Chapter 1
Water Resources, Livelihood Vulnerability and Management in Rural Desert Communities of Jaisalmer, India

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Abstract Water is the lifeblood of natural life on our planet. Climate change and augmented use of the resource has goaded it to scarcity. Given its dearth, it is imperative to understand how water can be managed in order to sustain human populations. The concept, need and various approaches to manage water sustainably have been incorporated in this chapter. An empirical case study using mixed methods of research has been delivered to illustrate the Livelihood Vulnerability Index (LVI) of rural communities in the desert region of Jaisalmer, with special attention to vulnerability of people in terms of water. The LVI is constructed by using IPCC's 3 major dimensions: exposure, sensitivity and adaptive capacity. Seven major components and 42 sub-components have been included to conduct this research. Various local water management practices applied by the rural desert communities to sustain water have been briefly covered. Primary data collection through household and group surveys indicates how vulnerable these communities are present which indicates how their condition could worsen in the coming decades. Suggestions have been drawn to help ease the plight.

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1.1 Introduction

Water is one of the most essential resources on our planet. We cannot imagine life thriving without this resource. It is an indispensable component of our ecosystem and the essence of our life. The very beginning of human civilization began across water bodies like the river valleys of Indus, Nile, Euphrates, Tigris, etc. and this pattern continues even today as several major urban areas are located on coastal areas, across water bodies. Water resource has acted as a base for cultural, economic and social development. The belief that water is abundant as it covers 70% of the earth's surface is covered by water. This is false, as only 2.5% of all water is freshwater and only 1% is accessible. The major source of freshwater is rainfall which occurs as a result of 'hydrological cycle' and the other sources of freshwater include underground water and water from the melting of glaciers. There are several uses of water apart from the drinking purpose. An average human uses about 40 L of water per day in rural areas and 150 L of water in urban areas.

Water is no more an unlimited resource. According to the United Nations, water use has increased more than twice the rate of population increase in the last century. It is estimated that about 3.9 billion (which would be 40% of the world's population in 2050) will live in severely stressed water basins and the limited resource will need to support about 9.7 billion people by 2050. However, it is estimated that population pressure is not the only cause of scarceness of water. It is the excessive use, wastage and lack of conservation that is driving the world towards extreme stresses. It is expected that from now to 2050, the demand for water will increase by 400% from the manufacturing sector and 130% from the household sector.

This water insecurity will be exacerbated by recurring draughts, climate change, lack of proper diversion and conservation of flood and deluge water. Due to the inaccessibility and lack of availability of fresh water, optimizing it remains a challenge in different locations of the world. With increased vulnerabilities of global climate change and irrational use of water, managing and conserving water for our future generations will become increasingly difficult. The future holds unprecedented challenges which are yet to be encountered and this calls for alternate and sustainable strategies to manage water.

1.2 Concepts and Need of Water Management

The importance of water in twenty-first century is analogous to the importance that oil had in the twentieth century. However, there have been several alternatives to oil like natural gas, shale gas, solar energy, wind energy, etc. but, there is no alternative to

water. The issue is not its lack of adequate water for all, but its ludicrous and reckless overuse. Managing water resources is the key to a water-secure future. There is a need for systemic change in planning and water management.

Water resource management refers to the 'planning, development, review, assessment, decision making, distribution and optimum use of the resource keeping in mind the present limitation of the water and changing priorities of human use'. It is also referred to as a sub-set of water cycle management.

Water management is the management of water under a set of regulations and policies. Water was once an abundant resource available free of cost from natural sources, now it has become highly valuable due to increased droughts and overuse, to the level that it has become a priced precious commodity.

Water management lays a particular focus on how managing the resource lays an effect on the quality of life of both present and future generations. Managing water resources is inherently complex. It involves hydrological cycle, climate, humans, various ecosystems, plants, animals, etc. all these components are dynamic and interrelated. A change in any one of them may have a long-term impact which might be irreversible. Thus, several considerations need to be made while managing water.

In addition to the resource and the natural components, there are several other factors like various stakeholders and their interests, policies, politics, geographical boundaries and economic implications which need to be managed. Figure 1.1 shows the components involved in managing water resources.

Each one of us has a right to live in an environment of quality and have access to clean water for various purposes. The developed countries of the world have already developed a system of water management at all levels- national, provincial, local and domestic. However, in developing countries, this has to be done both through

Fig. 1.1 Components of Water Management. *Source* Prepared by author

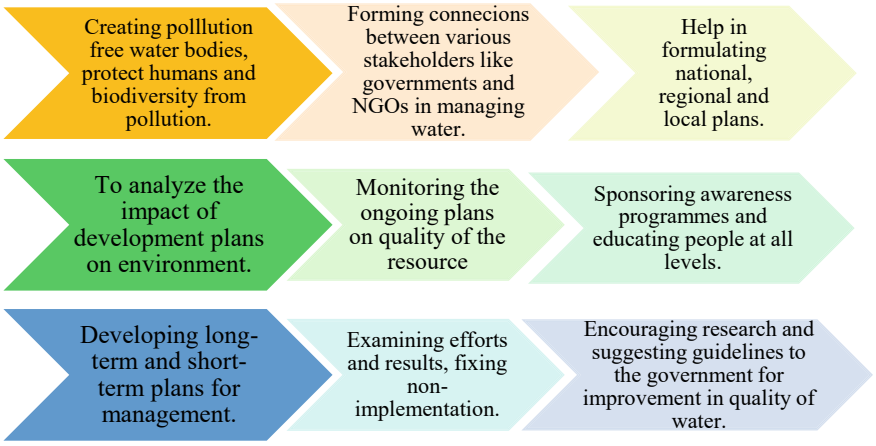

Fig. 1.2 Diagram representing various aspects (steps and methods) to be considered in water management. *Source* Prepared by author

legislation as well as people's participation. Even today, large number of people in India directly depend on nature and its resources to sustain their livelihood.

Therefore, it is essential to understand the functions and interaction of physical and societal elements of the environment to apply this knowledge in sound management programmes while conserving water and culture. "Although humans have made efforts to better comprehend the resource, their efforts to manage it has fallen short of preventing its deterioration and exhaustion, due to their continuous indulgence in exploitation for immediate gains. The complex nature of problems that could be caused when the planet runs dry of its water, not only need imaginative and innovative specialists and technology, but also the people's participation. A rigorous process of 'planning, review, assessment, decision making and likewise, which is necessary for real-life situations of limited resources and changing priorities is what is meant by management".

The essential aspects of water management are depicted in Fig. 1.2.

1.3 Approaches in Water Management

The increase in the urgency of managing water has become a priority all over the world due to the imposition of serious consequences which have or could be experienced by humankind. "Any plan that envisages the management of the resource must be based on the fact that each area or region has certain characteristics and can tolerate a range of physical conditions to a limited extent. Each human activity affects the resource favourably or unfavourably".

We can make use of our surroundings by two methods, either by modifying an area or region to change its capabilities or by adopting our needs and demands to

the capability of each region or area. The first method is much more intensive and is thus called, Intensive Management as it controls the physical features of the environment (example: changing the course of a river, constructing dams, channelling river water by modifications, etc.). Whereas, adopting our needs is a more sustainable, thoughtful, conscious and eco-friendly method of mutual co-existence while respecting nature for providing the resource (ex: waste disposal without overloading the water, rainwater harvesting, reuse of purified sludge water, storing rainwater runoff, etc.).

The other two approaches according to the World Conservation Strategy (1980) were: (i) Preservative Approach, according to this, humans should not disturb the natural system and should adjust according to it. However, since this is not applicable everywhere, imbalances of varied intensities could arise. (ii) Conservative Approach advocates that there should not be over-exploitation of the resources and conserving them is essential for sustainable development. Proper utilization and conservation are the prime objectives of water management. Figures 1.3 and 1.4 summarize different kinds of approaches used in water management.

Doxiadis (1977) has developed a science of planning settlements in balance with nature approach and has named it *ekistics*.

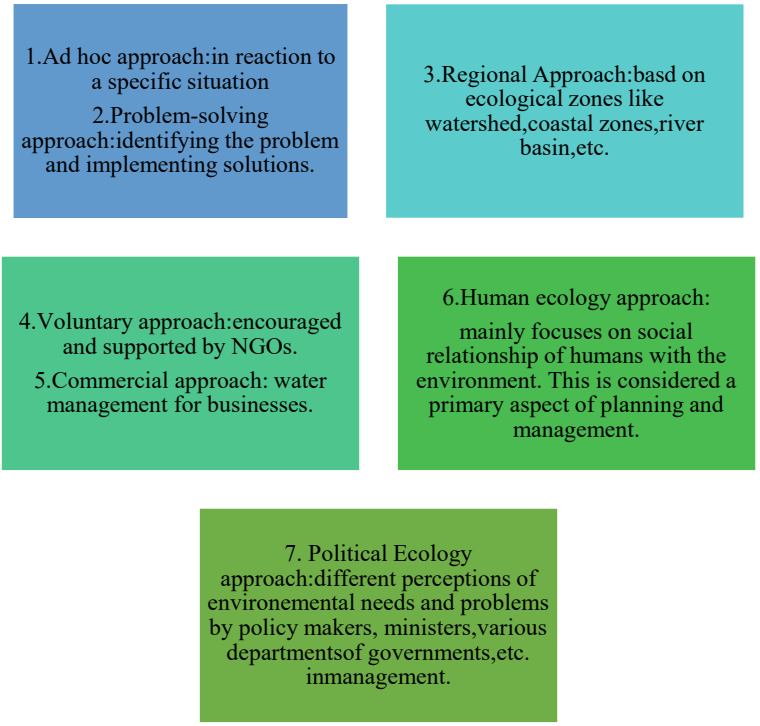

Fig. 1.3 Approaches in Water Management. *Source* Prepared by author

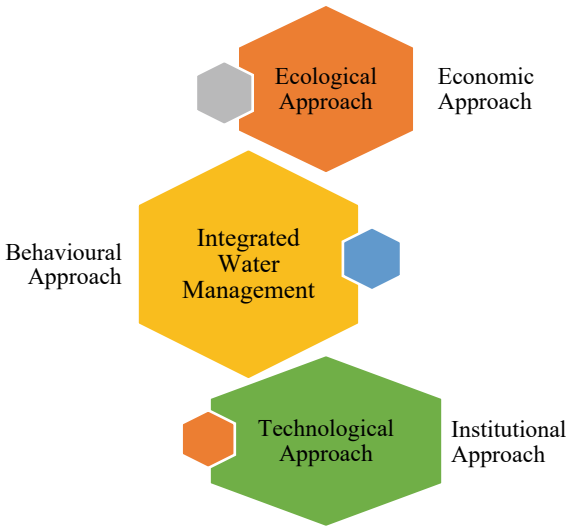

Fig. 1.4 Various approaches in Management of Water. *Source* Prepared by author

Water management systems is a means to assist different bodies and industries to ensure that the quality and quantity of water is maintained according to policies and objectives. Wate management needs to be an integrated and proactive approach to ensure a balanced view across all functions.

1.3.1 Ecological Approach

The ecological approach gained importance after Barrows proposed human ecology as a focus in geography in 1993. It is one of the new ways/approaches of managing natural resources that takes into account the entire ecosystem. This approach focuses on natural sciences and empirical methods. It studies how the environment influences the abundance and availability of a given resource and is a shared approach amongst hydrologists, geomorphologists, ecologists and biogeographers.

It stresses nature and limits of resources but is silent on human implications. It prioritizes ecological values over economic values. It balances recreational use, economic development and conservation of natural resources in a way that all the needs are met in a sustainable manner (ex: purification of water).

1.3.2 Economic Approach

"The economics of natural resources and the environment provides a set of theories and conceptual tools to monitor, analyze, evaluate and regulate". Economics enables

the creation of models for sustainable use of renewable natural resources such as 'water' which can be managed by economic tools of taxation, grants, subsidies, standards, permits and market rights.

1.3.3 Behavioural Approach

A behavioural approach for studying reactions to natural hazards and adaptation to floods was introduced by Gilbert White in 1945. This approach gained popularity as it added the 'human' dimension of 'behaviour' (decision making, practices and human activities in environment), to theories of interaction with environment. The behaviour of humans acts as a connecting link between ecological and social (human) systems. Thus, making it an essential component in managing natural resources.

Recognizing how the customs, actions, judgements and practices of humans are interlinked and affect the environment is the foremost stride in promoting sustainable resource management as it calls for attempts in remarkably changing behaviour (example: individual, community, regional, national and global efforts to conserve and manage water) and maintaining other behaviour patterns (example: application of traditional methods in conserving water, judicious use of water at individual, household and community level).

Factors that influence behaviour are knowledge, values, social norms, sociocultural factors, skills, economics, laws, policies and gender. The tools and methods of this approach are direct behavioural observation survey, interviews, community meetings, focus groups, matrices and contrastive analysis.

Behavioural interventions have proven effective in the field of resource conservation especially in water, energy resources. Mullainathan and World Bank argue that there is considerable scope for using behavioural insights to policy issues in the developing world, including those related to climate change and resource use.

1.3.4 Integrated Water Management

Integrated Water Resource Management is the proactive, holistic and system-based approach that integrated different aspect for resource management. Cairns and Crawford's (1991) definition: "Coordinated control, direction or influence of all human activities in a defined environmental system to achieve and balance the broadest possible range of short- and long-term objectives". Integrated Water Resource Management is better than other approaches in management because it is more inclusive, interconnected, goal oriented and strategic. Figure 1.5 is a representation of the dimensions included in Integrated Water Management.

Fig. 1.5 Represents the various dimensions included while managing water through the IWRM method

1.3.5 Institutional Approach

Institutional approach refers to an approach, typically used by an organization. It is an approach that is applied and proven to be effective in achieving goals of resource management. An Institution is the backbone of any resource management.

Institutions are responsible for regulating, maintaining policies and programmes regarding any resource. They play a role in regulating and implementing policies. It focuses on the analysis of formation of institutional arrangements in response to the changing needs and is biased to economic, political law and business administration institutions which emphasize the role of social political and economic organizations in determining economic events. Hence, the success and failure of water management are tied up with institutional structure, the pattern of agencies, laws and policies which pertain to water resource issues. (Ex: Upper Yamuna River Board, Central Water Commission New Delhi.)

1.3.6 Technological Approach

Information technology mainly counts tools of data science, remote sensing and GIS, in natural resource management which have great potential in decision making. Resource data are to analyse and present the information needed to develop sustainable resource management programmes in different sectors. Remote sensing helps in data acquisition. GIS application has enlarged the horizon of data assimilation.

1.4 Case Study

Livelihood Vulnerability in Rural Desert Communities of Jaisalmer, India.

1.4.1 Study Area

Jaisalmer district is the western most region of Rajasthan. It is bordered in the north and west by Pakistan, in the east by Jodhpur district and in south by Barmer district. It stretches between 25° 58′ 12.47″ to 28° 04′ 45.94″ north latitude and 69° 25′ 31.11″ to 72° 22′ 35.22″ east longitude and covers an area of approximately 38,487.2 km^2. Major part of this district does not have a systematic drainage system, so the whole district is part of an 'Outside' Basin. Jaisalmer district is divided into three blocks and three divisions, administratively. It has 639 towns and villages, out of which three are block headquarters. The three divisions are Pokhran, Fatehgarh and Jaisalmer. Rural area in this study is considered to be the countryside, away from the main city, where maximum population depended majorly on agricultural and animal rearing income and where services like health, education and sanitation were appalling (Plate 1.1).

1.4.2 Source of Data Collection

The study is based on the primary data collected from field surveys, conducted in Jaisalmer, Pokhran and Fathegarh divisions of Jaisalmer district. Several villages like Amar Sagar, Deva, Baramsar, Ramdevri, Pokhran village, were included. Secondary data was collected from several literatures, University libraries and related government departments. The data was analysed and is presented in the form of tables, charts and graphs. For cartographic work, ArcGIS 10.5 was used. Livelihood Vulnerability Index (LVI) was used.

This index has been delineated to dispense a heuristic tool that can be applied by policy makers, government and non-government development organizations and social welfare practitioners to comprehend several social factors like health, demography, occupation and access to natural, economic and social resources, useful in analysing climate vulnerability at community or district level. The tool is pliable such that it can be modified according to the area of focus and the appropriate desideratum of the geographical area. Both, composite index and sectoral vulnerability scores can be separated to intervene by picking the potential dimensions, as required.

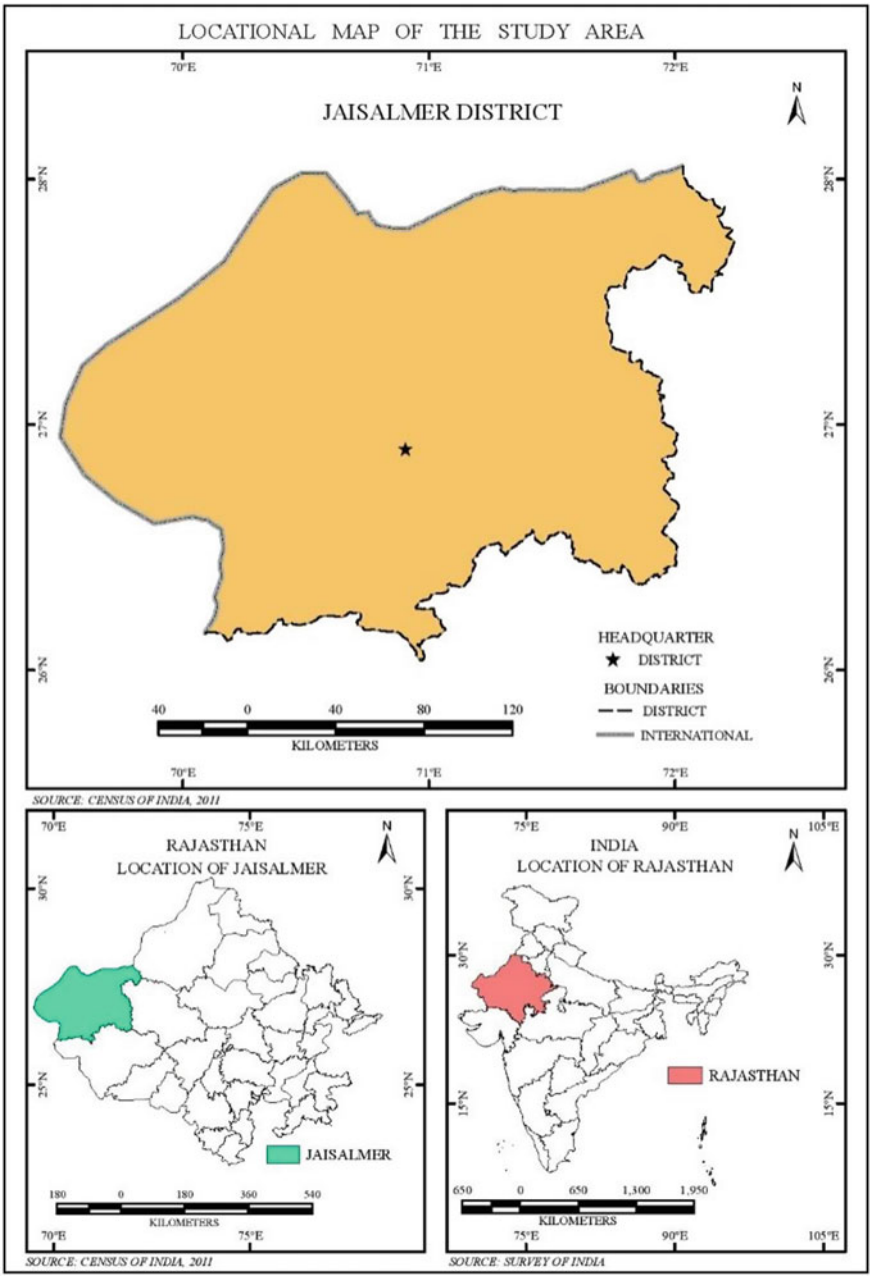

Plate 1.1 Map representing location of the Study Area. *Source* Prepared by author using ArcGIS software

1.4.2.1 Primary Data

Survey of 36 households was conducted to collect data on socio-demographics, livelihoods, social networks, health, food and water security, natural disasters and climate variability. It was then aggregated using a composite index and differential vulnerabilities were compared. This pragmatic approach can be used to monitor vulnerability, programme resources for assistance and/or evaluate potential programme/policy effectiveness in data-scarce regions by introducing scenarios into the LVI model for baseline comparison. A variety of methods were used for primary data collection such as questionnaire survey, focussed group interviews, tourist interviews and administrative individual interviews so as to obtain first-hand information, a general picture of the area. Later, proceedings towards specific issues of water, sanitation, health and other aspects were obtained. It was difficult to cover all villages due to paucity of time and financial constraints.

1.4.2.2 Secondary Data

Vulnerability analysis involves the inclusion of varied techniques to interlink and assesses human-ecological interactions with their social and biophysical surroundings. Such assessments have been employed in several contexts, including "USAID's Famine Early Warning System (FEWS-NET) (USAID 2007), World Food Programme's Vulnerability Analysis Mapping tool for targeting food aid (World Food Programme 2007) and other geographic analyses that include data on biodiversity, health, poverty and globalization" (O'Brien et al. 2004; UNEP 2004).

This study attempts to quantify multidimensional concerns by substituting these issues in the form of indicators which are combined to create a composite index to include a diversified range of variables. Various methods have been applied to combine indicators of the Human Development Index like health, education, standard of living and life expectancy to depict the well-being of the communities of the surveyed region.

Livelihood Vulnerability Index (LVI) comprises exposure, sensitivity and adaptive capacity as its three major dimensions and it can be represented as a "single value index or broken down into its three major dimensions".

To evaluate the deviation of water allocation and use from a pre-established standard for Water Poverty Index, the Gap Method by Sullivan et al. (2002, p. 1204) was used. HDI and WPI are samples of the composite indices which were calculated using weighted averages of each indicator. Most of the indicators reckon on the IPCC's way of "defining vulnerability as a function of exposure, sensitivity and adaptive capacity" (IPCC 2001).

"Exposure is defined as the magnitude and duration of the climate-related exposure such as a drought or change in precipitation. Sensitivity is recognized to be the degree to which the system is affected by the exposure and adaptive capacity is the system's ability to withstand or recover from the exposure" (IPCC 2001).

Formulating the indicators involved the use of two approaches. Expressing LVI as a composite index comprising of seven major components was the first approach and aggregating the seven components into IPCC's 3 major dimensions (exposure, sensitivity and adaptive capacity) was the second approach. These approaches called for the necessity of collecting primary data through questionnaire surveys at household level in order to build the index. This approach of constructing the index can be used to present a framework in order to cluster and classify the indicators on the district level in order to make it explanatory for planning adaptation and developmental activities by policy makers.

Adoption of household data is advantageous as it steers away from the perils of using secondary data and fills a gap in knowledge as most vulnerability and climate models are enforced and exhibited at large scales. This approach could be essential to present precise projections at various levels that would be beneficial for community development IPCC (2007a, p. 443).

1.4.3 Techniques and Analysis

Calculating the LVI: composite index approach:

LVI incorporates seven major components that are: "socio-demographic profile, livelihood strategies, social networks, health, food, water, water vulnerability, natural disasters and climate variability". Each of these components encompasses various sub-components or indicators.

"Even though the major components comprise of different number of sub-components, a balanced weighted average approach is used where each sub-component contributes equally to the overall index" (Sullivan et al. 2002). A straightforward, 'easy to apply' and 'comprehend' approach of applying equal weights to all major components has been done as we intend to develop an 'assessment tool' which can be accessible to a diverse set of users in resource deficient settings. The weighing scheme is simple and can be adjusted by future users as desired.

"Since each sub-component was measured on a different scale, it was essential to standardize each as an index. The equation utilized for the conversion was adapted from the one used in Human Development Index to calculate life expectancy index, which is a ratio of difference of actual life expectancy, a pre-selected minimum and range of pre-determined maximum and minimum life expectancy".

$$\text{Index}_{sd} = \frac{s_d - s_{\min}}{1/4 s_{\max} - s_{\min}} \tag{1.1}$$

where s_d is the original sub-component for district d and $s_{\min}$ and $s_{\max}$ are the minimum 1and maximum values, respectively, for each sub-component determined using data from both districts. For example, the 'average time to travel to reach the primary water source' sub-component ranged from 5 to 945 min in the district we

surveyed. These minimum and maximum values were used to transform this indicator into a standardized index so it could be integrated into the water component of the LVI. For variables that measure frequencies such as the 'percent of households reporting having heard about conflicts over water resources in their community,' the minimum value was set at zero and the maximum at 100.

$$\text{Index}_{\text{sv}} = \frac{S_v - S_{\min}}{S_{\max} - S_{\min}},$$

Will be enabled if the value of indicators has a positive relationship with vulnerability.

$$\text{Index}_{\text{sv}} = \frac{S_{\max} - S_v}{S_{\max} - S_{\min}},$$

Max–min approach will be enabled if the above condition is not met. Where S_v is the actual value of indicator in the series. $S_{\min}$ and $S_{\max}$ are the minimum and maximum values of indicators in the series. After each was standardized, the sub-components were averaged using Eq. 1.2 to calculate the value of each major component.

$$\frac{M_d \text{¼} \times \text{P}\, ni \text{¼} 1 index_s di}{N} \tag{1.2}$$

where, M_d = one of the seven major components for district d [Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Networks (SN), Health (H), Food (F), Water (W), or Natural Disasters and Climate Variability (NDCV).

$\text{index}_{sd} i$ represents the sub-components, indexed by i, that make up each major component.

n is the number of sub-components in each major component. Once values for each of the seven major components for a district were calculated, they were averaged using Eq. 1.3 to obtain the district level LVI:

$$\text{LVI}(\text{I}_d)_{= d} \text{¼}\, i \text{¼} 1 \; \frac{w M_i M d i w_{SDP} SDP_d \text{þ}\, w_{LS} LS_d \text{þ}\, w_{SN} SN_d \text{þ}\, w_H H_d \text{þ}\, w_F F_d \text{þ} w_W W_d \text{þ} w_N NDCV_d}{w SDP \text{ þ } w LS \text{ þ } w H \text{ þ } w SN \text{ þ } w F \text{ þ } w W \text{þ} w NDC} \tag{1.3}$$

where LVI_d, the Livelihood Vulnerability Index for district d, equals the weighted average of the seven major components. The weights of each major component, w_{Mi}, are determined by the number of sub-components that make up each major component and are included to ensure that all sub-components contribute equally to the overall LVI (Sullivan et al. 2002). In this study, the LVI is scaled from 0 (least vulnerable) to 0.5 (most vulnerable).

1.4.4 Calculating the LVI-IPCC: IPCC Framework Approach

Exposure of the population studied is measured by the preparedness and awareness the rural communities received by the government authorities and the media, while climate variability is measured by the average standard deviation of the maximum and minimum monthly temperatures and monthly precipitation over a 6-year period. Adaptive capacity is quantified by the demographic profile of a district (ex: dependency ratio, average monthly income of households), the types of livelihood strategies employed (e.g. predominately agricultural, livestock diversification) and the strength of social networks (e.g. percent of residents assisting neighbours with chores, dependency on banking facilities, number of households attending social events). Last, sensitivity is measured by assessing the current state of a district's food, water security and health status. A special section of vulnerability of households to water has also been included. The same sub- components are outlined in Table 1.1 as well as Eqs. (1.1)–(1.3) were used to calculate the LVI-IPCC. The LVI-IPCC diverges from the LVI when the major components are combined. Rather than merge the major components into the LVI in one step, they are first combined according to the categorization scheme in Tables, using the following equation:

$$\mathrm{CF}_d \frac{1}{4} ni \frac{1}{4} 1 w_{Mi} M_{di} / w_M$$

where CF_d is an IPCC-defined contributing factor (exposure, sensitivity, or adaptive capacity) for district d, M_{di} is the major component for district d Indexed by i, w_{Mi} is the weight of each major component and 'n' is the number of major components in each contributing factor. Once exposure, sensitivity and adaptive capacity were calculated, the three contributing factors were combined using the following equation:

$$\mathrm{LVI—IPCC}_d \frac{1}{4} \delta e_d — a_d \text{þ} \, \mathbb{m} s_{d\ (FINAL\ CALCLUATION)} \tag{1.4}$$

where $\mathrm{LVI–IPCC}_d$ is the LVI for district 'd' expressed using the IPCC vulnerability framework, e is the calculated exposure score for district d (equivalent to the Natural Disaster and Climate Variability major component), 'a' is the calculated adaptive capacity score for district d (weighted average of the Socio-Demographic, Livelihood Strategies and Social Networks major components) and 's' is the calculated sensitivity score for district d (weighted average of the Health, Food and Water major components). We scaled the LVI-IPCC from −0 (least vulnerable) to 1 (most vulnerable).

Table 1.1 Major components and sub-components comprising the Livelihood Vulnerability Index (LVI) developed for Jaisalmer district

Major components	Sub-components	Explanation of sub-components	Survey question	Source	Potential limitations
Socio-demographic profile	Dependency ratio	Proportion of the populace under 15 and more than 65 years old to the populace somewhere in the range of 19 and 64 years old	Could you please list the ages and sexes of every person who eats and sleeps in this house?	Adapted from Domestic Household Survey (DHS) (2006). Measure DHS: Model Questionnaire with Commentary	Large extended families; Confusion about who is a member of the household; Lack of birth certificates
	Percent of households where head of household has not attended school	Level of family units where the leader of the family reports that they have gone to below 10 long periods of school	What is your educational qualification?		
	Average Monthly income in rupees	Average income less than Rs. 10,000 is recorded	What is your average monthly income?		
Livelihood	Number of households with family members working in a different community	Average number of families that report at any rate one relative who works outside of the network for their essential work action	How many people in your family go to a different community to work?	Adapted from World Bank (1997). Household Questionnaire: Survey of Living Conditions, Uttar Pradesh and Bihar	Confusion regarding who is a member of the family; Does not count members of the family who previously worked outside of community; Confusion about what is "outside of the community."

(continued)

Table 1.1 (continued)

Major components	Sub-components	Explanation of sub-components	Survey question	Source	Potential limitations
	Percent of households dependent solely on agriculture as a source of income	Percent of family units subordinate exclusively on agriculture as a wellspring of salary	Do you or someone else in your household raise animals? Do you or someone else in your household grow crops?	Adapted from World Bank (1997)	Survey only asked about the three primary sources of income for families in the area
	Average Agricultural Livelihood Diversification Index (range: 0.20–1)	The inverse of (the number of agricultural livelihood activities +1) reported by a household, e.g. A household that farms, raises animals and collects natural resources will have a Livelihood Diversification Index = 1/(3 + 1) = 0.25	Same as above	Adapted from DHS (2006)	
	Percentage of unirrigated land	Percentage of land that depends on rainfall for irrigation	Is the land rainfed?	Adapted from DHS (2006)	

(continued)

Table 1.1 (continued)

Major components	Sub-components	Explanation of sub-components	Survey question	Source	Potential limitations
Social Networks	Percent of households that receive assistance	Percentage of households that received help	In the past month, did relatives or friends help you and your family: (e.g. Get medical care or medicines, Sell animal products or other goods produced by family)	Adapted from DHS (2006)	Confusion about who is family (immediate) and who is a relative (extended); Reliance on self-reported types of help/support
	Percent households that attend social events	Percentage of number of households that visit their relatives (last 12 months)	Have you attended any social events in past 12 months?	Adapted from World Bank (1997)	
	Percent of households that have not gone to their local government for assistance in the past 12 months	Percentage of households that reported that they have not asked their local government for any assistance in the past 12 months	In the past 12 months, have you or someone in your family gone to your community leader or bank for help?	Adapted from WHO/RBM (2003)	Reliance on self-reported money exchanges; Does not consider exchange of non-monetary goods Reliance on self-reported visits to government; Recall bias (more likely to remember going to government for dire issues
Migration	Percent of households where people have migrated	Percentage of households that have at least one migrant	Has anyone from your family migrated for employment or education?	Developed for the purposes of this questionnaire	

(continued)

Table 1.1 (continued)

Major components	Sub-components	Explanation of sub-components	Survey question	Source	Potential limitations
	Percent of households where people migrate for employment	Percentage of people who could not find job in their home town and had to move elsewhere	Same as above	Developed for the purposes of this questionnaire	
	Percent of households where people migrate for education	Percent of households where at least one member has gone out of village to study	Same as above	Developed for the purposes of this questionnaire	
	Monthly remittances received from migrant workers (less than Rs. 10,000)	Percentage of people who received remittances	Do you receive any remittances? How much?	Developed for the purposes of this questionnaire	Hesitation in disclosing the correct amount
Health	Average time to reach hospital (minutes)	Average time it takes the households to get to the nearest health facility	How long does it take you to get to a health facility?	Developed for the purposes of this questionnaire	No watches; Subjective estimates of travel time
	Percent of households with family members with chronic illness	Percentage of households that report at least one family member with chronic illness. Chronic illness was defined subjectively by respondent	Is anybody in your family chronically ill (they get sick very often)?	Developed for the purposes of this questionnaire	"Chronically ill" was subjectively defined by respondent

(continued)

Table 1.1 (continued)

Major components	Sub-components	Explanation of sub-components	Survey question	Source	Potential limitations
	Percentage of households with family members going to doctor for allopathic treatment	Percentage of households where all family members take allopathic treatment	Do all family members resort to allopathic treatment or still believe in taking homoeopathy/Traditional medication?	Developed for the purposes of this questionnaire	
	Average households who do not have proper toilet facilities	Average number of households that do not have a well-built pucca toilet and who practice open defecation	Does your house have a toilet inside its premises?	Developed for the purposes of this questionnaire	
Food	Percent of households dependent on family farm for food	Percentage of households that get their food primarily from their personal farms	Where does your family get most of its food?	Adapted from World Bank(1997)	No specification regarding the year in question
	Average Crop Diversity Index (range: >0 to 1)	The inverse of (the number of crops grown by a household +1). For, e.g. A household that grows guar, bajra, jow and millet will have a Crop Diversity. Index $= 1/(4 + 1) = 0.20$	What kind of crops does your household grow?	Developed for the purposes of this questionnaire	

(continued)

Table 1.1 (continued)

Major components	Sub-components	Explanation of sub-components	Survey question	Source	Potential limitations
	Percent of households that do not save crops	Percentage of households that do not save crops from each harvest	Does your family save some of the crops you harvest to eat during a different time of year?	Developed for the purposes of this questionnaire	
	Percent of households that do not save seeds	Percentage of households that do not have seeds from year to year	Does your family save seeds to grow the next year?	Developed for the purposes of this questionnaire	No specification regarding the year in question
	Average number of months households struggle to find food (range: 0–12)	Average number of months households struggle to obtain food for their family	Does your family have adequate food the whole year, or are there times during the year that your family does not have enough food? How many months a year does your family have trouble getting enough food?	Developed for the purposes of this questionnaire	
	Percent of households that depend on government subsidy and agriculture for food	Percentage of households where the family is solely dependent on what they cultivate and on government's subsidy for food	Do you consume what you grow and depend on government subsidies?	Adapted from DHS (2006)	

(continued)

Table 1.1 (continued)

Major components	Sub-components	Explanation of sub-components	Survey question	Source	Potential limitations
	Percentage of people who consume vegetarian food only	Percentage of people who are unable to afford non-vegetarian food to fulfil their protein requirement	Do you prefer vegetarian food over non-vegetarian food?	Adapted from DHS (2006)	
Water	Percent of households that utilize a natural water source	Percentage of households that report a well, an oasis, or hole as their primary water source	Where do you collect your water from?	Adapted from World Bank (1997)	Confusion when families have multiple water sources
	Average time to water source (minutes)	Average time it takes the households to travel to their primary water source	How long does it take to get to your water source?	Developed for the purpose of this questionnaire	No watches; Subjective estimates of travel time; Different family members collect water
	Percent of households that do not have a consistent water supply	Percent of households that receive irregular supply of water	Do you receive water every day?		Recall bias (more likely to remember several consecutive days of water shortage)
	Inverse of the average number of litres of water stored per household (range: >0 to 1)	Average amount of water saved by households	What containers do you usually store water in? How many litres?		Lack of understanding of containers

(continued)

Table 1.1 (continued)

Major components	Sub-components	Explanation of sub-components	Survey question	Source	Potential limitations
Natural disasters and climate variability	Percent of households that did not receive a warning about the pending natural disasters	Percentage of households that did not receive a warning about the most severe flood, drought and cyclone event in the past 6 years	Did you receive a warning about the flood/cyclone/drought before it happened?	Adapted from Williamsburg Emergency Management (2004)	Subjective definition of "warning."
	Percent of households with an injury or death as a result of the most severe natural disaster in the past 6 years	Percentage of households that reported either an injury to or death of one of their family members as a result of the most severe flood, drought, or cyclone in the past 6 years	Was anyone in your family injured in the flood/cyclone drought? Did anyone in your family die during the flood/cyclone/drought?	Household Natural Hazards Preparedness Questionnaire	Recall bias (severe injuries are most likely to be remembered)
	Mean standard deviation of the daily average maximum temperature by month	Standard deviation of the average daily maximum temperature by month between 1998 and 2003 was averaged for each province	District data; weather station based in the state capital	Adapted from Williamsburg Emergency Management (2004)	Reliance on average data; Short time period

(continued)

Table 1.1 (continued)

Major components	Sub-components	Explanation of sub-components	Survey question	Source	Potential limitations
	Mean standard deviation of the daily average minimum temperature by month	Standard deviation of the average daily minimum temperature by month between 1998 and 2003 was averaged for each province		Developed for the purposes of this questionnaire	Reliance on average data; Short time period
	Mean standard deviation of average precipitation by month	Standard deviation of the average monthly precipitation between 1998 and 2003 was averaged for each province		Developed for the purposes of this questionnaire	Reliance on average data; Short time period
Water Vulnerability	Percentage of households dependent on community wells	Percentage of households who have only community well as their source of drinking water	What is the source of your drinking water?	Instituto Nacional de E statistica (2007)	Confusion due to recall bias
	Percentage of households dependent on pipeline (tapped water supply)	Percentage of households that receive regular tap water	Do you receive regular tap water?	Developed for the purpose of this questionnaire	
	Percentage of households dependent on water tanker for drinking purpose	Percentage of households that have the capacity to buy water delivered by tankers	Do you purchase tank water for drinking?		

(continued)

Table 1.1 (continued)

Major components	Sub-components	Explanation of sub-components	Survey question	Source	Potential limitations
	Percentage of households dependent on water only from Indira Gandhi Canal	Percentage of households that are situated near the IGC and use its water on daily basis	Do you receive water from Indira Gandhi Canal? Do you use this water source or depend on other sources?		
	Percentage of households receiving water from more than two sources	Percentage of households where people receive water from more than two water sources available. (ex: one for drinking and other for domestic purposes)	Do you receive water from multiple sources?		
	Average distance from water source (in kilometres)	Average distance the people from households need to travel in order to fetch water	How far do you travel in search of water?		
	Percentage of households where women and children travel to water sources	Percentage of households where women and their children travel in groups to fetch water for the daily requirements of living	Who goes to fetch water from your family?	Developed for the purpose of this questionnaire	Men travelled in certain areas, however mostly it was women and children. Hesitant in replying

(continued)

Table 1.1 (continued)

Major components	Sub-components	Explanation of sub-components	Survey question	Source	Potential limitations
	Average months of water scarcity	Average number of months during which households face maximum scarcity of water	Do you face water scarcity? If yes, for how many months?	Developed for the purpose of this questionnaire	Exaggerated responses
	Percentage of households that do not have water storing facilities	Percentage of households that do not have an underground or rooftop tank to save water and only save in drums	Do you have underground/rooftop water tank to save water? If not, how do you store it?	Developed for the purpose of this questionnaire	
	Percentage of households that drink impure water	Percentage of people who store rainwater in tanks and consume it directly without purifying it	Do you boil/purify water before drinking?	Developed for the purpose of this questionnaire	
	Average decline in groundwater level	Percentage of households that complained about increased water table depth	Has the depth of underground water availability increased?	Developed for the purpose of this questionnaire	

(continued)

Table 1.1 (continued)

Major components	Sub-components	Explanation of sub-components	Survey question	Source	Potential limitations
	Percentage of households that cannot afford to purchase Jar/Jerry can water	Percentage of households that cannot afford to purchase jar water during social event like festivals or marriages	Do you purchase jar water in social gatherings?	Developed for the purpose of this questionnaire	
	Percentage of households that cannot pay for clean water for all activities	Percentage of households that cannot afford to pay for a clean supply of water	Do you pay for the water you use?	Developed for the purpose of this questionnaire	
	Percent of households who struggle to get clean water by paying	Percentage of households who somehow manage to pay for a clean supply of water	How easy is it to get a clean supply of water by paying for it?	Developed for the purpose of this questionnaire	
	Percentage of households where people suffer from water borne health problems	Percentage of households where family members face health problems due to consumption of impure water	Has the consumption of impure water caused any health issues to any family member?	Developed for the purpose of this questionnaire	Subjective definition of health problems
	Percent of households that received water polluted with fluoride/nitrate/arsenic	Percentage of households that receive water infested with a high amount of chemicals	Does the water you consume contain any chemicals?	Developed for the purpose of this questionnaire	

Source Prepared by author

Table 1.2 Categorization of significant segments into contributing elements from the IPCC (Intergovernmental Panel on Climate Change) vulnerability definition for computation of LVI-IPCC

IPCC contributing factors to vulnerability	Major components
Exposure	Natural disaster and climate variability
Adaptive capacity	Socio-demographic profile, Livelihood strategies, Social Networks
Sensitivity	Migration, food, health, water security

1.4.5 Results

Each interview lasted 30 min on average and was carried out in Hindi language as it was the language common to the households of the region. Respondents were natives of the villages of Amar Sagar, Deva, Baramsaar and Ramdevri (Pokhran) in Jaisalmer. Interviewer was a native speaker of Hindi language and is trained in sample design, survey technique and confidentiality protocol.

Table 1.2 describes the major components and contributing factors of vulnerability.

Table 1.3 shows the maximum and minimum calculated LVI based on the sub-components of the major components described in Table 1.2.

Table 1.4 represents indexed major components and sub-components of the contributing factors.

Table 1.5 depicts the overall LVI of Jaisalmer.

1.4.6 Inference of the Tabular Data

1.4.6.1 Adaptive Capacity

Socio-demographic profile: the dependency ratio of the rural communities of the desert region of Jaisalmer was high (0.715) and it showed a higher proportion of young children below the age of 15 as compared to older population (above 65). Rural households where the population is not educated above 10th standard was very high (0.86) which shows high vulnerability in terms of education level. Most of the respondents had not completed high school and dropped out after 8 years of formal schooling. The illiteracy was as high as 86.11% as compared to the state average of approximately 27.01%. The average reported age of the respondents was 50 years old (males) and 45 years old (females). The average monthly income of most of the households was less than Rs. 10,000 and it shows a high vulnerability (0.805). Most of the families were joint in nature with about 10 members in one household.

Table 1.3 Livelihood Vulnerability Index (LVI) sub-components values and minimum and maximum sub-component values for Jaisalmer district, Rajasthan, India

Major Component	Sub-component	Units	Jaisalmer	Maximum value in Jaisalmer	Minimum value in Jaisalmer
Socio-demographic profile	Dependency ratio	Ratio	0.479	421	202
	Percentage of households where head of the house is not educated till high school	Percent	86.11	100	0
	Percentage of households where average income is less than Rs. 10,000	Percent	80.5	100	0
Livelihood strategies	Average number of households with family members working in a different community	Percent	0.6136	100	0
	Percent of households dependent solely on agriculture as a source of income	Percent	52.77	100	0
	Average agricultural livelihood diversification index (livestock)	1/#Livelihoods	0.78	12	9.361
	Percentage of unirrigated land	Percent	74.07	100	0
Social networks	Percentage of households that received assistance	Percent	19.44	100	0
	Percentage of households that do have not attended any social events in 12 months	Percent	30.33	100	0
	Percent of households that do not go to the government for assistance	Percent	**77.77**	100	0
Migration	Percent of households where people have migrated	Percent	19.44	100	0

(continued)

Table 1.3 (continued)

Major Component	Sub-component	Units	Jaisalmer	Maximum value in Jaisalmer	Minimum value in Jaisalmer
	Percent of households where people migrate for employment	Percent	16.66	100	0
	Percent of households where people migrate for education	Percent	3	100	0
	Monthly remittances received from migrant workers (less than Rs. 10,000)	Percent	16.66	100	0
Health	Average time to reach hospital (minutes)	Minutes	1240	34.44	5
	Percent of households with family members with chronic illness	Percent	11	100	0
	Percentage of households with family members going to doctor for allopathic treatment	Percent	72	100	0
	Average households who do not have proper toilet facilities	1/# toilets	25	100	0
Food	Percent of households dependent on family farm for food	Percent	41.66	100	0
	Average Crop Diversity Index (range: >0 to 1)	1/#crops	0.221	1	0.16
	Percent of households that do not save crops	Percent	36.11	100	0
	Percent of households that do not save seeds	Percent	30.5	100	0
	Average number of months households struggle to find food (range: 0–12)	Months	0.51	9	3
	Percent of households that depend on government subsidy for food	Percent	30.55	100	0

(continued)

Table 1.3 (continued)

Major Component	Sub-component	Units	Jaisalmer	Maximum value in Jaisalmer	Minimum value in Jaisalmer
	Percentage of people who consume vegetarian food only	Percent	50	100	0
Water	Percent of households that utilize a natural water source	Percent	33.33	100	0
	Average time taken to reach water source	Minutes	945	26.25	5
	Percent of households that do not have a consistent supply of water	Percent	61.11	100	0
	Inverse of the average number of litres of water stored per household	1/Litres	37.5	40	10
Water vulnerability	Percentage of households dependent on community wells	Percent	13.8	100	0
	Percentage of households dependent on pipeline (tapped water supply)	Percent	16.66	100	0
	Percentage of households dependent on water tanker for drinking purpose	Percent	22.22	100	0
	Percentage of households dependent on water only from Indira Gandhi Canal	Percent	8	100	0
	Percentage of households receiving water from more than two sources	Percent	41.66	100	0
	Average distance from water source (in kilometres)	1/#distance	1.5	2	0
	Percentage of households where women and children travel to water sources	Percentage	68.9	100	0

(continued)

Table 1.3 (continued)

Major Component	Sub-component	Units	Jaisalmer	Maximum value in Jaisalmer	Minimum value in Jaisalmer
	Average months of water scarcity	1/#months	2.08	3	1
	Percentage of households that do not have water storing facilities	Percent	16.66	100	0
	Percentage of households that drink impure water	Percent	83.33	100	0
	Average decline in groundwater level	1/#groundwater level	11.91	15	9
	Percentage of households that cannot afford to purchase Jar/Jerry can water	Percent	66.6	100	0
	Percentage of households that cannot pay for clean water for all activities	Percent	38.88	100	0
	Percent of households who struggle to get clean water by paying	Percent	61.11	100	0
	Percentage of households where people suffer from water borne health problems	Percent	52.7	100	0
	Percent of households that received water polluted with fluoride/nitrate/arsenic	Percent	58.33	100	0
Natural disasters and climatic variability	Percentage of households that did not receive a warning about an upcoming natural disaster	Percent	72.2	100	0
	Percent of households with an injury or death due to natural disaster	Percent	13.8	100	0

(continued)

Table 1.3 (continued)

Major Component	Sub-component	Units	Jaisalmer	Maximum value in Jaisalmer	Minimum value in Jaisalmer
	Mean standard deviation of monthly average of maximum temperature (2011–2019)	Celsius	1.29	1.54	1.01
	Mean standard deviation of monthly average minimum temperature (2011–2019)	Celsius	0.99	1.46	0.64
	Mean standard deviation of monthly average precipitation (2011–2019)	Millimetres	19.92	73.76	3.82
	Mean standard deviation of monthly wind speed (2011–2019)	km/h	0.59	0.93	0.33

Source Made by author. Source: prepared by author on the basis of primary survey data

Livelihood Strategies: the rural households showed a high vulnerability on livelihood strategies component (0.666). 52.27% households depend solely on agricultural income and most of them depend on both agriculture and livestock. The rural households owned a large variety of domestic animals like cattle, sheep, dogs, goats and a few households owned camels as well which shows a diversification index of 0.78. Every household owned at least nine animals. A large number of households owned land of up to 10 bighas. Large land owners owned about 52 bigha land and small land owners had about two bigha land.

The agricultural land is mostly rainfed in this region and people lack the means to irrigate their fields due to scarcity of water in the arid region. This makes them highly dependent on rainfall for watering their fields (0.747) only 25.94% households have regularly well irrigated farms. Apart from them, a major chunk of population (61.3%) comprised tenants as well who owned no land and worked on the agricultural farms of others. Most of their income was generated through agriculture related work for which they worked in different communities.

Social Networks: The social networks of the rural households seem to be strong with an overall vulnerability of 0.424. A large number of households depend on informal means of receiving and lending money/assistance. The households have a well-knit network wherein they help each other in times of need in medication, lending money, food, cattle. The vulnerability in this aspect is low at 0.194. The households are very

Table 1.4 Indexed major components and sub-components and overall LVI of Jaisalmer

Sub-components	Jaisalmer	Major components	Jaisalmer
Dependency ratio	0.479	Socio-demographic profile	0.715
Percent of households where head of household has not attended school	0.861		
Percent of households where monthly income is less than Rs. 10,000	0.805		
Percent of households with family members working in a different community	0.613	Livelihood strategies	0.666
Percent of households dependent solely on agriculture as a source of income	0.527		
Average agricultural Livelihood Diversification Index (livestock)	0.78		
Percentage of unirrigated land	0.747		
Percentage of households that receive assistance	0.194	Social networks	0.425
Percentage of households that have not attended any social events in 12 months	0.305		
Percent of households that have not gone to their local government for assistance in 12 months	0.777		
Percent of households where people have migrated	0.194	Migration	0.139
Percent of households where people migrate for employment	0.166		
Percent of households where people migrate for education	0.03		
Monthly remittances received from migrant workers (less than Rs. 10,000)	0.166		
Average time to reach health facility	0.84	Health	0.669
Percent of households with family members with chronic illness	0.305		
Percentage of households with family members going to doctor for allopathic treatment	0.72		

(continued)

Table 1.4 (continued)

Sub-components	Jaisalmer	Major components	Jaisalmer
Average households who do not have proper toilet facilities	0.25		
Percent of households dependent solely on family farm for food	0.416	Food	0.268
Average number of months households struggle to find food	0.513		
Average Crop Diversity Index	0.341		
Percent of households that do not save crops	0.366		
Percent of households that do not save seeds	0.55		
Percent of households that depend on government subsidies for food	0.305		
Percent of households that consume only vegetarian food	0.5		
Percent of households that utilize natural sources of water	0.33	Water	0.676
Average time taken to reach water source	0.85		
Percent of households that do not have a consistent water	0.611		
Average water stored in litres	0.916		
Percent of households that did not receive warning about an upcoming disaster	0.722	Natural disasters and climate variability	
Percent of households with an injury or death as a result of natural disaster	0.138		
Mean standard deviation of monthly average of average maximum daily temperature (years: 2011–2019)	0.528		
Mean standard deviation of monthly average of average minimum average temperature (years: 2011–2019)	0.426		
Mean standard deviation of monthly average precipitation	0.230		
Mean standard division of monthly wind speed	0.433		

(continued)

Table 1.4 (continued)

Sub-components	Jaisalmer	Major components	Jaisalmer
Percentage of households dependent on community wells	0.138	Water Vulnerability	0.452
Percentage of households dependent on pipeline (tapped water supply)	0.166		
Percentage of households dependent on water tanker for drinking purpose	0.222		
Percentage of households dependent on water only from Indira Gandhi Canal	0.08		
Percentage of households receiving water from more than two sources	0.416		
Average distance from water source (in km)	0.726		
Average months of water scarcity	0.541		
Percentage of households where women and children travel to water sources	0.689		
Percentage of households that do not have water storing facilities	0.166		
Percentage of households that drink impure water	0.833		
Average decline in groundwater level	0.486		
Percentage of households that cannot afford to purchase Jar/Jerry can water	0.666		
Percentage of households that cannot pay for clean water for all activities	0.388		
Percent of households who struggle to get clean water by paying	0.611		
Percentage of households where people suffer from water borne health problems	0.527		
Percent of households that received water polluted with fluoride/nitrate/arsenic	0.583		

Source Prepared by author

Table 1.5 Calculations showing LVI-IPCC for Jaisalmer district

Contributing factors	Major components for Jaisalmer district	Major component values for Jaisalmer district	Number of sub-components per major component	Contributing factor values	LVI-IPCC VALUE for Jaisalmer
Adaptive capacity	Socio-demographic profile	0.715	3	0.607	
	Livelihood strategies	0.665	4		
	Social Networks	0.425	3		
	Migration	0.139	4	0.430	
Sensitivity	Health	0.480	4		0.083
	Food	0.374	7		
	Water	0.676	4		
	Water vulnerability	0.452	16		
Exposure	Natural disasters and climate variability	0.413	6	0.412	

Source Prepared by author

social and regularly attend all festivals, marriages and auspicious events together. The ones who have not attended any functions are low 0.305.

These sub-categories show that the people are not left on their own terms when they are in need. Households have mostly resorted to informal means of borrowing and lending money and have avoided the formal banking credit and loan facilities even though 63% of the respondents owned bank accounts, they do not use it. They depend on their immediate relatives or friends for money due to which they show a high vulnerability of 0.777 due to lack of possession of a formal bank account. They have not approached their local government for assistance and borrow and receive in-kind assistance. Total adaptive capacity values are represented in Table 1.6.

Table 1.6 LVI-IPCC contributing factors to vulnerability for rural communities of Jaisalmer

IPCC contributing factors to vulnerability	Jaisalmer
Exposure	0.412
Adaptive capacity	0.607
Sensitivity	0.430
LVI-IPCC	0.083

Source Prepared by author
The LVI-IPCC is on a scale from −1 (least vulnerable) to 1 (most vulnerable)

1.4.6.2 Sensitivity

Migration: the rural households of Jaisalmer have reported low numbers of people migrating to other districts for work and education. The overall vulnerability is 0.139. The people who migrated for work show low vulnerability as only 19.44% people have moved out of the village. 16.6% people migrated for job opportunities and 3% for education. The monthly remittances they received was very less and only a few of them received them on a regular basis.

Health: Jaisalmer households reported travelling an average of 35 min and a high of 50 min to reach health care facilities. Adding all indicators, the vulnerability of the households in terms of health is high at 0.667 vulnerability of average time taken to reach health facility is 0.84. 61% of the households reach their nearest community hospital within 30 min. 27% people take about 45 min to 1 h and only 11.11% take over an hour.

Not many households have reported chronic illness which makes their vulnerability a medium of 0.305. Only 30.5% of the respondents had at least one family member who was chronically ill. However, the members of the household who were suffering from diabetes, high blood pressure and joint pains were over 65 years of age and had age-related health issues. Only one female member from a household in Baramsar village reported TB (tuberculosis). Cases of malaria have been reported in areas through which Indira Gandhi Canal passes. Most of the people resorted to allopathic means of medication. About 25% of the households surveyed did not have a toilet/ proper sanitation facility inside their house. This shows that the goal of hundred percent open defecation free has not been achieved, however, there has been a drastic improvement in the number of households with toilets inside their premises.

Food: the rural households of Jaisalmer reported struggling to find adequate food for their families (0.513). The struggle was maximum after the cropping season ended. About 41.6% families rely solely on agriculture for income. The average cropping season in Jaisalmer lasts for 3 months during the monsoon season after which the families tend to consume what they grow or find alternative means of food such as meat, meat products. However, most of the households depend on vegetarian food (0.5). Farmers grow about an average of three crops at least, some grow five. The most common crops found in this region are guar, pearl millets (bajra), sorghum (jowar), sesamum, groundnuts, aloe vera, wheat and barley are rarely grown in rabi season. Therefore, the vulnerability in terms of crop diversification is low 0.341 which means that the farmers grow at least three types of crops. 36.6% percentage of farmers do not save crops and 55% do not save seeds for the next season which makes them vulnerable more as compared to those who save. This shows that they buy new seeds for the next season and do not consume crops that they produce. There is a certain class of households, the landless and the tenants who only depend on the government's subsidy for food (0.035). They receive rice at a price of Rs. 3/kg

and wheat at Rs. 2/kg. The sensitivity of the rural communities is represented in Table 1.6.

1.4.6.3 Exposure

Natural Disaster and Climate Variability: Jaisalmer has reported several dust storms. The drought-like condition prevails all year round. The percentage of households reported to receive no warning about any upcoming dust storm or drought was 72.22%. There were very few cases of disaster related injuries or deaths (13.8%). Households reported that they faced extremely strong summer months and biting cold winters for over 3–4 years continuously and the temperature has increased every year. The skies are clear and sunshine is received for all 365 days of the year. They are more vulnerable to climate change impacts (0.412). The vulnerability in high and low temperatures months was 0.52 and 0.426. The average wind speed calculated for 12 months over 10 years is 43 kmph and the average precipitation is 23 cm. Table 1.6 shows the exposure of communities to changing climate conditions.

1.4.7 Water Availability

Water is an extremely precious resource in Jaisalmer. About 33% of the rural households depend on open sources of water to meet their daily needs. Open sources include water from oases and wells. 61.11% of those who receive piped water, complain of irregular supply. The members of the household travel an average of about 26.25 min to reach the water source, the shortest duration being 5 min and the maximum being 60 min (to and fro). 30.5% of the respondents travel more than an hour in search of water. Jaisalmer households reported storing 37.5 L of water every day and about 91.6% of the households save water, out of this, 38.88% of the households save 20–40 L of water per day, 30.5% households save less than 20 L of water. Only a small portion save above 40 L.

Table 1.7 The Ground water resources as per 31.03.2013 data

Block	Allocation for domestic and industrial requirement	Net G.W. availability for future irrigation Development	Stage of G.W. Development	Category of Block
Jaisalmer	11.2878	3.8811	332.71	Over exploited
Sam	8.2513	15.2119	125.33	Over exploited
Sankra Pokhhran	6.071	4.8415	331.66	Over exploited

Source CGWB, Jaipur

Table 1.8 The Ground water resources as per 31.03.2013 data

Block	Area of block	Total annual ground water recharge	Natural discharge during non-monsoon season	Net annual ground water availability	Existing gross ground water for irrigation	Existing gross G.W. for domestic and industrial use	Existing gross ground water draft for all uses
Jaisalmer	115,951	21.8423	1.8582	19.984	53.2718	13.2167	66.4885
Sam	21,194.8	28.483	2.8483	25.6347	19.5125	12.6146	32.1271
Sankra Pokhran	5615.2	19.8406	1.8395	18.0011	52.8013	6.901	59.7023

Source CGWB, Jaipur

Table 1.9 Categorization of aquifers of different blocks on the basis of Stage of Development

Categorization on the basis of stage of development of ground water	Block name
Critical	Sam
Over exploited	Sankra Pokhran, Jaisalmer

Source CGWB, Jaipur
Basis for categorization: Ground water development $\leq$ 100%—Critical and > 100%—Over Exploited

Table 1.7 provides information on net ground water availability for future irrigation development and status of ground water development in the three blocks of Jaisalmer, i.e. Sam, Pokhran and Jaisalmer.

Natural discharge during non-monsoon season, existing gross ground water for irrigation, industrial use and other uses on the basis of 2013 data is shown in Table 1.8.

Categorization on the basis of stage of development of ground water (critical and over exploited) is represented in Table 1.9.

1.4.8 Water Vulnerability

Water woes remain a common thread in the lives of people of Jaisalmer. Struggling to access drinking water has become a norm for people in Thar Desert, irrespective of the season. From red-tapeism to environmental clearances, various factors have kept the efficiency of water projects low. Rajasthan's relationship with summer is not a pleasant one. The shortage of water in the region only adds to the misery of the people. 13.8% of the people depend only on open sources of water to meet their daily needs. They depend on oasis, *beris (*traditional percolation tanks that get recharged at night with freshwater), open wells and take multiple rounds to fetch. 16.6% of the households have a tapped water pipeline. The water from this source is salty and

cannot be used for drinking purposes, similar is the case with the water from Indira Gandhi Canal which serves the water needs for the villagers of Ramdevri, Pokhran (8%). They too complain of the same problem that the water cannot be used for drinking due to the high amount of fluoride and salts in it. 22.22% households depend on supplies from the water tanker of PHED which delivers water from surrounding districts. This tanker supplies drinking water to each village at a gap of about one week due to which the households have to rely on multiple sources of water and this, in turn, increases their vulnerability. About 41.6% of the households depend on stored rainwater, tank water and water from wells and beris for drinking and tap water and water from Indira Gandhi Canal for other domestic purposes. Women and children are the ones who travel long distances of about 3 to 4 km every day in order to fetch water for the family in every season (Figs. 1.12, 1.13).

"*I have seen my mother and other family members struggle to get drinking water in my childhood. Now, I see my wife and daughters-in-law go through the same trouble. Nothing has changed*," says 75-year-old Hemant Ram, a resident of Baramsar village in Jaisalmer block.

Women, accompanied by their children, in this region continue to go through the ordeal of walking long distances to access potable water, even after years of political promises and pretence to improve availability of water to this region. Surprised to see a herd of cows out of which only three cows belonged to Manisha Devi, I asked why she was drawing water for animals that belonged to other households. "*It's a common practice here. Whoever comes to the* ***Beri*** *around this time provides water to the animals gathered here*," she said. The strong sense of community Manisha displays is not uncommon in this arid region.

The struggle to find water is the same in 3–7 °C or 45–50 °C. However, maximum scarcity is felt during summer (May to July). The vulnerability touches 0.541.

"*We avoid taking bath for 10–15 days and don't wash clothes for around 20 days," says 55-year-old Kamla Devi. "We depend on the water tanker*," says Sonu. "*Since it costs around Rs. 800 to Rs. 1,000, we call it once in 10 days. The animals are also given less water than what they require*," she says, adding that they have lost several livestocks to harsh summers.

Maximum households store drinking water in underground tanks which have a capacity of about 1000 L which lasts them an entire year (Fig. 1.14 provides more details). About 16.66% people do not have the infrastructure or the ability to store water on such a large scale so they try saving certain amounts on a daily basis. 66.66% of the villagers cannot afford to purchase jerry cans or jar water for providing drinking water to guests in marriages and social events.

61% of the people directly consume water without purifying it. They lack resources and are hardly able to meet their daily needs so boiling water and purifying it prior to drinking, is out of question. Due to this reason, maximum population (especially the old) suffer from problems such as knee and joint pain, yellowing of teeth, haziness in vision (cataract in almost all old people) and falling of hair. This is due to the high amount of fluoride in the water. About 58.3% of the households complained of impurities in water. Most of the older population has developed a hunch back and their joints have become stiff, young people start to look old sooner

due to the high amount of salinity in water. Increased content of fluoride is due to high rate of exploitation of groundwater.

1.4.9 Inference of the Spider Web Chart

The results of major component calculations are presented collectively in a spider diagram. The scale of the diagram ranges from 0 (less vulnerable) at the centre of the web, increasing to 0.5 (more vulnerable) and to 1 (most vulnerable). Figure 1.6 represents the vulnerabilities of each major component which in turn comprises several sub-components to present an overall web. The households of Jaisalmer are most vulnerable in terms of dependency ratio (0.715) which is followed by water availability (0.676) and their livelihood strategies (0.665).

In terms of various aspects of water vulnerability, the households show that they are affected by scarcity and are vulnerable at a higher side (0.452). They are more vulnerable in getting access to health facilities (0.480) and they have a well-knit system of social networks. However, since maximum households surveyed do not hold bank accounts, the average vulnerability increased to (0.425). The households are very prone to facing natural hazards (0.413) such as dust storms and all year round dry conditions, the monthly average of maximum and minimum temperate is also at extremes. They have also seen moderate floods in 1992, 1994, 1996, 1998, 2007 and 2008. The rural communities are not informed by the government regarding an

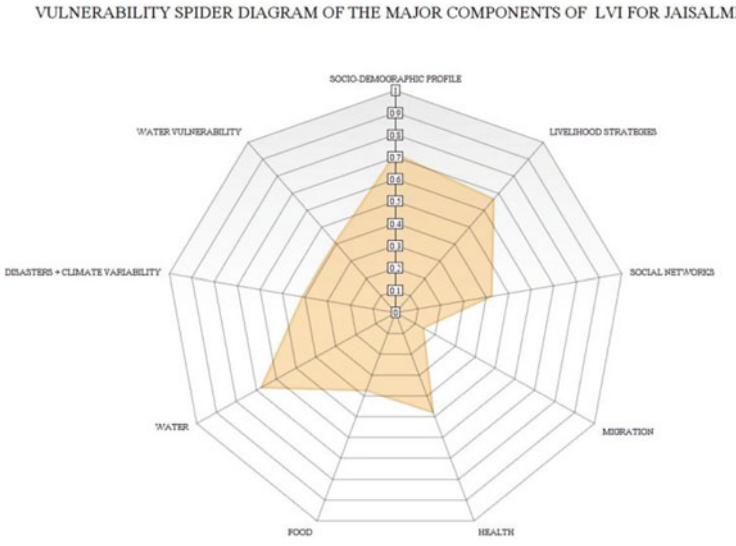

Fig. 1.6 Spider web chart diagram of the major components of LVI-IPCC for Jaisalmer district. *Source* Prepared by author

upcoming storm and have to save their own lives. The casualty rate is low due to a strong interlinked community.

Maximum households of the village households are unaware of any water related schemes of the government and complain about lack of effectiveness in management of water by the authorities. The residents say that the water that is delivered to them through tankers is clean, water from other sources looks clean, has no odour but the people have shown signs of water related health problems.

The major problem that they complain of is travelling long distances to collect water multiple times a day (Fig. 1.10 shows the time taken (in %) to reach water source). The ones who have a tapped water supply complain of impurity in water and it cannot be consumed for drinking so they too are highly vulnerable. The people who buy water through tankers complain of irregularity.

In terms of food, the households are moderately secure. 37.4% of the population is vulnerable as their crop diversification index is low, they are unable to save crops or seeds for the next season, they are major tenants and work on the farms of big landlords. They have a hand-to-mouth earning thus, they are vulnerable. Lack of water makes the cropping season short to about only 4 months after which the communities depend on their livestock. Thus, those who do not own land, at least own livestock to insure themselves in tough times. 75% of the households' own cows, 38.8% own goats, 8% own sheep and 0.2% own camels. Thus, the rural communities of Jaisalmer are more vulnerable and exposed to the vagaries of nature and show a high degree of vulnerability.

1.4.10 Inference of the Vulnerability Triangle

Figure 1.7 shows a vulnerability triangle, which plots the contributing factor scores for exposure, adaptive capacity and sensitivity. The triangle illustrates that Jaisalmer may be more exposed (0.412) to climate change impacts. accounting for the current

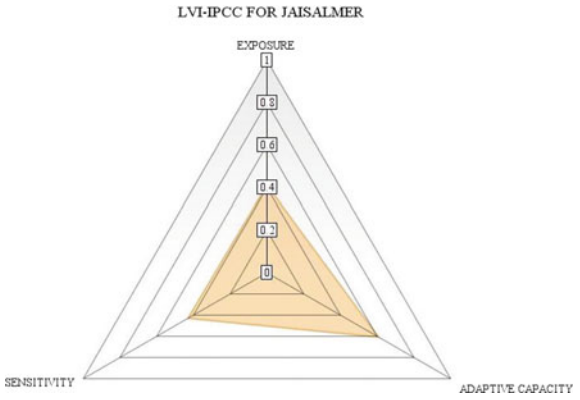

Fig. 1.7 Final IPCC contributing factors to vulnerability for Jaisalmer. *Source* Prepared by author

health status as well as food and water security, the rural households are more sensitive to climate change impacts (0.430). Based on demographics, livelihoods and social networks, Jaisalmer showed a higher adaptive capacity (0.715). The overall LVI-IPCC scores indicate that households are very vulnerable (0.083) but have shown tendencies to adapt.

1.5 Water Management Techniques in Jaisalmer

Water Conservation and Artificial Recharge

In Jaisalmer, water is harvested in two ways such as: surface water harvesting and groundwater harvesting. Within surface water, one can identify two different modes such as those which are harvesting the rainwater in the form of roof top harvesting and those which collect the surface runoff at suitable sites from well-defined at times well maintained catchment areas. Storing and harvesting of water is controlled by physical conditions such as climatic factors and surface morphology. Figure 1.9 depicts various means of water sources used by households (village communities) in Jaisalmer.

1. Talaab/Talai

Talabs are reservoirs. They may be natural, such as the ponds (pokhariyan). A repository territory of under-five bighas is known as a talai; a medium estimated lake is known as a bandhi or talab; greater lakes are called sagar or samand. They fill water systems and drinking needs. These were not just built by the leaders of the little realm yet in addition by the dealers and Banjaras. A portion of these Talaabs (Image 1.1) are made by certain networks to take care of the drinking water issue. For instance, 'Gomat' a small village near Pokaran, in Jaisalmer district has its own source of water for domestic utilization.

2. Kueen, Kuan and other similar structures

All these structures are the means of groundwater harvesting. Some of these structures are examples of subsurface water harvesting. The term subsurface water denotes shallow groundwater, availability of which largely depends on rainfall conditions of previous monsoon season. For instance, Kueen, Beri and Kuan are the structures used to get percolated water.

'Kueen' is a small form of dug wells. Old Kueen is now lined with stone walls. In old days Kueen was lined only with interlocking stone blocks. In other types of lining the Kueen has rope lining. This is done by 'Chelwanji' the people who are skilled persons to do rope tinning in the Kueen up to 30–60 m deep and only 1.5–2.5 m in diameter. Kueen (Image 1.2) is particularly observed in the areas of interdunal depressions.

Water availability through Kueen is controlled by the rainfall amount received and the seepage of surface water. Kueens are observed in groups and generally located

Image 1.1 A Talaab with Panghat in Pokhran

Image 1.2 Kueen in Deva village, Jaisalmer

outside the settlement. People believe that the greater number of Kueens in the area do not affect the subsurface water availability. In fact, they dug more Kueens to harvest groundwater at its optimum and believe that the subsurface water can be harvested only when there is enough rainfall in the monsoon season. The rainwater percolates down up to subsurface below level that can be harvested, however further downward the movement of water becomes slow and potentials of getting water beyond 50–60 m greatly reduced.

3. Beri

Beri is the smallest structure among the family of dug wells. Beri is observed in very few areas of Rajasthan like, 'Thaat' village off Pokaran-Devikot road in Pokaran tahsil, of Jaisalmer district. This area is only along the ephemeral streams and in the areas where subsurface stratum is more impervious than the overlying stratum. Beris are also dug in the reservoir of the Johad or Medhbandi (soil bund used to divert surface runoff in depressions or in the Johad reservoir). In the areas of very high temperature like Jaisalmer, when water from reservoirs dries out, the percolated water can be used through the Beri.

4. Tanka and Kund

Roof top rainwater harvesting is a traditional system in many parts of Jaisalmer. Wherever possible the people of Jaisalmer have tried to collect the rainwater. Tanka is the most popular rainwater harvesting structure in Jaisalmer. This structure is constructed below the ground. The size of Tanka depends on the demand of users. When the Tanka is used for family then it is small in size and is generally called 'Kund'. When it is for any community, the size of such Tanka is bigger. Some Kunds that are smaller in size are also called Kundi. The catchments for these structures are either the roofs of houses or paved surfaces or unpaved surfaces particularly demarcated for the purpose. Many such Kunds are observed in villages of Jaisalmer. Figure 1.12 provides a percentage wise estimate of methods of water storage by households in the surveyed area (Images 1.3, 1.4, 1.5 and 1.6).

1.6 Practical Implications of LVI of the Surveyed Area

The major vulnerability components shown in the spider web chart provides information about which characteristics contribute most to climate vulnerability in Jaisalmer. These in turn might be programmed for community assistance. For example, although Jaisalmer suffers from recurrent droughts and an all-time dryness, we observed that many households have adapted by storing water in plastic/metal drums which have a capacity of about 200 L. Similarly, they use traditional means of storing water like kueen, beri (underground water storage methods) and johad, kund and talab which are used surface water harvesting. Underground tanks which hold up to 1000 L of rainwater are a common sight in most of the households that are better off than the ones that are landless.

Image 1.3 Kund at Sam block

Image 1.4 Tanka at Deva village

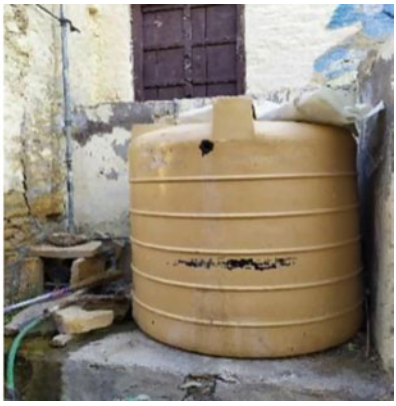

Image 1.5 Matka and drum

Image 1.6 Interior of a Kuaan/Water well

These practices have likely decreased the vulnerability of travelling long distances in search of water. Similarly, although the households reported struggles to find food for 5 months or more per year, 64% households store crops which helps them sustain their need for food for the rest of the months.

This shows that the households are engaged in sustainable food management practices (Fig. 1.8). About 45% of the people store seeds for the next season which suggests that education on seed preservation and seed diversification would constitute an appropriate intervention for Jaisalmer households, despite having a secure status in terms of food. The region needs to invest in programmes aiming to increase livestock production and enhance livelihood support in rural areas.

Migration: Migration is seen in need of immediate medical conditions or income needs. the percentage of people who migrated remains low (19.4%). Those who fail

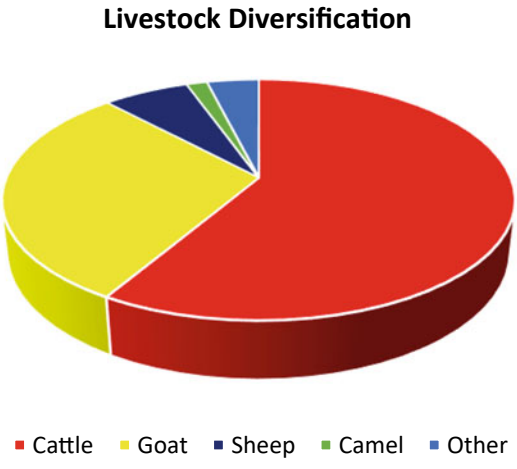

Fig. 1.8 Pie chart representing variety of livestock domesticated by the rural households. *Source* Prepared by author with primary survey data

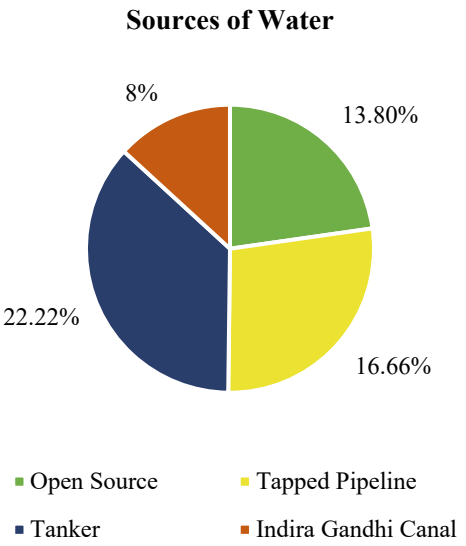

Fig. 1.9 Pie chart representing the sources of water used by rural households. *Source* Prepared by author with primary survey data

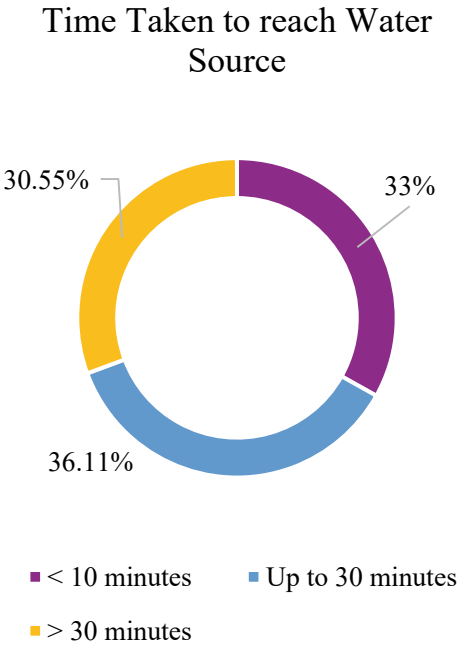

Fig. 1.10 Donut pie chart showing time taken (in %) to reach water source. Source Prepared by author with primary survey data

to find work in the village have adapted by sending the male members and children for better employment and education to meet the livelihood stability.

Health: The rural communities have shown resilience in recovering from and protecting themselves from diseases and infections after the construction of primary health care centres. They are also aware of saving the girl child and the ill-effects of defecating in the open due to awareness created by the government. They have thus resorted to keep sanitation a priority.

Social assistance: The borrow-lend money and receive-give assistance averages were created to measure the degree to which households rely on family and friends for financial assistance and in-kind help. It was assumed that a household that receives money or in-kind assistance often but offers little assistance to others is more insecure and vulnerable compared to those with excess money and time to help others.

Since the familial structure was joint in nature and comprised of a greater number of people with immediate family and friends, these living arrangements may have influenced the way in which residents judged 'helping' versus 'obligation'. Community bonds and high-level trust among households are important for decreasing vulnerability to climate change impacts. However, these social characteristics can be more difficult to measure than measuring food security and health indicators.

Other measures of social capital include a household's range of contacts or access to formal government structures, access to information, agricultural and technical support, degree of gender equity as well as the number of social groups to which a household belongs. Despite the challenges in quantifying social networks, their inclusion in climate vulnerability assessment is essential as many adaptation behaviours depend on collective insurance mechanisms such as agricultural cooperatives.

Water scenarios can be summarized through charts prepared by the researcher in Figs. 1.9, 1.10, 1.11, 1.12, 1.13 and 1.14 through data received during primary survey of the region. Their in-line descriptions have been covered in the previous sections.

1.7 Conclusion

All blocks of the district have over exploited groundwater, thus, leaving a very limited scope of further groundwater development for consumption. The area is devoid of sustained surface water bodies. Villages of Jaisalmer block could be attributable to better means of livelihood as compared to the other regions due to close proximity to the city and thus witnessed higher commutation from the villages to the city.

Villages of Pokhran block were found to be more vulnerable and exposed in terms of water and climate change and variability. Unawareness regarding pending natural disasters, fluctuation in precipitation and temperature, illiteracy, large family sizes and inadequate access to medical care are some of the dimensions in which the people of this block are vulnerable. There was an increase in the vulnerabilities of farming communities in the region towards extreme climatic events.

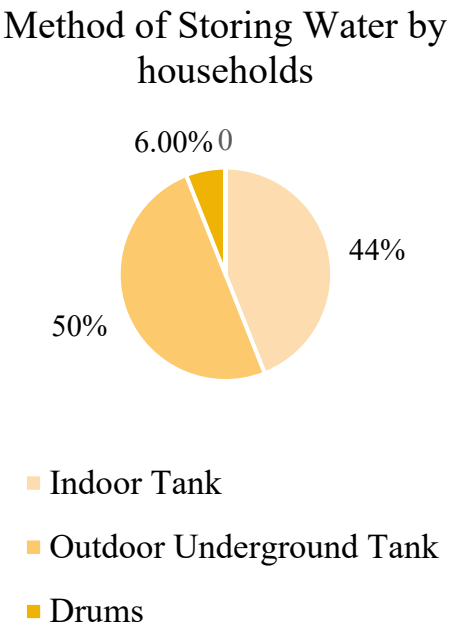

Fig. 1.11 Pie chart depicting water storage methods by rural communities of Jaisalmer. *Source* Prepared by author with primary survey data

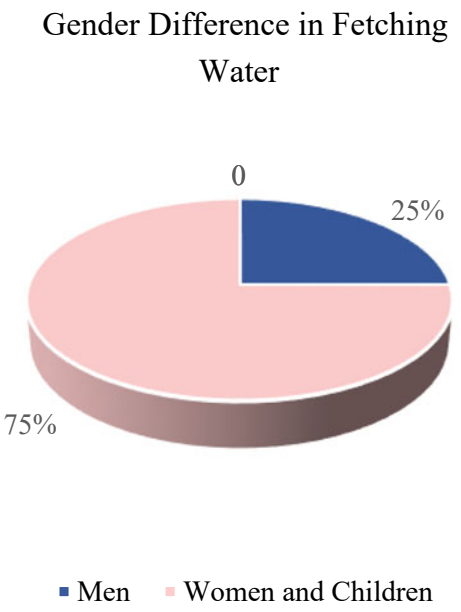

Fig. 1.12 Gender disparity in fetching water is represented. *Source* Prepared by author with primary survey data

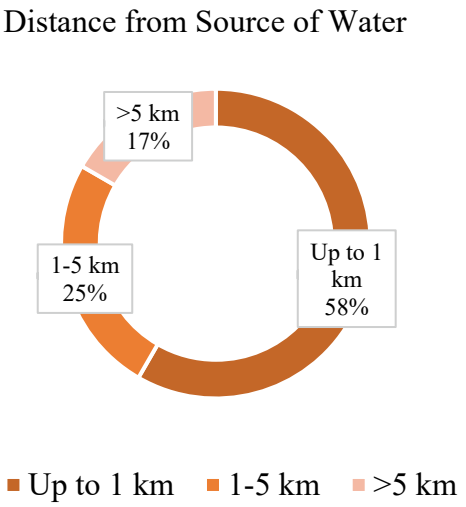

Fig. 1.13 Donut pie representing distance travelled by people to fetch water. Source Prepared by author with primary survey data

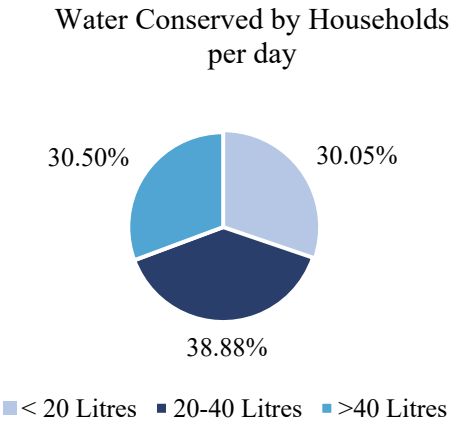

Fig. 1.14 Pie chart showing percentage of households preserving different quantities of water per day. *Source* Prepared by author with primary survey data

Sam region was highly vulnerable in terms of natural phenomena like dust storms, water availability, health and food resources. This region was found to be the most sensitive region to extreme climatic events probably because of the region's inadequate access to immediate resources. The findings of this study have important policy relevance that could enable the rural communities of the desert region to better adapt to the effects of climate change and variability.

The westernmost region and the interior deserts regions should be given priority by both government and donors in terms of income generation, water sources and food security projects in order to reduce the water and livelihood. The government has done an impressive job in providing employment to people through MNREGS to clean wells. However, there is the need to improve water supply in the region by

undertaking measures such as construction of tankas and kunds in order to reduce the duration to get to far off water sources like beris.

If a hypothetical assumption regarding the continuation of the present kind of development and management practices, then by the year 2045, the irrigated area will further reduce by 28% whereas, the population would increase by 88%. This highlights the need for sustainable use of water resources and specific attention should be given to the quality of water.

1.8 Suggestions

In order to meet the future drinking water and irrigation requirements the following suggestions could be taken into account:

Halophilic or salt-tolerant crops could be grown in areas with brackish groundwater.

Deep groundwater exploration can be done in areas that fall under a 'relatively' safe category like, in the Sam region, expanses beneath the tertiary and Lathi formations, it is possible to carry out further groundwater development exploration for development.

Water for everyday consumption should be used from conservation and harvesting structures like tankas, rooftops and underground water storage which would help in reducing the groundwater extraction. This is the need of the hour since large number of aquifers of the region has the potential to recharge by surface water from the IGNP (Indira Gandhi Nahar Project) system and rainwater discharge during the rainy years.

Construction of small check dams and earthen dams could be done at appropriate locations to store rainwater and increase groundwater recharge which will, as a result, replenish and increase water levels in wells.

Heavy withdrawal of groundwater for agriculture and drinking purpose, from potential zones in areas like Chandan-Bhairawa and Lathi need to be controlled as the water development has crossed 100%. Awareness programmes to educate the urban and rural communities regarding conservation of groundwater resources and training in rainwater harvesting will be beneficial to check decline in water level and make sure of its justified use. Financial assistance for groundwater development in over exploited, critical and semi-critical areas should not be encouraged. Use of water saving devices such as sprinklers and close field distribution channels should be promoted.

Reduction in the wastage of water and controlling irrigation by reducing the pumping hours according to the minimum requirement of water per field, according to the crop sown could be helpful in optimizing and effectively managing the requirements of modern agricultural techniques. Crops that require low amount of water and are cost-effective need to be selected for the desert regions rather than cultivating rice which is a water intensive crop. Agriculture extension services could go a long way in providing knowledge and skills to farmers to adopt alternate crops that demand lesser water.

Traditional methods of water harvesting in Rajasthan are structures that were designed back in the fifteenth century. They were constructed not merely with experience but were scientific in their architecture. This can be witnessed all along Western Rajasthan where the science can still be explained by the local community. Each drop of water is saved such that the rural networks of Jaisalmer are not devoid of the resource. This is the most impressive adaptation method based on sustainable scientific techniques that have helped in the continuance of existence of people in the region. However, now, increasing the 'ideas of development' had caused a spike in salinity, fluoride, nitrate and chloride content in groundwater. Detailed scientific research is required by geologists, hydrologists, engineers, environmentalists and social scientists to study the rocks of the region, groundwater flow, depth of water table and continuously monitor them to suggest sustainable groundwater management which has been polluted due to industrialization and pollution.

This study is proof of compelling changes in the climate, water availability and adaptation techniques utilized by the people of Jaisalmer. Change is the only factor that is persistent in this tough environment. Therefore, there is immense need to conserve, preserve and defend this environment, its biodiversity and its people.

Community participation in managing cross-scale and multi-level concerns could be an effective way of protecting the region from losing its resources. Climatic vulnerability, social vulnerability and livelihood vulnerability studies need to be carried out extensively along with monitoring their exposure, sensitivity, adapting capacity and resilience to perturbations with the support of the government, NGOs and community level action demands attention be included in formulating policies and programmes which target the specific region of Jaisalmer according to the social, environmental, economic and political needs of this region.

This case study, thus, shows us the methods of using traditional knowledge in conserving, storing and managing water through sustainable means, without harming the environment. It also shows us the use of a well-developed integrated and ecological approach in water management.

References

Aalst V, Cannon MK, Burton T (2008) Community level adaptation to climate change: the potential role of participatory community risk assessment. Glob Environ Change 18(1):165–179

Adger WN (2003) Social aspects of adaptive capacity. In: Smith JB, Klein RJT, Huq S (eds) Climate change, adaptive capacity and development. Imperial College Press, London, pp 29–49

Adger WN, Brooks NN, Bentham G, Agnew M, Eriksen S (2004) New indicators of vulnerability and adaptive capacity. Tyndall Centre Technical paper 7.

Adger WN, Arnell NW, Tompkins EL (2005) Successful adaptation to climate change across scales. Glob Environ Change 15(2):77–86

Adger WN, Agrawala S, Mirza MMQ, Conde C, O'Brien K, Pulhin J, Pulwarty R, Smit B, Takahashi K (2007) Assessment of adaptation practices, options, constraints and capacity. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate Change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report

of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 717–743

Adger WN, Agrawal S, Mirza MMW, Conde C, O'Brien KL, Pulhin J, Pulwarty R, Smit B, Takahashi K (2007b) Assessment of adaptation practices, options, constraints and capacity. Climate Change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 719–743

Adholeya A, Dadich PK (2008) Production and technology of bio-diesel: seeding a change. TERI Press, The Energy Resource Institute, New Delhi, p 256

African Development Bank (AfDB), Asian Development Bank, UK DfID, Netherlands DGIS, European Commission DG for Development, German BMZ, OECD, UNDP, UNEP, World Bank (2003) Poverty and climate change. Reducing the vulnerability of the poor through adaptation. Department for International Development

Arora M, Singh RD, Kumar R (2010) Impact of climate change on water resources. Yojana 54:36–40

Bandyopadhyay A, Bhadra A, Raghuwanshi NS, Singh R (2009) Temporal trends in estimates of reference evapotranspiration over India. J Hydrol Eng 14:508–515

Bhattacharya S (2007) Lessons learnt for vulnerability and adaptation assessment from India's First National Communication. Winrock International

Bhuiyan C, Singh RP, Kogan FN (2006) Monitoring drought dynamics in the Aravalli Region (India) using different indices based on ground and remote sensing data. Int J Appl Earth Obs Geoinf 8:289–302

Bhuiyan C, Flügel WA, Singh RP (2009) Erratic monsoon, growing water demand, and declining water table. J Spat Hydrol 9:1–19

Brenkert AL, Malone EL (2005) Modeling vulnerability and resilience to climate change: a case study of India and Indian States. Clim Change 72:57–102

Brown P, Reddy VR, Bandi M, Chiranjeevi T, Reddy DR, Roth C (2010) Adapting to climate variability in semi-arid regions: a study using sustainable rural livelihoods framework. LNRMI Working Paper No.1, Hyderabad.

Central Ground Water Board (2007) Ground Water Scenario: Western Region, Jaipur, Rajasthan. Ministry of Water Resources, Government of India

Central Ground Water Board (2010) Ground Water Scenario of India 2009–10. Ministry of Water Resources, Government of India

Central Ground Water Board (2011) Ground Water Scenario in Major Cities of India. Ministry of Water Resources, Government of India

Central Ground Water Board, Government of India, Western Region, Jaipur and Ground Water Department, Government of Rajasthan, Jodhpur (2011) Report on Dynamic Ground Water Resources of Rajasthan

Central Water Commission National Institute of Hydrology (2008) Preliminary Consolidated Report on Effect of Climate Change on Water Resources. Government of India

Commissionerate of Watershed Development & Soil Conservation (2010) Perspective & Strategic Plan for Development of Rainfed and Watershed areas in Rajasthan for 18 Years Period. Government of Rajasthan Rural Development and Panchayati Raj Department, Jaipur

Critchfield HJ (2012) Theories of climate change, general climatology. PHI Learning Private Limited, New Delhi, pp 238–245

Das S, Chatterjee A, Chatterjee K (2005) Community adaptation to drought in Rajasthan. Inst Dev Stud Bull 36:33–52

De US, Dube RK, Rao GSP (2005) Extreme weather events over India in the last 100 years. J Indian Geophys Union 9:173–187

Department of Environment (2010) Rajasthan State Environment Policy 2010, including Rajasthan Environment Mission. Government of Rajasthan

Department of Science and Technology (1994) Resource Atlas of Rajasthan. Government of Rajasthan, Jaipur, p 231

Dhaka BL, Chayal K, Poonia MK (2010) Analysis of farmers' perception and adaptation strategies to climate change. Libyan Agric Res Centre J Int 1:388–390
Dickson E, Jacobsen M, Danilenko A (2010) Climate change and urban water utilities: challenges and opportunities. Water Working Notes. Note No. 24
Disaster Management and Relief Department (2009) Drought management manual. Government of Rajasthan
Global Environmental Change 17, 12–24
Goyal RK (2009) Water Scenario of Rajasthan under the changing Climate. Workshop on Water Scenario, Efficient Use and Management in Rajasthan. Central Ground Water Board, Western Region, Jaipur, 13–14 Mar 2009
Guhathakurta P, Sreejith OP, Menon PA (2011) Impact of climate change on extreme rainfall events and flood risk in India. J Earth Syst Sci 120:359–373
Gupta V (2005) Climate change and domestic mitigation efforts. Econ Pol Wkly 40:981–987
Hahn MB, Riederer AM, Foster SO (2008) The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change—a case study in Mozambique, pp 74–76
Hahn M, Riederer M, Foster S (2009) The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change—a case study in Mozambique. Glob Environ Change 19(2009):74–88
Hamilton K, Fay M (2009) A changing climate for development. Finance Dev 46:10–12
Helm D, Hepburn C (2009) Economics and politics of climate change. Oxford University Press, New York, p 576
Hulme M (2003) Abrupt climate change: evidence, mechanisms and implications. Phil Trans: Math Phys Eng Sci 361:2001–2021
Hunt A, Watkiss P (2011) Climate change impacts and adaptation in cities: a review of the literature. Clim Change 104:13–49
Hurd BH (2008) Coping and adaptation to the changing climate: concepts, issues and challenges. Ann Arid Zone 47:221–231
Indian Meteorological Department (1988) Climate of Rajasthan State, Government of India, New Delhi
Indian Meteorological Department (2010) Climate of Rajasthan State, Government of India, New Delhi
IPCC (2001) Climate Change 2001: impacts, adaptation, and vulnerability. Contribution of Working Group II to the Third Assessment Report. Cambridge University Press, Cambridge, UK
IPCC (2007a) Climate Change 2007: impacts, adaptation, and vulnerability. Contribution of Working Group II to the Fourth Assessment Report (Chap. 9). Cambridge University Press, Cambridge, UK
IPCC (2007b) Climate Change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report (Chap. 11). Cambridge University Press, Cambridge, UK
Jain JK (1993) Climatic conditions of Rajasthan. Natural and Human Resources of Rajasthan. Scientific Publishers, Jaipur, pp 37–50
Jain SK, Keshri R, Goswami A, Sarkar A, Chaudhry A (2009) Identification of drought-vulnerable areas using NOAA AVHRR data. Int J Remote Sens 30:2653–2668
Jaipur Singh RL (1995) India: A Regional Geography, National Geographical Society of India, Varanasi, pp 49–55
Kasperson RE, Kasperson JX (2001) Climate change, vulnerability, and social justice. Risk and Vulnerability Programme, Stockholm Environment Institute, Stockholm
Kasperson JX, Kasperson RE, Dow K (2001) Introduction: global environmental risk and society. In: Kasperson JX, Kasperson RE (eds) Global environmental risk. United Nations University Press, New York
Lindenberg M (2002) Measuring household livelihood security at the family and community level in the developing world. World Dev 30:301–318
Loaiciga H (2003) Climate change and ground water. Ann Assoc Am Geogr 93:30–41

Mahajan G (1989) Evaluation and development of groundwater. Ashish Publication House, New Delhi, p 317
Malhotra SP (1978) Socio-economic structure of population in Arid Rajasthan. CAZRl, Jodhpur, 51 p. Malhotra SP 1984. Traditional agroforestry practice in arid zone of Rajasthan. In: Shankarnarayan KA (ed) Agroforestry in Arid and Semi-Arid Zones, CAZRl, Jodhpur, pp 263–266
Mall RK, Singh R, Gupta A, Srinivasan G, Rathore LS (2006) Impact of climate change on Indian Agriculture: a review. Clim Change 78:445–478
Malone EL, Brenkert A (2008) Uncertainty in resilience to Climate Change in India and Indian States. Clim Change 91:451–476
Measham TG, Preston BL, Brook C, Smith TF, Morrison C, Withycombe G, Gorddard R (2010) Adaptation to climate change through local municipal planning: barriers and opportunities. Socio-Economics and the Environment in Discussion CSIRO. Working Paper Series 2010-05, 1–25
Ministry of Earth Sciences (2010) Climate Profile of India. India Meteorological Department. Government of India
Ministry of Environment and Forests (2006) National Environment Policy. Government of India
Ministry of Environment and Forests (2009a) Climate Change and India: towards preparation of a comprehensive climate change assessment. Government of India
Ministry of Environment and Forests (2009b) State of Environment Report: India, Government of India, New Delhi.
Ministry of Environment and Forests (2010a) India: Taking on Climate Change-24 Recent Initiatives Related to Climate Change, Government of India
Ministry of Environment and Forests (2010b) Climate Change And India: A 4×4 Assessment (A Sectoral and Regional Analysis for 2030s). Government of India
Mirza M (2003) Climate change and extreme weather events: can developing countries adapt? Clim Policy 3:233–248
Misra VC (1967) Geography of Rajasthan, National Book Trust, New Delhi, p 188
Mitchell T, Tanner T (2006) Adapting to climate change: challenges and opportunities for the development community. Institute of Development Studies
Moench M, Dixit A (2004) Adaptive capacity and livelihood resilience—adaptive strategies for responding to floods and drought in South-Asia. The Institute for Social and Environmental Transition, Boulder, Colorado, USA and the Institute for Social and Environmental Transition, Nepal
Moss RH, Watson RT, Zinyowera MC, Dokken DJ (1997) The regional impacts of climate change: an assessment of vulnerability. Intergovernmental Panel on Climate Change
Narain P, Khan MA, Singh G (2005) Potential for Water Conservation and Harvesting against Drought in Rajasthan, Drought Series: Paper 7, International Water Management Institute. Working Paper 104
Noss RF (2001) Beyond Kyoto: forest management in a time of rapid climate change. Conserv Biol 15:578–590
O'Brien K, Leichenko R, Kelkar U, Henry Venema G, Aandahl H, Tompkins A, Javed S, Bhadwal S, Barg LN, West J (2004) Mapping vulnerability to multiple stressors: climate change and globalization in India. Glob Environ Change 14:303–313
Olmos S (2001) Vulnerability and adaptation to climate change: concepts, issues, assessment methods. The Climate Change Knowledge Network
Organization for Economic Co-operation and Development (2002) Climate Change: India's perceptions, positions, policies and possibilities. Climate Change and Development
Pareek A, Trivedi PC (2011) Cultural values and indigenous knowledge of climate change and disaster prediction in Rajasthan, India. Indian J Tradit Knowl 10:183–189
Planning Commission (2011) Rajasthan Development Report. Academic Foundation, New Delhi, p 65
Rajasthan Pollution Control Board (RPCB) (2009) State Environmental Atlas, Rajasthan, Jaipur

Rajasthan State Pollution Control Board (1994) State Environment Atlas of Rajasthan, Government of Rajasthan, Jaipur
Rao AS (1992) Climate, climatic changes and Paleo-Climatic Aspects of Rajasthan. Geological Facets of Rajasthan, 38–44
Rao AS (1996) Climatic changes in the irrigated tracts of Indira Gandhi Canal Region of Arid Western Rajasthan, India. Ann Arid Zone 35:111–116
Rathore LS, Mall RK, Gupta A, Singh R, Singh RS (2006) Water resources and climate change: an Indian perspective. Curr Sci 90
Reddy VR (1996) Urban water crisis-rationale for pricing. Rawat Publications, Jaipur, p 180
Reddy BS, Assenza GB, Assenza D, Hasselmann F (2009) Energy efficiency and climate change: conserving power for a sustainable future. SAGE Publications India Pvt Ltd., New Delhi
Sahai S (2008) Climate change and agriculture: reinventing the crop cycle. Gene News 3:2–3
Sathaye J, Shukla PR, Ravindranath NH (2006) Climate change, sustainable development and India: global and national concerns. Curr Sci 90
Schipper ELF (2007) Climate change adaptation and development: exploring the linkages. Tyndall Centre for Climate Change Research. Working Paper No. 107, 1–28
Singh RB, Mal S (2009) Environmental Change and Biodiversity: Uttarakhand Experiences. Rawat Publications, New Delhi, p 246
Singh N, Singh S, Kar A, Joshi DC, Ram B, Kumar S, Vats PC, Raina P, Kolarkar AS, Dhir RP (1992) Desertification Mapping in Western Rajasthan. Ann Arid Zone 31:237–246
Singh VS, Pandey DN, Gupta AK, Ravindranath NH (2010) Climate change impacts, mitigation and adaptation: science for generating policy options in Rajasthan, India. Rajasthan State Pollution Control Board Occasional Paper No. 2/2010
Sreejith OP, Guhathakurta P, Menon P, Mazumdar AB (2010) Changes in extreme rainfall events and flood risk in India during the last century. National Climate Centre. India Meteorological Department. Pune
Srivastav R (2008) Need to buffer rainfed agriculture. Gene News 3:8
State Remote Sensing Application (1999) Centre Groundwater Atlas of Rajasthan, Department of Science and Technology, Government of Rajasthan, Jodhpur
State Remote Sensing Application Centre (2010) Soil Resource Atlas of Rajasthan. Department of Science and Technology, Government of Rajasthan, Jodhpur, p 270
Sullivan C (2006) Global change impacts: assessing human vulnerability at the sub-national scale. In: Presented at the International River Symposium, Brisbane
Sullivan C, Meigh JR, Fediw TS (2002) Derivation and testing of the water poverty index phase 1, Final Report. Department for International Development, UK, 2002
Sullivan C, Meigh J (2005) Targeting attention on local vulnerability using an integrated index approach: the example of the climate vulnerability index. Water Sci Technol 51:69–78
Tadross MA, Hewitson BC, Usman MT (2005) The interannual variability of the onset of the maize growing season over South Africa and Zimbabwe. J Clim 18:3356–3372
Tanner T, Yamin F, Mitchell T (2005) Linking climate adaptation: a research agenda. Inst Dev Stud Bull 36:126–130
The Energy and Resources Institute (2003) Coping with Global Change: Vulnerability and Adaptation in Indian Agriculture
The Energy and Resources Institute (2006) Adaptation to Climate Change in the context of Sustainable Development
Tideman E, Khatana V (2004) Drought coping Strategies in Semi-Arid India. Indo-German Bilateral Project
Todd C (1829) Annals and Antiquities of Rajasthan, GBD, Jaipur
Tompkins EL, Adger WN (2004) Does adaptive management of natural resources enhance resilience to climate change? Ecol Soc 9:10
UNEP (2004) Poverty-biodiversity mapping applications. In: Presented at: IUCN World Conservation Congress, Bangkok, Thailand, 17–25 Nov 2004

United Nations (2009) Drought risk reduction framework and practices: contributing to the implementation of the Hyogo framework for action. United Nations secretariat of the International Strategy for Disaster Reduction. Geneva, Switzerland
United Nations Environment Program (2011) A practical framework for planning pro-development climate policy
United Nations Framework Convention on Climate Change (2007) Climate change: impacts vulnerabilities and adaptation in developing countries
United Nations General Assembly, 1997. S/19-2. Programme for the Further Implementation Agenda 21. 19th Special Session, 23–27 June, New York
USAID (2007) Famine early warning systems network (FEWS-NET). http://www.fews.net/. Accessed 24 Dec 2007
Vincent K (2004) Creating an index of social vulnerability to climate change for Africa. Working Paper 56, Tyndall Centre for Climate Change Research and School of Environmental Sciences, University of East Anglia
Vincent K (2007) Uncertainty in adaptive capacity and the importance of scale
Vulnerability and Adaptation Program in Semi-Arid India (2009) Climate Change Vulnerability & Adaptation from Rajasthan and Andhra Pradesh. Swiss Agency for Development and Cooperation
White DA (2000) Drought Policy monitoring and management in arid lands. Ann Arid Zone 39:105–129
WHO (2005) Immunization coverage cluster survey—reference manual. WHO Document Production Services, Geneva, Switzerland
WHO/Roll Back Malaria (2003) Economic impact of malaria: household survey. Williamsburg Emergency Management, 2004. Household natural hazards preparedness questionnaire. Peninsula Hazard Mitigation Planning Committee, Williamsburg, VA
Wilhite DA (2000) Drought planning and risk assessment: status and future directions. Ann Arid Zone 39:211–230
World Bank (1997) Survey of living conditions: Uttar Pradesh and Bihar. Household Questionnaire, Dec 1997–Mar 1998
World Bank (2008) Climate change: impacts in drought & flood affected areas: case studies in India. Social, Environment and Water Resources Management Unit
World Bank (2010) Villages in Andhra Pradesh Innovate to Fight Drought and Climate Change
World Food Programme (2007) Vulnerability analysis and mapping (VAM). http://www.wfp.org/operations/vam/. Accessed 24 Dec 2007
Wu S, Bates B, Kundzewicz ZW, Palutikof J (2008) Climate change and water. Intergovernmental panel on climate change. IPCC Secretariat, Geneva
Yamin F, Rahman A, Huq S (2005) Developing the linking climate adaptation network: progress and prospects. Inst Dev Stud Bull 36:123–125