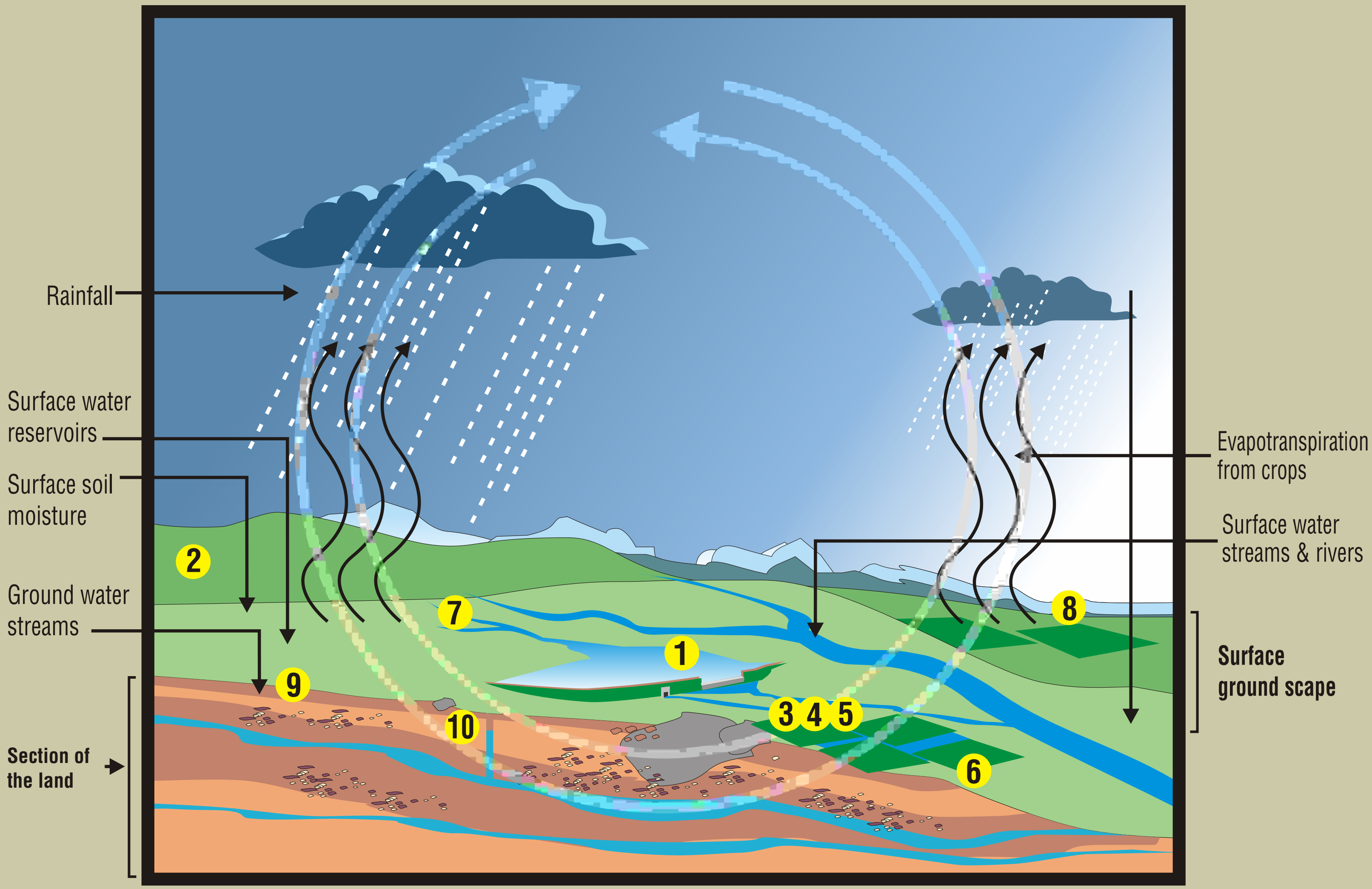
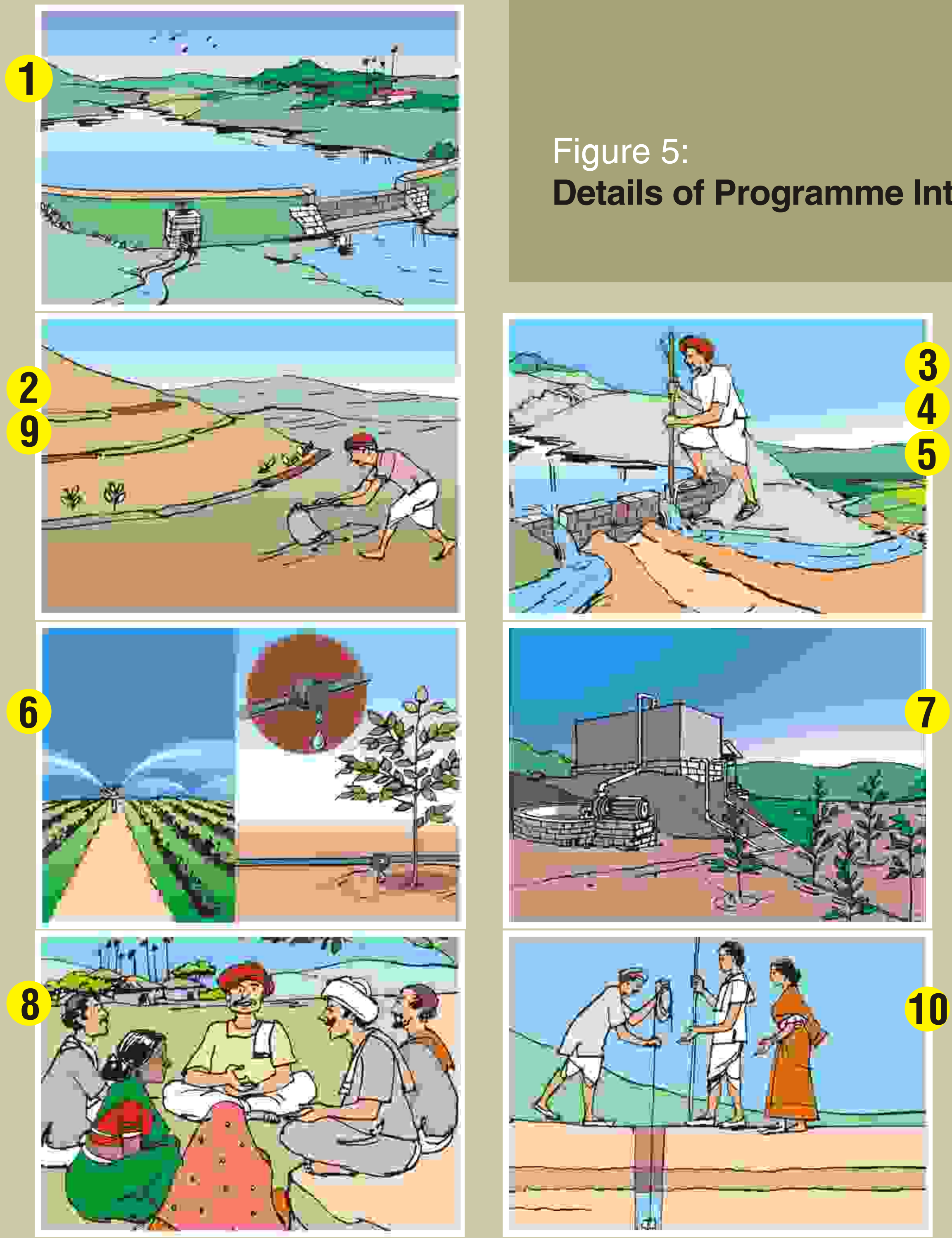


Figure 5:
Details of Programme Interventions



Index for programme interventions:

1. increasing water storage capacity of tanks through desilting and restoration of bunds (Kothur and Srirangapur, Andhra Pradesh);
2. reducing run-off, enhancing soil moisture and groundwater recharge through land treatment on hillsides (Amda, Rajasthan);
3. enhancing rainwater storage capacity and groundwater recharge through renovation and upgrading of small water harvesting structures (Amda and Kundai, Rajasthan).
4. improving water distribution efficiency between tank and fields through construction of a well engineered pipes system with water chambers (Kundai, Rajasthan);
5. improving water distribution efficiency through upgrading of harren system (Amda, Rajasthan);
6. enhancing irrigation efficiency through better irrigation technology, i.e. sprinklers and drip-irrigation (Kothur, Andhra Pradesh);
7. increasing water distribution efficiency through the installation of a water bank (Kundai, Rajasthan);
8. enhancing water management capacity of the communities through formation of water management committees and water user groups for tanks, harren system and water bank (all 4 programme villages);
9. enhancing soil water retention capacity through application of silt to fields, with co-benefits for soil fertility (Kothur and Srirangapur, Andhra Pradesh); and

10 enhancing awareness on groundwater overuse through participatory crop water budgeting with a view to changing cropping patterns towards less water intensive crops (Kothur and Srirangapur, Andhra Pradesh).

The V&A pilot programme in particular recognized the value of traditional systems that were developed over decades, in some cases over centuries, to sustain agricultural activities in the face of climate variability. Climate variability and erratic rainfall patterns have always been a major concern for agriculture-based livelihoods in semi-arid areas in India. The programme design therefore aimed to take the traditional coping strategies of communities and adapted traditional technologies as an entry point for identifying measures to help increase the resilience of the agricultural systems against future climate risks[1]. Examples of traditional irrigation and water management systems that have been revitalized under the V&A pilot programme include tanks and community-based tank management systems in Andhra Pradesh, small water harvesting structures, the harren system and community-based harren management in Rajasthan.

[1]It should be noted that not all traditional rural water management practices are appropriate in the context of present day population pressures. Under the V&A programme, only those traditional practices and techniques were considered for revitalization that provide feasible and sustainable solutions under current conditions.

5. Situation analysis of water resources in villages selected for implementation of the V&A pilot programme

5.1 Water resources in Kothur and Srirangapur, Mahabubnagar district, Andhra Pradesh

Both villages that were selected for implementation of the V&A pilot programme in Andhra Pradesh are located in the semi-arid Mahabubnagar district. The topography of the district is characterized by an undulating terrain, dotted with granitic outcrops and sheet rocks. The average total annual rainfall in Mahabubnagar district is 604mm. The south-west monsoon, which accounts for the large part of the annual rainfall, is highly erratic. The villages Kothur and Srirangapur, which were selected for implementation of the V&A pilot programme, are located respectively in Midjil Mandal in the north-east of the district, and in Kondurg Mandal in the northern part of the district.

Traditionally, tanks constituted a major source of irrigation water in both villages, but their importance has declined drastically over the second half of the 20th century. At the time of the baseline survey, the area under tank irrigation has been reduced to a small share of the total irrigated are in both villages. Tank water is distributed to the fields through open channels, leading to high conveyance losses of 40-60 per cent. Maintenance of the tanks has been poor, resulting in heavy siltation of the tank beds, dysfunctional sluices, and silted or damaged water distribution channels.

Kothur, being located on the banks of the Dundubi stream and its tributaries, has 40 open wells, which formerly had good recharge potentials during monsoons and were used as irrigation sources. Now only 24 of the open wells are functional for a few months after the monsoons. In Srirangapur, about 75 per cent of the open wells are dry. Farmers in both villages are increasingly dependent on borewells as primary irrigation sources. The first borewell in Kothur was drilled in 1987. Today, the village of 224 households has a total number of 120 borewells, out of which only 70 are functional. In Srirangapur, comprising 187 households, out of the 80 borewells that have been drilled, 60 are functional. Farmers usually drill wells at sites identified by local water diviners or hydro geologists. The average depth of borewells in the villages was 70 feet before 1990, increased to 120 feet in the 1990s and is now between 150 and 200 feet, in Srirangapur even up to 350 feet. The drilling of borewells is affecting the existing filter wells and open wells. All the borewells have been drilled and are operated privately, with no organized borewell sharing between farmers.

Electricity for operation of pumps is fully subsidized by the State Government of Andhra Pradesh, which undermines effective incentive structures for judicious use of groundwater, as higher pumping costs from deeper aquifers do not accrue to those who take the decision on the amount of groundwater drafted. Electricity connections are usually drawn from the existing power lines and eventually "regularized".

Kothur village and Midjil mandal are marked as "over exploited" according to the latest groundwater resource estimation (Andhra Pradesh Groundwater Department, 2009). Drilling new wells is accordingly prohibited under the Andhra Pradesh Water, Land and Trees Act (APWALTA), which controls groundwater development. Srirangapur, in contrast, is marked as a "Safe" groundwater zone. Even though there is no immediate threat of over-exploitation in this village, it will be important to monitor the levels and ensure judicious use of groundwater resources given the rapidly growing number of borewells.

At the time of the baseline survey, there had been no introduction of water efficient irrigation facilities like drip irrigation or sprinklers in either of the villages.

In Kothur, 70 per cent of the total area of 680 ha are under cultivation, out of which 25 per cent are sown more than once. There is no forest and pasture land in Kothur. Most of the cultivable waste lands (22 per cent of the total area) have turned alkaline due to continuous irrigation and high evaporation conditions.

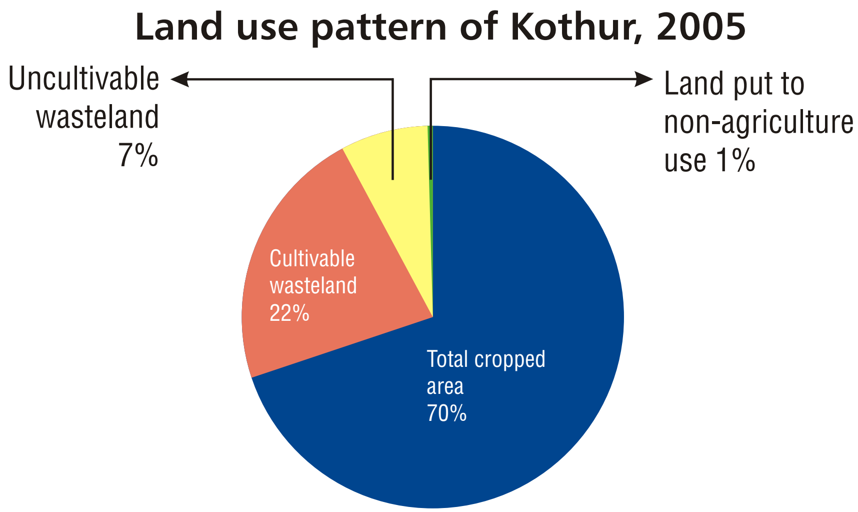


Figure 6: Land use pattern of Kothur, 2005

In Srirangapur, the net sown area constitutes 80 per cent of the total land area. Only 9 per cent of the cultivated area are sown more than once. A small portion of the total land area is under miscellaneous tree crops and groves (1 per cent).

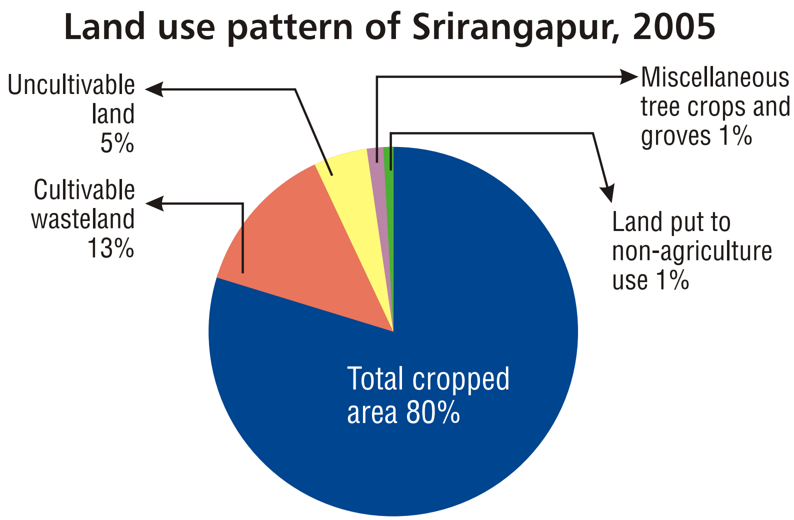


Figure 7: Land use pattern of Srirangapur, 2005

Traditional crops in both villages are redgram, castor, jowar and others. In Srirangapur, there has been a shift to commercial crops like coriander, cotton and maize over the last 20 years. Maize has also become a preferred commercial crop in Kothur.

It must be noted that Srirangapur, which is located at a distance of 80 km from Hyderabad and only 45 km from the new international airport, which was opened in 2008, is affected by the rapid urbanization process that has picked up in the district. A drastic surge in land prices within the last 5 years (prices are now 20 times higher than in the baseline year of 2005), new employment opportunities in the rapidly developing manufacturing sector in the area and new marketing opportunities for agricultural products are all generating new livelihood options for the community and might lead to a transition of economic and social patterns in the village over the medium term. Several farmers have started cultivating vegetables like tomatoes, chilies and brinjal, which can be marketed easily in Shadnagar (at a distance of only 12 km) and Hyderabad. In addition, some farmers in Srirangapur have taken up floriculture. There is also a mango orchard of 2 ha in this village.

5.2 Water resources in Amda and Kundai, Udaipur district, Rajasthan

Udaipur district in Rajasthan comprises of two distinct physiographic divisions, i.e. the western Aravalli mountain ranges, characterized by hilly and rugged terrain, and the eastern plain, which has a more or less leveled topography with occasional outcrops of older rocks. One village in each of these two divergent zones was selected for implementation of the V&A pilot programme, namely Amda in Jhadol Tehsil and Kundai in Vallabhnagar Tehsil. The district is marked by low and highly erratic rainfall, with an average annual rainfall of about 600 mm and droughts occurring almost every 3 years. The rainfall is mainly received through the southwest monsoon: More than 90 per cent of the total annual rainfall occurs during the 4 monsoon months from June to September.

In Amda, there are 42 wells, including 33 open wells and 9 bore wells. Of these, 38 wells generally have water for about 8 months in a year. In Kundai, there are 107 wells, including 104 open wells and 3 tube wells. Of the 107 wells in Kundai, 64 are in operation. The average depth of open wells in Kundai is 20 meters, and the pre-monsoon average water level is 15 - 16 meters, whereas the post monsoon level is 5-6 meters. The average depth of tubewells is 120 meters.

Groundwater availability is very limited due to poor and restricted permeability of the underlying compact banded gneissic formations. The water level is generally at a depth of 8 to 10 meters below ground level. During summer season water levels decrease considerably resulting in shortage of water for human and cattle consumption.

Both villages are marked by a prevalence of rainfed agriculture. In Amda, in the baseline year of 2005 irrigated land constituted only 1.13 per cent of the total land area (18 ha), whereas 21 per cent of the total land (333 ha) was unirrigated arable land and 23 per cent (371 ha) cultivable waste land. The area of irrigated arable land had come down considerably from 24.84 ha in 1990 to 18 ha in 2005 due to variability in rainfall and resulting depletion of groundwater resources.

Figure 8: Open well in Amda, Udaipur district, Rajasthan

Land use pattern in Amda, 2005

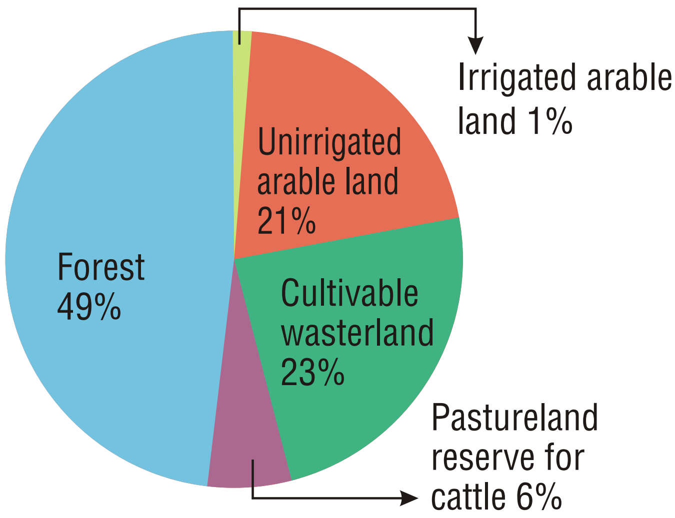


Figure 9: Land use pattern in Amda

In Kundai, the share of irrigated land was considerably higher at 10 per cent of the total land area (63 ha), unirrigated cultivable land 16 per cent (103 ha) and private uncultivable land and government wasteland almost 50 per cent of the total land (Figure 10).

Land use pattern in Kundai, 2005

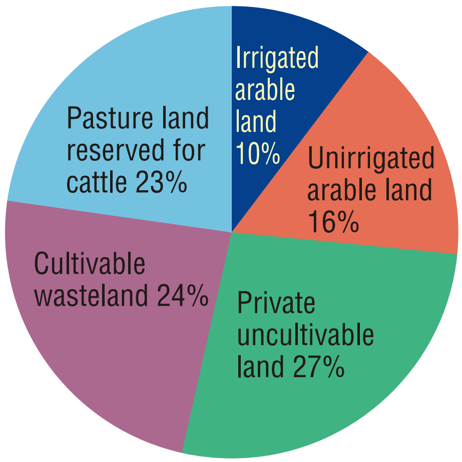


Figure 10: Land use pattern in Kundai, 2005

Poor irrigation facilities have been identified as a major main constraint to agricultural productivity in both villages even during kharif season[2], given the very high rainfall variability in the area.

Maize is the major kharif crop in both the villages, followed by *gawar* (Cyamopsis Tetragonoloba), til (Sesamum indicum), sorghum and urad. Wheat is the main rabi crop[3], followed by jowar (sorghum), mustard and Barley.

There are four small water harvesting structures in Amda and six in Kundai. The efficacy of the water harvesting structures at the time of the baseline data collection was partly compromised, due to heavy siltation of the water storage areas behind the structures and breaks in the structures themselves.

Structure traditionally used to facilitate irrigation in semi-arid hilly parts of Rajasthan is the harren system, which is a system of open diversion channels that carry irrigation water from a water storage area to the fields through gravity flow. Farmers' earlier practice was to construct a temporary earthen bund across a stream at a higher elevation in order to create a temporary water reservoir. From this reservoir, water was distributed through the harren to fields located at lower levels in the valley or plain parts of the villages. In Amda, there are two such harren systems, each of them designed to bring water from a water harvesting structure to the fields of 26 and 41 farmers, respectively. The earthen channels used to require substantial maintenance every year after the monsoon season as they are at high risk of damage due to animal crossings and heavy rainfall. The harren systems are very important irrigation facilities in the village, covering about one third of the total irrigated area.

[2] The cropping season in the monsoon period from June to October is called kharif season.
[3] The cropping season in the dry period from November to March is called rabi season.

6. Activities under the V&A pilot programme in Mahabubnagar district, Andhra Pradesh

6.1 Crop water budgeting exercise

In Andhra Pradesh, the situation of unsustainably high levels of groundwater use which has led to critical or overexploited groundwater resources calls for efforts to increase awareness around groundwater scarcity. This was recognized by the V&A programme, which has taken an integrated approach to irrigation water issues, considering not only water availability and management, but also water demand. One objective therefore was to help farmers in Mahabubnagar district in Andhra Pradesh understand that current groundwater utilization levels will inevitably amount to overexploitation, leaving the community more vulnerable to more erratic rainfall patterns in the future.

A crop water budgeting (CWB) exercise was identified as an appropriate participatory tool to increase the understanding of the cycle of rainfall, groundwater recharge, water utilization and groundwater levels among farmers. The basic idea of a CWB exercise is to analyze whether the annual groundwater draft matches the annual groundwater recharge. The exercise was carried out in both villages under the V&A programme in 2008. It was intended to provide the basis for developing community-based water use plans and a common crop plan that were in balance with expected availability of groundwater resources. Ultimately, the CWB was an approach to build the response capacities of the farming community to climate induced changes in the availability of water resources.

The groundwater and crop water budgeting analyses were carried out at the micro-watershed level of the villages, thus confining them to the geographic areas over which the communities have direct command[4]. There are different optional models for CBW implying varying degrees of hydrological accuracy. In order to keep the analysis free from scientific subtleties and fully transparent for the community, a simple equation of available groundwater versus water requirements of crops planned for rabi season was employed.

Two crop water budgeting workshops were conducted in 2008 in Kothur and Srirangapur. In Kothur, 43 farmers participated in the workshop, and in Srirangapur 35 participants, respectively. The workshop facilitators prepared the exercise by collecting rainfall data and specific information on relevant parameters around groundwater recharge and crop water requirements. Sources of information were the Groundwater Estimation Committee under the Ministry of Water Resources, Government of India, and the Indian Council of Agricultural Research (ICAR). Subsequently, an inventory of irrigation water sources in both villages, including discharge capacities, numbers of pumping hours and days for all wells was undertaken, and cropping patterns of past years were compiled in a participatory approach with the communities.

During the workshop, the gathered data was entered in pre-programmed excel sheets which generated the results automatically. The core part of the calculation was to aggregate the groundwater available for irrigation during Rabi season and compare it to the crop water requirements for Rabi.

Figure 11: Participatory crop water budgeting, Srirangapur, Mahabubnagar district

[4] It must be noted here that topographical watersheds do not necessarily coincide with aquifers, which would have to be taken into account for a fully accurate analysis; however, given that awareness raising among the community was the core objective of the exercise, this simplification seemed justifiable.

Groundwater available during Rabi was assessed in two steps: First, the groundwater balance at the end of Kharif season emerging from recharge and draft during the period from June to October was estimated. Second, an estimate of the recharge during Rabi was made. Water required for irrigation of Rabi crops was calculated separately. The final step was to consolidate the two figures and thereby manifest pressures on groundwater resources. Details of the calculations for both villages are provided in box 1.

Box 1: Crop water budgeting for Kothur and Sriranagpur, 2008

Step 1: Groundwater balance after rainy season

The groundwater balance at the end of Kharif season was estimated with a simple equation of total recharge and total draft during this period. For total recharge, rainfall received from June to October and recharge through secondary sources like tanks, ponds and check dams were considered.

a) Recharge through rainfall: For figures on total rainfall received, an average of district level rainfall data over the past 10 years was employed, which was 537.10 mm for the period June to October. The groundwater recharge rates were estimated based on recommendations by the Groundwater Estimation Committee (GEC) under the Ministry of Irrigation, Government of India, which provides standard values of infiltration capacities for different categories of geological formation in different climatic zones. In Mahabubnagar district, the geological formations underlying the hydrological unit are weathered granite, gneiss and schist with low clay content. The expected recharge rate under these geo-hydrological conditions is about 11% of the total rainfall received. For Kothur, which has a catchment area of 680 ha, the resulting total expected recharge is about 401,570 m^3. For Srirangapur with a catchment area of 840 ha it is 496,280 m^3.

b) Recharge through secondary sources: The two intact percolation tanks in Kothur and seven percolation tanks in Srirangapur were considered as secondary recharge sources. In Kothur, the recharge from the two tanks with a total water spread area of 18 acres and a duration of water stored in these tanks of 5-6 days was estimated to be about 8970 m^3. In Srirangapur, the secondary recharge through the seven existing tanks of a total water submergence area and a 20 to 300 days of water storage was estimated at 2250 m^3.

c) Groundwater draft from June to October: The estimation of groundwater draft during the period June to October was based on the number of functional borewells and dug wells, the number of pumping days and the number of pumping hours per day in each village. In Kothur, the total number of functional borewells was 67 with an average discharge of 17,198 liters per hour. The daily average pumping time was 6 hours on 75 days in the period from June to October. The resulting total draft was 518 520 m^3 for the same period, excluding consideration of groundwater draft for drinking and other purposes which are not within the focus of the irrigation water monitoring exercise. For Srirangapur, the total number of functional borewells was 47 and the average discharge per well was 13 430 liters per hour. With a daily average pumping time of 7 hours and 100 pumping days during June to October, a total draft of about 518,520 m^3 was calculated.

The total groundwater balance for each village at the end of Kharif season was captured in a simple equation:

groundwater recharge from rainfall (June - October)

\+ groundwater recharge from secondary sources, i.e. tanks (June to October)

\- Total draft from borewells (June - October)

= Groundwater available at the end of Kharif season

Step 2: Recharge during Rabi season

For the period from November to May, recharge through rainfall was calculated in analogy to the Kharif season,as 11% of total rainfall received. In Kothur, the recharge from 67.60 mm on an area of 680 ha was 50,570 m^3. In Srirangapur, with the same rainfall figure and an area of 850 ha, the total recharge between November and May was estimated to be **62,460 m^3.**

Table 1: Calculation of groundwater available at the end of Kharif season for Kothur and Srirangapur

	Kothur	Srirangapur
groundwater recharge through rainfall June - October	+ 401 750 m^3	+ 496 280 m^3
groundwater recharge from secondary sources, i.e. tanks	+ 8 970 m^3	+ 2 250 m^3
total draft from borewells (June - October)	- 518 520 m^3	- 441 980 m^3
Groundwater available at the end of Kharif season	**-107 800 m^3**	**+ 56 550 m^3**
groundwater recharge through rainfall November - May	+ 50 570 m^3	+ 62 460 m^3
Water available for irrigation during Rabi	**-57 230 m^3**	**+119 010 m^3**

Step 3: Water requirements of Rabi crops

The next step was to analyse the cropping patterns for Rabi of the past 3 years (2005-06, 2006-07, 2007-08) and estimate the associated water requirements. Standard ranges of crop water requirements specified by the Indian Council of Agriculture Research (ICAR) were used to estimate specific crop water requirements under the given climatic conditions. The total water utilized during Rabi was calculated considering water consumed by each crop and area of land under each crop. Table 2 provides details for both villages.

As indicated by the calculation in table 1, the groundwater available for the irrigation of Rabi crops was +119 010 m^3 in Srirangapur. This amount was however not sufficient to meet the calculated water requirement of 400 300 m^3 for irrigation of Rabi crops. In Kothur, the balance was even worse with a negative account already after Kharif and the Rabi rainfall not balancing out the groundwater deficit.

Table 2: Crop water requirements for Rabi for Kothur and Srirangapur

Crop	water requirement as per ICAR estimate	medium estimated water requirement applied	area under cultivation in Kothur	water requirement in Kothur	area under cultivation in Srirangapur	water requirement in Kothur
Rice	900-2500 mm	1500 mm	56 ha	840 000 m³	22 ha	330 000 m³
Tomato	600-800 mm	700 mm	2 ha	14 000 m³	6.8 ha	47 600 m³
Fodder	350-550 mm	450 mm	4 ha	18 000 m³	-	-
Sunflower	500-700 mm	550 mm	3.2 ha	17 600 m³	0.8 ha	4 800 m³
Mango	350-600 mm	400 mm	3.2 ha	12 800 m³	-	-
Chilly	500-800 mm	700 mm	-	-	2	14 000 m³
Crossandr/ Flori-culture	300-600 mm	500 mm	-	-	0.6 ha	3 000 m³
Guava	350-600	450 mm	-	-	0.2 ha	900 m³
Total	**-**	**-**	**68.4 ha**	**902 400 m³**	**32.4 ha**	**400 300 m³**

Outcome

The result from the CWB exercises was that the groundwater balance at the end of the hydrological year was under deficit in both villages. The results were discussed at the workshops, and it was highlighted that as a result from this imbalance between groundwater recharge and draft, groundwater levels would inevitably decline further and cause existing borewells to run dry over the medium term. Participants expressed their comprehension of the emerging threat. Options discussed to address the issue included a shift in cropping patterns towards less water intense crops, at least for subsistence crops[5], or further enhancing the capacities of the existing water harvesting structures.

A systematic monitoring of the outcome of the crop water budgeting workshop is a special challenge. Qualitative interviews and focus group discussions will be possible options to analyse the effect of the participatory exercise in terms of increased awareness around groundwater scarcity. Data on shifts in cropping patterns as an impact of the awareness raising efforts are still to be collected and compiled at the time of the preparation of this case study.

6.2 Rehabilitation of tanks

6.2.1 Physical interventions on tanks

In semi-arid areas in South India, particularly in Andhra Pradesh, tanks are a traditional system of harvesting rainwater runoff and storing it for multiple purposes. In many dryland areas in Andhra Pradesh, in the past tanks were the main water conservation bodies and facilitated irrigation either through surface water flows or by enhancing groundwater recharge. Tanks were also used to sustain other livelihood activities including fisheries and livestock rearing. Local communities used to form institutions for tank management to ensure adequate maintenance of the tanks and to oversee the

[5] Considering the higher economic return on water-intensive crops such as cotton and maize as compared to less water-intensive crops like sorghum and pulses, trade-offs in the livelihood basis have to be considered when suggesting changes in cropping patterns. It is beyond the scope of this study to put forward a viable and sustainable cropping pattern for the communities in the area.

regulations in place for water use by various stakeholders (Narsimah Reddy and Murali, 2006).

The second half of the 20th century witnessed a significant decline of area under irrigation from tanks in Andhra Pradesh. The proportion of area under tank irrigation as a share of total irrigated land decreased from 40% in 1955 to 18% in 1999 (Venkateswarlu, 2004). The major factor that contributed to the dwindling importance of tanks was the introduction and rapid spread of new water lifting technologies, which in combination with highly subsidized power supply for agricultural purposes led to a replacement of tanks by bore wells as the main source of irrigation. One implication of this transition was the disintegration of traditional institutions for tank management and maintenance, often resulting in progressive siltation of tank beds and degradation of tank breaches. Encroachments of the silted tank beds for agriculture, housing and infrastructure facilities such as roads further contributed to rendering tanks defunct in many areas.

There are in total 14 tanks in the two villages selected for implementation of the V&A pilot programme in Andhra Pradesh, 8 in Kothur and 6 in Srirangapur. Both villages had largely abandoned irrigation from these tanks at the time of the baseline survey in 2005 due to their poor condition and limited water storage capacity, resulting from progressive neglect. The V&A pilot programme recognized the important role of these tanks for water harvesting and groundwater recharge and as water supply buffers during dry spells. In the face of climate variability and change with more erratic rainfall, and given the already unsustainable levels of groundwater abstraction in the area, rehabilitation of selected tanks was identified as a potential approach to enhancing the resilience of the communities.

A stocktaking of water resources in both villages revealed that two tanks in each village deserved particular attention in the attempt to rehabilitate tank irrigation and were accordingly prioritized for treatment under the V&A pilot programme. Activities included the restoration of bunds, renovation of feeder channels and drainage lines, removal of vegetation from the tank bed, and desilting of the tank bed combined with application of the silt on farmers' fields. The costs for excavations were covered by project funds, while the beneficiaries paid for the transportation of silt to their fields by tractors.

The process of tank restoration is illustrated by the case of Pulivoni kunta (tank) in Kothur village in box 2.

Figure 12: Tank desiltation in Kothur Mahabubnagar district, Andhra Pradesh

Box 2: Tank rehabilitation Physical interventions on Pulivoni kunta, Kothur

The *Pulivoni Kunta,* located on the north-eastern side of Kothur village, receives ample inflows from a large catchment area during the rainy season and has a command area of 450 acres. It was built around 100 years ago as an irrigation tank, but had become dysfunctional due to breaches in the bunds caused by a number of extreme rainfall events over the last 2 decades. The water storage capacity of the tank was significantly reduced, with regular overflowing on one side of the tank during the rain season. The first step towards rehabilitation of the tank was the repair of the breaches in the bunds. Subsequently, a detailed technical appraisal of the tank and the topography of the command area was undertaken with a view to setting up an efficient water distribution system for irrigation. As a result from this appraisal, it was suggested to bring water from the tank to storage points in the command area through closed pipes in order to optimize the gravity flow and minimize seepage losses. Accordingly, two water chambers were constructed in the command area, which were connected to an already existing sluice in the tank bund through a pipeline of about 100 m length and an aqueduct channel to bridge a trench.

6.2.2 Management of tanks through sub-committees under the Smart Framers Club

The revitalization of community-based management structures for the tanks was considered a core part of the tank restoration intervention under the V&A pilot programme. It was seen as an important element of strengthening the local capacities to deal with the increasing stresses on water resources in the light of climate change variability and change.

Due to the decline of the functionality of the tanks in Kothur and Srirangapur, there were no tank management structures in place in the baseline year of 2005. With the initiation of the tank renovation works in 2007, committees for water management were formed as sub-committees under the Smart Farmers Clubs (SFCs)[6]. In both Kothur and Srirangapur, SFC sub-groups were formed for each of the treated tanks by farmers who own land in the command areas. The groups do not hold frequent meetings, but rather come together on specific occasions to discuss issues pertaining to tank and water management. Usually the groups meet once at the onset of the Kharif season. In Srirangapur, one important decision taken by a water management committee was to avoid additional borewells in a half-kilometer periphery around the tank and rather optimize the use of water available in the tank and from the existing borewells for irrigation. The groups have also met whenever the communities faced situations of water scarcity due to less than normal rainfall to discuss how the tank water should be best utilized.

Outcome

As a result of the intervention, the entire command area of the tank of 150 acres has been brought back under tank irrigation. The water distribution efficiency was improved significantly as compared to the earlier system through the structure of closed pipes and water chambers, which have helped to minimize water loss.

For some farmers in the command area who depended completely on borewell irrigation before the intervention, the restored tank irrigation facility has reduced the need for groundwater consumption. They have substituted the use of borewells with the use of tank water during the monsoon season and for a number of irrigations after the monsoon. For a total of 25 families who earlier had no access to irrigation of their fields in the command area, the intervention has allowed for the cultivation of two crops per year, one in Kharif and one in Rabi season, on their previously fallow lands.

In addition, the benefits from the desilting activities were twofold: First, the excavations helped to

[6] The SFCs were constituted as community organizations to take an active role in the implementation of V&A programme interventions and to manage the resources created through the programme.

increase the water storage capacity of the tanks. Second, the application of silt with its high concentration of organic matter on farmers' fields has helped to enhance the water retention capacity of the soil and ensured good crop yields while reducing the need for chemical fertilizers.

6.3 Drip irrigation and sprinklers

As extensive irrigation and evaporation have resulted in alkaline soils in several plots in Kothur village, large areas of land have become uncultivable, which facilitated the rapid spread of *Prosopis Julifora* over the last decades. Hence, an attempt was made to bring this land back under productive use by introducing tolerant horticulture crops, namely embalica, sapota, orange and mango trees. The optimal technology for judicious water management for cultivating these perennial crops is drip irrigation.

Ten units of drip irrigation schemes were set up in Kothur to irrigate horticulture crops on an area of 6.83 ha owned by 12 farmers. Of the total cost of the intervention, of Rs 42,000, including the cost of 300 plants, 70 per cent were covered by funds from the Andhra Pradesh Micro Irrigation Project (APMIP) and the District Water Management Agency (DWMA), the remaining 30 per cent were covered by the V&A programme funds. In addition, 2 units of sprinklers were installed, which have enabled four farmers to grow improved fodder grasses on an area of 10 acres of land with highly efficient use of groundwater. Fifty percent of the funding for the sprinklers was mobilized from the Department of Agriculture, Government of Andhra Pradesh, under the Andhra Pradesh Micro Irrigation Project (APMIP), and the remaining 50 per cent were covered by V&A Programme.

7. Activities under the V&A pilot programme in Udaipur district, Rajasthan

7.1 Treatment of hillside fields

In the Aravali mountain ranges, a combination of topographic, geological and climatic conditions render large parts of the surface highly prone to soil erosion. The problem is exacerbated as continued population growth has lead to intensified cultivation of sloping lands and associated fragmentation of native vegetation. Climate change is expected to further aggravate soil erosion through surface runoff from sloping hillside as precipitation is projected to become more erratic with heavier extreme rainfall events and longer intermittent dry and warm gaps (Kumar et al., 2006). Land and water conservation on hillsides in Amda village was therefore identified as a priority intervention to help increase available water resources in the programme area and thereby reduce vulnerability to adverse impacts of climate variability and change. To design appropriate land and water conservation strategies to retain soil, water and nutrients on hillsides, the V&A pilot programme drew upon the programme partners' past experiences with watershed development programmes in the area (e.g. Mahnot et al., 2003).

Figure 13: Hill side field in Amda, Udaipur district, Rajasthan, after treatment

The first step in the process was to raise awareness among the community in Amda about the vulnerability of the hillsides in absence of appropriate land management in the light of climate change and climate vulnerability. A number of community meetings were held in the village in 2006 and 2007 to discuss the necessity of adopting appropriate measures on the sloping lands and available options, including construction of physical structures, establishing vegetative barriers and implementing integrated watershed management plans that harmonize upstream and downstream land use system within a watershed. To further deepen the understanding of the issues among the community, a practical training was organized in June 2007 to demonstrate to farmers the effects of land degradation and soil erosion due to improper management, and present them some site specific suitable measures.

In a village meeting in summer 2007, four farmers expressed their interest to experiment with the suggested water and soil conservation measures on their fields. A first round of physical works was taken up accordingly on a total of 10 acres of land lying on hillsides. The activities comprised mainly the construction of loose stone check dams of suitable dimensions to check velocity of run-off in steep and broad gullies. These structures help to control channel erosion and stabilize local vegetation. Subsequently, the farmers sowed maize, arhar and urad dal on the treated lands. The farmers each contributed 30 per cent of the labor cost. The physical works in this first round of treatments were completed in May 2007.

Observing the positive effects of the initial treatments, the community continued discussing the options for preventing soil erosion and controlling run-off from sloping lands in village meetings. Several farmers indicated an interest to also treat their lands to improve soil and vegetation cover. A comprehensive plan was prepared accordingly with the farmers for a second round of treatments including a broader range of soil and water conservation measures:

- **Contour trenches** were excavated along the contours across the slope of the land in the upper and middle reaches. Bunds were formed downstream along the trenches with the excavated material taken out of the trenches.

  It was recommended that the intervals between the contour trenches should be adjusted to the specific characteristics of the sloping land (5-6 m for 15-20 per cent slope ratios, but only 4-5 m for 20-30 per cent slope ratios). The contour trenches on the hillsides break the sloping length, thereby reducing velocity of water flows and reducing soil erosion. The results are in situ moisture conservation and enhanced infiltration of water and recharge of groundwater.

- **Loose stone check dams** were constructed on steep drainage lines as a measure to check the velocity of erosive run off. This technology was identified as particularly appropriate for the selected sites, given the abundant availability of loose stones. On some of the lands earlier constructed check dams that were found damaged were renovated and upgraded.

- **Field stone bunds** were constructed at the lower parts of the hillsides to further reduce run-off velocity and at the same time allowing soil to settle along the bunds.

- **Vegetative measures** were added in order to stabilize earthen bunds that were formed downstream of the contour trenches with the excavated material. Castor seeds were sown on these bunds. Farmers chose castor seeds for plantation as the plant is highly robust and its seeds provide additional income when sold as oil seeds in the local market.

In this second round of treatments, 23 farmers eventually took up work on their lands, comprising a total area of 59 acres spread over 6 localities. The farmers were given field training by V&A programme experts for the construction of these measures. The total costs of the physical interventions were Rs 184,540. The cost sharing agreement was that 30 per cent of the labour cost was to be contributed by the beneficiaries. The daily rate of labour cost was set according to the norm under NREGA (National Rural Employment Guarantee Act), which was Rs 100 at the time of the intervention. As the physical works are highly labor intensive, farmers decided to take up the works in a joint effort and organized themselves in groups to treat the lands sequentially. The works in the second phase were initiated in the summer months of 2008 and completed before the onset of monsoon. The farmers sowed maize, arhar and urad on these lands.

Outcome

The daily rainfall data recorded in the Amda village mini agromet observatory for the months of June, July and August 2008 show highly erratic rainfall and significant gaps between rainy days. The sowing of Kharif crops was done in the first and second week of July. It was observed

Figure 14: Hillside field in Amda, Udaipur district, Rajasthan, after treatment

that maize and arhar grown on fields on untreated hillsides was suffering from the adverse precipitation patterns and plants were drying out. In contrast, the crops grown on treated sloping lands were found to prosper much better, with greener and healthier plants. This was resulting from the water conservation effect of the trenches and bunds which provided sufficient moisture during dry spells.

7.2 Renovation of Water harvesting structures

Small water harvesting structures constitute an important element of communities' traditional systems of maximizing water availability in semi-arid areas in India, particularly in rainfed areas. There is a wide range of traditional models of small water harvesting structures in Rajasthan, including anicuts, check dams, farm ponds, naadis, stop dams, weirs etc. These water harvesting structures help to control water run-off and reduce erosive activity, usually through a dam or wall built across a small stream. The up-stream area is submerged during the rainy season, and the stored water is used for irrigation and other purposes, including drinking water for livestock.

The multiple benefits offered by traditional water harvesting structures in semi-arid areas Rajasthan include:

- increased soil moisture;
- erosion control;
- reduced damage from flash floods;
- support for vegetation growth and recovery;
- recharge of groundwater and increased water availability in downstream wells;
- water storage for irrigation and other purposes for human and animal consumption.

There are four small water harvesting structures in Amda and six in Kundai, built under different government and donor programmes. For the communities, they form a decentralized irrigation system under the control of farmers. They are vital for meeting irrigation requirements during dry spells in the Kharif season and enable the growth of certain Rabi crops. Hence, they constitute a basis for sustainable livelihoods of the communities in the face of climate variability and change. The situation analysis carried out in the two villages under the V&A programme in 2005 revealed that the existing structures were partly dysfunctional and water storage capacity reduced due to sedimentation and damage of walls. Notably, it was found that some of the structures had not been robust enough to withstand heavy rainfall and flash floods that occur repeatedly in the area. The design used was probably not appropriate in the face of more extreme weather events which are expected to be more frequent and intense as a result of climate change in the region (Kumar et al., 2006). Accordingly, the renovation and upgrading of these structures was included under the V&A pilot programme activities to enhance the resilience of the communities to current and future climate risks.

Kundai

The 'Dhudh Talai' water harvesting structure in Kundai was constructed about 40-50 years ago for the purpose of storing water for village cattle and for recharging the wells located downstream of the structure. The structure was damaged by heavy rainy spells and flash floods in 2006, leading to reduced water storage capacity due to leaks in the dry stone masonry wall. Moreover, farmers noted that the structure was lacking an adequate spillway for excess water.

In 2007, after visits by technical staff from AFPRO and Sahyog Sansthan as well as soil and water conservation experts of the V&A Advisory Committee, it was decided to take up a comprehensive renovation of the structure including upgrading of the spillway. As per the experts' recommendations, a new cement wall adjacent to the old masonry wall with a foundation of at least 2 meters depth was required to ensure adequate stability against floods and to minimize water losses due to leakages. Further, to ensure the long-term functionality of the structure, it was decided to take up in-situ water and soil conservation measures on the degraded ridges in the catchment of this structure and develop it as common pasture land.

Figure 15: Dhudh Talai water harvesting structure after rainy season before renovation under V&A Pilot Programme

The beneficiaries of the Dhudh Talai water harvesting structure held a meeting in the month of May 2007 and approved the plans for the renovation of the structure. They agreed to contribute 20 per cent of the total cost in the form of labour. They approached the Gram Panchayat of Kundai village to seek permission for the initiative.

The physical works commenced in the first week of June 2007 and were completed by the end of the same month. The following steps were taken:

- Excavation of the main wall foundation (of a length of 35 m and a depth of 2 m) and masonry work;
- Construction of a concrete main wall (of a length of 35 m, width of 1 m and height of 2 m);
- Construction of a waste weir (of a width of 5 m and a depth of 1 m).

In total, 770 unskilled labour days and 63 mason labour days were needed for these works. The total cost of the intervention was Rs 445,220.

Outcome

After the intervention, the storage capacity of the Dhudh Talai water harvesting structure was extended to 5000 m^3, and the catchment area to about 35 ha (figure 15). There are five wells located in close vicinity downstream from the structure. Rainfall in the first monsoon after the renovation of the Dhudh Talai water harvesting structure was only 480 mm, which is 20 per cent below average. Therefore only 25 per cent of the storage capacity was realized in the structure. In spite of this, positive results in terms of groundwater recharge in the wells located downstream were recorded, and farmers could expand their winter crop cultivation accordingly. The area under wheat cultivation in Rabi season in the command area of the structure increased by 23 per cent from 6.7 ha to 8.2 ha, and the area under barley cultivation by 36 per cent from 1.4 ha to 1.9 ha respectively. In addition, vegetable cultivation was taken up on an area of 0.9 ha, and moong dal cultivation on an area of 0.5 ha. during summer season (after harvesting of Rabi crops).

Figure 16: Dhudh Talai water harvesting structure after rainy season and renovation under V&A pilot programme.

Amda

In Amda, two water harvesting structures located on different streams, namely *Parai* and *Bhutiya,* were prioritized for renovation under the V&A pilot programme.

The Parai water harvesting structure was constructed in 1989 as a water storage structure to feed the attached harren system (see chapter 8.3). The structure was completely damaged during monsoon floods in the year 2006. In spite of the repairs undertaken by the farmers, it did not provide sufficient irrigation water to sustain the wheat cultivation during Rabi 2007-08.

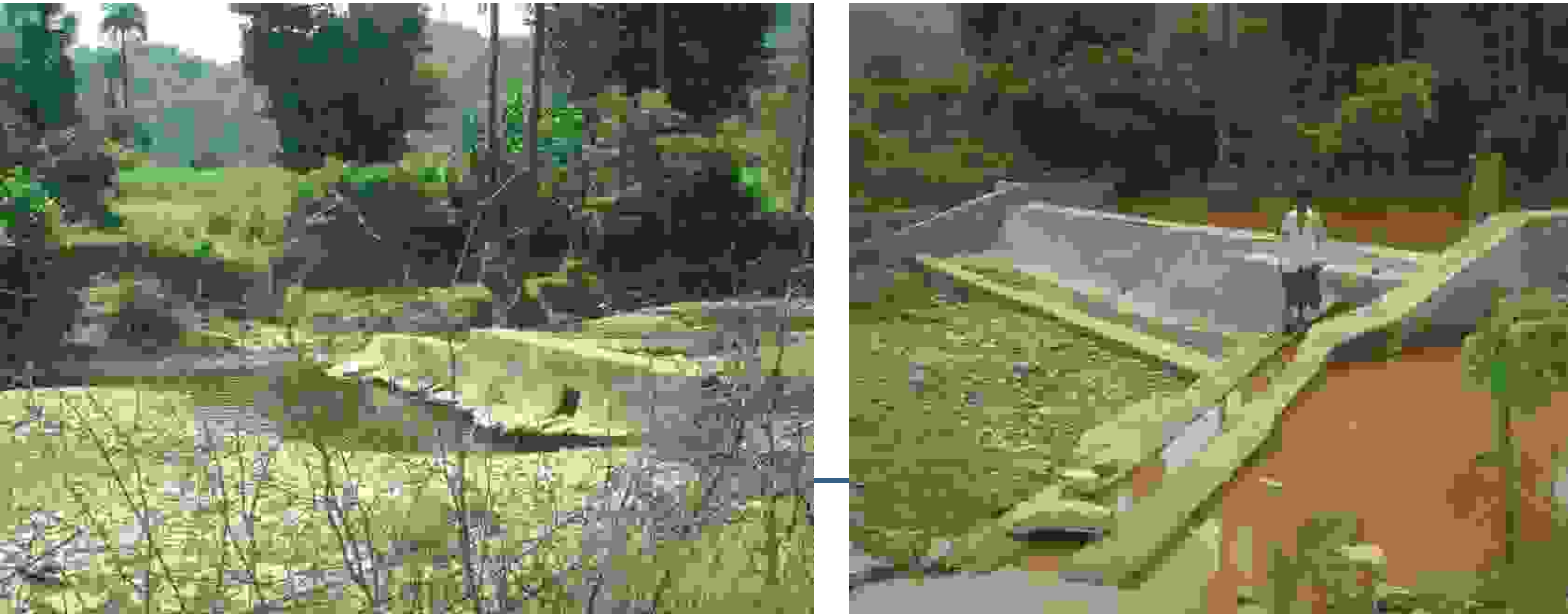
The Parai water harvesting structure has a command area of 7.52 ha, with a total of 27 households, all small and marginal farmers belonging to scheduled tribes, who depend on this water harvesting structure for irrigating Rabi crops. The group of beneficiaries expressed a strong interest to repair the structure before the onset of monsoon in 2008. Accordingly, AFPRO and Vikas Sansthan staff visited the site in April 2008. In a subsequent discussion with the beneficiaries, it was concluded that the necessary repair works should comprise the following:

- Construction of a new main wall (of a length of 25m);
- Extension of the head wall;
- New construction of side walls upstream and downstream of the main wall;
- New construction of an apron (energy dissipater).

The beneficiaries held a series of meetings to discuss the detailed plans for the intervention. They agreed to contribute 30 per cent of the labor cost for the completion of the physical works. The works were taken up in May and completed by the beginning of June 2008. In total, it involved 393 unskilled labour days and 110 mason (skilled) labour days.

The Bhutiya water harvesting structure is linked to a harren system of 780m (see chapter 7.3). The command area of this water harvesting structure cum harren is 9.44 ha, with 41 small and marginal

Figure 17: Paria water harvesting structure in Amda, Udaipur district, Rajasthan before and after renovation under the V&A Pilot Programme



farmers depending on the system for irrigation. It was decided to upgrade the water harvesting structure as a complement to the improvements of the harren system in order to achieve maximum benefits (see chapter 7.2). The plans for upgrading the structure were discussed with the beneficiaries, and the physical works were undertaken in the first week of June 2008. The cost sharing arrangement was the same as in the case of the Paria water harvesting structure, with a 30 per cent labour contribution by the beneficiaries.

The following steps were taken up:

- height extension of the main wall (by 0.9 m);
- extension of the head wall;
- addition of new sluice gates;
- new construction of an apron (energy dissipater).

The works were completed with an input of 250 unskilled labour days and 54 mason labour days. The total cost of the intervention was Rs 229,650.

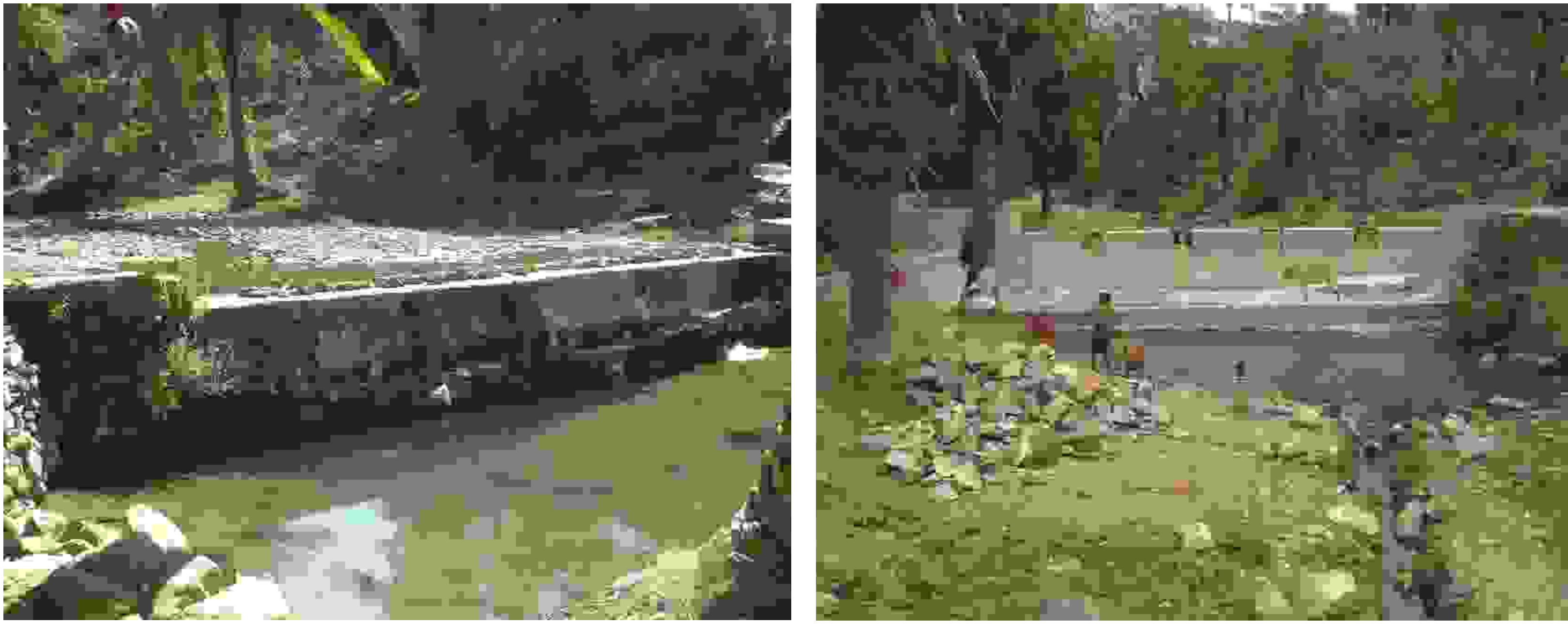


Figure 18: Bhutiya water harvesting structure in Amda, Udaipur district, Rajasthan, before and after renovation under the V&A Pilot Programme

Outcome

During the initial monsoon rains in 2008, the Paria water harvesting structure was overflowing. It can be noted that through the renovation of the structure, a potentially severe damage of the agricultural land downstream from the structure through heavy soil erosion could be prevented. At the time of the completion of this study, data are still to be collected and analyzed to measure the outcome of Paria

renovation in terms of enhanced irrigation potential.

For a further analysis of the outcome of the intervention on the Bhutiya water harvesting structure, see chapter 8.2 on the Bhutiya harren.

7.3 Upgrading of a harren system

In Amda village, community discussions initiated under the V&A pilot programme around vulnerability to climate variability and change and adaptive capacity pointed to the importance of the traditional harren system for the supply of irrigation water to farmers fields after the rain season. It facilitated cultivation of crops during Rabi season and also ensured that irrigation could be provided to sustain crops during dry spells in the Kharif season. Farmers expressed that the harren was a life line for the village as it secured their agricultural activities which are the main source of livelihood for the community.

It was established that the harren system was vulnerable to damage during heavy rain spells as the earthen channel was washed away by surface runoff. Another downside of the system of earthen channels was that especially during dry periods there was ample loss of water as it was carried to the fields, resulting in a shortage of available irrigation water and sometimes loss of crops. Accordingly, it was decided to renovate and upgrade the existing harren systems under the V&A pilot programme in order to increase the water distribution efficiency by reducing seepage. It was proposed to the community that this could be done by concrete lining of the channels.

Table 3: Overview of main features of 2 harren systems in Amda village - 2006

Features	Bhutiya harren	Parai harren
number of households using the harren for irrigation	41	26
potential area of land under irrigation	23 Acres	20 Acres
length of harren channels	900 meters	915 meters
source of water	Water harvesting structure and well at top end of the harren	only water harvesting structure at top end of the harren
condition of source water harvesting structure	requires minor improvement	totally damaged through heavy rains in 2006; left flank is damaged and right flank is completely washed away by the flood; needs completerenovation

Source: Primary data from Amda, Udaipur district, Rajasthan, provided by AFPRO Udaipur.

In meetings held on 11th and 25th of September 2006, the community prepared a first proposal for lining of the harren channels. In November 2006, an appraisal of the two main harren sites, namely Bhutiya and Parai (see an overview of main features of both harrens in table 3 below), was carried out jointly by a team of technical advisers from AFPRO, field staff of Vikas Sansthan, and farmers. Based on this appraisal and discussions with the community, it was decided that at this point the renovation of the Bhutiya water harvesting structure and harren should be prioritized given that these were in a much better state and results would be easier to achieve. Regarding the Parai harren, it was concluded that a first step should be to completely reconstruct the Parai water harvesting structure in a more robust way, and then take up lining of the harren channels.

The next preparatory step for the physical works was a topographic survey of the Bhutiya harren conducted by a technical adviser to measure the level differences between the source and tail end, and to design engineering plans for increasing the capacity, gradient of the harren and for lining of the harren.

The physical works were started in May 2007 with the repair of the water harvesting structure and the cleaning and excavation of the existing earthen channel. For the first phase of the harren works, completed in June 2007, wherein a concrete foundation for over 500 m and lining of 400 m of channel was undertaken, the labour input was 1064 person days, including 863 days of unskilled and 201 days of skilled labour. The works had to be interrupted at the onset of the monsoon when farmers had to work on their fields. At the end of Kharif season, the harren users held a meeting to discuss the remaining work on different sections of the harren. Further lining of another 260 m of harren channels was completed by the end of December 2007. The total cost of the intervention was Rs 323,070.

Figure 19: Bhutiya harren in Amda, Udaipur district, Rajasthan before and after lining under the V&A Pilot Programme

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Table 4 provides a comparison of the superior features of lined harren channels as compared to the earthen channels. In brief, the lined channels enable water flowing from the source to the field at a higher velocity and with less seepage losses.

Table 4: Comparison of earthen and lined harren channels

Earthen channel	Lined channel
Irregular shape and size	Uniform shape and size
Significant seepage losses	Negligible seepage losses
High risk of damage from erosion and animal movement	Very low risk of damage
Obstructions in water flow due to growth of weeds etc	No obstruction in water flow
Annual restoration and maintaining works are very labour intensive	Restoration needed only once in several years; annual maintenance works are much less time-consuming

Before the intervention, there was no formal harren user group for management of the harren. However, there were strong informal arrangements. All harren users held a meeting every year shortly before harvesting of the kharif crops (i.e. end September) to plan the renovation and maintenance works that needed to be done; the work was organized and undertaken jointly. Water distribution was overseen by a small number of senior community members.

An institution building process was initiated in 2006 as part of the intervention, as users expressed that there was a need for more formal arrangements for better management and equitable water distribution. A harren user group was formed with membership of all 41 harren user households. Through the lining of the harren, the cleaning and maintenance works required before the harren can be taken into operation have become much easier. They can now be undertaken by a single person and do not require a joint effort.

The scope of responsibilities of the harren user group has therefore shifted to management and water distribution as priority issues. The principle of equitable water distribution as per area unit has been reinforced by the user group. In addition, the group has come to the joint agreement that each farmer can start irrigating his land by the time his section of the harren is ready for operation. Above that, it was agreed that farmers will get priority right for irrigating their field when their crops are at a critical stage.

Figure 20: Lined harren channel in Amda, Udaipur district, Rajasthan

Box 3: Reflection of a senior community member on the harren and the transformation under through the V&A programme

Ram Singh, a seventy-eight year old farmer of Amda says, "This harren was constructed by my great grand father. He mobilized the entire community to build an earthen bund for water harvesting on the Bhutiya stream. Further, they constructed a channel in a way that water could be distributed by gravity to a maximum area of land for irrigation. For three generations we have been repairing the channel every year. However, now our children will be spared this cumbersome process, and sufficient irrigation for the crops will be ensured."

Outcome

The results of the harren lining in combination with the renovation of the Bhutiya water harvesting structure have various dimensions.

First, there was a notable increase in irrigation water availability. Water stored in the water harvesting structure in 2008 lasted until the end of November. The area under irrigation during Rabi season increased by 31 per cent, from 18 acres in the baseline year of 2006/07 to more than 23 acres in Rabi 2007 and 2008. This significant increase was realized in spite of much lower levels of annual rainfall in 2007 and 2008, as compared to 2006 (in 2006, 1158 mm of rainfall were recorded for Jhadol Block; in 2007 and 2008 it was only 556 mm and 626.9 mm respectively).

More than half of the area that had come under irrigation through the intervention was located at the tail end of the harren, where open wells had earlier been the only source of irrigation water. In Rabi 2007/08, four out of five irrigations were done with water from the Bhutiya water harvesting structure and facilitated by the lined harren.

The renovation of the harren has benefitted all socio-economic groups of the community. The harren user group reflects the land-holding structure of the Amda village community, i.e., the share of marginal, small and big farmers in the user group corresponds to the respective shares for the total village. Notably, the intervention even had a manifested pro-poor effect, as it enabled 8 marginal farmers to take up a second crop in Rabi season on their previously unirrigated fields.

Another aspect of results of the lining was that the duration for irrigation per ha of land could be reduced from 30 hours to 24 hours. Farmers stated that this was an important improvement for them as they could use the saved time for other productive activities.

More importantly, a significant amount of labour days could be saved on maintenance and renovation of the channels: Earlier, the earthen channels required annual repairs as they were prone to erosion and damage through roaming animals. A total of 200 days of labour had to be invested per year, which could now be saved through the more robust structure.

The lining of the harren also triggered additional private investments by some farmers in pipes to carry the water from a harren outlet to their fields.

As it is mainly wheat for domestic consumption that is cultivated during Rabi, the impact of the harren upgrading is manifested mainly in enhanced security of subsistence agriculture. However, some farmers sell surplus of their Rabi yields on a local market. It was stated that they have been able to reduce the share of gram and increase the share of wheat (which requires more water, but yields a higher market value) on the fields under harren irrigation. In addition, the more efficient water distribution has reduced the pumping hours to lift water from the open well, resulting in a saving of fuel. The saving of expenses for fuel has further improved the financial situation of the households.

7.4 Water Bank in Darjia Talai of Kundai Village

In Darjia Talai hamlet of Kundai village an improved irrigation system in the form of a water bank was introduced to bring a higher share of the cultivable land of the community of 12 tribal small and marginal households under irrigation.

Only one open dug well exists in Darjia Talai to meet the irrigation and drinking water requirements of the community. The well is situated at a low-lying point in the valley, which makes the conveyance of irrigation water to the higher lying fields a special challenge. Before the intervention, the farmers were using plastic pipes and open drainage channels to distribute water to those fields close to the well. A substantial proportion of the 4.2 ha of agricultural land of Darjia Talai remained under rainfed conditions as water could not be brought from the well to these fields. An efficient water conveyance and distribution system was therefore identified as a means of increasing the productivity and drought resilience of the agricultural system of the community. Interventions included renovation and upgrading of the existing open dug well, installation of two water reservoirs, one of them at a higher elevation for irrigation of fields below through gravity flow, and a system of pipes.

A series of meetings were held with the farmers of Darjia Talai to discuss the proposal of setting up a water bank. A plan of action was prepared with the community, and the following steps were taken accordingly:

- A geographic appraisal was undertaken to prepare a topographic map of the area with 1 meter contour intervals which depicted the elevation of the different land holdings and the well.
- A land use map of the Darjia Talai territory was prepared on the basis of land record data from the revenue department. Data on cropping patterns of Kharif and Rabi of 2006-07 were compiled.
- Yield tests and a short duration pumping tests were taken up in the open dug well to measure the availability of groundwater in different seasons.
- Renovation and upgrading works on the well were initiated accordingly. Two horizontal drillings were made with advice from a local water diviner in order to enhance the recuperation capacity of the well. In addition, the well was equipped with an electric pump for lifting water and connected to the electricity grid, in order to replace the three diesel pumps sets used earlier.

- The community provided all the labour inputs for the well renovation while material costs were covered by V&A programme funds.
- The engineering design for two water storage tanks and pipe systems to lift water from the well to the tanks and distribute it from the tanks to the fields were prepared by experts in consultation with the farmers of Darjia Talai.
- The two tanks with storage capacities of 10,000 and 50,000 liters were constructed, one near the open well and another one at a higher elevation to irrigate fields through gravity flow.
- A network of underground pipelines was installed to convey water from the well to the tanks and to distribute it across fields of all households of the community with minimal loss. A total of 125 pipes were laid out in six rows.

The installation of tanks and pipes was completed in the month of July 2008. The total cost of the physical intervention was Rs 365,532. To ensure adequate management, equitable water distribution and maintenance of the infrastructure, a water user committee was formed.

Outcome

Through the installation of the water bank, the area under irrigation in Darjia Talai was increased from 2.17 ha to 3.26 ha. Out of the 12 households of Darjia Talai, 10 households benefitted from the intervention, with a largely equitable distribution of additional irrigated land amongst the families.

The enhanced capacity of the well can now sustain the drinking water needs of the community throughout the year and the irrigation requirements of the total land under irrigation. A minimum of 8 irrigations could be done during Kharif and Rabi of 2008-09. The facility has even allowed for the cultivation of vegetables and green fodder for animals after the harvesting of the Rabi crops.

The benefits from the improved irrigation infrastructure became evident in the Kharif season after the completion of the works. The rains were interrupted by several dry spells, which put the maize crops in a water stress situation that would have posed a severe risk to the survival of the crops under rainfed conditions. Through the newly installed water bank and irrigation facility the entire maize crop could be saved.

The community reported that earlier conflicts used to come up occasionally over water use and water distribution across the households. External mediators had to be called to resolve the conflicts. Ever since the installation of the water bank and the improvement of water availability, no major conflicts have occurred as the community had not faced a situation of water scarcity. However, a final conclusion regarding the effectiveness of the new management system and the work of the water user committee can only be drawn after the community has weathered a year of significantly below average rainfall which has not yet occurred since the intervention.

Figure 21: Cultivation of fodder with water bank irrigation in Darjia Talai, Kundai, Udaipur district, Rajasthan.

8. Conclusions

A wide range of approaches aimed at reducing the vulnerability of agricultural systems to water-related climate change impacts have been piloted under the V&A programme in two different semi-arid areas in India: Mahabubnagar district in Andhra Pradesh and Udaipur district in Rajasthan. The areas are characterized by high variability of rainfall from year to year and by erratic rainfall patterns within monsoon seasons. Climate change projections for both areas indicate that rainfall is likely to emerge even more unpredictable, erratic and concentrated in the future, and that the risk of dry spells and droughts is likely to increase (Kumar et al., 2006). Total annual precipitation is expected to increase in Andhra Pradesh, whereas Rajasthan is expected to receive even less annual rainfall in the future.

The key determinants of vulnerability of the agricultural systems differ between the two areas selected for implementation of the V&A pilot programme:

Mahabubnagar district, Andhra Pradesh: Traditionally, tanks played an important role in this area as community-managed water harvesting structures, surface water reservoirs and irrigation sources. However, their importance has declined drastically over the last decades in the course of a rapid spread of private borewells incentivized by subsidized power supply for irrigation, which has led to unsustainable levels of groundwater exploitation.

Udaipur district, Rajasthan: Agricultural systems in the area are largely rainfed, with only small proportions of land under irrigation mainly from open wells and small water harvesting structures. As geological and economical conditions are less conducive for groundwater irrigation as compared to the situation in Andhra Pradesh, traditional surface water irrigation structures have been kept in use over the years, albeit with poor reinvestment and maintenance. Further, the undulating dry terrain is highly exposed to soil erosion resulting from heavy rainfall after long dry periods in the absence of adequate soil conservation measures. Adaptive capacity among the poor communities is particularly low with a prevalence of small and marginal land holdings, high rates of illiteracy, especially among women, and limited access to services and markets.

The V&A pilot programme has aimed to improve the productivity and resilience of the agricultural systems to water stress due to climate variability and change in a three-fold approach: Measure were piloted (i) to increase the amount of water available for agricultural production; (ii) to improve water management in order to make the available water resources more productive; and (iii) to reduce the water requirements of the production system. Rehabilitation of existing infrastructure and investments in new structures were taken up in response to proposals made by local user groups, after discussion and approval by Gram Sabhas.

(i) The programme has found that the following measures were effective in controlling rainfall run-off and increasing water availability for productive use in agriculture:

- **Rehabilitation of tanks in Mahabubnagar district, Andhra Pradesh**
  Through de-siltation of tank beds and restoration of bunds, the water storage capacity of the tanks could be enhanced significantly. As a result, large areas of land have been brought back under tank irrigation. This has reduced pressures on groundwater and enabled farmers who had no access to irrigation to take up cultivation of previously fallow fields.

- **Treatment of hill sides in Udaipur district in Rajasthan**
  The construction of contour trenches, loose stone check dams, field stone bunds and planting of vegetation along trenches across sloping fields has significantly enhanced soil moisture and helped crops growth over periods of erratic rainfall. Treated lands are much better prepared to bridge dry spells and are more resilient to climate risks.

- **Renovation and upgrading of small water harvesting structures in Udaipur district in Rajasthan**
  The renovation and upgrading of existing water harvesting structures has helped to increase water availability in the storage areas behind the structures. It has also enhanced groundwater recharge, making more water available in the wells downstream from the structures and allowing for a larger area of land to be brought under irrigation. It was found that the structures needed to be built in a more robust way to withstand heavy rainfall and flash floods that are expected to occur with increased frequency and intensity due to climate change in the future.

  Small water harvesting structures are critical elements of traditional irrigation systems in the area to enable the cultivation of Rabi crops and help bridge dry spells during the monsoon season. Restoring these structures and supporting their maintenance is therefore an important contribution to the resilience of the communities against climate risks.

(ii) The following interventions were found to help improve water management and increase the efficiency of water use in the agricultural systems:

- **Installation of a system of closed pipes and optimization of gravity-based water distribution in Mahabubnagar district in Andhra Pradesh**
  A system of closed pipes to convey water from a tank outlet to water chambers, and subsequently to farmers' fields, has helped to minimize seepage losses and optimize water flows in a tank irrigation system, thereby helping to increase the area under tank irrigation. Replacing open channels by closed pipes and designing well- adjusted systems for the topographic features of the area can help to enhance water distribution efficiency.

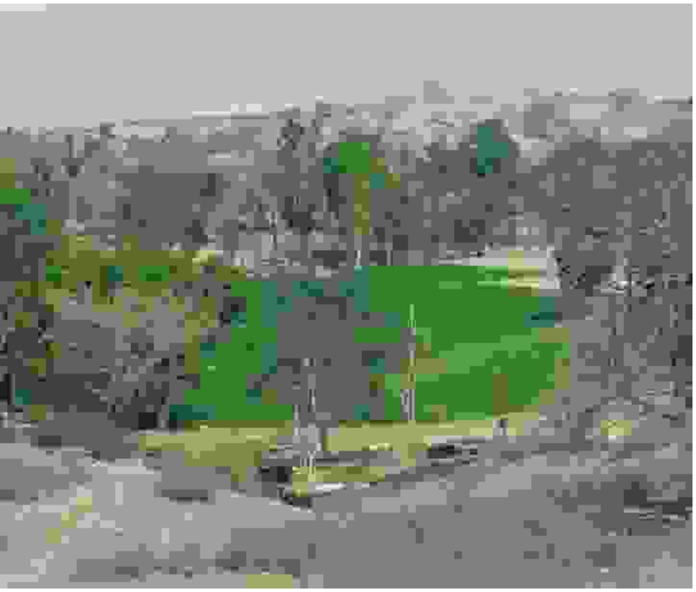
- **Installation of more efficient irrigation technology in Mahabubnagar district, Andhra Pradesh**
  Drip irrigation is an optimal water-saving irrigation technology for perennial horticulture crops. The installation of drip irrigation systems for cultivation of embalica, sapota, orange and mango trees on alkaline soils has helped to bring barren fields back in productive use. Sprinkler irrigation was found to be a good solution for fodder cultivation on low quality soils under high water use efficiency.

- **Renovation and upgrading of harren system in Udaipur district, Rajasthan**
  The renovation and concrete lining of harren channels has significantly enhanced the water distribution efficiency of the system. The intervention has enabled the harren users to increase their production of Rabi crops and secure Kharif crops during dry spells. In addition, the maintenance of the lined harren is less time consuming than before, when repairs were required every year to bring the earthen channels back into operation. The harren users can

save 200 days of labour every year due to the intervention.

Upgrading of traditional irrigation structures like the harren that are well adjusted to the topographic characteristics of the area can increase the productivity and climate resilience of agricultural systems, and thereby help communities to better cope with adverse effects of future climate change.

Figure 22: The installation of a water bank in Kundai, Udaipur district, Rajasthan, has helped to bring more land under irrigation and thereby make livelihoods more resilient against climate risks.



- **Installation of a water bank in Udaipur district, Rajasthan**

  The installation of water tanks at an elevated position, charged from a low lying well through a system of closed pipes, can help to bring fields in the upper ranges of a catchment under irrigation with minimal water losses. This has enabled the community to expand their agricultural activities during Rabi season and even to cultivate vegetables after Rabi. The risk of crop losses in the face of dry spells during Kharif season is much reduced on the irrigated fields.

- **Formation of water management committees and water user groups for tanks, harren system and water bank**

  Water management committees or water user groups have been formed to oversee the equitable distribution of irrigation water among farmers and ensure adequate maintenance of the renovated or newly installed irrigation facilities. The revitalization of community-based management structures was considered a core part of the interventions under the V&A pilot programme, with a view to strengthening the local capacities to deal with increasing stresses on water resources. The water management committees appointed for tank maintenance in Kothur and Srirangapur (Andhra Pradesh) have proved to be effective institutions for community-based decision making around irrigation water issues. The effectiveness and sustainability of the other community-based water management organizations is yet to be validated.

(iii) The following interventions were tried out under the programme as measures to help reduce the water requirements of the production systems:

- **Application of silt excavated from tank beds to fields in Mahabubnagar district, Andhra Pradesh**

  The application of silt from tank beds on farmers' fields has helped to enhance the water retention capacity of the soil, and also ensured good crop yields while reducing the need for chemical fertilizers. Farmers were willing to cover part of the costs. However, the prospect of twofold benefits from tank bed excavation (i.e., silt application on fields and enhanced tank capacity) had not triggered an autonomous initiative by the communities earlier.

- **Participatory crop water budgeting exercise in Mahabubnagar district, Andhra Pradesh**

  A crop water budgeting (CWB) exercise was identified as a possible tool to enhance awareness among communities of limited groundwater resources, and to make unsustainable levels of groundwater draft more transparent to users. Ultimately, the participatory CWB was tried as a measure to build the response capacities of the farming communities to climate-induced changes in the availability of water resources.

The results of the CWB calculations in Srirangapur and Kothur indicated that current levels of groundwater irrigation will inevitably lead to, or aggravate, the overexploitation of the resource. Options were discussed with the communities to address the issue, including a shift to less water intense crops, or further enhancing the capacities of existing water harvesting structures. In order to systematically assess the outcomes and impacts of the CWB workshop, i.e. enhanced awareness and a long-term change in cropping patterns, an adequate monitoring and evaluation framework is still to be developed.

Overall, the V&A pilot programme has identified a range of measures to enhance the resilience of agricultural systems in semi-arid areas in India to risks associated with climate variability and climate change. In particular, it has demonstrated that traditional adaptation strategies which rural communities have developed over decades or centuries to deal with adverse climate conditions like scarce and erratic rainfall, provide a valuable entry point for such measures.

An important aspect of all interventions was the social mobilisation for improving water availability and sustainable water utilization through joint initiatives. It was a core objective to enhance the capacities of the communities to independently plan and implement similar measures in the future. Communities have assumed responsibility for maintenance and repair of the structures created under the V&A pilot programme. Through the formation of community-based groups for managing water and irrigation facilities, communities are now in a better position (i) to seek information on existing government programmes and schemes for improving infrastructure around agricultural water use, and (ii) to leverage funding from these sources. In combination with various exposure visits and awareness raising initiative, these processes of social mobilisation have helped to strengthen the capacities of communities to deal with increasing stresses on water resources.

A number of lessons can be learned from the experiences made in implementing the piloted measures under the V&A pilot programme, and some conclusions can be drawn with regard to options for replicating and up-scaling the activities:

- Several of the technologies adopted, like in-situ soil and water conservation measures, water harvesting structures, and water distribution systems, need to be adapted to the specific topographic and climatic characteristics of the area and the site. The involvement of experts with sound experience in the construction of such measures is inevitable. It is also vital to ensure that the larger structures that are meant to last for several years are designed so as to withstand extreme weather events which are expected with higher frequency and intensity in many areas in the future.
- Extension efforts in rainfed areas have been focusing on disseminating inputs (like seeds and fertilizers) rather than water management knowledge. Extension staff could play an important role in helping farmers learn how to manage their water, land and crops in a sustainable way.
- Some of the physical activities, incl. the soil and water conservation treatments on hillside fields, were preceded by considerable awareness raising efforts undertaken by programme

field staff. When farmers saw the positive effects on other fields in the village, their interest to adopt similar measures grew significantly. Hence, an effective way of mobilizing communities for treatments of hillsides can be to introduce treatments on a limited area of land with a group of pioneer farmers.

- Undertaking a crop water budgeting exercise requires substantive capacities and basic hydrological knowledge on the side of the facilitators. Replication of this measure at a larger scale will therefore depend on capacity building efforts initiated by Agriculture, Irrigation or Groundwater Departments, and supported by policies, plans and programmes at national level. The agriculture extension system and universities could play an active role in the development of a sound capacity building strategy for CWB. Facilitators for participatory CWB exercise workshops at village level could be agriculture extension agents or NGOs.
- The National Rural Employment Guarantee Scheme (NREGS) offers an option for communities to mobilize funds for replication or up-scaling of some of the labour-intensive activities piloted under the V&A programme, namely:
  - renovation of tanks, incl. works on tank bunds, removal of vegetation from tank beds and excavation of tank beds;
  - soil and water conservation treatments of hillside fields belonging to small and marginal farmers;
  - renovation of water harvesting structures, incl. desilting of water storage areas behind the structures; and
  - renovation and up-grading of harren channels.
- India's National Action Plan on Climate Change, unveiled by the Prime Minister's Office in 2008, highlights the increasing stress on water resources due to climate change, and points to the need to “increase efficiency of water use, explore options to augment water supply in critical areas, and ensure more efficient management of water resources”. It calls for measures to enhance groundwater recharge and to augment storage capacities of surface water storage structures, including through the renovation of existing tanks. Dryland agriculture is identified as a priority area for climate change adaptation. The Plan emphasizes the need for improved methods to conserve soil and water, enhanced capacity to cope with climate risks among farming communities, and financial support to enable farmers to invest in and adopt relevant technologies to overcome climate related stresses. The activities piloted under the V&A programme thus offer valuable options for the implementation of the NAPCC and should be considered as low-cost strategies in the design of any programmes emerging under the plan.

9. References

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