Climate Change

Vulnerability & Adaptation Experiences from Rajasthan & Andhra Pradesh

Introduction

INDIA

inter cooperation
Natural Resource Management
Rural Economy
Local Governance and Civil Society

MSSRF

AFPRO
Action For Food Production

iNFRAS

Schweizerische Eidgenossenschaft
Confederation suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Agency for Development and Cooperation SDC

Climate Change

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Introduction

V&A

Climate Change

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

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Acronyms

AFPRO	Action for Food Production
GDP	Gross Domestic Product
GoI	Government of India
IC	Intercooperation
JIG	Joint Implementation Group
MANAGE	National Institute of Agriculture Extension Management
MoEF	Ministry of Environment and Forests
MSSRF	M.S. Swaminathan Research Foundation
PRECIS	Providing Regional Climates for Impacts Studies
SC	Steering Committee
SDC	Swiss Agency for Development and Cooperation
SRI	System of Rice Intensification
V&A	Vulnerability and Adaptation

Foreword

The Swiss Agency for Development and Cooperation (SDC) initiated a process oriented programme in the semi-arid regions of India on Vulnerability Assessment and Enhancing Adaptive Capacity to Climate Change (V&A), in 2005. The aims of this programme include strengthening the resilience of local communities to conditions of unfavourable weather, like adverse alterations in temperature and precipitation leading to the more frequent occurrence of drought and to use the experiences for policy development processes at various levels. Over 60 percent of the cultivated area in India is rain fed and unfavourable and uncertain rainfall patterns will seriously affect the food, drinking water and livelihood security of millions of children, women and men. Since the initiation of this project, the emphasis on proactive research on adaptation mechanisms has increased at the national level.

The present decade may mark the beginning of a new climate era, characterized by extreme and often unpredictable weather conditions and rise in sea levels. The recent Climate Conference in Copenhagen unfortunately failed to get a global commitment to halt economic growth currently based on high carbon intensity. The Climate Conference due to be held in Mexico in December 2010 will probably generate the political commitment essential to restrict the rise in global mean temperature to not more than 2^{o}C. Even a 2^{o}C rise will adversely affect crop yields in South Asia and Sub-Saharan Africa, which already have a high degree of prevalence of endemic hunger. It will also lead to the possibility of small islands getting submerged. **The greatest casualty of Climate Change will be food, water and livelihood security.**

Farmers of the world can help to avoid serious famines by developing and adopting climate resilient farming systems. 2010 has been declared by the United Nations as the **International Year of Biodiversity.** Biodiversity is the feedstock for a climate resilient agriculture. We should therefore redouble our efforts to prevent genetic erosion and to promote the conservation and sustainable and equitable use of biodiversity. This is the goal of another SDC supported project in the field of biodiversity conservation being implemented by MSSRF in Tamil Nadu, Kerala and Orissa.

2010 will also witness a major Conference at the United Nations Headquarters in New York, to review the progress made since the year 2000 in achieving the U N Millennium Development Goals. The first among these goals is reducing hunger and poverty by half by 2015. Unfortunately the number of hungry children, women and men, which was 800 million in 2000, is now over a billion. This is partly due to a rise in food prices globally, thereby making it difficult for the poor to have access to balanced diet at affordable prices. There is no time to relax and the farmers of the world must redouble their efforts to increase food production through an ever-green revolution pathway of increasing productivity in perpetuity without associated ecological harm. Without the total commitment of the two billion farmers of the world to produce more by adopting climate resilient farming systems, the goal of "food for all and for ever" cannot be reached.

For the V&A study, the States of Rajasthan and Andhra Pradesh were chosen for developing climate change adaptation measures. The districts chosen were Udaipur in Rajasthan and Mehabubnagar in Andhra Pradesh. The approach adopted was to bring about a blend of traditional wisdom and modern science through farmer participatory research. The participatory research and knowledge management systems adopted under this programme during the past five years have provided many useful insights

for policies and strategies towards developing a climate resilient farming and livelihood security system. Five of the meaningful V&A interventions were the following.

- **Water conservation and sustainable and equitable use:** Families in the desert regions of Rajasthan have long experience in harvesting every drop of rain water and using it economically and efficiently both for domestic and agricultural use. The traditional methods were reinforced with modern scientific knowledge, like the gravity flow method of water management.
- **Promoting fodder security:** Livestock and livelihoods are intimately related in arid and semi-arid areas. The ownership of livestock is also more egalitarian. The sustainable management of common property resources, particularly pasture land, is essential for ensuring fodder security. Therefore, high priority was given to the regeneration of pasture land and the equitable use of grazing land.
- **More crop per drop of water:** In areas where water for irrigation is the constraint, it is important that agronomic techniques which can help to increase yield and income per drop of water are standardized and popularized. One such method introduced under this project is the System of Rice Intensification (SRI). SRI was popularized in Andhra Pradesh, since this system of water and crop management helps to reduce irrigation water requirement by 30 to 40 percent. This method thus helps to avoid the unsustainable exploitation of the aquifer.
- **Weather Information for All and Climate Literacy:** What farmers need is location specific meteorological information at the right time and place. Generic weather data will have to be converted into location-specific meteorological advice. For this purpose, mini-agro-meteorological stations managed by the local community were established. This has helped to impart to Climate Literacy as related to food, water and livelihood security.
- **Strengthening Community Institutions:** Effective implementation of adaptation measures will need active group cooperation and community participation. Steps were taken to involve the grassroot democratic institutions like **Panchayats** and **Gram Sabhas.** Also, Smart Farmers' Clubs were organized to give the power of scale in water harvesting, soil health management and other adaptation measures undertaken by farmers with small holdings.

The above interventions were supported by training and skill development and education and social mobilization. A Training Manual was prepared by MSSRF for training one woman and one male member of every Panchayat as **Climate Risk Managers.** Such local level Climate Risk Managers are well trained in the art and science of managing weather abnormalities. The present project has highlighted the need for location specific adaptation measures and for participatory research and knowledge management. The V&A interventions have also highlighted the need for mainstreaming gender considerations in all interventions. Women will suffer more from Climate Change, since they have been traditionally in charge of collecting water, fodder and fuel wood, and have been shouldering the responsibility for farm animal care and post-harvest technology. All interventions should therefore be pro-nature, pro-poor and pro-women.

The last five years have been an extremely rewarding learning period. The results and experience have shed light on the way forward. It is clear that to promote location specific and farmer-centric adaptation measures; India will need a Climate Risk Management Research and Extension Centre at each of the 127 agro-ecological regions in the country. Such centres should prepare Drought, Flood and Good Weather

Codes what can help to minimize the adverse impact of abnormal weather and to maximize the benefits of favourable monsoons and temperature. Risk surveillance and early warning should be the other responsibilities of such centres. Thus the V&A programme has laid the foundation for a **Climate Resilient Agriculture Movement** in India. The importance of such a Movement will be obvious considering the fact that 60 percent of India's population of 1.1 billion depend upon agriculture for their livelihood. In addition, India has to produce food and feed for over 1.1 billion human, and over a billion farm animals. Scaling up the findings of the current project is therefore the pathway for a sustainable food, water and livelihood security system in rural India.

Acknowledgements

We place on record our gratitude to the following for making this study possible.

- **Swiss Agency for Development and Cooperation** (SDC) for providing the financial and intellectual support and guidance to this task.
- **Local Communities** of the project villages, field workers of local NGO partners, ***Sahyog Sansthan, Vikas Sansthan*** from **Rajasthan** and ***Eco-club India*** **from Andhra Pradesh** for their untiring work and enabling us to broaden our understanding of field realities.
- **AFPRO** field units of Rajasthan and Andhra Pradesh for their efficient coordination and support services in every stage of the project.
- **MANAGE,** Hyderabad, for their role in organizing Trainers' Training Programmes.
- **INFRAS** and **Intercooperation** for the backstopping support.

MSSRF for its invaluable inputs as the lead agency coordinating the project and providing technical guidance.

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Chairman
M S S waminathan Research Foundation
Chennai

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This publication would not have been possible without the active collaboration of several partners of the Vulnerability Assessment and Enhancing Adaptive Capacity to Climate Change in Semi Arid Regions in India or the "V&A" programme.

At the core of the programme are residents of the four pilot villages Amda and Kundai in Udaipur district, Rajasthan; and Srirangapur and Kothur in Mehboobnagar district, Andhra Pradesh. We gratefully acknowledge their partnership and hope the programme has contributed to a better understanding and improved capacities to deal with climate variability and potentially, climate change.

The pilot projects were implemented with the active support of field NGOs - Sahyog Sansthan and Vikas Sansthan in Rajasthan and Eco- club in Andhra Pradesh. These organizations could leverage their keen understanding of natural resources and their rapport with the community to assess the vulnerability of rural livelihoods to climate risks and implement a set of pilot activities that sought to minimize them.

The AFPRO field units in Rajasthan and Andhra Pradesh, ably supported by colleagues from Delhi, provided coordination and technical support. We thank them for their support in data collection, facilitating numerous field visits and for ensuring that field realities are well reflected in the documentation.

The M S Swaminathan Research Foundation (MSSRF), the National lead organization, was responsible for project management, coordination, technical support and policy dialogue. Prof. M.S. Swaminathan, as the Chairperson of the Project Steering Committee, provided the vision and continued guidance that shaped this programme. We express our deep gratitude to him.

We thank the Swiss Agency for Development and Cooperation (SDC) for their dedicated support, both in terms of financial assistance and intellectual contributions. We express our gratitude to Mr. Francois Binder, the Country Director, for his whole-hearted support as also Dr. Jagannath and Dr. Viswanathan who ably steered the programme.

Dr. Othmar Schwank, Executive Director INFRAS, the lead international consortium partner, energized the team with ideas and insights on the links between climate science, development challenges and global policies.

Lastly, we wish to place on record our gratitude to the Intercooperation team that contributed to the technical content, monitoring and sound documentation of the experiences. Several colleagues from India and Bern - Dr. Carmenza Robledo, Ms. Annet Witteveen, Mr. Vishnu Sharma and Dr. B Ramkumar, worked closely over the past four years. Dr. C K Rao and Mr. Devanshu Chakravarti provided valuable inputs to several case studies in this compilation. Ms. Sreelatha and her team supported document production and quality control processes which are vital elements of such a task.

We hope you find this publication useful and it contributes, in a small way, to helping people deal with the "adaptation deficit" in many rural regions of the world.

Rupa Mukerji Anna Bruderle

Introduction

In recognition of the impending consequences and impact of climate change for rural communities in the semi-arid regions of India, the Swiss Agency for Development and Cooperation (SDC) initiated a process-oriented programme on '*Vulnerability Assessment and Enhancing Adaptive Capacity to Climate Change in Semi Arid Regions in India*' *(V&A)* in 2005.

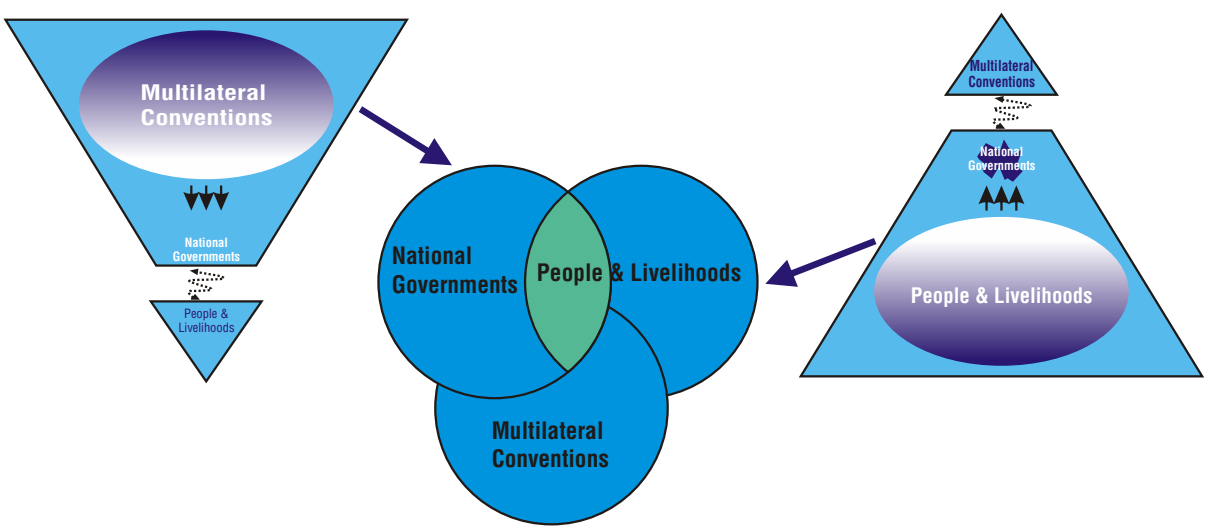
The **overall goal** of the V&A Programme in India was to secure the livelihoods of rural poor and vulnerable communities by promoting adaptation measures that enhance their capacity to better cope with adverse impacts of climate change and by improving their disaster preparedness.

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.

In brief, the programme was aimed at reducing vulnerability of rural livelihood systems to climate risks through selected pilot interventions in key livelihood sectors, with a view to informing and catalyzing policy dialogues at different national and international decision levels using the emerging field experiences. The programme has taken a multi-level action learning approach in order to reduce the gap between realities of climate variability and change and respective adaptive strategies at community level and decision-making around climate change adaptation at national and international levels **(Figure 1).**

Figure 1: V&A approach: Linking community-level findings to national and international policy making.



Institutional partnerships

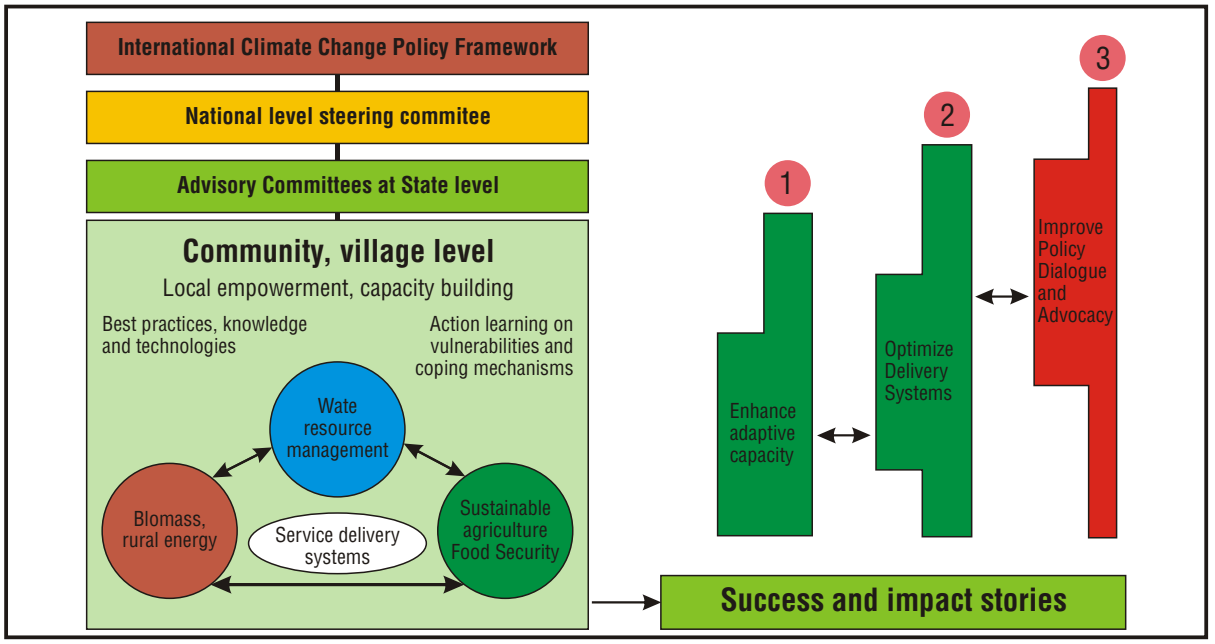
The programme is built on the collaboration among various actors with complementary strengths. It aims at generating synergies with other relevant programmes and ongoing activities of SDC in India as well as with relevant programmes of the Government of India (GoI) **(Figure 2).**

A **National Consortium** was formed to take the overall responsibility for managing and operationalising the programme. The National Consortium comprised three partners, namely the M.S. Swaminathan Research Foundation (MSSRF), Action For Food Production (AFPRO), and the National Institute of Agriculture Extension Management (MANAGE). "The National consortium established, guided and managed the field activities providing valuable scientific technical and operational support to the field NGOs and communities".

An **International Consortium,** constituted by Intercooperation (IC) and INFRAS, took a backstopping role and provided services as per demand from SDC and the national programme partners. The International Consortium contributed to the conceptual planning of the programme by bringing in international experiences and global exposure, provided quality assurance throughout the programme implementation, supported the development of an appropriate monitoring framework, and facilitated continuous exchange with ongoing policy processes at the international level. In addition, the final documentation and the development of the training curriculum was anchored in the International Consortium.

The Swiss Agency for Development and Cooperation (SDC) provided financial support for the programme, assumed a steering role, contributed to overall programme development, and facilitated linkages with the GoI.

Figure 2: Institutional set-up, approach and main objectives of the V&A programme.



Box 1 provides a brief profile of each of the agencies involved in the implementation of the programme.

Box 1: Agencies involved in the implementation of the V&A programme

The **Swiss Agency for Development and Cooperation (SDC)** is Switzerland's international cooperation agency within the Federal Department of Foreign Affairs, and is responsible for the overall coordination of development cooperation activities and humanitarian aid of the Swiss Government. In India, SDC has been active since 1963. With India emerging as a global power, SDC's programme today is moving away from traditional development cooperation towards collaboration based on common interests and shared investments. The programme focuses on addressing the global challenge of climate change, with the ultimate goal of reducing poverty. A key feature of this new programme is the exchange of know-how and technologies between Switzerland and India as well as the promotion of cooperation between developing countries. For more information, see http://www.sdcindia.in

M. S. Swaminathan Research Foundation (MSSRF) is a 20-year-old non-profit organization. The vision of MSSRF is to link science and society. The basic mandate of MSSRF is to impart a pro-nature, pro-poor and pro-women orientation to a job-led economic growth strategy in rural areas through harnessing science and technology for environmentally sustainable and socially equitable development. MSSRF has recognised strengths in scientific and social research, policy dialogue, community action, capacity building and outreach and dissemination.
For more information, see http://www.mssrf.org

Action For Food Production (AFPRO) is an Indian socio-technical non-governmental organization working for the development of the rural poor through effective natural resource management solutions. It provides technical guidance, backup support and capacity building input to grassroot-level NGOs for the implementation of environmentally friendly projects for water, food security, livelihoods and allied areas. AFPRO has nine field units strategically located all over India. It has a multidisciplinary team of professional staff, having a deep understanding of the rural settings, and facilitates communities in problem identification and finding feasible, affordable and appropriate options in the local context to sustain and multiply the outcome.
For more information, see http://www.afpro.org

The National Institute of Agricultural Extension Management (MANAGE) is an apex national institute set up in 1987 as an autonomous society under the Ministry of Agriculture, Government of India. MANAGE is the Indian response to the challenges of management in a rapidly growing agricultural sector. As a management institute, MANAGE has a mandate to assist the State Governments, the Government of India and other public sector organizations in effective management of their agricultural extension and other agricultural management systems. MANAGE facilitates the acquisition of managerial and technical skills by extension officers, managers, scientists and administrators in all sectors of agricultural economy to enable them to provide most effective support and services to farmers and fishermen for practicing sustainable agriculture.
For more information, see http://www.manage.gov.in

Intercooperation (IC) is recognised for supporting partners in international and development cooperation. It has had a lead role in the implementation of development programmes in the field of natural resource management in various states, including in semi-arid regions of India. IC, as a NGO accredited by the UNFCCC, has extensive experience and expertise in climate change. Climate

change mitigation and adaptation projects and programmes at different levels in Asia and Latin America have been a core part of IC's portfolio since the late 1990s. Currently, Intercooperation is involved in designing tools for planning, implementing and monitoring adaptation measures at the national and local levels. Through its longstanding involvement in SDC projects in Andhra Pradesh and Rajasthan, Intercooperation has developed a network of local organizations in these areas, besides in 5 other states of India.

For more information on Intercooperation in India, see http://www.intercooperation.org.in For information on Intercooperation's global portfolio, see http://www.intercooperation.ch

The INFRAS Consulting, Policy Analysis and Research Group (INFRAS) is a recognized consulting company in Switzerland and abroad. INFRAS has long-standing experience in development cooperation, including in the provision of technical assistance, facilitation of technology and knowledge transfer, and development of strategies and proposals in the area of global environment, especially climate change. INFRAS has been implementing research and development projects in India for more than a decade. INFRAS also closely follows and contributes to ongoing international policy dialogues and has access to relevant international fora. One element of the role of INFRAS in the V&A programme therefore was to ensure that the programme design and documentation was in line with and relevant for the concepts under debate in the UNFCCC process. For more information see http://www.infras.ch

For an effective steering of the programme and coordination among the different partners, the programme set-up included a **Steering Committee** and a **Joint Implementation Group (JIG)** as a main responsible body for programme implementation **(see Figure 3).** Responsibilities of the JIG included operational decision-making, operational planning and budgeting, mandating implementing partners, resource distribution, and monitoring and evaluation.

Figure 3: Institutional set-up for implementation of the V&A programme

Programme design and history

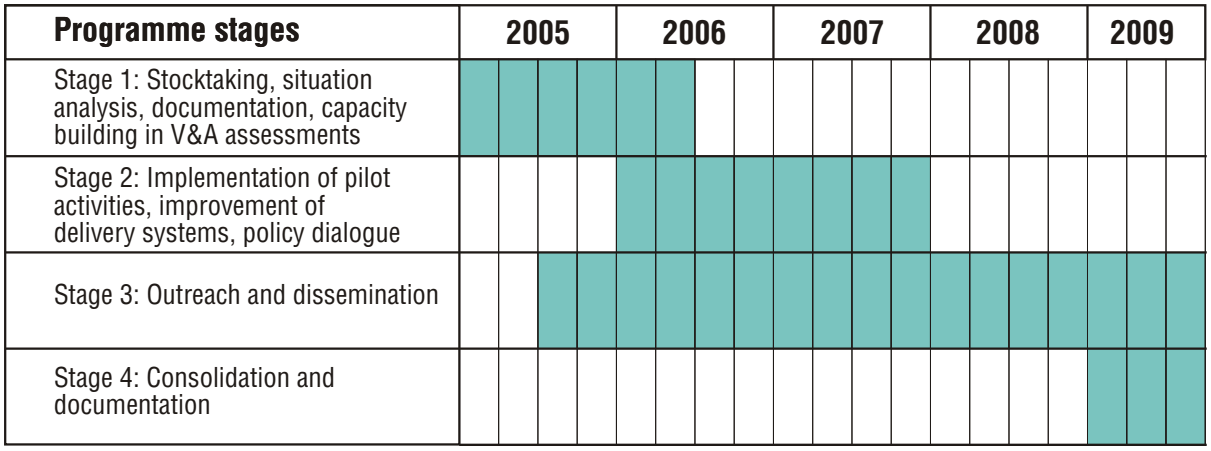
The V&A programme design was the outcome of an inclusive stakeholder process of consultations and workshops at different levels. The local communities in the semi-arid areas selected for programme implementation were the primary stakeholders and took a center stage in consultations for programme design. The stakeholder body involved in the process also comprised local, state and central governments, service providers, including line departments and government agencies in charge of extension services, selected NGOs, CBOs, and relevant research institutions.

The V&A programme was implemented in three overlapping stages, with an initial stocktaking and documentation period, an implementation period, and a period of consolidation, focusing on outreach, networking and dissemination **(Figure 4).** It was also decided to analyse and document the most important field experiences such that they feed into national policies and missions and international frameworks. Five specific areas of V&A interventions were identified as most relevant for the ongoing policy dialogues on climate change adaptation:

- improved water management;
- development of pasture land for ensuring fodder security;
- the System of Rice Intensification (SRI);
- the role of local community institutions for enhancing adaptive capacity; and
- mini agro-meteorological labs for local level weather monitoring.

The present set of case studies is a reflection of four years of programme implementation and the documentation.

Figure 4: Overlapping stages of V&A programme implementation 2005-2009.



Geographic focus of the V&A programme

India's initial National Communication to the UNFCCC, 2004 highlighted that the livelihoods of the majority of people living in India, notably in rural areas, are threatened due to the impact of climate change. The livelihoods of rural communities are primarily based on climate-sensitive natural resources.

At the same time, their endowment of physical, financial and human resources is low, which leaves them with poor adaptive capacities and makes them highly vulnerable to the expected impact of climate change.

The main source of livelihood for the rural population is based on agriculture. Rain-fed agricultural systems, which constitute over 60 percent of the country's crop area, are most directly impacted by variability of rainfall and longer-term changes in precipitation patterns. Areas under irrigation will also feel the consequences if the climate changes as projections indicate. Glaciers are expected to recede, rainfall patterns are likely to change, with increased severity and frequency of droughts and higher intensity of floods in some areas, all resulting in reduced quantity of available run-off and reduced groundwater recharge. In addition, projections indicate that rising temperatures will enhance crop water demand, resulting in increased water-pumping requirements and subsequent decrease in groundwater levels.

Another major concern associated with climate change in India is the prospect of a significant biodiversity loss. About 70 percent of the vegetation in India is likely to find itself less than optimally adapted to its present location, making it more vulnerable to adverse climatic conditions. The impact on forests will have adverse socio-economic implications for forest dependent communities and the national economy.

Box 2: Climate change projections for India

High-resolution climate change scenarios for India, generated by PRECIS (Providing Regional Climates for Impacts Studies, a high-resolution climate modeling system developed by the Hadley Center), indicate a rise in annual mean surface air temperature for all parts of India. Temperatures are likely to rise by 3-5°C and 2.5-4°C in A2 and B2 emission scenarios by the end of the 21st century, with warming more pronounced over the northern parts of India. The warming is also expected to be relatively greater in winter and post-monsoon seasons than in the summer monsoon season **(Figure 5)**

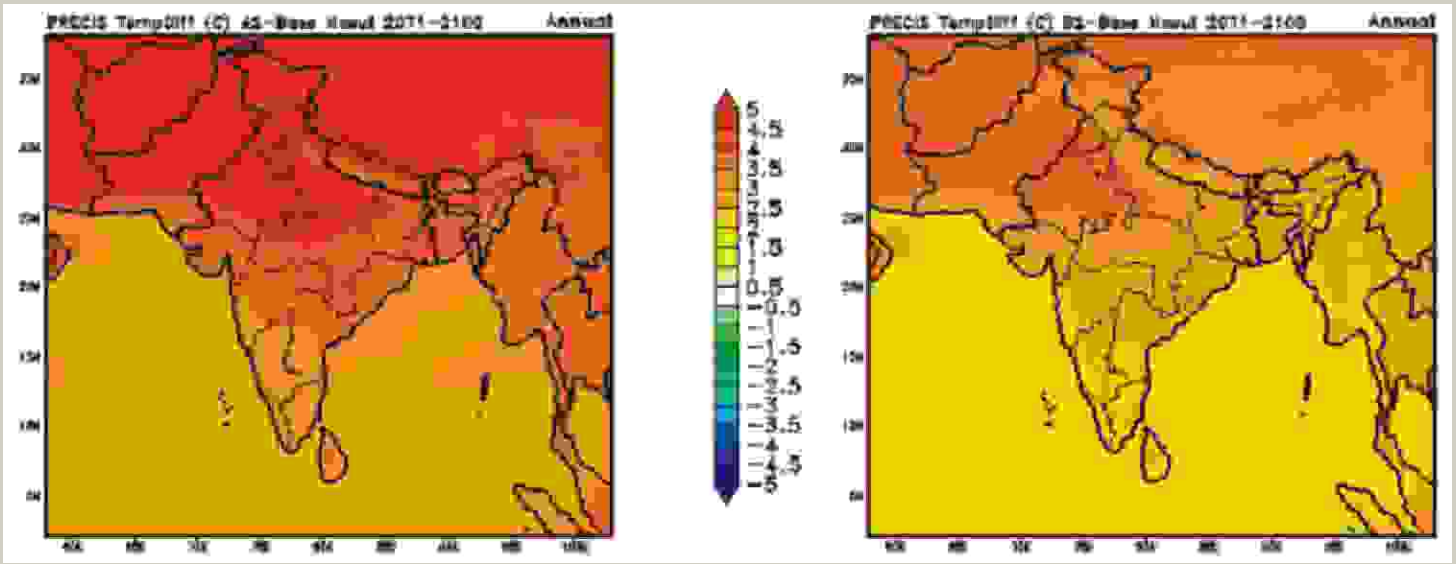


Figure 5: Projected changes in surface air temperature towards the end of 21st century, for A2 and B2 scenarios.

As regards precipitation, the model predicts increases for all parts of India, except for Punjab, Rajasthan and Tamil Nadu. A 20 percent rise in all India summer monsoon is expected for the period 2071-2100. In northeast India, precipitation is likely to increase more than the national average **(Figure 6).**

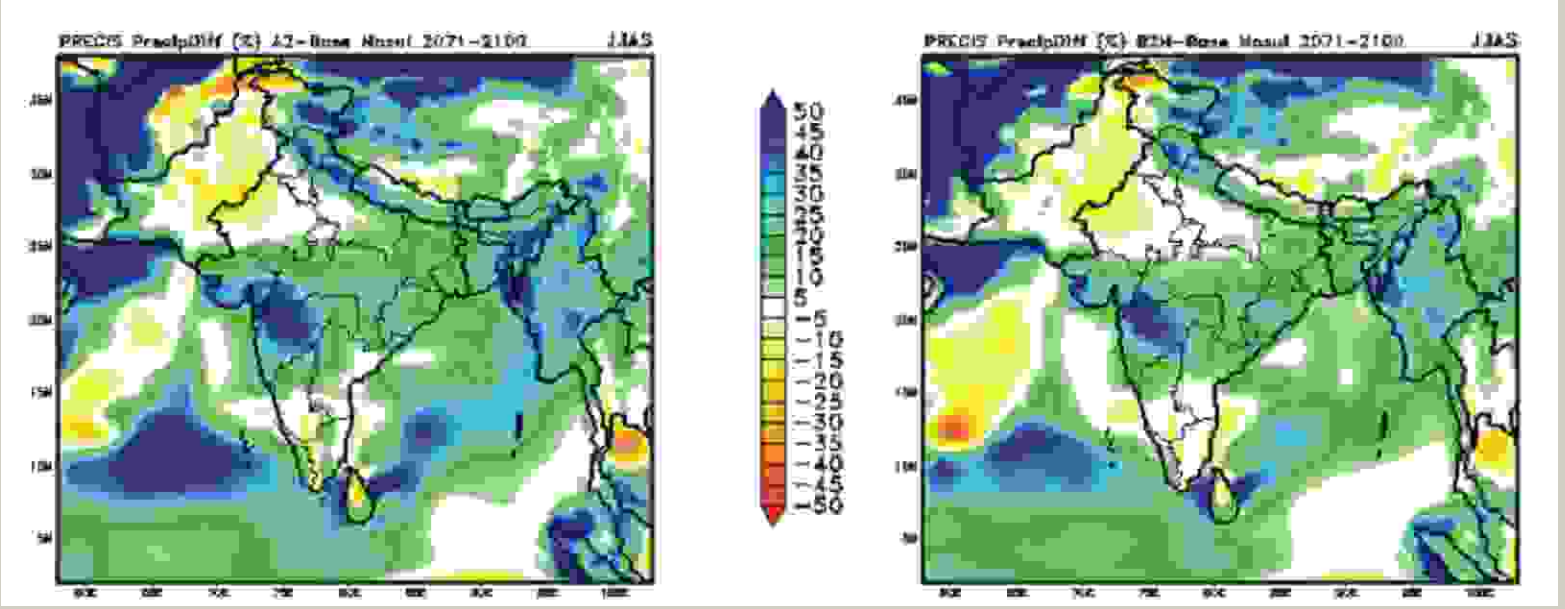


Figure 6: Projected changes in summer monsoon precipitation towards the end of 21st century, for A2 and B2 scenarios.

The all-round warming seen in the seasonal mean temperatures is reflected in the extreme temperatures also. Both days and nights are expected to get warmer, with night temperatures likely to increase at much higher rates than day temperatures. While the lowest minimum temperatures are expected to be warmer by more than 5°C over most parts of the country, the highest maximum temperatures show an increase of only 2°C.

In terms of extreme precipitation, there is a general increase in both 1-day and 5-day extremes. In particular, there is a marked increase in the severe rainfall activities over an extensive area covering the Western Ghats and northwestern peninsular India including Maharashtra and the adjoining parts of Andhra Pradesh, Madhya Pradesh and Karnataka.

Source: Kumar et al (2006): High resolution climate change scenarios for India in the 21st century, in Current Science, Vol. 30, No. 3.

When assessing the vulnerability of different regions in India, the arid and semi-arid areas are considered to be among the most vulnerable (besides coastal zones). Annual rainfall amounts to only 100-400 mm in arid areas, and 400-800 mm in semi-arid areas in India, with a very high coefficient of variation, ranging from 40 to 70 percent. Low and erratic rainfall coupled with extreme temperatures and intense solar radiation results in frequent crop failures and considerably affects the agricultural economy in these regions.

Figures 7 and 8 indicate arid and semi-arid regions of India and the degree and nature of water stress in different regions. Andhra Pradesh in the south-east and Rajasthan in the north-west of India, are among the areas that are likely to come under most pressure due to climate change. As available water resources are already scarce, increasing variability of rainfall and risk of droughts will have severe consequences

Figure 7: Arid and semi-arid regions of India.
Source: Velayutham et al., 1999.

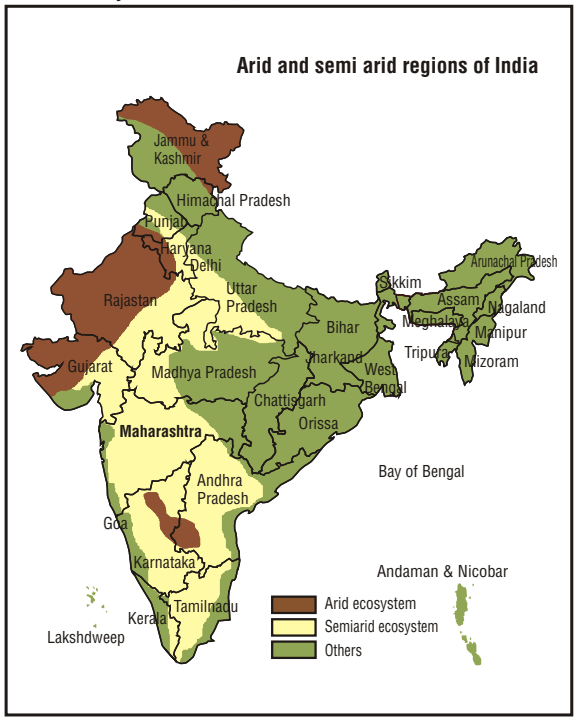
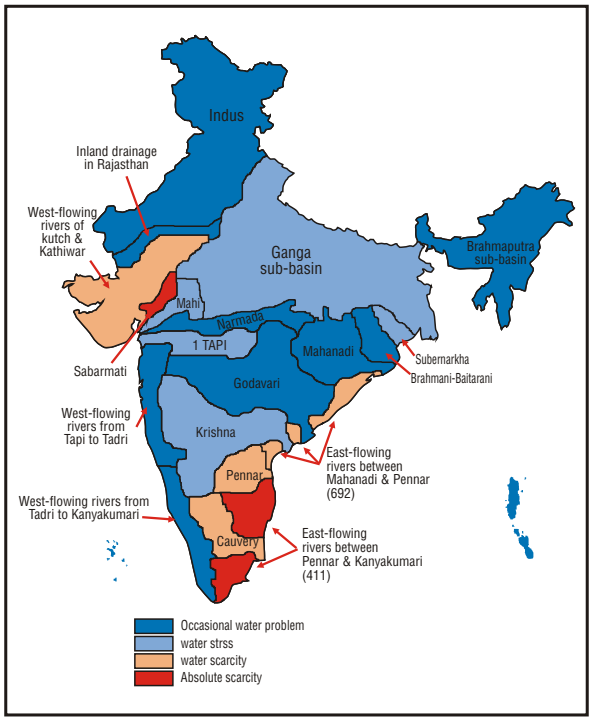


Figure 8: Degree and nature of water stresses in different regions of India.
Source: TERI GIS Database, 2001, based on Chitale, 1992.



for peoples' livelihoods. These areas were therefore selected for the implementation of the V&A programme.

Specific districts and sites in Rajasthan and Andhra Pradesh were identified for programme implementation through a multi-stakeholder process and a set of pre-defined criteria. The criteria included (i) manifestation of climate hazards; (ii) evidence of social organization at village level; (iii) presence of local partners and service providers. Climate data from the past 30 years were analyzed to assess the climate risk situation in different districts in the two States, and a situation analysis was carried out to map the biophysical and socio-economic profiles of the districts and to appraise the status of the delivery systems.

Based on the findings, two villages in Mahabubnagar district in Andhra Pradesh, namely Kothur and Srirangapur, and two villages in Udaipur district of Rajasthan, namely Amda and Kundai, were identified for programme implementation.

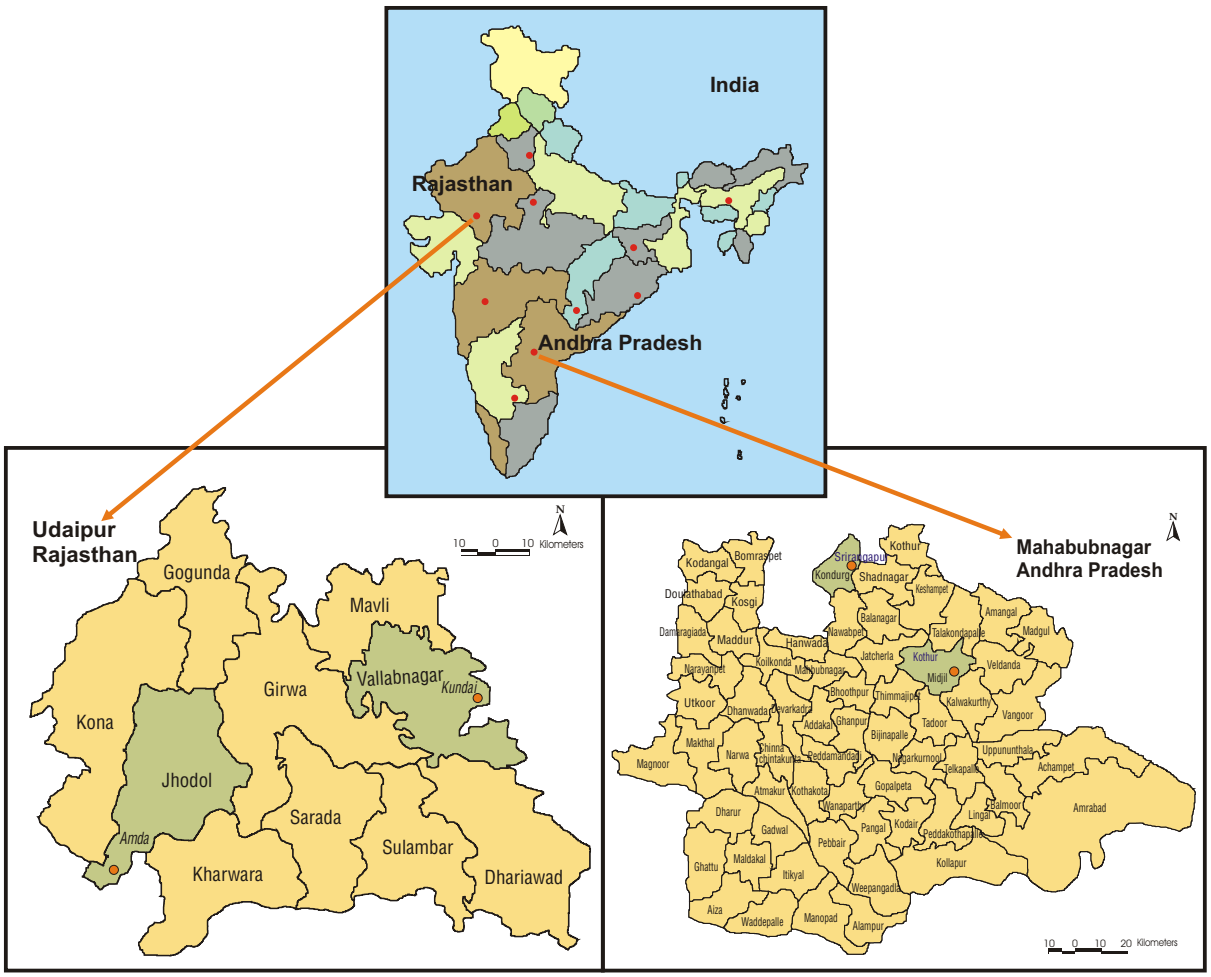


Figure 9: Location of Programme Villages.

Climate change impacts in Udaipur district, Rajasthan, and Mahabubnagar district, Andhra Pradesh

The following section provides a concise description of the current and projected future climate conditions in the semi-arid areas selected for implementation of the V&A programme. It must be noted that to date, high-resolution scenarios to predict climate change impacts at the scale of sub-national regions are generally marked by high uncertainty and only offer vague information on the future distribution of rainfall, particularly in variability and extremes. Scientists are working to further develop downscaled climate models. The Indian Institute of Tropical Meteorology has applied the regional climate modeling system PRECIS developed by the Hadley Centre for Climate Prediction and Research, for India (Kumar et al., 2006), and the results are employed here to provide a notion of the expected climate trends in the areas selected for implementation of the V&A programme.

For an analysis of climate change impacts on natural and human systems, particular attention is to be given to projected trends in the occurrence of extreme weather events, such as droughts, heat waves and floods. Changes in average weather conditions, while important, often provide an incomplete or even misleading image of future climatic conditions in a region. For example, even though annual rainfall in many areas of India may be expected to increase, the risk of acute water shortages in the same areas is also expected to increase, as rainfall will be more erratic and concentrated over fewer rainy days in the year.

Udaipur district, Rajasthan

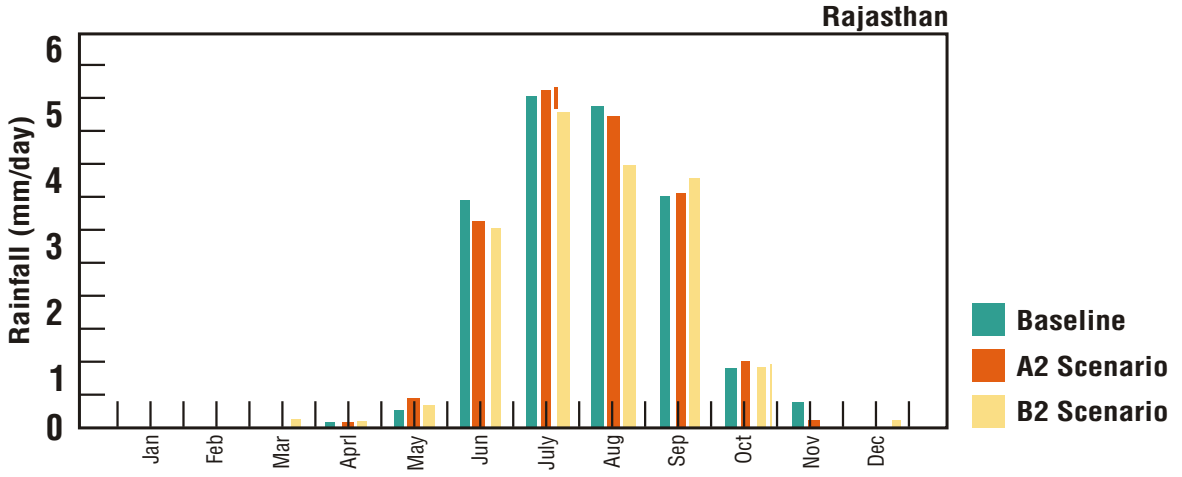
Present climate conditions

Udaipur district in southern Rajasthan falls in the agro-ecological sub-region (AESR) 4.2, described as the hot semi-arid region in the Northern Plain (and Central Highlands) that includes the Aravali Mountains. 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. More than 90 percent of the total annual rainfall occurs during the 4 monsoon months from June to September (South West monsoon). Therefore, the length of growing period is 90-120 days. Maximum daily temperatures range between 35°C and 45°C in summer, and between 20 and 24°C in winter. During cold spells in winter, night temperatures can drop to below 5°C.

Climate change projections and impacts on the natural system

The mean annual surface air temperature in Rajasthan is likely to increase by 2-4°C towards the end of the 21st century. Mean annual precipitation is predicted to decrease slightly, whereas the extreme precipitation is expected to increase in frequency and intensity. Maximum 1-day precipitation is expected to increase by 20 mm, and maximum 5-day precipitation by 30 mm in the period 2071-2100. Figure 10 provides an overview of the projected changes in the annual precipitation cycle.

Figure 10: Baseline and future projections (2071 - 2100) of mean annual cycles of precipitation for Rajasthan, as simulated by PRECIS



Source: Kumar et al. (2006).

[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.

Intense rain occurring over fewer days implies increased frequency of floods during the monsoon season, as well as higher losses of rainwater as direct runoff and reduced groundwater recharge. Many existing structures for rainwater harvesting and flood control may not be robust enough to withstand more intense extreme weather events

The expected changes in the precipitation pattern are also likely to aggravate problems of soil erosion in undulating and mountain areas of Rajasthan. Run-off during heavy rain spells is among the most important factors causing soil degradation, taking away huge amounts of soil particles and nutrients from sloping lands. With the occurrence of more torrential rains after longer intermittent dry and warm gaps, sediment discharge from the dry and barren surface will be enhanced.

Mahabubnagar district, Andhra Pradesh

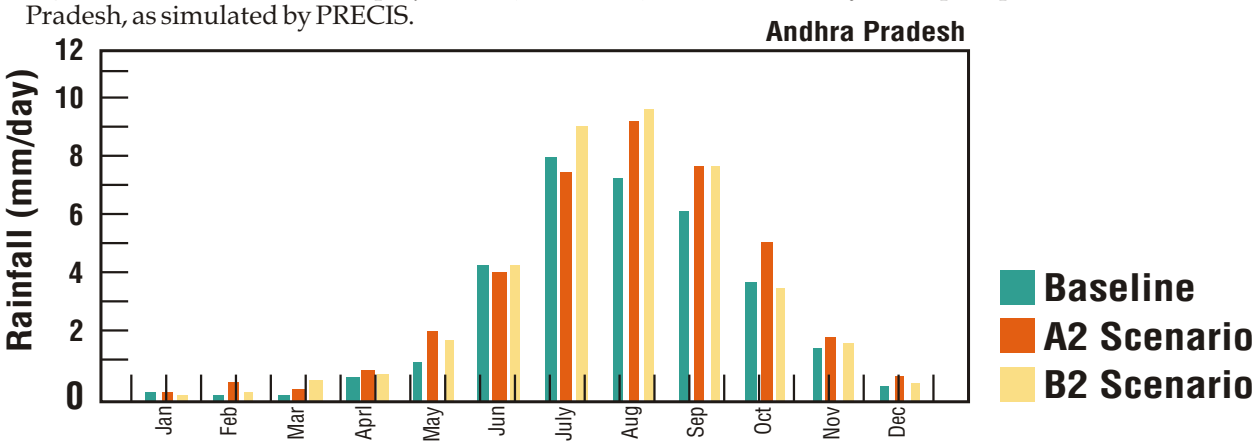
Present climate conditions

Mahabubnagar district in Andhra Pradesh falls in the agro-ecological sub-region (AESR) 7.2, characterized by hot moist summers and mild and dry winters, with a length of growing period of 120-150 days. Total annual rainfall in the district averages around 600 mm, whereby 70 percent of this is received during the south-west monsoon period from June to October. The daily maximum temperature during the period ranges from 17°C to 42°C, and the minimum temperature during the winter season, i.e. from November to January, ranges from 17°C to 19°C.

Climate change projections and impacts on the natural system

The mean annual surface air temperature in the area is likely to increase by 2-3°C towards the end of the 21st century. Average daily precipitation is expected to increase throughout the annual cycle (figure 11, with total summer monsoon precipitation (from June to September) expected to rise by 15-20 percent. Extreme precipitation events are predicted to become more intense: Maximum 1-day precipitation is likely to rise by 40 mm, and maximum 5-day precipitation by 60 mm in the period 2071-2100. At the same time, the frequency and intensity of dry spells and droughts is expected to increase.

Figure 11: Baseline and future projections (2071 - 2100) of mean annual cycles of precipitation for Andhra Pradesh, as simulated by PRECIS.



Source: Kumar et al. (2006).

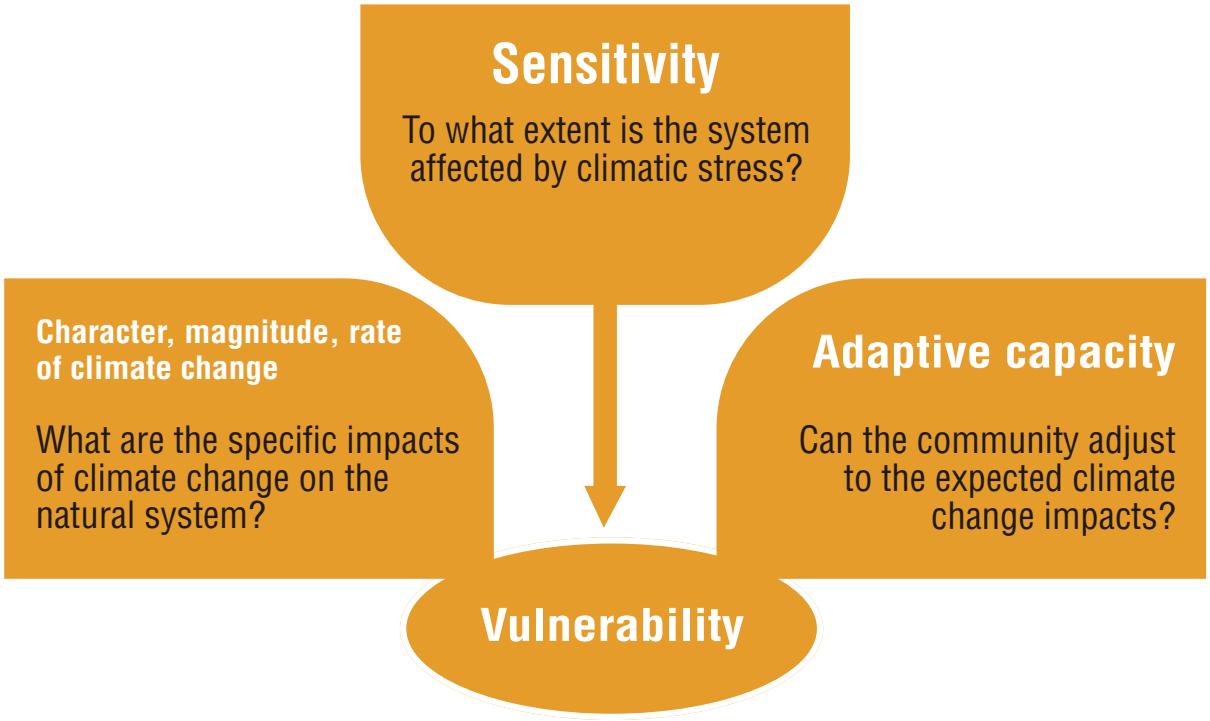
The trend towards more erratic and concentrated rainfalls will enhance the levels of surface run-off and reduce groundwater recharge potentials in the area. Similarly, soil moisture is expected to increase during the months of monsoon, but decline throughout the rest of the year (Lal and Singh 2001).

Assessment of vulnerability of the selected programme sites to climate variability and change

A comprehensive assessment of the vulnerability to climate variability and change of the communities selected for implementation of the V&A programme was undertaken in the first programme phase.

There are different factors, which determine the vulnerability of communities to the effects of climate change. Communities may experience similar manifestations of climate change in completely different ways, depending on how sensitive their livelihoods are to climatic factors, and on the capacity of the community to adapt to changes (Figure 12).

Figure 12: Vulnerability to climate change as a function of various factors



Sensitivity considers the extent to which a system can be affected by climate change. Livelihood activities that are based on climate-dependent natural resources, like water, soil, forests, etc. are more sensitive to climatic stress than activities that involve climate-robust capital. For example, the agriculture sector is in general much more sensitive than the manufacturing sector (although it can be affected by extreme events, reduction in water supplies, power disruption etc.,). The livelihood systems of four villages in which the V&A programme was implemented, are marked by high climate sensitivity, with agriculture as the main source of income in all four villages.

The adaptive capacity of a community to changes in the natural system, including climate change, is again a function of various factors, including

1. the community's endowment with physical, financial and natural capital;
2. access to technology;
3. access to information on climate variability and change, and skills to make use of the information (i.e. human capital);
4. institutions and the degree to which a community is organized (i.e. social capital); and
5. equitable distribution of resources (societies with relatively more equitable resource distribution will be better able to adapt than societies with less equitable distribution).

In other words, the higher a community's endowment with the 5 forms of livelihood capital - physical, natural, social, human and financial - the higher its adaptive capacity. This also means that the level of adaptive capacity tends to be positively correlated with the level of economic and social development.

Box 3: Definition of vulnerability by the Intergovernmental Panel on Climate Change

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change to which a system is exposed, along with its sensitivity and adaptive capacity.

Sensitivity is the degree to which a system can be affected, negatively or positively, by changes in climate. This includes change in mean climate and the frequency and magnitude of extremes. The effect may be direct (for example a change in crop yield due to a change in temperature) or indirect (such as damage caused by increased frequency of coastal flooding due to sea-level rise).

Adaptive capacity is a system's ability to adjust to climate change (including climate variability and extremes), to moderate potential damage, to take advantage of opportunities or to cope with consequences.

Source: IPCC, Fourth Assessment Report, 2007.

Accordingly, the assessment of adaptive capacity of the communities selected for implementation of the V&A programme in the baseline year of 2005 was structured around the 5 categories of livelihood assets or capital.

Tables 1 to 4 provide an overview of livelihood resources with which the communities are endowed and associated special challenges and constraints to adaptive capacity.

Table 1: Endowment of livelihood resources of Amda, Udaipur district, Rajasthan (2005)

Capital	Situation	Adaptive capacity: Special constraints and strengths
Human and social capital	Amda has a total population of 1931 (385 households). The large majority of the population (83 percent) is tribal. The total literacy rate is 24 percent (33 percent among the male and only 15 percent among the female population). Due to low agricultural productivity and lack of employment opportunities, many young people migrate to Gujarat to gain income as agricultural laborers. Knowledge among the villagers about appropriate land management, options for irrigation technologies, and alternative farming practices (e.g. organic practices) is very low.	(-) High illiteracy especially amongst women, who play a key role in agricultural management - major constraint to information dissemination and involvement of key stakeholders in decision making. (-) Restricted knowledge around agriculture and land management. (-) Weakening of human and social capital through out-migration.
Financial capital	Amda has 13 savings and credit groups (2 women and 11 men groups); all these groups are linked with local commercial banks for credit activities; 165 households are associated with Self Help Groups. There is no market in the village where small and marginal farmers could sell their surplus products.	(+) Relatively good structures in place to facilitate access to financial services. (-) Lack of market access.
Natural capital	Amda is located in the western Aravali mountain ranges, characterized by hilly and rugged terrain. Of the total land area, 49 percent is forestland; irrigated land is only 1 percent, of the total land, 21 percent is unirrigated arable land. The forest area is marked by a high degree of biodiversity, with a wide range of varieties of trees, grasses, medicinal herbs and wild animals; for about 3 percent of the total village population forest products are the main source of livelihood; the forest area is the primary source of fuel for cooking and domestic purposes. Private and common pasture lands are marked by high soil and vegetation degradation. There has been a remarkable change in land use pattern since 1990: about 40 ha of cultivable wasteland have been turned into cultivated rainfed area; in the same period, the area under irrigation has further declined from 25 to 18 ha due to decline in irrigation water availability.	(-) High and increasing dependence on rainfed agriculture. (-) Land not suitable for agriculture, risk of further land degradation. (+) High biodiversity in forest. (-) Risk of deforestation with increasing population growth pressure. (-) Lack of fodder production to sustain the livestock population of the village. (-) Groundwater scarcity, especially in summer.

Table 1: Endowment of livelihood resources of Amda, Udaipur district, Rajasthan (2005)

Capital	Situation	Adaptive capacity: Special constraints and strengths
Natural capital	Groundwater is available in very limited quantities due to poor and restricted permeability of the underlying compact banded gneissic formations; the water level is generally 8-10 m below ground level; during summers, the water level tends to sink further resulting in shortage of water for human and cattle consumption. Marginal farmers with less than 1 ha land are about 54 percent, small farmers with 12 ha land are 30 percent, and only 16 percent have more than 2 ha of land holding. The most important crops cultivated in the kharif season are maize, gawar, til, sorghum, arhar, rice, pulses, ginger, turmeric and musli (medicinal plant). The main rabi crops are wheat, mustard, barley, gram, and sorghum.	
Physical capital	Seeds used are of rather poor quality. Almost all families keep animals; there are 1925 cows, 770 buffaloes, 3850 goats, 1000 chicken; the cows are mainly of a local breed which has low yields of milk. There are 33 open wells and 9 bore wells in the village, most of which have water only for about 8 months in a year. There are 4 small low cost water harvesting structures with limited water holding capacity due to heavy siltation of the water storage areas behind the structures and breaks in the structures. There are 2 traditional harren systems which facilitate irrigation water distribution through earthen channels; the harrens cover 1/3 of the total area under irrigation. There are 13 operational hand pumps for drinking water in the village; a total of 28 families have no access to these pumps and fetch drinking water from small ponds along the bank of river, which tend to get muddy during the rain season. There is a lack of animal health care facilities. People cook on unimproved stoves mainly with firewood, dry shrubs and dry cow dung. Women walk on an average 4-5 km per day for collecting firewood in bundles which weigh 20-25 kg.	(+) High number of livestock, which serve as a secondary source of income and augment nutrition, but also as a security for times of stress. (-) Low productivity of cattle. (-) Lack of access to safe drinking water for some families. (-) Lack of irrigation facilities; low efficiency of existing facilities. (-) No access to modern energy in the village.

Source: Primary data from the V&A programme Situation Analysis (2006).

Table 2: Endowment of livelihood resources in Kundai, Udaipur district, Rajasthan, 2005

Capital	Situation	Adaptive capacity: Special constraints and strengths
Human and social capital	Kundai has a population of 150 households. The community is heterogeneous with several families belonging to scheduled castes and scheduled tribes. The village has a middle school, a primary health center, and a cooperative society office. School attendance among girls in the village is above average level in the area, with at least one girl from almost every household completing secondary education. Due to a lack of employment opportunities, young people often migrate to nearby towns for wage labour. Knowledge among the villagers about appropriate land management, options for irrigation technologies, and alternative farming practices (e.g. organic practices) is very low.	(+) Relatively good education levels among female youth. (+) Education and health care facilities are relatively good. (-) Restricted knowledge around agriculture and land management. (-) Weakening of human and social capital through out-migration.
Financial capital	There are 4 active Self-Help Groups (SHGs) for savings and credit activities in the village, 2 of them women SHGs, one men group and one mixed group. There is a local market for the sale of surplus agricultural products in a nearby village. There is a milk collection centre of Udaipur Dairy Cooperatives in the village. The block headquarter (Bhinder) for sale and purchasing of grains, meat and wool is at a distance of 15 km.	(+) Very good market access for the sale of milk. (+) Relatively good market access for the sale of surplus agricultural products.
Natural capital	Kundai is located in the eastern plain of Udaipur district, which is characterized by a leveled topography with occasional outcrops of older rocks. There is no forest land in the village. The share of irrigated land is 10 percent of the total land area, unirrigated cultivable land 16 percent, and private uncultivable land and government wasteland almost 50 percent of the total land area. This land is generally barren and spread over low-lying ridges. Private and common pasture lands are marked by high soil and vegetation degradation, and productivity of pastures is very low; there is shortage of fodder especially during low rainfall years and during summer months.	(-) High dependence on rainfed agriculture. (-) Lack of fodder production to sustain the livestock population of the village. (-) high incidence of insect pests. (-) Limited groundwater availability for drinking and irrigation, especially during summers. (-) shortage of firewood. (+) High number of livestock, which serve as a secondary source of income and augment nutrition, but also as a security for times of stress.

Table 2: Endowment of livelihood resources in Kundai, Udaipur district, Rajasthan, 2005

Capital	Situation	Adaptive capacity: Special constraints and strengths
Natural capital	Groundwater availability is dependent on annual rainfall; the underlying gneissic complex rocks are hard and compact. Average depth of open wells is 20 m, and pre-monsoon average water level is 1516 m, and post monsoon is 5-6 m. Quality of groundwater is good, suitable for irrigation and domestic purposes. Insect pests have lately caused enormous damage to crops, but also to trees and other plants. The large majority of households in the village are small and marginal farmers. The most important crops cultivated in the kharif season are maize, gawar, til, sorghum, arhar, rice, pulses, ginger, turmeric and musli (medicinal plant). The main rabi crops are wheat, mustard, barley, gram, and sorghum.	
Physical capital	There are 353 cows, 237 buffaloes, 573 goats and 223 sheep; the number of cows and buffaloes has increased significantly in the village over the last years; the cows and buffaloes are predominantly of local traditional non-descript breed which have low yields of milk. The major source of irrigation in the village is groundwater; of 107 wells in the village, 64 are in operation; 10 of these are electrified, 4 use diesel pumps and 50 use bullock motes. There are 4 old small water-harvesting structures in the village which help to recharged nearby open dug wells, the water holding capacity in these structures is however limited due to siltation; the Gram Panchayat has constructed two new water harvesting structures under the National Food for Works Programme. There are also 13 hand pumps in different localities of the village, not all of which are operational; drinking water is also drawn from open wells, which tend to go dry in summer. People cook on unimproved stoves mainly with firewood, dry shrubs and dry cow dung. Women walk on average 4-5 km per day for collecting firewood in bundles which weigh 20-25 kg.	(-) Lack of irrigation facilities; low efficiency of existing facilities. (-) Lack of access to safe drinking water for some families. (-) No access to modern energy. (-) Low productivity of cattle. (+) Dairy development is on the rise in the village.

Source: Primary data from the V&A programme Situation Analysis (2006).

Table 3: Endowment with livelihood resources of Srirangapur, Mahabubnagar district, Andhra Pradesh, 2005

Capital	Situation	Adaptive capacity: Special constraints and strengths
Human and social capital	Srirangapur has a total population of 923 (187 households). The majority of the community belongs to Backward Castes (BC) and Scheduled Castes (SC); there is no tribal population in the village. Most of the children go for middle and secondary schools and colleges in nearby towns. The overall literacy rate is 50 percent (62 percent among men and 38 percent among women). 188 marginal and small farmers earn their income primarily from agricultural labour. Only 24 persons migrate on a seasonal basis for labour in construction and agriculture; only four villagers have migrated permanently.	(+) Income opportunities in close proximity to the village low migration - comparatively low risk of human capital outflow.
Financial capital	There are 8 women Self-Help Groups and 5 Rhythu Mithra Sangham Groups in the village. Srirangapur is located at a distance of 80 km from Hyderabad and only 45 km from the new international airport, which was opened in 2008 and has triggered a rapid urbanization process in the area with a drastic surge in land prices, new employment opportunities and new marketing opportunities for agricultural products; accordingly, several farmers have started cultivating vegetables like tomatoes, chilies and brinjal; some farmers have also taken up floriculture. There is also a mango orchard of 2 ha in this village.	(+) Relatively good structures in place to facilitate access to financial services. (+) Excellent market access for a range of horticulture and floriculture products; opportunities for diversification of agricultural activities. (+) Employment opportunities in manufacturing sector for income diversification of households.
Natural capital	The net sown area in the village constitutes 80 percent of the total land area; only 9 percent 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 percent), which means that there is no land available for forest and pasture lands. Soil types in the village are mainly red soils and (60 percent) and black cotton soils (40 percent), which are suitable for growing diverse crops. The majority of farmers are marginal and small landholders.	(+) Fertile soils. (+) Groundwater availability is good; 100 percent subsidization of electricity for the operation of pumps for irrigation and high dependence on groundwater for irrigation call for careful monitoring of groundwater levels. (-) Lack of availability of common land / grazing land posing a constraint to livestock rearing.

Table 3: Endowment with livelihood resources of Srirangapur, Mahabubnagar district, Andhra Pradesh, 2005

Capital	Situation	Adaptive capacity: Special constraints and strengths
Natural capital	Traditional crops are redgram, castor, jowar and others; there has been a shift to commercial crops like cotton and maize over the last 20 years, and of late also to vegetables like tomatoes, chilies and brinjal. Srirangapur is marked as a "safe" groundwater zone; however, agricultural activities are highly dependent on groundwater irrigation; groundwater exploitation will therefore have to be carefully monitored. Traditionally, livestock rearing is an important element of most families' livelihood portfolio. However, the number of families rearing milk animals has come down over the last 10 years due to decreased availability of grazing land. Drinking water is available throughout the year through 2 hand pumps.	
Physical capital	The construction of the new international airport (located only 45 km form Srirangapur) has triggered a rapid urbanization process in the area, accompanied by expansion and upgrading of transport and other physical infrastructure. There are a several open wells in the village; however, 75 percent of them are dry; farmers are increasingly dependent on borewells as primary irrigation sources; out of the 80 borewells that have been drilled, only 60 are functional. The average depth of borewells has increased from 70 feet in 1990 to 150 in 2005, and some borewells are up to 350 feet deep. There are 6 tanks in Srirangapur; even though tanks played an important role as irrigation sources traditionally, their water holding capacity has been reduced over the last decades due to poor maintenance. Electricity for the operation of pumps for irrigation is 100 percent subsidized by the government. Most families burn fuel wood for domestic cooking; fetching firewood involves substantial amount of women's time; 65 families use LPG for cooking, however only on an irregular basis, as LPG refilling costs are too high.	(+) Good and improving transport and other physical infrastructure in the area. (-) Functionality of tanks is heavily compromised due to poor maintenance. (-) Non-affordability of modern energy for cooking.

Source: Primary data from the V&A programme Situation Analysis (2006).

Table 4: Endowment with livelihood resources of Kothur, Mahabubnagar district, Andhra Pradesh (2005)

Capital	Situation	Adaptive capacity: Special constraints and strengths
Human and social capital	Kothur has a total population of 1462 (224 households). The majority of the community belongs to Backward Castes (BC) and Scheduled Castes (SC); there is no tribal population in the village. The village has a primary and a middle school and most of the children go to school. The overall literacy rate is 43 percent (57 percent among men and only 29 percent among women). 255 men and women make a living from agricultural labour; only few people migrate on a seasonal basis for construction and agricultural labour.	(-) High illiteracy amongst women, who play a key role in agricultural management - major constraint to information dissemination and involvement of key stakeholders in decision-making. (-) High percentage of landless households.
Financial capital	There are 15 women Self Help Groups (SHGs) for savings and credit activities in the village. Very few farmers cultivate vegetables for market sale due to a lack of market access. Dairy is a major livelihood activity and there is a milk collection centre in Kothur.	(+) Relatively good structures in place to facilitate access to financial services. (-) Lack of market access for vegetables. (+) Good marketing facility for milk.
Natural capital	70 percent of the total land area (680 ha) are under cultivation, out of which 25 percent are sown more than once. The village has no forest and pasture land. Almost 30 percent of land area is marked by sandy soils, and around 50 percent by black soils. Most of the cultivable waste lands (22 percent of the total area) have turned alkaline due to continuous irrigation and high evaporation conditions. This area is marked by a fast spread of prosopis juliflora. The majority of farmers are marginal and small land holders. Traditional crops are redgram, castor, jowar and others; maize has become a preferred commercial crop over the last decades. Consecutive droughts over the last 2 decades have reduced the productivity of the pastures, which has resulted in fewer families keeping livestock. Drinking water is available throughout the year through hand pumps and through an overhead tank which is filled through pipes.	(-) High loss of cultivable land as soils are turning alkaline. (-) Overexploited groundwater resources. (-) Reduction of livestock population due to recurrent droughts leading to fodder shortage; loss of livelihood asset and security.

Table 4: Endowment with livelihood resources of Kothur, Mahabubnagar district, Andhra Pradesh (2005)

Capital	Situation	Adaptive capacity: Special constraints and strengths
Natural capital	The groundwater resources of the village are marked as "over exploited"; drilling new wells is accordingly prohibited. Livestock is an important asset for to cope with drought situations, and for a majority of households livestock is an important element of their livelihoods. However, the number of animals in the village has decreased, most significantly in buffalos, bullocks and cows, over the last 2 decades due to recurrent droughts.	
Physical capital	Kothur 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. Farmers are increasingly dependent on borewells as primary irrigation sources: the village has a total number of 120 borewells, out of which only 70 are functional. The average depth of borewells has increased from 70 feet in 1990 to 150 in 2005. There are 8 tanks in Kothur, out of which 3 are non-functional; even though tanks played an important role as irrigation sources traditionally, their water holding capacity has been reduced over the last decades due to poor maintenance. Electricity for the operation of pumps for irrigation is 100 percent subsidized by the government. Most families burn fuel wood for domestic cooking; fetching firewood involves substantial amount of women's time; only 35 families are using LPG gas connections; for the majority of households, LPG refilling costs are too high.	(-) High dependence on groundwater for irrigation, but limited capacity of borewells due to groundwater overexploitation. (-) Functionality of tanks is heavily compromised due to poor maintenance. (-) Non-affordability of modern energy.
Source: Primary data from the V&A programme Situation Analysis (72006).		

Field activities implemented under the V&A programme

The pilot activities carried out under the V&A programme at the community level in the villages in Andhra Pradesh and Rajasthan were of diverse nature and took different approaches and entry points for enhancing the adaptive capacity of the communities in response to the constraints identified. The programme included interventions for improved land and water management, energy conservation, promotion of best agronomic practices, introducing systems for improved weather-based farming decisions and awareness creation.

Measures for adaptation to climate variability and change can be categorized through different frameworks, and institutions working in the area of climate change adaptation have highlighted various parameters along which adaptation approaches can be classified. The measures taken up under the V&A programme can generally be characterized as follows:

a. The V&A interventions have sought to **build response capacity** and **improve management of climate risks:**

McGray et al. (2007) discuss the difficulties of defining "adaptation" considering the significant overlap between activities for development and adaptation. They suggest a continuum for framing adaptation approaches, ranging from a development to an adaptation end, with measures falling into the following four broad categories: (i) addressing drivers of vulnerability; (ii) building response capacity; (iii) managing climate risks; and (iv) confronting impacts of climate change. As the explicit and primary objective of the V&A programme was to build resilience against climate risks, and as all measures addressed patterns of current climate variability, they fall into categories (ii) and (iii) of this framework.

b. The V&A interventions were **no-regret rather than climate-justified** measures:

Given the considerable uncertainty about how exactly climate change will manifest itself at the scale of sub-national regions in India, the V&A programme was designed in a way that all interventions will benefit the communities independent of the character and magnitude of climate change, even under a scenario where climate variability will continue to range within the current spectrum. The programme thus also accounted for the fact that strengthening capacities of communities to cope with current climate variability and extremes and supporting adaptation to expected future climate change tend to be mutually supportive.

c. The V&A programme included interventions **building on traditional knowledge,** but also the **introduction of advanced knowledge systems:**

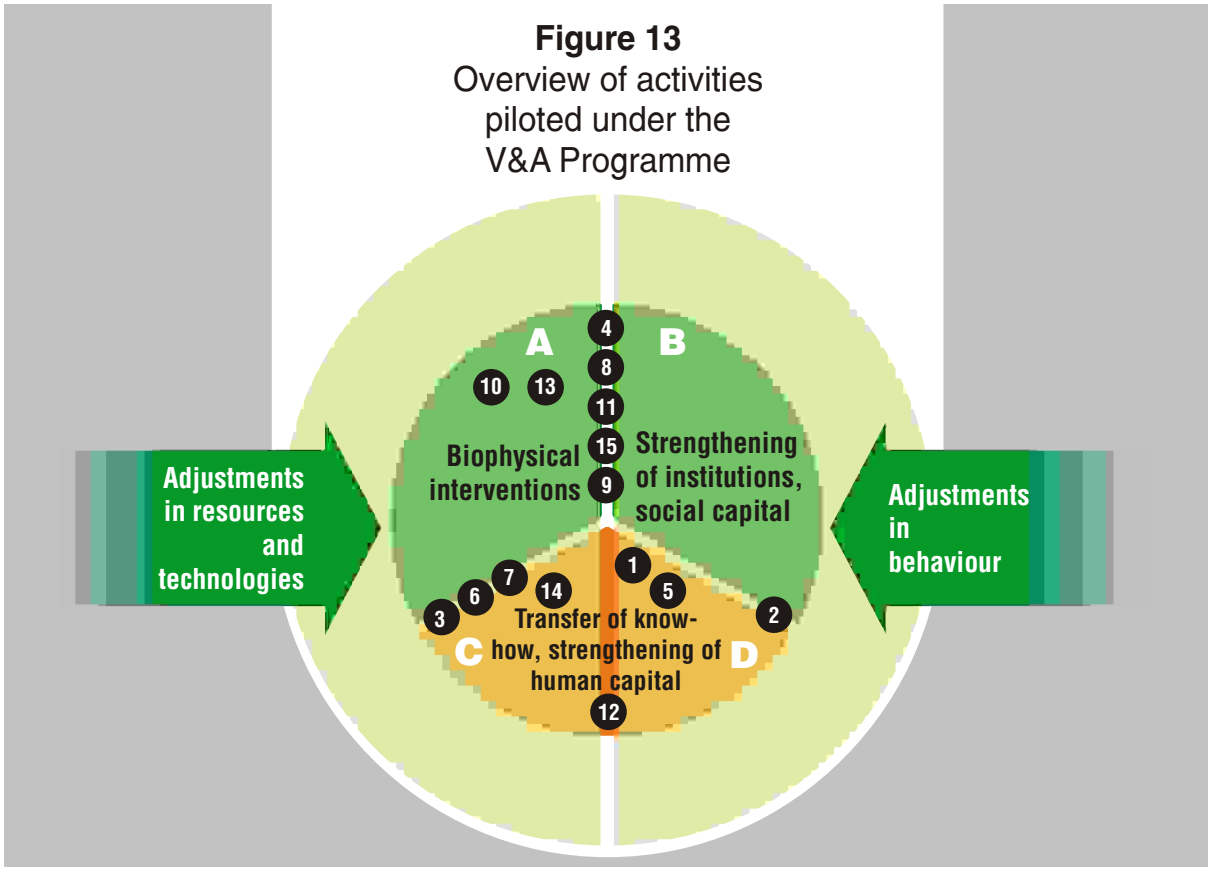
The V&A pilot programme recognized the value of traditional systems that were developed over decades, in some cases over centuries, to sustain agricultural activities in the face of climate variability. Climate variability and erratic rainfall patterns have always been a major concern for agriculture-based livelihoods in semi-arid areas in India. The programme design therefore took traditional coping strategies of communities and adapted traditional technologies as an entry point for identifying measures to help increase the resilience of the communities' livelihood systems against future climate risks (e.g. the renovation of traditional water harvesting structures and the revitalization of traditional community-based institutions for sustainable management of natural resources). However, some interventions of the V&A programme employed innovative strategies

and provided the communities with access to modern scientific achievements and new technologies (e.g. germplasm management such as improved goat breed and introduction of mini agro-meteorological labs for local-level weather monitoring).

Figure 13 provides a full picture of the set of activities piloted under the V&A programme. It indicates that the programme took an integrated approach, comprising biophysical interventions, strengthening of institutions and social capital, and transfer of know-how for enhancing the communities' endowment with human capital. The biophysical interventions enhanced the adaptive capacities of the communities through adjustments in resources and technologies, whereas strengthening of social capital can be classified as adaptation through adjustments in behaviour. Transfer of know-how to the communities results in adjustments in technologies as well as in behaviour.

Several biophysical interventions were complemented through efforts to strengthen the communities' capacities to manage the physical resources created or enhanced through the programme. These interventions are placed in figure 13 at the intersection between the two categories of adaptation.

Figure 13: Overview of activities piloted under the V&A programme



1. Awareness raising campaigns on climate change through community events, wall paintings etc. (D)
2. Formation of Smart Farmers Clubs (see case study 4) (B+D)
3. Introduction of village agro-met observatories and training of community members as climate risk managers who develop and communicate agro-advisories for crop and livestock management based on the local level weather data (see case study 5) (A+C)
4. Revitalisation of tanks, application of silt to fields for enhanced soil water retention capacity and soil fertility, and formation of water user groups for management and maintenance (in Kothur and Srirangapur, Mahabubnagar district, AP; see case study 1) (A+B)
5. Participatory crop water budgeting exercise for creating awareness around unsustainable levels of groundwater use (in Kothur and Srirangapur, Mahabubnagar district, AP; see case study 1) (D)
6. Treatment of alkaline soils with charcoal (in Kothur, Mahabubnagar district, AP) (A+C);
7. Treatment of hillside lands for soil and water conservation (in Amda, Udaipur district, Raj; see case study 1) (A+C)
8. Renovation and upgrading of small water harvesting structures for enhancing water storage capacity and groundwater recharge (Amda and Kundai, Udaipur district, Rajasthan; see case study 1) (A+B)
9. Upgrading of traditional harren system (open diversion channels) for improved water distribution efficiency and formation of water management committees for management and maintenance of the harren (Amda, Udaipur district, Rajasthan; see case study 1) (A+C)
10. Introduction of efficient irrigation technology, i.e. sprinklers and drip-irrigation (Kothur, Mahabubnagar district, Andhra Pradesh; see case study 1) (A);
11. Installation of a water bank for enhanced water distribution efficiency and formation of a water management committee (Kundai, Udaipur district, Raj; see case study 1) (A+B);
12. Promotion of the System of Rice Intensification (in Kothur and Srirangapur, Mahabubnagar district, AP; see case study 3) (D);
13. Promotion of improved chullahs (A);
14. Improvement of goat breeds and training of community members as buck managers / goat breeders (Amda and Kundai, Udaipur district, Raj) (C);
15. Development of common and joint private pastures and formation of pasture management committee (Amda and Kundai, Udaipur district, Raj; see case study 2) (A+B).

Monitoring and Evaluation

Towards developing conceptual clarity around the various field level interventions, a set of site specific hypotheses for different sectors were developed in June 2007 which facilitated the development of a monitoring and evaluation framework:

- Hypothesis Energy: Biomass based energy production offers an alternative coping strategy for households vulnerable to climate change impacts in semi arid areas.
- Hypothesis Water: Community's access to weather monitoring and prediction data combined with

community managed water resource systems can lead to greater water use efficiencies and improved adaptive capacities.

- Hypothesis on Land Use: Village level land use maps can provide a basket of options for different rainfall scenarios (drought, normal, excess). They can lead to stabilisation of yields from rain-fed farming, greater food and economic security.
- Hypothesis Livestock: Livestock rearing is an important coping strategy in the face of enhanced climate variability. Buffer stocks of fodder (including tree fodder) and good breeds of livestock can be important risk reduction strategies and can enhance adaptive capacities.

The experiences and outcomes of some of the interventions in this pilot programme are reflected in the set of five case studies in this compilation. While each experience is presented in short individual booklets, the interventions are closely interlinked and build upon each other, working through the same set of community institutions.

The titles of case studies are:

1. Vulnerability reduction and adaptation to climate change in semi-arid India - Water Resource Management
2. Vulnerability reduction and adaptation to climate change in semi-arid India - Pasture Land Development
3. Vulnerability reduction and adaptation to climate change in semi-arid India - The System of Rice Intensification
4. Vulnerability reduction and adaptation to climate change in semi-arid India - Community-based Institutions
5. Vulnerability reduction and adaptation to climate change in semi-arid India - A Weather-based Farming Model for Communities

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Case Studies:

Vulnerability Assessment and Enhancing Adaptive Capacity to Climate Change in Semi Arid Regions of India (V&A) Programme