DEALING WITH A DIFFERENT DESERT

Gravis

Duke UNIVERSITY

DEALING WITH A DIFFERENT DESERT

Vulnerability and Adaptation to Climate Change in the Thar

Ben Soltoff

Gravis

Duke UNIVERSITY

Dealing with a Different Desert

2014

GRAVIS

Written by

Ben Soltoff

Edited by

Prakash Tyagi

Organized by

GRAVIS

3/437,458, MM Colony, Pal Road

Jodhpur 342 008 Rajasthan, India

Phones: 91 291 2785317, 2785116

Fax: 91 291 2785116

www.gravis.org.in

Supported by

Duke University, US

ISBN 978-81-965767-8-3

Table of Contents

FOREWORD

Around the globe, climate change has had its impacts on people's lives in the recent past. Those impacts have led to changing weather patterns, variations in food production systems and water availability and onset of acute and chronic disaster situations. The Desert of Thar in India has also been experiencing those changes. Home to over 23 million people, Thar is the most densely populated desert eco-system in the world and has been under the constant grip of drought for a very long period.

As climate change continues as a phenomenon, that has seen its impacts in the forms of changing rain patterns, evolving crop practices and associated food and water availability situations. GRAVIS as a leading organization of the region has extensively focused on mitigating droughts in Thar over the last 30 years.

It was being felt that a research document on the impact of climate change in Thar would be very helpful to understand various aspects. Therefore, this research in the leadership of Ben Soltoff was organized. The focus was to understand people's perceptions and practices in this context and to develop a set of future recommendation to address climate change.

I sincerely thank Hart Fellowship Programme of Duke University, US for their support to this study. A special word of thanks goes to Ben soltoff for his sincere efforts in this research and in writing the document. GRAVIS field team and communities of Thar played very important roles too, and deserve a word of gratitude.

I hope the study is read with interest by individuals and organizations in different parts of world that are interested in climate change in desert environments.

Prakash Tyagi

Executive Director, GRAVIS

AUTHOR'S NOTE

It is tempting to view a traditional society like the rural Thar as a still life, a place untouched by time or the unrelenting forces of change. Like the roughest features of the desert landscape, certain aspects of life in the Thar remain as they have been for hundreds of years. The people maintain a close connection to the land, depending on agriculture as a central component of their livelihoods and identities, and they continue to practice the social customs of their ancestors, in ways that are sometimes charming and sometimes antiquated.

But the winds of change have not neglected the region. Change is evident in the mobile phones that allow effortless communication across great distances. It is evident in the motorbikes and paved roads that enable swift, smooth passage through the desert. And it is evident in the electrical connections that bring light into so many households. These changes reach more and more people every day.

Less evident but just as widespread is the change in climate, a change that will only intensify in the near future. While the Thar has long experienced severe heat and extreme variability in rainfall, it is now getting hotter, with a greater potential for crippling drought. Climate change poses a direct threat to agriculture and also aggravates other social and environmental problems, heightening not only the risk of ruin for vulnerable households but also the necessity for action on the part of anyone with a stake in rural development.

In most matters of climate change, the best time to act was yesterday, but today comes in a close second. Although stopping climate change requires a massive global reduction of greenhouse gas emissions, an effort that is making cumbersome progress in the international arena, adapting to climate change can start locally, with methods that are participatory and empowering.

This report, GRAVIS' first to deal directly with climate change, is a crucial and timely effort. Climate change is a complex problem that affects many facets of rural life, so it is well suited to GRAVIS' bottom-up, holistic approach. Further research and, more importantly, the implementation of climate-oriented projects will build vital resilience in villages, lessening the potential devastation of a transformed and brutal climate.

Having spent almost a year with GRAVIS, I am fully confident in the organization's ability to accomplish the daunting tasks that lie ahead. Its admirable Gandhian ideology and decades of hard work in the field serve as a continuing inspiration to me, and I extend my deepest gratitude to everyone who made this report a reality. One thing in the Thar that will always remain unchanged is the strength and resolve of the human spirit.

Ben Soltoff

SUMMARY

Although climate change is occurring on a global scale, it's most acute effects are felt locally. Subsistence farmers in the developing world are especially vulnerable, because not only are they exposed to the largest geophysical and ecological changes but also because they face large social barriers, often related to poverty, that prevent them from adapting to those changes. Adaptations to climate change can take many forms, and while some involve new technologies, many derive from traditional practices that have been practiced for hundreds of years.

In India, as in most parts of the world, climate change is not a concern for the distant future. It is already occurring. The Indian climate has gotten hotter over the past several decades, and it is expected to keep getting hotter in the coming years. The Thar Desert, like the rest of India, has seen a strong trend of warming in the recent past, but the trends for rainfall are less clear. Rainfall in the region has been highly variable for as long as it has been recorded. Predictions are mixed as to how rainfall will change in the future, but whatever happens, conditions are likely to become even more adverse than they are now.

In addition to rainfall variability, the Thar also faces severe problems of overpopulation and overexploitation of groundwater, both of which place stress on already scarce resources. Changes in the climate will exacerbate these problems, and these exacerbating effects are likely be more damaging in the long term than the changes themselves.

The results of focus groups and surveys in Jodhpur district provide detailed insight into villagers understanding of climate change, their perceptions of past change, their expectations for future change and their practices related to water, agriculture, livestock, ecosystems, employment, and drought. The surveys confirm that climate change will exacerbate a variety of existing problems, ranging from tube well irrigation to debt. On a positive note, villagers currently implement many traditional practices that make them resilient to climate variability. By continuing and improving these practices, they can adapt to future changes. However, the benefits of such practices are limited, and villagers will also need to seek alternatives to agriculture as a source of livelihood.

Rural communities in the Thar can become more resilient to climate change by continuing and improving practices of rainwater harvesting, implementing principles of agro-ecology, engaging in responsible animal husbandry, conserving ecosystems, receiving assistance with loans, diversifying income sources, keeping the population within reasonable limits, and generally staying informed about climate change adaptation.

PART I. INTRODUCTION

Although climate change is a global problem, with varied and widespread effects, it also has acute local impacts, and the people who struggle the most are those with the least capacity to respond, people like the rural poor of the Thar Desert. They depend on a favorable climate to survive and have few resources to adapt to change. Heat waves and droughts often mean hunger and thirst for the rural poor, leading to health problems and possibly death.

For decades, GRAVIS has been keenly aware of the connection between climate and poverty. GRAVIS' founders felt compelled to establish a rural development organization in the Thar Desert partly because they knew that the brutality of the climate posed a harrowing challenge for desert dwellers. Thus, many of GRAVIS long-running projects have boosted climate resilience in villages, helping communities respond to a variable climate and prepare for future change. However, the science of climate change has come a long way since then; there is more to the picture than year-to-year variation. The climate is undergoing long-term shifts as a result of human activity, and those shifts will become increasingly apparent in the near future. GRAVIS now aims to deal directly with the subject of climate change, and this report serves as a preliminary exploration of the topic.

GRAVIS

Established in 1983, Gramin Vikas Vigyan Samiti (GRAVIS) is an Indian non-governmental organization that works on rural development and community empowerment in the Thar Desert of Rajasthan. GRAVIS emphasizes a holistic, bottom-up approach, engaging communities in every step of project planning and implementation. Its development efforts focus on disadvantaged and marginalized communities, integrating them into society, regardless of their caste, gender, age, economic, or religious background. The organization started as a single field centre in Gagadi village and now operates in more than 1000 villages in six districts of Rajasthan: Jodhpur, Jaisalmer, Barmer, Bikaner, Nagaur and Pali. Its initiatives deal with subjects such as water security, agriculture, education, health, gender rights, ageing, and people's organizations.

What is climate change?

The term “climate change” encompasses a slate of long-term environmental shifts associated with the build-up of heat-trapping gases in earth's atmosphere(1). Gases such as carbon dioxide and methane allow heat to pass towards the earth, but they prevent it from escaping, holding warmth in a manner broadly comparable to what happens in a greenhouse. Because of this comparison, the phenomenon is generally known as “the greenhouse effect” and the gases responsible are called “greenhouse gases.” For most of human history, the greenhouse effect has been beneficial, protecting the planet from the cold reaches of outer space and making in it livable for a wide array of life forms, including people. Without greenhouse gases, life on earth would almost certainly freeze to death. However, as is the case with most things in nature, the greenhouse effect requires a fine balance. A lack of greenhouse gases will cause the planet to become too cool, and an excess of them will cause the planet to become too warm. Right now, the world is experiencing the latter. Large emissions of greenhouse gases from human activities such as fossil fuel combustion and deforestation have tipped the scales in favor of warming.

Although the most direct consequence of the greenhouse effect is an increase in the average temperature at earth's surface, commonly known as global warming, the phenomenon also entails a wide range of other impacts, such as droughts, storms, wildfires, and rising sea levels(2). The term “climate change” refers to all of these effects and more. It is a problem that influences most aspects of human life on earth, including water, agriculture, ecosystems, health, international relations, and culture.

Often, climate change gets confused with climate variability, but these concepts are very different. The term “climate variability” describes the alteration in climate that occurs from season to season or year to year. For instance, temperatures are warm in summer and cool in winter, or one year can have high rainfall while another has low rainfall. The term “climate change,” on the other hand, describes directional change over a span of many years. For example, it can entail an increase in average summer heat over the course of a century or a decrease in average rainfall over the course of a decade. The key value to consider here is the mean. Variability involves fluctuation around a relatively constant mean, while change involves a shift in the mean itself.

Some people doubt the existence of climate change or its relationship to human activities, but these doubts are unfounded(1). Even though large unknowns remain about the extent of climate change and its specific impacts, and even though, like all science, climate science involves a small degree of uncertainty, the scientific basis of climate change is unequivocal, and the threat is undeniable. Climate change exists, it results from human activity, and it is happening now.

Vulnerability

In order to understand climate change vulnerability in the Thar, it is essential to first understand the general concept of vulnerability. Rather than posing a threat in itself, vulnerability represents the capacity of an individual or a community to deal with an external challenge. Although vulnerability alone does not cause damage, a more vulnerable group will suffer greater damage than a less vulnerable group when faced with the same hardship. Furthermore, vulnerability results from social factors like poverty more than it results from physical factors like environmental conditions(3). Frameworks for sustainability science maintain that vulnerable communities are not just exposed to hazards but are also more sensitive and less resilient in the face of those hazards(4). Although poor communities tend to be more vulnerable, vulnerability is not entirely synonymous with poverty. Some groups may fare better than others during times of plenty, only to suffer rapid reversals of fortune during times of misfortune.

Poor subsistence farmers are especially vulnerable to climate change. Their vulnerability stems from their geographic location in tropical and sub-tropical regions (which are expected to experience stronger effects than temperate regions), their low incomes, and their dependence on the natural environment. As a result of low income and other factors, subsistence farmers face many social barriers that prevent them from changing their agricultural practices, and many may need to seek alternative forms of livelihood(7). On a national scale, development appears to reduce a country's climate sensitivity, meaning that less developed countries are more sensitive to change(8). Even if climate change leads to a minimal decrease in global crop production, as farmers implement new agricultural strategies, developing countries will still bear the brunt of the problem, because they have the lowest capacity to adapt(9). It has been estimated that climate change will cause crop yields in developing countries to decrease up to 10% by the year 2060(10).

As a developing country with a large rural population, India is particularly vulnerable. A macro-economic study comparing India and the United States found that rising temperatures would generally cause much more severe effects in India(11). Given the many complex factors involved, the exact agricultural impacts of climate change in India are uncertain(12). However, this uncertainty has not stopped researchers from projecting future yield. One study projected that a 2°C increase in temperature would lead to an 8.4 percent decrease in total agricultural revenue across India, even when paired with a seven percent increase in precipitation(13). Due to the combined effects of population growth and climate change, gross per capita water availability in India could potentially decrease from about 1,820 cubic meters per year in 2001 to about 1,140 cubic meters per year in 2050, leading to vast disparity between supply and demand(14). Although Rajasthan is unlikely to experience the most extreme physical effects of climate change, social factors make it one of India's most vulnerable states. A district-level analysis showed high levels vulnerability across Rajasthan due to a dangerous combination of high climate sensitivity and low adaptive capacity(15)(Figure 1). The state is sensitive to climate because it is arid and highly dependent on the monsoon, and it has low adaptive capacity on account of its degraded soils, lack of groundwater, and limited social development.

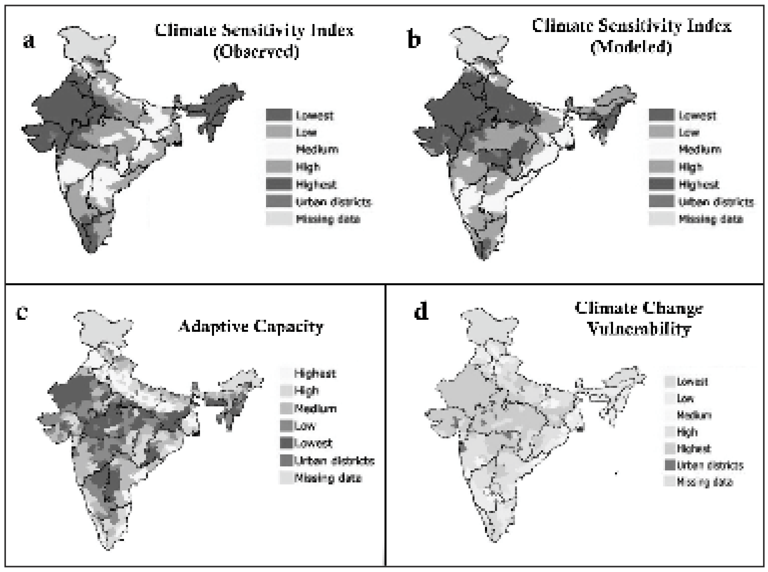


Figure ,. District-level climate change vulnerability analysis in India

Adaptation

In the context of climate change, the term "adaptation" refers to a change in practices or an implementation of technology that reduces the impact of an altered climate. Although adapting to climate change is no substitute for reducing global greenhouse gas emissions, focusing on adaptation is both beneficial and necessary. Carbon dioxide and other greenhouse gases remain in the atmosphere for long periods of time after they are emitted, so even if emissions were to cease this instant, the earth would continue to warm due to the gases already present in the atmosphere(1). This phenomenon is called committed warming. Because climate change is, to some degree, unstoppable, the question is not whether people should adapt but how they should adapt. Another benefit of adaptation is that it can be successfully accomplished at the grassroots level. Communities can do little to mitigate climate change on their own, but adapting requires minimal outside support. As climate change intensifies, adaptation will become an integral part of community empowerment.

Adaptation is especially important in developing countries, because they are more vulnerable to the effects of climate change. The gradual nature of the change gives them an advantage in that they can adapt early, before the changes become too severe(8). However, adaptation will not necessarily reduce the disparity between developed and developing countries, because it not only decreases negative effects but also increases positive effects(16). If there are winners and losers with regard to climate change, then adaptation will help the losers to lose less, but it will also help the winners to win more.

Although making suitable climate change adaptations has clear benefits for the future, the process entails much uncertainty in the present. Individuals do not always know which adaptations are most suitable, and they must determine how much short-term loss to endure for the purpose of long-term gain. In that sense, adaptation is closely linked to the science of economics, which has long provided valuable insight into how poor, rural individuals make decisions. An early study found that farmers in India could allocate scarce resources efficiently, despite their lack of economic training, because they had learned from many years of ancestral and personal experience(17). Later studies found that farmers in the Indian semi-arid tropics were reluctant to invest in new strategies because they were averse to risk, and that risk aversion was less a result of personal characteristics and more a result of external constraints—primarily lack of credit and information(18, 19). Ironically, the factors that make the rural poor averse to risk also prevent them from buying insurance. Lack of credit prevents farmers from having enough cash up front to pay for insurance, and lack of information causes farmers to doubt whether insurance is reliable(20, 21). When loans are available, they are in high demand. Surveys in rural South India found very high discount rates among villagers, meaning that money was worth much more to them in the present than it was in the future(22). As a result, they easily fell into debt because they felt that the value of having money right away was greater than long-term cost of a loan. With regard to implementation of new and unfamiliar innovations, economic studies have found that even if farmers are initially resistant, they will eventually implement new technologies once these technologies became necessary to cope with a particular environment(23). While these economic studies are not explicitly about adaptation, they analyze situations in which the rural poor must decide between their present and future interests. In such situations, they are able to make sound decisions, but they are slow to respond to change because they have few funds on hand, low capacity for risk, and inadequate access to information.

Adaptation strategies are rarely "one size fits all." Determining the most effective measures for a given area requires a thorough understanding of the local environment and culture. In the Thar Desert, many commonly advocated adaptation measures are variations on traditional methods that have been practiced for hundreds of years. Given the region's harsh climate and history of environmental variability, the abundance of traditional methods to cope with erratic conditions is no surprise. A key coping mechanism is rainwater harvesting, which has been practiced in the Thar in one form or another since the earliest instances of human settlement(24). A widely cited study of Indian water scarcity describes rainwater harvesting as an essential way to prevent devastating water shortages in India by the middle of the century(14). Collecting rainfall has immediate benefits as well, helping rural villages to become more resilient and self-sufficient(25). In general, communities have successfully handled water scarcity in the Thar through bottom-up participatory approaches, especially those based on traditional methods of dealing with a variable climate(26). All over the world, subsistence farmers have become resilient to climate shocks by maintaining traditional farming practices(6), and the Thar is no exception. Households in arid Rajasthan have developed many strategies for coping with drought, including animal husbandry, fallow systems, mixed cropping, agro-forestry, sale of assets, migration, dependence on wealthy community members, and modification of consumption patterns(27).

A more recent strategy for adapting to a variable climate in the Thar has been groundwater irrigation via tube wells. This method allows the farmers who can afford it to withstand irregular rainfall patterns, as they irrigate their fields with aquifers rather than precipitation. However, clearest impact of climate change in India will be an increase in temperature, which reduces the efficacy of groundwater irrigation as an adaptation strategy(28). While tube wells shield crops very effectively from rainfall variability, they do little to shield crops from heat.

Adaptation has its shortcomings. A global-scale economic study of various adaptation scenarios found that the only way to increase cereal production in the midst of climate change was to increase irrigation, but the required increase was probably not feasible in the real world, as it most likely exceeded the global supply of freshwater(9). In their most extreme scenarios, adaptation was not enough to forestall the negative effects of climate change, especially the risk of hunger in developing countries. Although agricultural adaptation can be effective in response to moderate levels of climate change, more severe levels of change will require more severe measures, like switching from agriculture to alternative forms of livelihood(29). These changes will take a toll on food production. If climate change continues on its current course, a reduction in global food supply is inevitable.

Climate trends in India

Modest climate change is already occurring in India, most clearly with regard to warmer temperatures, and more extreme changes are expected for the future. Since 1970, hot days and hot nights have become more frequent, while cold days and cold nights have become less frequent, and hot weather has gotten more intense(30). However, even though warming has been observed in most regions of the country, maximum temperatures have not exceeded their statistically computed limits(31).

Temperatures across India are expected to continue increasing in the future, while changes in rainfall are expected to vary regionally. Computer models have projected that, by 2100, average temperatures in India will increase by 1 to 5°C in every region, with the most extreme increases occurring in the northwest, and models have also projected that, by 2100, monsoon rainfall will increase or stay the same in most regions, with the notable exception of western Rajasthan, where a modest decrease is projected(32) (Figure 2). Another model has predicted 3.5 to 5.5°C of surface warming over the Indian subcontinent during the 2080s, with the largest increase occurring during winter(33). This model has also predicted a 5 to 25 percent decline in winter rainfall and a 10 to 25 percent increase in summer rainfall, as well as increased variation in rainfall timing and increased intensity of rainstorms, with a higher probability of extremes. However, despite any long-term effects on rainfall, year-to-year variation in the summer monsoons will continue to overshadow climate change in the short term(34).

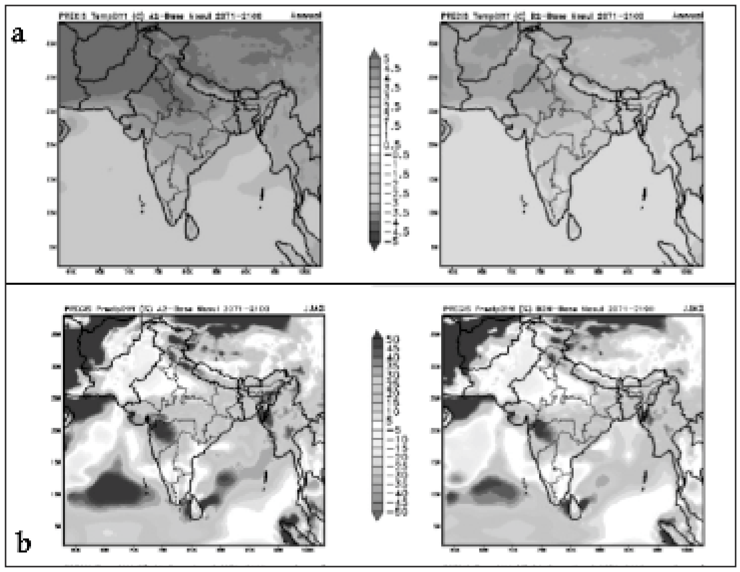


Figure 2. (a)Monsoon rainfall increase or stay in most area of India
(b) Average temperature increase in every year in India by 1-5 ˚C (32)

Climate trends in the Thar

Over the past century, the Thar Desert has experienced a moderate to severe increase in temperature, but with regard to rainfall, year-to-year variation has greatly overshadowed any long-term effects. From 1900 to 2000, records show a significant upward trend in average daily maximum temperature (with an overall increase of 0.8°C) and a significant downward trend in average daily minimum temperature (with an overall decrease of 0.5°C)(35). The past four decades, however, have entailed severe and consistent warming. From 1971 to 2010, the records show a significant upward trend in average daily maximum temperature (with an overall increase of 1.4°C) as well as a significant upward trend in average daily minimum temperature (with an overall increase of 1.3°C)(36). The climate records show no significant trends in rainfall amount, timing, or intensity(35, 36, 37). Year-to-year variability tends to obscure any long-term trends. Records from three different sources show a standard deviation in yearly rainfall amount that is at least 37.3% of the average, meaning that the rainfall amount in a given year could be as high as 40% above average, as low as 40% below average, or anywhere in between without justifiably being considered abnormal. Rainfall timing shows less variation, with standard deviation below 10% of the average in all records.

The analyzed climate records are based on measurements that were taken mainly at weather stations in Jodhpur district. While these measurements are the most consistent and reliable sources of information, the Thar Desert is a large region with weather patterns that vary not only in time but also in space. Temperatures and rainfall can be extremely different from one place to another, so it is important to acknowledge that the trends measured at weather stations may not match the trends in rural villages.

The smaller the area in question, the greater the difficulty of predicting the future effects of climate change, so few predictions exist for the future of the Thar Desert. According to the earlier map of projected changes in temperature and rainfall (Figure 2), western Rajasthan is generally expected to get hotter, and overall rainfall amounts are expected to decrease slightly or stay the same (32). Regarding rainfall, the region may follow the trends predicted for the whole of India, with rainfall becoming more variable, and storms becoming more intense (33). Furthermore, warming is expected to increase the amount of water that evaporates from earth to the atmosphere in the Thar, making the region even more water-stressed than at present (38), and western Rajasthan is likely to experience both moderate drought and severe drought more frequently (39).

Environmental degradation in the Thar

The Thar Desert has faced a growing suite of environmental challenges since the mid-20th century and possibly even earlier. Anthropogenic climate change is far from the first issue to disturb the environmental balance. The Thar is the mostly densely populated arid ecosystem in the world, and its heavy concentration of human life has put great strain on limited resources. Overpopulation has led to groundwater exploitation, farmland expansion, erosion, degradation of pastures, and ultimately, desertification. The effects of climate change cannot be understood without understanding these other environmental issues, because they are strongly interconnected.

While people have inhabited the Thar in appreciable numbers since the 4th century BCE, just after the invasion of Alexander the Great, the population remained fairly stable until the early 20th century, at which point it began to vault upward (40). The number of people living in the Thar doubled between 1921 and 1961 and then doubled again by 1991. Since 1901, the population of arid Rajasthan has grown exponentially at a rate of 2.06% per year (Figure 3) (41). Its decadal growth rate has consistently exceeded the rest of India and until recently, Rajasthan as a whole, rising to a maximum of 37.5% between 1971 and 1981 (Figure 4). In a rural setting like the Thar,

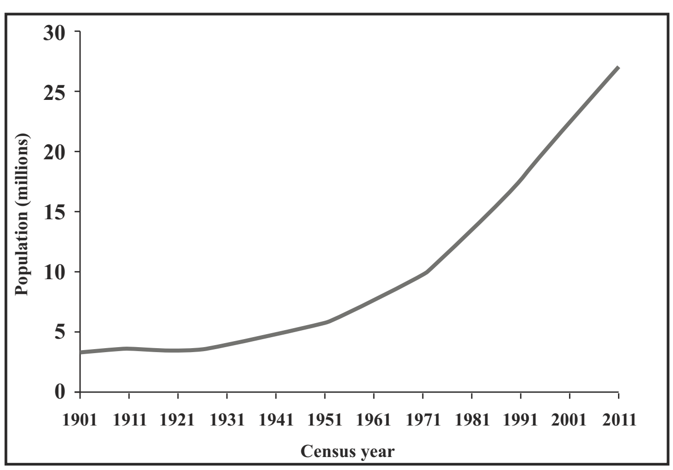


Figure 3. Population of arid Rajasthan over time according to the India Census

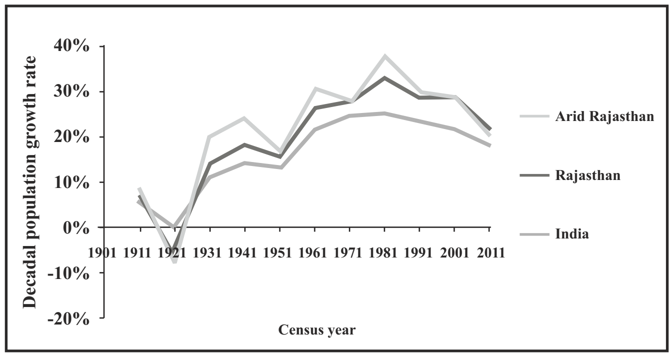


Figure 4. Decadal Population growth rate in arid Rajasthan

The unfettered expansion of agriculture, accompanied by the widespread construction of canals and tube wells, has altered the landscape in profound ways, threatening the sustainability of desert life (40). During the latter part of the 20th century, the increased demand for farmland caused many farmers to abandon fallow systems, which are methods of conserving the soil by not planting crops in certain fields in certain years. Farmers also expanded farmland onto marginal zones, dunes, and pastures, three types of land important for desert conservation. The increased livestock populations then overgrazed the remaining pastures, leading to further degradation. The desert climate of the Thar, which is characterized by scarce and highly variable rainfall, cannot support heavy agriculture, and while people have developed many practices to deal with arid conditions, these practices were not enough to sustain the agricultural boom of the 20th century. Instead, the expansion in farmland depended on irrigation from canals and tube wells. In the case of tube wells, far more water has been extracted than replaced, causing water tables to lower dramatically.

Similar environmental degradation has occurred throughout Rajasthan. Remote sensing techniques have revealed that when villages in eastern Rajasthan switch from primarily rainfall irrigation to primarily groundwater irrigation, the water table drains immensely (42). The declining water table in these villages, along with decreased rainfall, leads to a decrease in agricultural land, and less productive environments (like wasteland, open scrub, and built-up land) become more common. As a state, Rajasthan leads India in environmental degradation, containing the largest area of degraded land in an absolute sense and also one of largest proportions of degraded landed relative to total area (43).

PART II. RESEARCH FINDINGS

Summary of methods

The findings in this section are based on focus group and survey results from three blocks (Baap, Osian, and Phalodi) in Jodhpur district, Rajasthan, India. They are the product of original research conducted on the part of GRAVIS staff and volunteers, and they have not been published anywhere else. As part of this research, 14 focus group discussions were conducted in late 2012 (October to December), followed by 158 household surveys in early 2013 (February to March). These surveys drew several topics of inquiry from a previous survey of farmers' adaptation practices, conducted in multiple countries in Africa (44). Following data collection, statistical analysis was conducted on Microsoft Excel and IBM SPSS. The findings were supplemented with information from various experts on rural development and environmental science in the Thar, obtained through literature review and personal communication. For the surveys, the sampling procedure was not entirely random, due to the limited capacity of the field staff, so generalizations from the data will be made cautiously, if at all. In many respects, these findings are preliminary and require further confirmation before they can be asserted with full confidence.

Ben Soltoff, a researcher from Duke University in the United States, organized and conducted much of the research while working with GRAVIS during the study period. His role as a young, male foreigner may have influenced the responses he received due to the cultural and linguistic differences between him and the study population. He conducted focus groups and surveys with the help of translators and members of the GRAVIS field staff, and it is both possible and probable that information was lost in translation. This risk is somewhat lower for the surveys, because Hindi-speaking GRAVIS field staff conducted most of the surveys independently, in order to increase the sample size. However, even the Hindi versions of the survey documents were originally translated from English and then further explained in Marwari (the local language of Jodhpur district), so translation was still a prominent issue. The fact that most people conducting the research were affiliated with GRAVIS in some capacity may also have influenced the results, because respondents may have been unwilling to speak openly about certain subjects, or because they may have mischaracterized their socio-economic situation in hopes of receiving additional support.

Despite these limitations, the findings of this research provide useful information on the state of climate change vulnerability in the Thar, and as long as they are supplemented with future research and responsible oversight, they can guide potential responses to climate-related adversity.

Familiarity with Global Warming and Climate Change -

Summary : In focus groups and surveys, rural villagers generally exhibited a low to moderate understanding of global warming and climate change, despite their occasional claims to the contrary.

In focus groups, most participants had little to no familiarity with the concepts of global warming and climate change. The few participants who claimed familiarity with those concepts often had serious misconceptions about what they entailed and how they occurred. Some participants said that changes were a result of pollution from nearby urban areas like Osian (ignoring the much larger impact of large cities like Delhi and Mumbai). One participant talked about how diseases like swine flu travel through the air from other countries and cause itching. Several participants brought up the hole in the ozone layer. Some said that earthquakes were caused by climate change. Many people attributed changes in the climate and to nature or to religious forces. Very few people said that climate change was a long-term phenomena caused by humans through emission of greenhouse gases. In one village, even the Sarpanch, an influential local leader, admitted to having very little understanding of climate change.

In surveys, respondents initially indicated a high degree familiarity with both global warming and climate change, but follow-up questions revealed that most of these respondents, like focus group participants, did not firmly grasp the nature and causes of the phenomena. Almost 70% respondents said that they were familiar with either the term “global warming” or the concept of the planet getting hotter over time, but only 22.7% said that global warming was a long-term change caused primarily by humans. Furthermore, 80% of respondents said that they were familiar with either the term climate change or the concept that patterns of temperature and rainfall were changing all over the world, but only 29.2% said this was a long-term change caused primarily by humans.

Respondents understanding of global warming and climate change differed significantly and surprisingly among blocks. In one block, Baap, a majority of respondents said global warming and climate change were long-term phenomena caused primarily by humans, while in another block, Osian, none of the respondents acknowledged these facts. It is unclear why such differences were present in the data, although they are possibly an indication of bias on the part of the facilitators. Translation issues were especially prevalent in this part of the research, because the terms “global warming” and “climate change” do not have the same implications in Hindi and Marwadi that they have in English, even when translated. As a result, the facilitators may have given supporting explanations that swayed the respondents' answers.

Climate Perceptions and Expectations -

Section summary: People in the Thar Desert perceived and expected changes in climate with an apparent bias for the extreme, including increased summer heat, increased winter cold, decreased rainfall amount, and delayed rainfall timing. Perceptions matched these extremes more closely than they matched actual measured conditions. Expectations generally followed perceptions, suggesting that villagers develop their expectations for the future based on what they have observed in the past. However, many focus group participants talked about climate-related superstitions as an alternative method of developing expectations. Respondents who were familiar with global warming as a long-term trend were more likely to perceive and expect warming, and those who were familiar with climate change as a long-term trend were more likely to perceive and expect change in rainfall. Tube well users were less likely to observe or anticipate climate change, especially with regard to rainfall.

Perceptions :

In focus groups, participants discussed year-to-year variation more readily than long-term change, but when prompted to discuss changes they had observed over many years, most groups mentioned delayed rainfall timing, decreased rainfall amount, and increased summer heat. Answers on winter cold were mixed, with some participants noticing an increase and other noticing a decrease. This disparity was apparent in descriptions of specific occurrences. One participant who noticed a decrease in winter cold said that water used to freeze in the winter but recently it did not freeze. A participant who noticed an increase in winter cold said that people in the village had started wearing more wool, and another said that it got so cold that even the sticks turned black. Participants rarely mentioned the frequency of rainstorms, focusing more on rainfall amount and timing. Along with changes in climate, some groups also noticed changes in species, such as the increased rarity of certain plants and the disappearance of a reptile known as the two-faced snake.

In surveys, the respondents described more extreme changes in the case of every climatic factor with the exception of rainstorm frequency, suggesting a bias towards the extreme. A majority of respondents said that they had perceived increased summer heat, increased winter cold, decreased rainfall amount, and delayed rainfall timing (Figure 5). The only factor for which a majority of respondents did not perceive a consistent trend in any direction was rainstorm frequency, which is the only factor lacking an obvious extreme. A decrease in rainstorm frequency suggests decreased rainfall, while an increase in rainstorm frequency suggests an increase in severe storms. Therefore, the results are consistent with a bias towards the extreme. In the cases of winter cold and rainfall amount, the extremes contradict historical records. However, Jodhpur district includes a very large geographic area, so it is possible that measured trends at weather stations differ highly from actual trends in villages.

Perceptions often related to understanding of global change and to farming methods. Respondents who were aware of long-term global warming were significantly more likely to perceive an increase in summer heat. Similarly, respondents who were aware of long-term climate change were significantly more likely to perceive changes in rainfall amount and timing. Tube well users were significantly less likely to perceive changes in rainfall, due potentially to their reduced dependence on rainfall to support their crops.

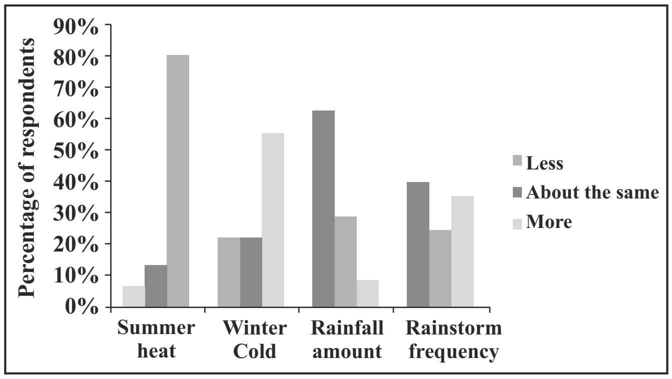


Figure 5. Survey result regarding perception of past climate change

Expectations :

Focus group participants were hesitant to make predictions about the future, but in most focus groups, participants mentioned that they expected lower amounts of rainfall in coming years. Rather than describing expectations, many participants described various superstitions regarding the future weather. For example, one participant said that six months to the day after fog was observed, rainfall would occur. Another participant said that if a man was walking and approached a bird or deer, then the number of steps he took before startling it would be the number of days until the next rainfall. Another said that when the rats come out, the rain follows. Several groups brought up a proverb that predicted how many years out of a hundred would involve certain levels of rainfall, including strong rainfall, moderate rainfall, moderate drought, and extreme drought. The numbers for this proverb were inconsistent. Many participants attributed climate to nature or religious forces and said that they could not know what to expect, especially in dryer blocks. Other participants expected that past trends would continue in the future.

Continuation of past trends was the climate expectation most clearly reflected in survey results. On average, respondents expected the same changes for the future that they perceived in the past: increased summer heat, increased winter cold, decreased rainfall amount, delayed rainfall timing, and no consistent trend of rainfall frequency. Furthermore, expectations of climate correlated strongly with perceptions (Figure 6).

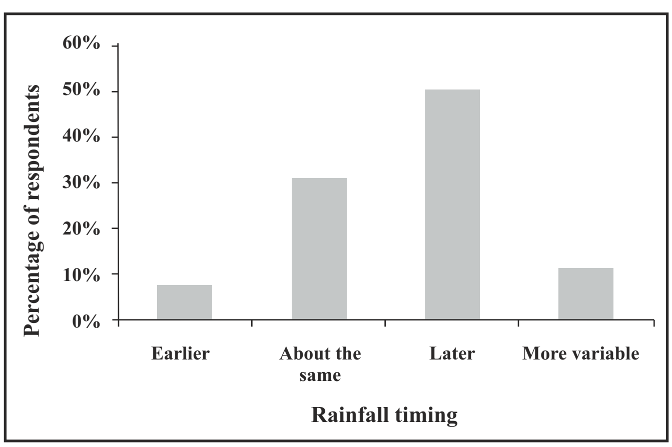


Figure 6. Survey result regarding future climate change

Like perceptions, expectations often related to understanding of global change and to farming methods. Tube well users were significantly less likely to expect a change in rainfall or a decrease in winter cold, and respondents who were aware of global climate change were significantly more likely to expect a change in rainfall.

Water Practices

Section Summary : Rainwater harvesting was a highly common practice among survey respondents and focus group participants, although the numbers might be inflated due to confusion between taankas used for rainwater harvesting and taankas used for storage purposes only. Survey respondents who relied on rainfall irrigation stored water for larger portions of the year, as did respondents who were aware of climate change and respondents who perceived or expected changes in rainfall.

In focus groups, residents of the Thar demonstrated a keen understanding of the relationship between rainfall and drinking water. Focus group participants said that drinking water depended heavily on the climate, because it was negatively affected by low rainfall. They mentioned that their most important sources of drinking water were taankas, tube wells, naadis, and government water tanks. They also said that if local drinking water resources were unavailable due to climate, they would purchase water from outside (from private tankers). They often obtained the money for these purchases from various forms of paid labour. Many people expected the government to provide water. They believed that if one water supply failed, then the government would set up another.

Survey respondents frequently used local rainwater as a source of drinking water, supplemented with water purchased from private tankers (Figure 7). About 80% of respondents said that they used household rainwater harvesting structures every year, and 10% used them only during drought, yet those numbers are probably inflated due to the prevalence of underground water storage tanks (taankas), which are not necessarily used for rainwater harvesting. Although the survey explicitly asked respondents if they used rainwater harvested from taankas, as opposed to water obtained from other sources and then stored in taankas, respondents may not have understood this distinction, or it may have been lost in translation. However, about 60% of respondents used communal rainwater harvesting structures every year, and those structures rarely contain water from sources other than rainfall, so respondents clearly depended on rainfall as a source of drinking water. Private tankers were another common method obtaining drinking water, with 55% of respondents using them every year. Around 40% of respondents used private tankers only during drought, confirming focus group findings that private tankers are an important fallback during periods of low rainfall. When respondents were asked to rank drinking water sources based on importance, they indicated that rainfall-harvesting structures were the most important, but as with earlier questions, the results might be skewed towards taankas. Private tankers were not included in the rankings because they bring water from a variety of sources and are not sources in their own right.

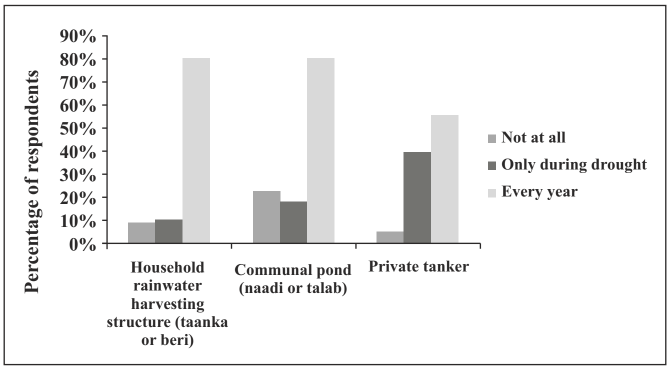


Figure 7. Respondents depends on rainfall as a source of drinking water

The amount of drinking water stored by respondents related closely to their irrigation methods and their perceptions and expectations about rainfall. Mean drinking water storage was 5.4 months worth of water. Tube well users stored significantly less drinking water than non-tube well users, and respondents who perceived or expected a decrease in rainfall or a change in rainfall timing stored significantly more drinking water than those who did not perceive or expect such changes.

Agricultural Practices

Section Summary: Survey respondents and focus group participants implemented many traditional agricultural practices known to foster climate resilience. Some practices, such as mixed cropping and agro-forestry, were highly common, while others, such as fallow systems and crop rotation, were less common. Survey respondents who used tube wells were more likely to implement less common practices, as were respondents who did not perceive changes in rainfall. Larger households and higher castes tended to store more crops, as did respondents who expected changes in rainfall and respondents who used rainfall irrigation.

Focus groups participants noted a strong relationship between climate and crop success. Many of them said that rainfall was especially important for crops, not only in terms of amount but also in terms of timing. Some took special effort to explain that late rainfall was not useful, even in large amounts, because many crops needed to be planted at certain times of year. The most common crops that they planted were pearl millet (bajra), green grams (moong), moth beans (moth), cluster beans (guar), sesame (til), and wheat. Most participants used only rainfall irrigation, but they said that rich farmers used tube wells for irrigation. Participants in many focus groups expressed concern that groundwater levels were decreasing and expected a problem of water availability in the future. Some participants connected this problem to overpopulation. In one group, participants said that they used to dig 400 feet for tube wells but more recently they needed to dig 1000 feet. One group said that NGOs should plant more trees and establish tube wells so that the whole area would be green and their children would prosper. Several groups mentioned a decrease in the fertility of the land over the past few decades. They said that this decrease led to a greater need for fertilizers and a decrease in crop yield. Many participants expressed an aversion towards chemical fertilizers, saying that vegetables grown with those fertilizers had adverse health effects and needed to be avoided. One group said that in earlier years, they used to implement a fallow system (cultivating crops in one field and leaving another empty, and then switching fields the following year), but due to lower availability of land in recent years, they needed to farm on every field every year. They attributed the lower availability of land to overpopulation. Most groups said that when food sources were unavailable due to poor climate, they purchased them from outside (from the market) with money earned through labor.

Survey respondents were mostly farmers. All but one respondent took part in some type of agricultural activity. Of the respondents who practiced agriculture, farming experience ranged from 1 to 48 years, with a mean of 22.6 years, and landholdings ranged from 1 bigha (0.4 acres) to 60 bighas (24 acres), with a mean of 21.7 bighas (8.7 acres). Most farming activities involved planting crops in fields. Only 4.4% of respondents owned household horticultural units, or kitchen gardens, which are very small orchards containing various types of fruit trees. Just over half of respondents sold their crops at the market. The rest presumably used their crops only for household food supply, although they did not say that explicitly. All participants who farmed used rainfall irrigation to some degree, even if they used other methods as well. Most respondents used only rainfall irrigation, although some also used tube wells, and a few also used canal irrigation, drawing water from the Indira Gandhi Canal or its offshoots (Figure 8). Most respondents used organic fertilizers, such as cow and goat manure, while few respondents used chemical fertilizers, and some used chemical pesticides (Figure 9). When respondents were asked to rank the crops that they grew based on relative importance, they indicated that the most important crops were those that grew solely with rainfall irrigation. These crops included pearl millet (bajra), mung beans (moong), moth beans (moth), cluster beans (guar), and sesame (til). Respondents were asked only to rank the crops they grew themselves, so these results are not surprising, as most respondents did not use tube wells or canals, which are required to grow most crops in the Thar other than the ones listed. The major exception was wheat, which was ranked highly despite requiring additional irrigation. It was most likely included because it is a key dietary staple and one of the most common crops planted in irrigated fields.

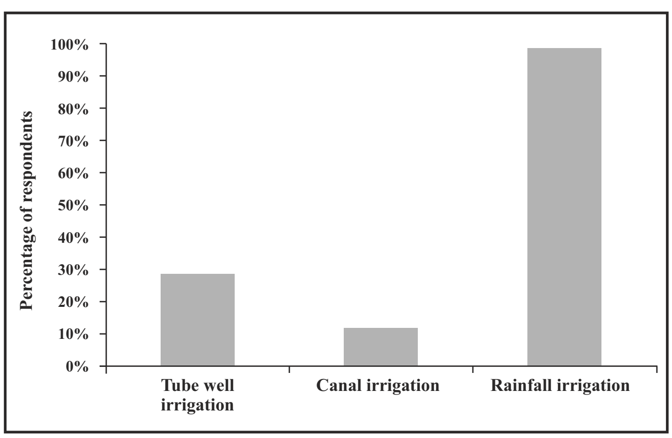


Figure 8. Respondents used tube well, Canal and rainfall water for irrigation

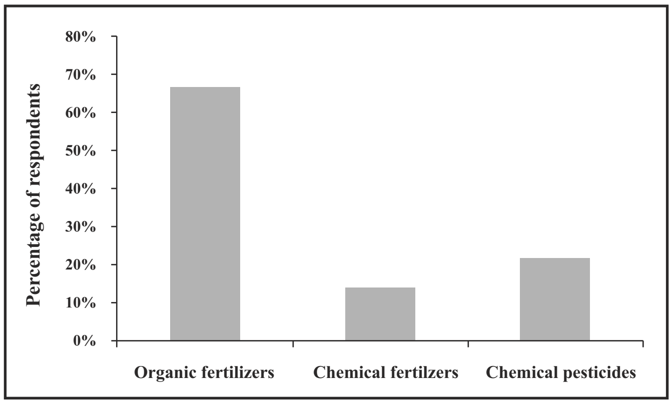


Figure 9 Percentage of respondents using fertilizers and pesticides

Survey respondents implemented many traditional agricultural practices that are known to boost climate resilience (Figure 10). Over 95% of respondents said that they planted multiple crops in the same field. This practice increases the chance of a successful harvest, because if one crop fails, another may succeed in its place. About 60% of respondents said that they planted multiple varieties of a given crop. This practice increases crop success in generally the same manner as planting multiple crop types: greater diversity leads to a greater chance that one variety will succeed where another fails. Close to 90% said that they practiced mixed farming, which is a term for growing crops and raising livestock as simultaneous livelihood strategies, rather than focusing on one or the other. This practice boosts resilience because one strategy can provide nutrition and income during times when the other strategy is unsuccessful. Just over 90% said that they wait to plant crops until after the first rainfall. This practice reduces the loss of income when the rainy season comes late or does come not at all, yet it does not work in every situation, because some crops need to be planted at certain times of year. Around 40% of respondents said that they implemented a fallow system, which means planting crops on a field some years and then taking a break from planting other years. About 54% said that they implemented a system of crop rotation, which is similar to a fallow system but involves switching crops instead of leaving the field for fallow. These practices can be used in conjunction with one another (planting one crop in the first year, planting another crop in the second year, and then leaving the field for fallow in the third year), and both practices reduce stress on the land and conserve soil fertility. Over 95% of respondents said that they stored seeds after harvesting crops. This practice reduces farming costs, because it prevents farmers from needing to buy seeds every year, and it allows farmers to plant only the most successful crops, leading to long-term increases in productivity. Close to 90% said that they practiced agro-forestry, which means leaving trees like khejri (Prosopsis cineraria) in agricultural fields. This practice prevents erosion and increases soil fertility, while also providing resources such as food, fodder, and firewood, even when crops fail. Around 80% said that they built khadins (small walls) around their fields. This practice maximizes the amount of rainwater that collects on the fields, reducing the amount of rainfall necessary to grow crops. Khadins are only suitable in one of the surveyed blocks, so the results for this practice seem to be inflated.

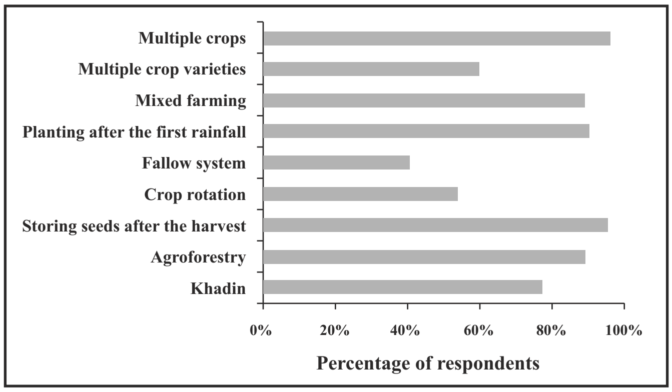


Figure 10. Percentage of respondents in any traditional agriculture practices

Implementation of traditional practices was often connected to irrigation methods. Tube well users were more likely to conduct certain practices, such as planting multiple crop varieties, letting fields lay fallow, and rotating crops. Tube well users were less likely to perceive or expect changes in rainfall, so they probably did not implement these practices as a response to climatic conditions but rather as a result of economic ability. Tube well users tended to be wealthier and could more easily afford to buy multiple seed varieties or to set aside extra land for fallow systems and crop rotation.

Survey respondents often bought food from the market to supplement agriculture, especially during times of drought. Most respondents bought food only during drought, some respondents bought food every year, and hardly any respondents did not buy food at all. The respondents who bought food mostly bought grains. Almost all of them bought millet (bajra), and exactly half bought wheat. Other purchases included moong, moth, til, guar, rice, and vegetables. Selling land was a much less common response to drought. Only 7.6% of respondents had ever sold all or part of their land.

The amount of food stored by respondents related closely to their irrigation methods and their expectations about rainfall. Mean food storage was 7.6 months worth of crops. Tube well users stored significantly less food than non-tube well users, and respondents who expected a decrease in rainfall or a change in rainfall timing stored significantly more food than those who did not perceive or expect a change in rainfall. Food storage correlated positively and significantly with household size and caste status, meaning that households with more members stored more food, as did households of a higher caste status

Livestock Practices

Section Summary: Almost all survey respondents and focus group participants owned some form of livestock, usually goats or cows. During drought, they would need to purchase fodder to support their livestock, usually from neighbours' or from the market. Respondents who perceived or expected changes in rainfall tended to store more fodder, as did those who relied on rainfall irrigation. Respondents who perceived or expected an increase in summer heat and respondents who were aware of long-term global warming were more likely to build shelters for their livestock.

About a third of survey respondents said that they would migrate somewhere else if environmental conditions became too harsh for their livestock. Respondents were more likely to express a willingness to migrate if they had a greater number of goats and sheep or if they relied on rainfall for irrigation.

In focus groups, participants emphasized the sensitivity of livestock to climate, the importance of fodder, and the possibility of livestock-related migration. They said that livestock depended on the climate because they were negatively affected by low rainfall, extreme cold and extreme heat. In adverse conditions, animals could get sick, produce less milk, and possibly die. Participants said that people with a lot of livestock would protect their animals from those risks by migrating to other areas, although many added that they themselves would not migrate. Some participants said that they built shelters to protect their livestock from extreme temperatures, or that they stored fodder to use during drought. Participants also said that if fodder were unavailable due to poor climate, they might need to purchase it from the market and then pay for this purchase with money earned through labor. Regarding types of livestock, the participants said that they owned mainly goats and cows. They said that some people owned camels and buffalo, but not as many, because those animals required larger amounts of fodder.

All survey respondents owned some form of livestock. Almost everyone owned goats, a large majority owned cows, and some owned buffalo, a few owned sheep, and very few respondents owned camels or donkeys (Figure 11). On average, the goat owners had about eight goats, the cow owners about two cows, the buffalo owners had one to two buffalo, and the sheep owners had about 27 sheep. There was one camel owner, with one camel, and also one donkey owner, with two donkeys. When asked to rank the livestock that they owned based on relative importance, respondents indicated that the most important livestock were cows and goats.

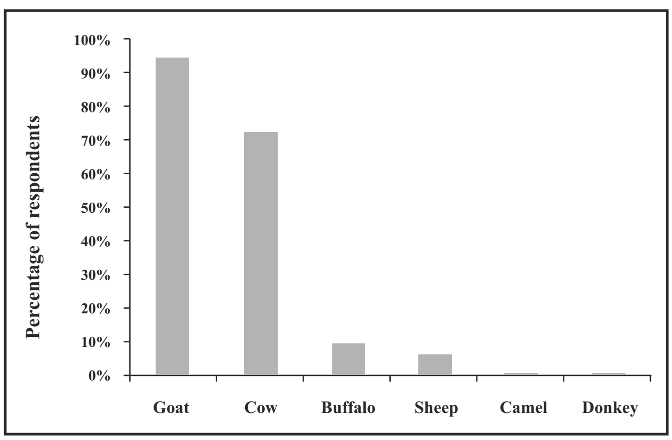


Figure 11. Percentage of respondents having livestock ownership by livestock type

Survey respondents often took part in market transactions related to livestock. Almost half sold livestock every year, and some sold livestock only during drought. Some respondents sold dairy products at the market. A few respondents bought dairy products every year, and some bought diary products only during drought, but over 75% did not buy dairy products at all, which was probably due to the ubiquity of dairy-producing livestock. Respondents did not need to buy dairy products because they had livestock of their own. Most respondents purchased fodder from one source or another (Figure 12). . A few purchased fodders from the market every year, and most purchased it from the market only during drought. Some purchased it from neighbours' every year, and most purchased it from neighbours' only during drought. None of the respondents purchased fodder from government depots or GRAVIS fodder banks every year, and some purchased it from these sources only during drought.

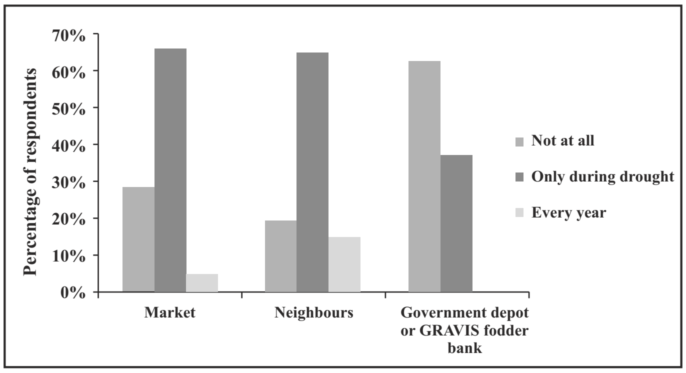


Figure 12. Fodder purchased by different source

The amount of livestock fodder stored by respondents related closely to their irrigation methods and their perceptions and expectations about rainfall. Mean fodder storage was 6.9 months worth of fodder. Tube well users stored significantly less fodder than non-tube well users, and respondents who expected a decrease in rainfall or a change in rainfall timing stored significantly more fodder than those who did not perceive or expect a change in rainfall. Fodder storage correlated positively and significantly with caste status and number of large livestock meaning that higher caste households stored more fodder, as did households with more cows or buffalo.

The practice of building shelters for livestock was connected to awareness and expectations of warming. Over 75% of respondents said that they built shelters for their livestock. Respondents were significantly more likely to build shelters if they were aware of long-term global warming, if they expected an increase in summer heat in the future, or if they owned more goats.

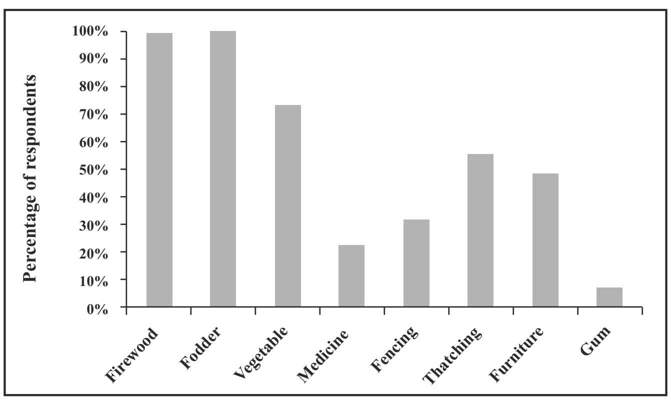
Willingness to migrate for livestock-related purposes was connected to tube well use and livestock ownership. About a third of respondents said that they would migrate to other areas in order to raise their livestock. Of the respondents who were willing to migrate, close to 20% said that they would go to Punjab, just over 20% said that they would go to Haryana, about 15% said that they would go to neighbouring villages, about 5% said that they would go to irrigated areas, and slightly under a third said that they would go wherever fodder was available. These answers were not mutually exclusive. Respondents were significantly more likely to express willingness to migrate if they owned more cows, goats, or sheep, and they were significantly less likely to migrate if they used tube wells.

Wild Plant Practices

Section summary: Survey respondents and focus group participants used wild plants for many daily purposes, most commonly firewood, fodder, and food. Tube well users were less likely to buy or sell wild plant products or to use wild plants as a food source. Respondents who perceived or expected changes in rainfall tended to store more firewood, as did those who relied on rainfall irrigation. Caste status and household size correlated positively and significantly with firewood storage.

In focus groups, participants described a variety of ways that they used wild plants. They listed many important plant species and readily talked about their uses, which included fodder, food, and firewood. Some of the participants said that they kept reserves of these resources in their homes, especially firewood. The participants explained that wild plants depended on the climate, because they were negatively affected by low rainfall, extreme cold and extreme heat. However, they also noted that wild plants were less climate-sensitive than other resources, because they were present in the environment during times of low rainfall or extreme temperature, although they became drier or smaller during those times. Many participants noted a strong relationship between trees and rainfall. Often, they believed that more rainfall led to more trees and also, conversely, that more trees led to more rainfall. Participants frequently mentioned trees as an indicator of the favorability of the climate. Many of them attributed climate-related hardships to deforestation.

Survey respondents used wild plants most commonly for fodder, firewood, and food. All of the respondents used wild plants for fodder, all but one of the respondents used wild plants for firewood, and almost three quarters of the respondents used wild plants for food (Figure 13). Other uses included thatching for roofs, furniture, fencing, medicine, and gum. Respondents were significantly less likely to use wild plants as a source of food if they used tube wells. When asked to rank wild plants based on relative importance, respondents indicated that khejri (Prosopsis cineraria) was by far the most important.



\Figure 13. Respondent uses wild plant

Survey respondents rarely took part in market transactions related to wild plants. Only about 15% of respondents sold wild plant products at the market. A few respondents bought wild plant products every year, some bought wild plant products only during drought, and most did not buy wild plant products at all. Respondents were less likely to buy or sell wild plant products if they used tube wells. Also, respondents were more likely to buy wild plant products if they lived closer to the nearest market.

The amount of firewood stored by respondents related closely to their irrigation methods and their perceptions and expectations about rainfall. Mean fodder storage was 7.3 months worth of firewood. Tube well users stored significantly less firewood than non-tube well users, and respondents who expected a decrease in rainfall or a change in rainfall timing stored significantly more firewood than those who did not perceive or expect a change in rainfall. Fodder storage correlated positively and significantly with caste status and household size, meaning that higher caste households stored more firewood, as did households that had more members.

Employment Practices

Section Summary : Although most focus group participants and survey respondents gained their livelihood primarily from farming, they often earned supplementary income through labour.

The Mahatma Gandhi National Rural Employment Guarantee Act (NREGA) was by far the most common source of work, followed by mines and irrigated farms. Some villagers migrated to other areas for work-related purposes.

Focus group participants emphasized that labour provided them with an essential source of supplementary income. They said that this income was especially important during times of drought, because they could use it to purchase resources that were unavailable as a result of late or inadequate rainfall. The participants said that they either found work locally or migrated to other areas, and they described NREGA, mining, and farm labour as the most important sources of employment.

Survey respondents occasionally migrated but mostly found work near their homes. Every household had at least one member who was employed in some capacity. The number of household members employed (in any capacity) ranged from one to seven, with a mean of about three. In close to a tenth of households, members migrated every year for employment, and in just over a fifth of households, members migrated only during drought, but in most households, none of the members migrated at all. Migrant workers left their households for mean of about seven months out of the year. They went mainly to other parts of Rajasthan or to neighbouring states like Gujarat, Punjab, and Haryana. Respondents were significantly less likely to migrate if they used tube wells.

Workers who did not migrate were most commonly employed in government programmes, mining, and farming on land owned by other people (Figure 14). The Mahatma Gandhi National Rural Employment Guarantee Act (NREGA) certifies 100 days of paid labour for any able Indian adult in a rural area and was the most prevalent source of employment among surveyed households. Most households had members employed in NREGA every year, some households had members employed in NREGA only during drought, and very few households did not have any members employed in NREGA at all. After NREGA, the next most common sources of employment were mining in quarries and working on farms owned by other members of the community (usually supported by tube wells). About half of households had members employed in these pursuits every year, some had members employed in these pursuits only during drought, and some did not depend on these pursuits at all. As far as other sources of employment, households sometimes had members employed in GRAVIS food-for-work and cash-for-work programmes, households occasionally had members employed cottage industries, and households very rarely had members employed in tourism.

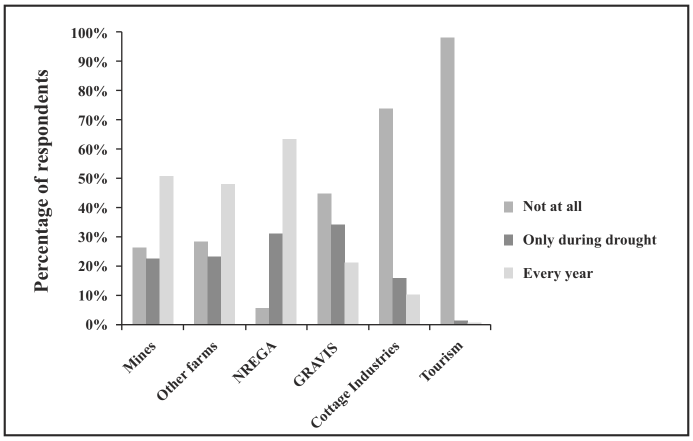


Figure 14. Fodder purchased by different source

Drought Practices

Section Summary : Taking loans and praying were the most common responses to drought among focus group participants and survey respondents. They obtained loans from neighbours more often than from the bank or from self-help groups (SHG). They more often reduced the quality of their food than the quantity of their food. Girls were more commonly taken out of school than boys, but only by a slight margin. Tube well users were less likely to implement most drought responses, with the exception of taking loans from the bank and consulting experts.

Focus group participants expressed a keen familiarity with the hardship of drought and mentioned several practices that they used to cope. Some focus group participants attributed climate variability and to nature or religious forces and claimed that they were helpless to respond. One participant joked that in response to hotter drier temperatures, people in the village would go hide under the bed. A few focus groups talked about loans as a response to environment-related hardship. Participants in one group said that if there were no rain, they would get caught in a downward spiral of money lending, wherein they would not have enough money to sustain their household or pay taxes, so they would need to keep taking more loans, falling deeper and deeper into debt. One group of female participants described the critical importance of self-help groups (SHGs) in their lives. The women said that some houses in the village were recently destroyed due to heavy rains, and the homeowners got loans from SHGs in order to rebuild.

Although survey respondents took many measures in response to drought, they depended most heavily on loans. As described in earlier sections, respondents often responded to drought by changing their practices with regard to water, crops, livestock, wild plants, and employment, yet they also implemented a range of more general responses. Most commonly, they borrowed money. Just over 90% of respondents took loans from their neighbours, about 70% took loans from a bank, and almost 25% took loans from an SHG (Figure 15). Respondents also changed their eating habits in response to drought. While some respondents said that they ate a lower quantity of food, over half said that they ate a lower quality of food. Some respondents took their children out of school, and this practice was slightly more common if the children were girls than if they were boys. Close to half of respondents postponed large expenditures, such as weddings or new houses. Over three quarters of respondents prayed for relief, and about one quarter of respondents consulted experts, including agricultural experts, environmental experts, water experts; GRAVIS staff members, older people, teachers, and local government officials.

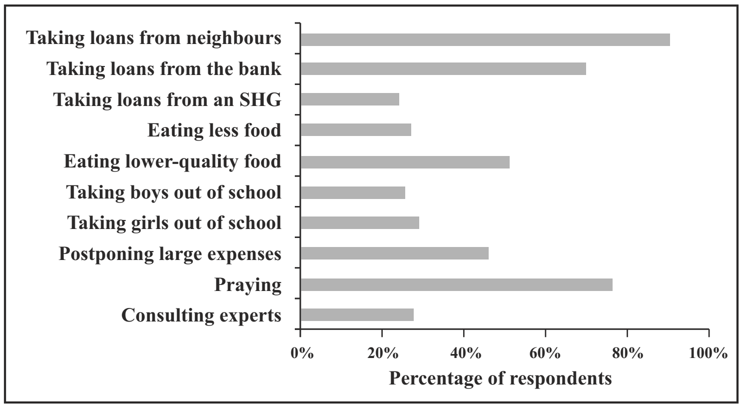


Figure 15. Drought response

Drought responses were most closely connected to tube well use. Respondents who used tube wells were significantly more likely to implement responses that relied on formal institutions—taking loans from banks and consulting experts—but significantly less likely to implement other practices—taking loans from SHGs, eating less food, eating lower-quality food, taking children out of school, postponing expenses, and praying. There were several significant relationships between drought responses and climate perceptions and expectations, but no clear overall trends, either positive or negative, suggesting that the responses were based on short-term necessity rather than long-term planning.

External Support

Sections Summary : In focus groups and surveys, residents of the Thar said that government and NGOs could most effectively help their communities through employment assistance and rainwater harvesting.

Towards the end of every focus group, participants were asked how external entities like government and NGOs could support their communities. The most common answers included taankas, naadis, khadins, and employment opportunities. Participants in one group said that NGOs could establish cottage industries for alternative sources of income and could also provide livestock for that purpose. Participants in another group said that NGOs could help with education and building schools, because if children got educated, they would be prepared to deal with future problems, and they would be able to educate future generations. Participants in a third group said more generally that government should handle the big projects (costing millions of rupees), while NGOs should handle the small ones.

Survey respondents most commonly listed work opportunities and rainwater harvesting structures as ways that government and NGOs could provide support (Figure 16). Most respondents gave an answer relating to employment or income, and many respondents mentioned rainwater-harvesting structures such as taankas, beris, khadins, or village ponds. Other suggestions included fodder provision. Pastureland, loan assistance, and education.

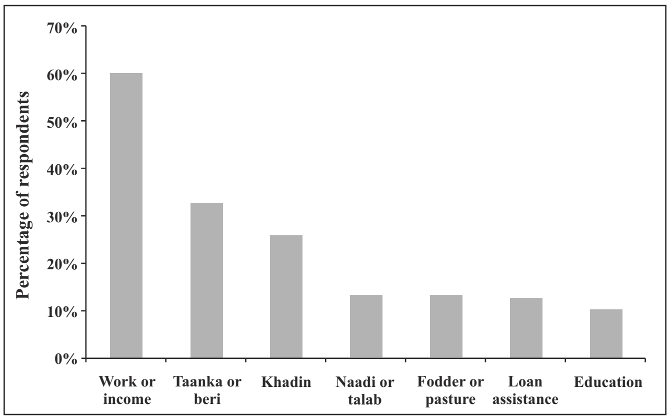


Figure 16. External support use by respondents

Block-level differences

Jodhpur district is a large, diverse area, and while many similarities exist among its blocks and villages, many differences exist as well. In the survey data, a key difference was tube well use. Tube wells were used commonly in Osian block, occasionally in Phalodi block, and not at all in Baap block (Figure 17). These differences were highly significant, reflecting differences in farming practices and aquifer salinity. Tube wells figure prominently in the conclusions of this report, so before proceeding to those conclusions, it is important to note that differences in tube well use may reflect differences among blocks not related to irrigation. However, because differences in irrigation strategy comprise some of the major differences among blocks, especially with regard to climate sensitivity, it stands as a reasonable assumption that the observed differences between tube well users and non-tube well users were not due to any confounding variables. The validity of this assumption can be tested in future research.

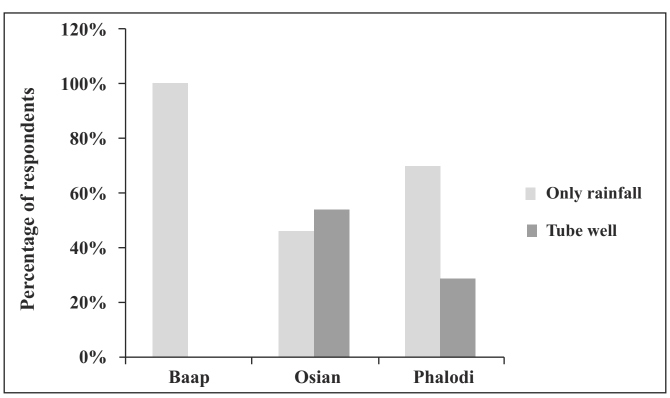


Figure 17. Source of water used in different blocks

PART III. CONCLUSIONS

A hotter future with highly variable rainfall

Climate change poses a distinct threat to communities of the Thar Desert. Substantial shifts in the climate are not a concern for the distant future, but rather they have already begun and will intensify in the coming years. The main change has been a severe increase in heat, but other expected effects include changes in rainfall amount, timing, and intensity. With regard to temperature, the changes observed and expected in the Thar match those observed and expected for the whole of India (30, 31, 32). Temperatures have increased substantially in the recent past, and they will continue to increase in the future. Changes in rainfall are more difficult to predict, but even so, the Thar is expected to differ from the rest of the country (32). While rainfall levels are expected to increase in many parts of India, rainfall levels in the Thar are expected to decrease or stay the same. However, rainfall timing in India is expected to become more variable, and rainstorms are expected to become more intense, with more frequent extremes (34), and these changes may very well extend to the Thar. Although the Thar received late rainfall in the years immediately preceding the study period, records suggest that these conditions are not indicative of a long-term trend; they fall within normal variability. Under any future scenario, rainfall in the Thar will continue to experience the dramatic short-term variation that has characterized the region for hundreds of years, and this variation will most likely overshadow any long-term shifts.

A bias toward the extreme

Villagers in the Thar Desert are firmly aware of changes in the climate, but their perceptions and expectations often differ from measured trends, and they show hardly any understanding of change on a global scale. When asked about their perceptions of past change or expectations for future change, villagers exhibited a clear and unsubstantiated bias towards the extreme, mentioning increased summer heat, increased winter cold, decreased rainfall amount, and delayed rainfall timing, occasionally in contrast to measured trends. It is possible that these villagers had been experiencing different conditions than weather stations due to local variations in climate, but the extreme nature of the differences suggests a deeply inaccurate view of long-term climate trends. Such inaccuracy does not mean that the people of the Thar are ignorant of the climate. A more likely explanation is that they are paying greater attention to short-term variability than to long-term change, which is reasonable in an area where extreme variability has characterized the climate for generations.

Limited understanding of global trends

In addition to lacking awareness of local climate change, residents of the Thar also lack awareness of global climate change. Focus group participants and survey respondents often claimed to know little to nothing about the concepts of global warming and climate change, and those who claimed to understand those concepts often indicated otherwise in follow-up questions. Focus group participants who claimed to understand global change made several statements that indicated severe misunderstandings about the extent and causes of this change, and survey respondents who claimed to understand global warming and climate change rarely recognized that these concepts entailed long-term changes caused by humans. The lack of understanding of global trends most likely reflects limited education and access to global news within villages.

Traditional practices to boost resilience

Despite their misconceptions of climate change on a local and global scale, residents of the Thar are highly familiar with local climate variability and ways of dealing with it, and this familiarity could prove to be one of their greatest assets in adapting to future change. Like year-to-year variability, climate change will have adverse effects on many key resources in the Thar. Unfavorable changes in rainfall and temperature could lead to lower supplies of water for household purposes and irrigation, reduced crop yields, sickness or death among livestock, and decreased output of wild plants, all of which threaten the health and livelihood of desert dwellers. Fortunately, communities have dealt with such challenges for generations and are prepared to continue dealing with them in the future.

Rainwater harvesting is a highly common practice, and people fully recognize its utility. By capturing and storing rainwater in structures such as taankas, beris, and naadis, residents of the Thar can maintain a somewhat stable household water supply even during periods of low rainfall. Many people use these structures, and those who do not often request them from government and NGOs.

The people of the Thar also implement a range of agricultural practices known to boost resilience, such as planting multiple crops on the same field, planting multiple crop varieties, mixing crops with livestock production, applying fallow systems, rotating crops, storing seeds after the harvest, keeping trees on fields, and building khadins. These practices increase diversity, so even if one component fails, another may succeed, and they also reduce stress on the land, allowing fields to maintain productivity for many generations. Such benefits are invaluable for coping with climate change.

In addition to growing crops, rural villagers in the Thar also raise livestock. These animals serve as vital sources of nutrition and income. Villagers protect their livestock from adverse conditions by building shelters and, in extreme circumstances, migrating to other areas.

The people of the Thar gain further supplementary resources from wild plants, mainly in the forms of food, fodder, and firewood. Although plants become smaller or dryer during times of unfavorable climate, they rarely disappear entirely, so they constitute an important fallback when other resources become unavailable.

On their own, these strategies offer only a small amount of sustenance, but a key advantage of resilience-boosting strategies is that they complement one another. By combining traditional practices related to water, agriculture, livestock, and wild plants, rural households in the Thar are able to make the most of scarce resources in a harsh climate.

Traditional practices provide crucial support in difficult times, but even when households use multiple strategies, they often fall short of what they need, and they must resort to other means to make ends meet. Families purchase all kinds of additional resources from the market, especially during circumstances of adverse climate. Their most common purchases include water, grain, and fodder—the basic elements required for them to sustain themselves and their livestock. Other resources, such as dairy products and items obtained from wild plants, are more consistently available but also less important. A household can survive without fruit and firewood but not without grain and water.

From subsistence farmers to rural labourers

In order to afford essential resources when crops fail and when rainfall is inadequate to supply drinking water, households depend on income obtained through various forms of labour. This reliance on labour is so widespread that to describe most people in the Thar as subsistence farmers would be misleading. They are subsistence farmers when favorable climate allows them to subsist on what they farm, and they are labourers when unfavorable climate makes such subsistence impossible. All evidence suggests that the latter situation is becoming far more common.

The most prominent source of employment is by far the Mahatma Gandhi National Rural Employment Guarantee Act (NREGA), to such a degree that this program has become a fixture in rural life, with almost every surveyed household participating. After NREGA the most common sources of work in the Thar are mines and irrigated fields, each employing a large majority of surveyed households. Some individuals migrate for purposes of employment, but most stay near their homes. The popularity of NREGA is likely due to the relatively high pay (set by the government rather than local mine-owners or landholders), the seasonal nature (only 100 days annually, allowing people to work in their fields the rest of the year), and the security of the guarantee. Residents of the Thar recognize the role that labour plays in their lives. When asked how government and NGOs could help their communities, most people mentioned employment opportunities in their answers. Subsistence farming alone is no longer sufficient to support rural life.

A dangerous spiral of debt

In addition to gaining income through labour, rural households also take loans and reduce expenses in order to afford essential resources during periods of adverse climate. When taking loans, they most commonly turn to neighbours, presumably the wealthiest members of the community, rather than banks or community groups. The conditions for these neighbourly loans are subject to little if any oversight, and the interest rates can be grossly high, so households risk falling quickly and deeply into debt. As climate conditions become more adverse in the future, families may need to take more loans without paying back their existing debt, leading to a dangerous downward spiral. Crippling debt might prove to be one of the most potent side effects of climate change in the Thar.

Indirect consequences

The indirect consequences of climate change could also extend to sectors such as culture, education, and health. When households lack funds during times of climatic hardship, they cut non-essential expenses by postponing major celebrations, taking children out of school, and reducing the quality of their food. Households have little support in making such difficult decisions. They are far more likely to turn to religion than to any sort of professional authority, probably because the nearest temple is much closer than the office of the nearest expert. Many of the poorest individuals in the study expressed attitudes of helplessness, saying that their fate was up to god and that they could do nothing to improve their lot. Although this hopeless attitude is unproductive and usually inaccurate, in situations of intense poverty and extreme climate change, it is profoundly understandable.

Tube wells shield against vulnerability

Not all households respond to climate in the same way, and differences in adaptation methods relate to certain common factors, most notably the use of groundwater irrigation. People who use tube wells have a distinctly different approach to climate and agriculture than people who do not use tube wells. They are less likely to perceive or expect changes in climate, less likely to store large amounts of water, grain, fodder, or firewood, more likely to implement land-intensive agricultural practices, less likely to migrate for livestock or employment purposes, less likely to buy or sell wild plant products, less likely use wild plants as a food source, less likely to implement informal drought responses, and more likely to implement drought responses relying on formal institutions.

Why do tube well users differ so fundamentally from the rest of the population of the Thar? Part of the story probably involves wealth. Tube well users tend to be richer than other community members, so they behave in different ways. However, it is also possible that tube wells act as a buffer between humans and the earth's natural systems. By pumping their water supply from deep under the ground, tube well users depend less on the climate and the surrounding environment. This independence from nature could explain why tube well users appear less sensitive to changes in the climate, less reliant on wild plants, and less inclined to store resources. It is important to note, however, that the rough nature of the survey makes it fairly prone to error, especially with regard to tube wells. Because irrigation practices differ so greatly among the three study blocks, it cannot conclusively be established whether trends are due to tube well use or to other block-wise differences. Still, tube wells most likely play an important role in household response to climate, and this study provides more than enough evidence to justify further research on the matter.

Additional factors connected to adaptation

Other notable factors that this study links to climate change adaptation include climate perceptions, climate expectations, and social status. Villagers who perceive and expect changes in the climate are often more likely to adapt to those changes, especially with regard to water, agriculture, livestock, and wild plants. The major exceptions to this trend are tendencies to implement various drought responses, such as taking loans and cutting expenses, suggesting that those practices serve as emergency measures rather than long-term responses to an altered climate. Furthermore, households in which the respondent perceives or expects a change in climate may have less need to take emergency measures, because they tend to keep larger stores of important resources. Households also tend to store more resources if they belong to higher castes, indicating a social disparity in climate preparedness. Additionally, the study confirms several factors of climate adaptation that are somewhat intuitive. For instance, if households own more livestock, they are more likely to take measures to protect those livestock.

Climate change exacerbates other risks

All evidence from this study indicates that the people of the Thar Desert are highly vulnerable to climate change. As subsistence farmers in the developing world, they are demographically inclined to suffer the worst effects of a changing climate, and this climatic burden exists not only in the literature but also in the field. Focus groups and surveys confirm that the people of the Thar are highly vulnerable. Although the Thar will not experience the harshest effects of climate change, its residents have a very low capacity to respond due to poverty and other constraints. Fortunately, the people of arid Rajasthan are far from helpless in the face of a changing and unfavorable climate, as communities in the Thar have dealt with natural climate variability and severity for centuries. The traditional practices they have developed to foster climate resilience will prove valuable means of adaptation in the years to come. However, these practices are unlikely to suffice in the wake of the most severe climatic hardships. In response to more frequent and intense droughts and heat waves, residents of the Thar are likely to turn to more extreme measures by finding alternative sources of income, taking loans, cutting expenses, and relying on groundwater irrigation.

These responses are connected. Even if poor residents of the Thar cannot afford tube wells themselves, they may work on large farms that use tube wells, or they may take loans from wealthy neighbours who use tube wells. The alarming aspect of such trends is their inherent lack of sustainability. If future climate shifts lead to a greater dependence on measures such as tube wells and loans, then villages in the Thar could fall into potentially irreversible situations of groundwater depletion and debt. And the poorest and most socially marginalized households will be the most susceptible. Because of such risks, the most worrying effect of climate change is not the change itself but rather its potential to exacerbate existing conditions of environmental degradation and social inequality. Based on these findings, climate change adaptation in the Thar requires an approach that acknowledges the complexity of the issue and confronts the full span of its consequences.

PART IV. RECOMMENDATIONS

While climate change undoubtedly poses a challenge for rural communities in the Thar Desert, appropriate action on the part of government, NGOs, and villagers themselves can lessen its impact. Rural poverty entails many hardships, and climate change is yet another obstacle in the path. It is not an imminent disaster to be feared but rather an impending problem to be solved. Based on the findings of this preliminary study, the following strategies are recommended for dealing with climate change in the Thar.

1. **Rainwater harvesting :** Capturing rainwater provides a renewable source of water for drinking, household purposes, and irrigation, and takes pressure off of limited groundwater supplies. It has been practiced in one form or another for hundreds of years in the Thar, but future projects can improve its reach and efficiency. Although rainwater harvesting does little to mitigate the most extreme droughts, which last for many months, it allows households to maintain a reliable and easily accessible water source for days or weeks between rainfall events. Also, structures such as taankas allow households to store water from outside sources, so villagers who own these structures do not need to fetch water as often, and they have the option of receiving large amounts of water from tanker trucks.

2. **Agro-ecology :** Restoring and maintaining traditional, ecologically sound farming methods will improve climate resilience by conserving soil and increasing diversity. These agro-ecological practices include planting multiple crops on the same field, planting multiple breeds of the same crop, combining livestock and agriculture, planting in accordance with rainfall patterns, implementing fallow systems, rotating crops, storing seeds after the harvest, keeping trees on agricultural fields, and building khadins where possible. Land-intensive practices, such as fallow systems and crop rotation, are especially important to preserve, because they have become less common in recent years, as rapid population has increased the demand for land. Groundwater irrigation poses a further threat to traditional practices. Although tube wells provide a viable and sometimes essential response to changing rainfall patterns in the short term, they are highly unsustainable in the long term, because they deplete groundwater supplies faster than they can be replenished. Also, tube wells do little to counter extreme heat, which is one of the most certain future effects of climate change.

3. **Animal husbandry :** Livestock animals provide rural households with valuable sources of nutrition and income, even when crops fail. By raising cows, goats, and other forms livestock, households obtain enough dairy products for their own consumption and then sell any extra at the market. If the livestock reproduce, then households gain further income by selling the young. Also, male animals often aid in physical labour, such as pulling plows or carts. In order to sustain

the benefits of livestock in a changing climate, households must provide their animals with shelter and other protections from climate-related adversity, and they must have consistent access to fodder.

4. **Ecosystem conservation :** The natural environment supplies many supplementary resources to rural households, especially when crops fail. The most important of these resources are food, fodder, and firewood. Although few households can survive solely on wild plants and trees, these ecological products provide an essential safety net during times of climate-related adversity. Conserving ecosystems through maintenance of communal lands and sustainable harvest of natural resources will allow this safety net to remain intact for future generations.

5. **Loan assistance :** In the short term, taking loans is by far the most common way that villagers respond to climate-related hardship, but in the long term, dependence on loans can lead to serious debt. GRAVIS should strive to ensure that loans are taken responsibly through the most effective channels. Community lending initiatives like SHGs can help with this objective. Households must also have ways of resolving their existing debt. If they regularly borrow more money than they can pay back, then they could easily get caught in a downward spiral, with debt being passed from one generation to the next.

6. **Income diversification :** In extreme cases of climate change, households will not be able to meet their needs solely with subsistence farming. They will need to purchase food, water, and other necessities from external sources, and in order to afford such purchases, they will need to find sustainable sources of income other than agriculture. Government employment programmes like NREGA are already standard parts of rural life, and they are likely to become even more important in the future. The greater number of livelihood options that rural households have available to them the better they will fare in a changing climate.

7. **Population management :** One of the root causes of environmental vulnerability in the Thar is growing strain on limited resources. Not only are resources in the region scarce, but also they must support a rapidly increasing population of people and animals. Life in the Thar will not be sustainable until the population stabilizes, and the added pressure of climate change makes the need for a steady population even greater. Changes in the climate will decrease the supply of resources, and population growth will increase demand. Such trends will inevitably heighten scarcity. Potential measures of managing population include providing family planning services, distributing contraception, and lessening restrictions on women.

8. **Education and capacity building :** If residents of the Thar are going to adapt to climate change, they must first understand that it exists. Climate change should be covered in future

training and education programmes, so that villagers know what to expect. Instead of conducting educational programmes specifically on climate-related topics, climate change can be incorporated into trainings on other subjects, highlighting the diverse changes that are in store and their relevance to rural life. Because villagers often have limited education and little understanding of global issues, climate-related education programmes should focus on the specific consequences of climate change for rural communities rather than broader issues of greenhouse gas emissions. While such concepts do not need to be avoided entirely, they are not the most important ideas for villagers to understand. The priority for education and capacity building should be to tell people what is expected to happen and then to show them how they can most effectively prepare. The establishment of a Climate Change Training Center in the Thar, possibly run by GRAVIS, would assist with this objective.

9. Further research : This report serves only as a preliminary exploration of climate change vulnerability and adaptation in the Thar. Any future programmes dealing with these issues should involve further research and assessment. A key area for future study is the connection between groundwater irrigation and climate change response. Comparisons between people who use tube wells and people who do not use tube wells in the same village could yield more definitive results than those that have so far been obtained. Other potential topics for future study include links between climate change and health, block- and village-level vulnerability assessments, and field-testing of adaptation strategies.

ACKNOWLEDGMENT

Special thanks to everyone at GRAVIS and the Hart Leadership Program who made this research possible, especially to Dr. Prakash Tyagi for coordination and guidance, to Dr. James Hamilton for serving as a dedicated and unfailingly responsive research mentor, to Dr. Kate Whetten for additional support and research advice, to Lauren Zalla, Fernande Legros for Elizabeth Osteen for logistical support, to Hanuman Singh and Pratik Tandon for their tireless translation efforts, to Dr. R.P. Dhir for supplying feedback and background information, and to Alma Blount for providing spiritual and programmatic direction.

Thanks also to Varsha Kothari, Rajendra Kumar, Shailendra Kumar, Praveen Kumar, Alice Ashby, James Loneragan, Alex Dzionara, Lia Garman, Rimjhim Mewara, Pragathi Shukla, and Rahul Mishra for their invaluable assistance in the office and to Tejpal Singh ji, Aman Singh ji, Srikanth ji, Manju ji, and Tejkaram ji for their invaluable assistance in the field.

Finally, thanks to Asharam Panwar, Bhikaram Punar, Bhuraram Panwar, Durga Jaipal, Jagdish Meghwal, Khem Singh, Bhoma Ram, Om Prakash, Naktharam, Narayanram Meghwal, Santosh Bishnoi, Sunil Kumar, Surjaram Parihar, Swarooparam, and Tejkar Ratnu for promptly conducting surveys and to all of the anonymous focus group participants and survey respondents who gave their time and energy to answer a few questions for the good of the community.

References

1. IPCC: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007.
2. IPCC: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 2007.
3. Adger, W. Neil. "Approaches to vulnerability to climate change." CSERGE GEC Working Paper (1996).
4. Turner, Billie L., et al. "A framework for vulnerability analysis in sustainability science." Proceedings of the National Academy of Sciences 100.14 (2003): 8074-8079.
5. Swift, Jeremy. "Why are rural people vulnerable to famine?" IDS Bulletin 37.4 (2006): 41-49.
6. Altieri, Miguel A., and Parviz Koohafkan. Enduring farms: climate change, smallholders and traditional farming communities. Vol. 6. Third World Network (TWN), 2008.
7. Morton, John F. "The impact of climate change on smallholder and subsistence agriculture." Proceedings of the National Academy of Sciences 104.50 (2007): 19680-19685.
8. Mendelsohn, Robert, Ariel Dinar, and Apurva Sanghi. "The effect of development on the climate sensitivity of agriculture." Environment and Development Economics 6 (2001): 85-101.
9. Rosenzweig, Cynthia, and Martin L. Parry. "Potential impact of climate change on world food supply." Nature 367.6459 (1994): 133-138.
10. Fischer, Günther, et al. "Climate change and world food supply, demand, and trade." Global Environmental Change 4.1 (1994): 7-23.
11. Mendelsohn, Robert, and Ariel Dinar. "Climate change, agriculture, and developing countries: does adaptation matter?" The World Bank Research Observer 14.2 (1999): 277-293.
12. Mall, R. K., et al. "Impact of climate change on Indian agriculture: A review." Climatic Change 78.2-4 (2006): 445-478.
13. Kumar, K. S., and Jyoti Parikh. "Indian agriculture and climate sensitivity." Global Environmental Change 11.2 (2001): 147-154.
14. Gupta, S. K., and R. D. Deshpande. "Water for India in 2050: first-order assessment of available options." Current Science 86.9 (2004): 1216-1224.
15. O'Brien, Karen, et al. "Mapping vulnerability to multiple stressors: climate change and globalization in India." Global Environmental Change 14.4 (2004): 303-313.

16. Reilly, John. "What does climate change mean for agriculture in developing countries? A comment on Mendelsohn and Dinar." The World Bank Research Observer 14.2 (1999): 295-305.

17. Hopper, W. David. "Allocation efficiency in a traditional Indian agriculture." Journal of Farm Economics 47.3 (1965): 611-624.

18. Binswanger, Hans P. "Risk attitudes of rural households in semi-arid tropical India." Economic and Political Weekly (1978): A49-A62.

19. Binswanger, Hans P. "Attitudes toward risk: Experimental measurement in rural India." American Journal of Agricultural Economics 62.3 (1980): 395-407.

20. Giné, Xavier, Robert Townsend, and James Vickery. "Patterns of rainfall insurance participation in rural India." The World Bank Economic Review 22.3 (2008): 539-566.

21. Cole, Shawn, et al. "Barriers to household risk management: evidence from India." Harvard Business School Finance Working Paper 09-116 (2012): 104-35.

22. Pender, John L. "Discount rates and credit markets: Theory and evidence from rural India." Journal of Development Economics 50.2 (1996): 257-296.

23. Feder, Gershon, and Dina L. Umali. "The adoption of agricultural innovations: a review." Technological Forecasting and Social Change 43.3 (1993): 215-239.

24. Pandey, Deep Narayan, Anil K. Gupta, and David M. Anderson. "Rainwater harvesting as an adaptation to climate change." Current Science 85.1 (2003): 46-59.

25. Mascarenhas, Michael. "Redefining Water Security through Social Reproduction: Lessons Learned from Rajasthan's 'Ocean of Sand'." IDS Bulletin 43.2 (2012): 51-58.

26. Harish, Kanupriya, and Mathews Mullackal. "Applying Bottom-up Participatory Strategies and Traditional Methods of Water Harvesting in the Thar Desert, Rajasthan." Coping with global environmental change, disasters and security. Springer Berlin Heidelberg, 2011. 983-996.

27. Rathore, Jai Singh. “Drought and household coping strategies: a case of Rajasthan.” Indian Journal of Agricultural Economics 59.4 (2004): 689-708.

28. Fishman, Ram Mukul. "Climate change, rainfall variability, and adaptation through irrigation: Evidence from Indian agriculture." Job Market Paper (2011).

29. Howden, S. Mark, et al. "Adapting agriculture to climate change." Proceedings of the National Academy of Sciences 104.50 (2007): 19691-19696.

30. Kothawale, D. R., J. V. Revadekar, and K. Rupa Kumar. "Recent trends in pre-monsoon daily temperature extremes over India." Journal of Earth System Science 119.1 (2010): 51-65.

31. Ganguly, Nandita D., and K. N. Iyer. "Long-term variations of surface air temperature during summer in India." International Journal of Climatology 29.5 (2009): 735-746.

32. Kumar, K. Rupa, et al. "High-resolution climate change scenarios for India for the 21st century." Current Science (Bangalore) 90.3 (2006): 334.

33. Lal, Murari, et al. "Future climate change: Implications for Indian summer monsoon and its variability." Current Science 81.9 (2001): 1196-1207.
34. Gadgil, Sulochana. "Climate change and agriculture-An Indian perspective." Current Science (Bangalore) 69.8 (1995): 649-659.
35. IMD: “Jodhpur.” www.imd.gov.in. India Meteorological Department. Accessed 21 January 2013. <http://www.imd.gov.in/section/nhac/mean/Jodhpur.htm# _JODHPUR>
36. Singh, D.V., et al. Agrometeorological Data Handbook of Jodhpur (1971-2010). Central Arid Zone Research Institute, Jodhpur, 2011.
37. IITM: “Meteorological Data sets for downloading.” www.tropmet.res.in. Indian Institute of Tropical Meteorology. Accessed 8 January 2013.
38. Goyal, R. K. "Sensitivity of evapotranspiration to global warming: a case study of arid zone of Rajasthan (India)." Agricultural Water Management 69.1 (2004): 1-11.
39. Parameshwarappa, K. G., et al. "Climate change and perspectives for Indian agriculture." Asian Journal of Environmental Science 5.2 (2010): 185-191.
40. Dhir, R. P. “Problem of desertification in arid zone of Rajasthan – a view.” Annals of Arid Zone 32.2 (1993): 79-88.
41. India Census: 1901-1911. Accessed 21 January 2013. <http://censusindia.gov.in/>
42. Javed, Akram, Sayema Jamal, and Mohd. Yousuf Khandey. "Climate Change Induced Land Degradation and Socio-Economic Deterioration: A Remote Sensing and GIS Based Case Study from Rajasthan, India." Journal of Geographic Information System 4.3 (2012): 219-228.
43. Ajai et al. “Desertification/land degradation status mapping of India.” Current Science 97.10 (2009): 1478–1483.
44. Maddison, David. The perception of an adaptation to climate change in Africa. Vol. 4308. World Bank Publications, 2007.

NOTES

Gramin Vikas Vigyan Samiti (GRAVIS) or Center of People's Science for Rural Development is a non-governmental, voluntary organization that takes a Gandhian approach to rural development by working with the poor of the Thar Desert to enable them to help themselves. Since its inception in 1983. GRAVIS has worked with over 55,000 desert families across over 1,200 villages in Rajasthan reaching a population of over 1 million, and has established over 2,500 Community Based Organizations (CBOs). Through its dedicated field work, as well as its research and publications, GRAVIS has come to occupy a leading position amongst the voluntary organizations in the region.

Gravis

3/437/ 458, MM Colony, Pal Road,
Jodhpur - 342 008 Rajasthan, India.

Phones : 91 291 2785 317, 2785 116
Fax : 91 291 2785 116
Email : email@gravis.org.in

www.gravis.org.in