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Case Study-05

Enhancing Institutional and Community Resilience to Climate Change Impacts in the Jodhpur City: Water Stress

Sridharan N; Pandey R U; Bhiwandiwala J; Mano A

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Contact: School of Planning and Architecture Bhopal

Email: ramapandey@spabhopal.ac.in

Website: www.spabhopal.ac.in

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Enhancing Institutional and Community Resilience to Climate Change Impacts in the Jodhpur City: Water Stress

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Abstract: The scarcity of water and intermittent flooding has now become a common phenomenon in cities across India. The traditional or latent knowledge was being used historically for water resilience in India. Jodhpur city in Rajasthan, taken up for this study, found apathy of public institutions as one of the causes of water stress in the city. Co-production of water is being undertaken through community efforts to address the water stress, using traditional methods. Through a detailed interview, visual observations and interactions with the officials, community-based individuals, local leaders, etc., the study approaches Jodhpur's water resilience in various wards within the city. The study through its scientific analysis brings out that, the water stress can be addressed through tacit knowledge and co-production of water.

1 Climate Resilient Urban Development and Water Stress

Climate change risks cannot be eliminated but adverse impacts can be minimized through adopting climate-resilient strategies to achieve the development goals. Water is one of the most vulnerable sectors to climate change impacts as per the analysis of the adaptation components of Nationally Determined Contributions (UNDP, 2019). Hence need further exploration to come up with strategies for building resilience. The concerns over the availability of water (Science, 2015) and inundation frequency arising out of the increase in extreme precipitation (Eekhout, et al., 2018) are affecting the cities. Water stress includes several physical aspects related to water resources, water scarcity, water quality, environmental flows, and the accessibility of water (U N Global Compact, 2014). India as per the World Resources Institute (WRI) report falls under the 'high' water-stressed category of countries (LUO, et al., 2015). The scarcity and flooding have now become a common phenomenon in cities across India. Delayed monsoons, overexploitation of groundwater, mismanagement in the water supply are the most common causes of water stress in the Indian context.

In arid and semi-arid regions, water resources are very sensitive to climate variability. In the Jodhpur region, climate change is projected to exacerbate water scarcity and increase the recurrence and intensity of droughts (Kahil, et al., 2015). According to the United Nations

Environmental Program (UNEP), 40% of the global terrestrial areas are vulnerable to desertification. The northwestern part (arid and semiarid region) of India, is one such area that falls under this. Water stress in the arid and semi-arid climatic zones of India is getting aggravated with time and needs to be looked from the perspective of enhancing community and institutional resilience through reckoning the practices adopted by communities. Communities in these places have been managing and coping up with stress effectively through traditional knowledge systems. Due to increased population pressure and limited water resources, dependency on the traditional system has been given away for an easy piped water system.

The exposure to water stress though is becoming well understood, but practices that increase the scope and strength of the relative vulnerability of communities to stress are not yet accounted for in decision making. Moreover, the interactions between the social systems and the natural systems that exist in the form of traditional knowledge systems require exploration for integration in the framework of community and institutional resilience. It is essential to understand what facilitates the empowerment of people, local organizations and governments to adapt to climate change stresses in a way that minimizes vulnerability and promotes long-term resilience.

1.1 Community Resilience

The policy attention has now shifted from vulnerability approaches to a Resilience perspective as it is a more proactive and positive community engagement approach (Kais & Islam, 2016). A study (Chapman, et al., 2018) focusing on psychological aspects highlights that community resilience is to be seen as combination of the 'static resources and characteristics' of the area acting as buffer to reduce vulnerabilities and the 'agentic qualities' of community itself to adaptively prepare, respond, and grow in response to environmental challenges or harmful event. The resilient community has a deep attachment to the place and community, with strong bonds between community members and active participation in community life (Chapman, et al., 2018). The way people organize within a place to respond to environmental or climatic challenges also depends on the ecological resilience of the natural settings in which people live (Cutter, et al., 2008). The traditional ecological systems that used to exist in a place to address the environmental stresses provides enough flexibility and empowers the communities to thrive and strive even in adverse situations. Community competence as reported in Chapman et al. (2018) for taking collective action and a sense of collective empowerment to creatively and flexibly deal with the challenges is an important quality of community resilience. A resilient community underlies the vulnerabilities and capacities of the community and its connection and interaction with the external environment (IFRC, 2014). The role of natural resources in mitigating the effect of disasters and how the stresses get aggravated due to its degraded conditions is well acknowledged by various researchers. Community resilience hence is not only a measure of the sustained ability of a community to utilize available resources to respond to, withstand, and recover from adverse situations but also how well the natural resources are conserved for improving the living conditions.

1.2 Institutional Resilience

The role of interdisciplinary institutions in addition to community and ecological resilience is extremely important in removing barriers that exist in implementing the proposed strategies for enhancing resilience to various environmental challenges. In the context of the responses to climate change impacts also, the emphasis is on to consider a range of factors such as Institutional; Political; Cultural; Physical; Social; Environmental; Economical, and Human for effectively building up the resilience (Turnbull, et al., 2013); (SPC, SPREP, PIFS, UNDP, UNISDR and USP, 2016). This reiterates our view that resilience for climate change encompasses all disciplines.

The research of Rodima-Taylor et al. (2012) highlights that institutions are decisive factors in enabling and shaping the adaptation strategies to the impacts of climate change. A clear climate change cause and effect of the existing institutions is required for formulating effective adaptation strategies (Oberlack, 2017). The interconnectedness between the informal, formal, endogenous and externally initiated institutions can be beneficial in the process of adaptation and innovation (Rodima-Taylor, et al., 2012). In the context of socio-ecological system, institutional resilience is i) to withstand disturbances and thus provide stability and reduce uncertainty, and ii) change to react to the uncertainties of a changing environment or change in the social systems (Young, 2010). Institutional resilience is about ensuring continuity of relatively stable institutions and flexibility to change in institutions that are easier to change (Herrfahrdt-Pähle & Pahl-Wostl, 2012). The institutional resilience, therefore considered for this study is to overcome the barriers that exist in the implementation of adaptive strategies and improving the linkages between community and institutions.

2 Case Study City Selection

2.1 Selection of the case study city Jodhpur

Semi-arid regions (SARs) are highly dynamic systems that experience extreme climates, adverse environmental change, and a relative paucity of natural resources. Due to physiographic constraints and harsh climate, Jodhpur has always experienced issues of water availability, water quality, water accessibility, and high temperatures. Despite the presence of a traditional water system, the region is under water stress. Contrastingly, the abundance of water in some parts of the city has also increased the water risks. Jodhpur is facing a major challenge of a rising groundwater table that is damaging the underlayer of the core city (UMC, 2018). It requires 24 hours pumping of excess groundwater to prevent flooding of the basement of buildings.

Mean annual rainfall (1971-2012) of the district is 374 mm whereas rainy days are limited to a maximum of 15 in a year. There is a shift in rainfall patterns as the rainy days have decreased but the intensity of rainfall has increased over the period. July used to be the wettest month but for the last few years, August has become the wettest month. The results of the Mann-Kendall test (90% confidence level) applied on rainfall data for a period from 1979 to 2014 indicates a significant increase in the rainfall for the month of September.

The city of Jodhpur falls in the Marwar (the desert), a water-scarce region located in the southwestern part of Rajasthan, India. Hence, the city is renowned to have in place a unique system, surviving for the last 500 years, to collect

rainwater through engineering excellence and thoughtfulness of the past rulers. Lying in the scrub-forest zone, it is the largest city in the region with 2% of Rajasthan's population. The potential of the region for harvesting rainwater due to its physiography (Figure 1) was one of the major reasons for the selection of the present location of the city by the then rulers. The plateaus located in the west, north and north-east part, of the city, serves as a water catchment for 50 functional surface water bodies like Nadis (small ponds used for storing water from an adjoining natural catchment during the rainy season), Talaabs (ponds), tanks, canals, and lakes (Pangare, 2015). The physiography indirectly feeds water to 154 groundwater bodies like wells, Baoris and Jhalaras (both step-wells) (Pangare, 2015). Jodhpur was the only city in India where every single drop of water used to be conserved but this has changed over the past years.

Jodhpur has the highest coverage of tap water in Rajasthan, which is incidentally, one of the reasons behind the degradation of the traditional water bodies. It is ironic to find a settlement located in a semi-arid region, which is water-scarce due to the fact that available water is not being utilized by the community

2.2 Contextual background of Jodhpur city

Jodhpur is the second-largest city in terms of population of the state of Rajasthan. Jodhpur city as per the Census of India 2011 had a 1,033,918 population, an increase of 21% in comparison to 856,034 population of 2001. The municipal corporation area of Jodhpur city is 233 sq.km (JMC, 2017). The notified urban area as per Jodhpur Master Plan 2023 has increased to 1,212 sq. km from 423 sq. km in Master Plan of 1996 (UMC, 2018). The city thus is expanding into peripheral areas due to the pressure of increasing population. Jodhpur historically is well connected by rail and road so developed as a trade center and houses many industries and is famous for its handicrafts. The heritage of the city attracts lots of tourists. The government is now focusing on developing Jodhpur as an educational and industrial hub of the region. The existing land use of the city and natural resources are mapped in Figure 1.

With the growth of institutional, industrial and residential areas, there is an increased demand for water supply. Jodhpur gets its daily supply of water from Rajiv Gandhi Lift Canal Water Supply Project (RGLC) since 1997. RGLC is a feeder canal from Indira Gandhi Canal which transports water from the Harike Barrage in Punjab state of India (more than 700km from Jodhpur). The city has about 80% coverage of water supply connections at the household level. The water supplied to the city had increased from 98 MLD in 1997 (CGWB, 2015) to 240 MLD in 2018 (UMC, 2018). This is well within the Service level Benchmark (SLB) of 135 liters per capita per day. The further augmentation of piped water supply from RGLC is not a sustainable solution, in the long run, the use of other local sources such as traditional water bodies can be explored to fulfill the future demand of water.

2.3 Historic evolution of the Jodhpur city and its supporting water system

The city with an imposing Mehrangarh fort on the top of the hill was founded in 1459 AD. The city started growing on the slopes of the hill in a way that respected the fort as the symbolic and physical center. The built form follows the topography of the land and the flow of water (Figure 2). The water harvesting network system

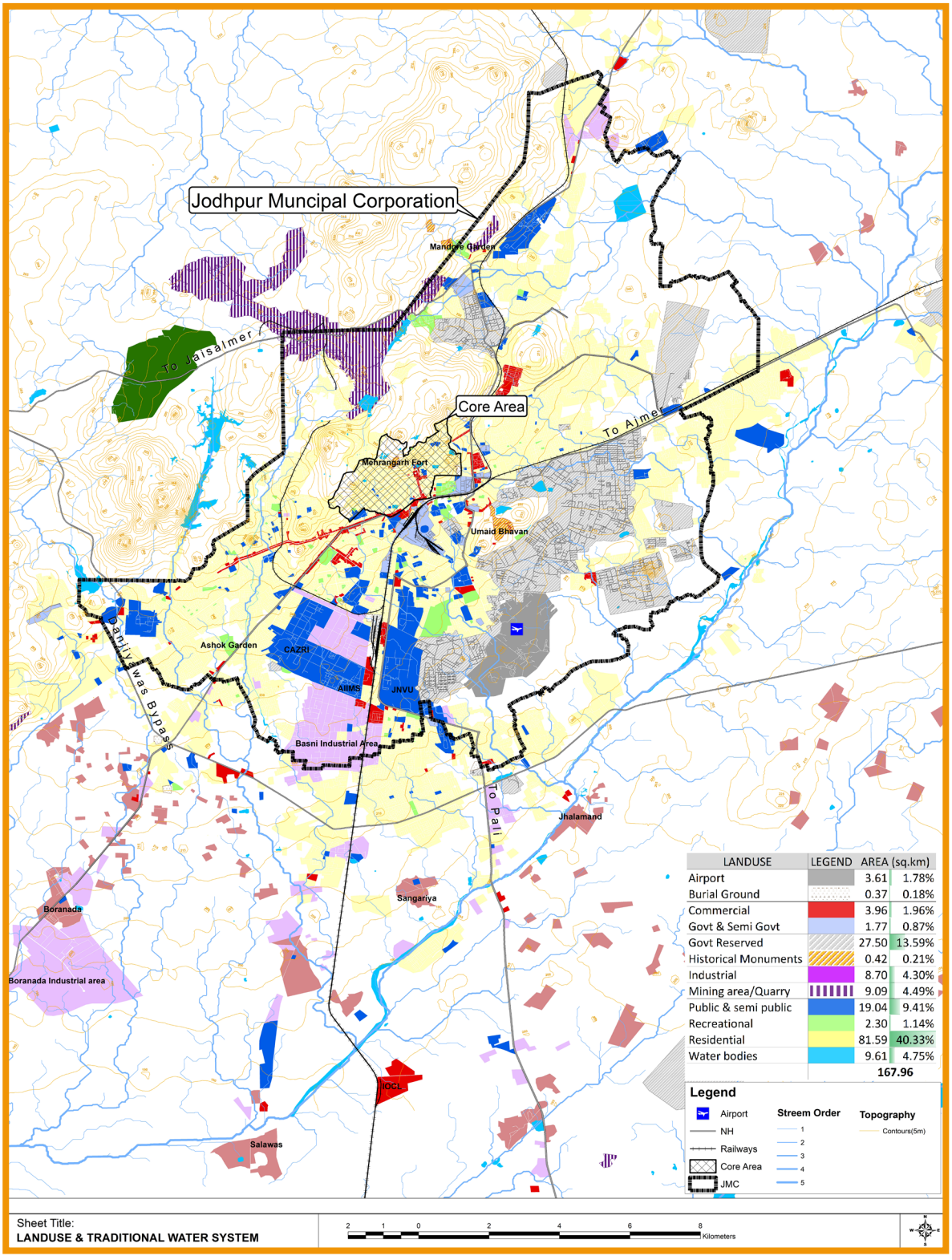

Figure 1. Existing Land use map of Jodhpur city
Source: (SPA Bhopal MPEP Second Semester, 2019)

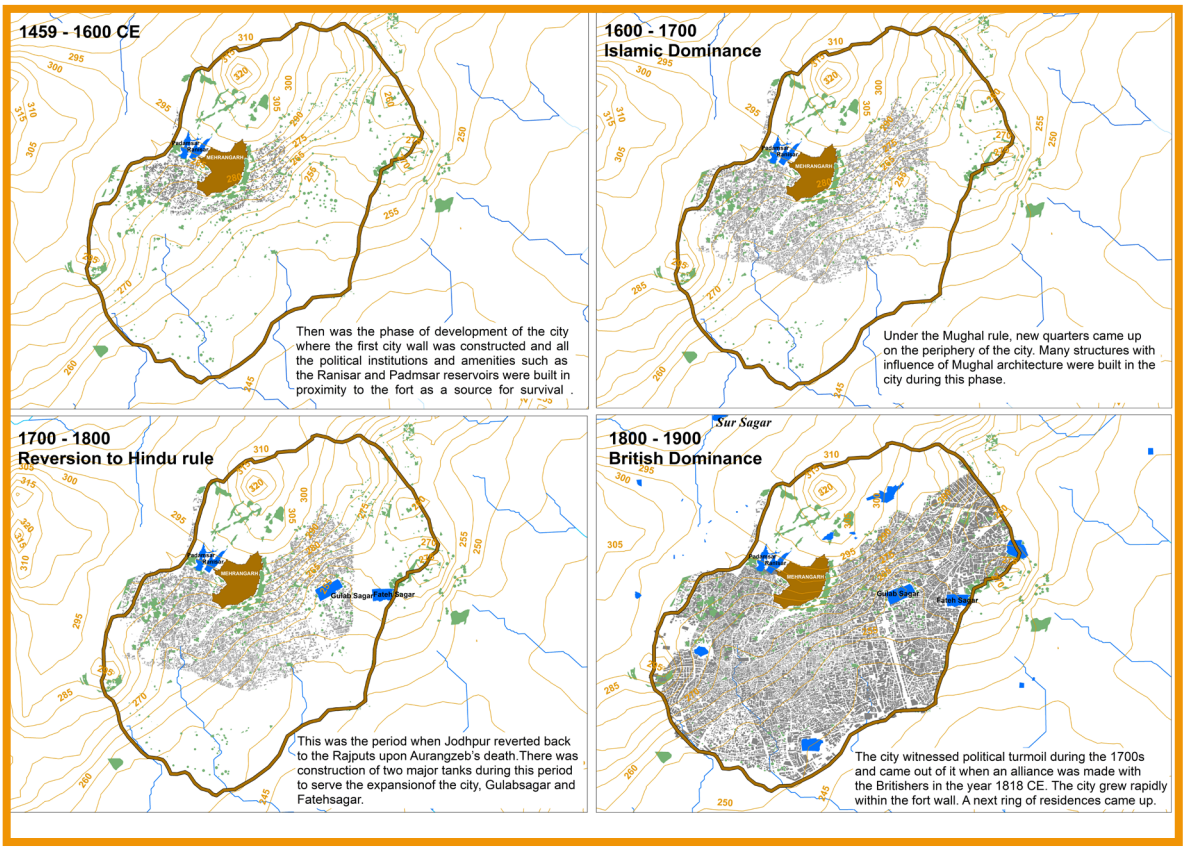

Figure 2. The four phases of the historical growth of the core city of Jodhpur
Source: (SPA Bhopal MPEP Second Semester, 2019)

in the city has evolved with a great understanding and knowledge of its terrain predominantly to harvest even a single drop of rainwater. The water harvesting system has advanced with the expansion of built spaces from 1459 to 1818 AD in four phases (Figure 2). In the first phase, Ranisar and Padmasar reservoirs were built. Many other small tanks and step-wells were constructed in the second phase followed by two important tanks Gulab Sagar and Fateh Sagar in the third phase. The rest of the water bodies within the fort wall were built in the fourth phase. The city has extended extraordinarily after independence outside the historic core up to the periphery in the river basin of then perennial river Jojhri.

In spite of the harsh climatic conditions with hostile terrain, the water system was so durable that it was a main source of water for the city until the public water system supply was introduced in 1897-98. For rainwater harvesting, a hierarchy of water storage structures like lakes (Jheel), ponds (Talabs), step-wells (Baoris/Jhalaras), Nadi (Small pond) and Wells (Kuan/Bera) were built in Jodhpur by the then rulers. According to the survey conducted by the School of Desert Sciences (SDS) in 1989, 229 water bodies were identified of which 75 were surface water bodies and 154 groundwater bodies (Pangare, 2015).

3 Framework of the study

3.1 Methodology adopted

This is an exploratory study conducted through empirical research. The study emphasises the use of qualitative research methods to have

an in-depth understanding of the challenges related to water stress from the perspectives of the study population. The focus of the study was to assess water stress as perceived by the residents in terms of how water has emerged as a concern, how it is affecting their day to day life, how they are responding to these concerns both as an individual and a community, who all are the actors to resolve the concerns and how they are performing? The data in such cases was to be collected through stakeholder interviews, discussions and observations. The framework analysis method is most suitable (Gale, et al., 2013) as compared to other qualitative research methods such as phenomenology, ethnography, discourse analysis, and grounded theory, for analysing systematically the data collected through qualitative surveys. The framework analysis method was therefore selected for conducting this study. Framework method presents a structured overview of summarised qualitative data in a matrix, whereby the content of each interview is entered into a grid with each row representing a respondent and each column an area of investigation (ISTAT, 2017).

The various qualitative survey methods adopted in this research are in-depth interviews, focus group discussions, and observations. Interviews were conducted in the identified survey locations to capture how much people are aware of the changes happening in their surroundings with respect to water systems and the sense of belonging they have and what all mechanisms they have adopted over the years to resist these changes. Group discussions were conducted with residents as well as city officials managing the city. The city officials were asked about the current practices adopted in managing the water, wastewater system and solid waste management of the city.

Framework analysis method followed three major steps of open coding where the organization of raw data into transcript was done, axial coding in which categories were highlighted through keywords from the transcript and lastly selective coding where these categories were linked to formulating a story of final interpretation. The analysis led to understand different aspects of institutional and community resilience towards water stress.

Remote sensing techniques such as NDVI (Normalized Difference Vegetative Index); NDWI (Normalized Difference Water Index); NDBI (Normalized Difference Built-up Index) were used to identify Spatio-temporal changes in vegetation, water and built-up areas within the city. The final outcome of the study focused on developing a conceptual framework where the emphasis was on using the local context and experiences of the community to build resilience.

3.2 Sites for detailed study

The growth pattern of the built-up areas, variations in vegetation cover along with the spatial changes in the water bodies led to the selection of study areas in the periphery of the city. The temporal analysis of NDWI indicates a significant reduction of surface water bodies in core and peripheral areas from 16.38sq. km. in 2001 to 11.4 sq. km. in 2018. Water bodies are getting encroached in the core area while in peripheral area depletion of water bodies were noticed due to anthropogenic activities such as disposal of effluent from industries and sewage of the city. The degrading conditions of water resources (Murty, 2016) (CGWB, 2015)were further corroborated with the evidence related to the water quality and on-field reconnaissance survey.

The three selected sites (Figure 3) in the periphery includes 1) Salawas village, showcasing urban transformation, located alongside discharge

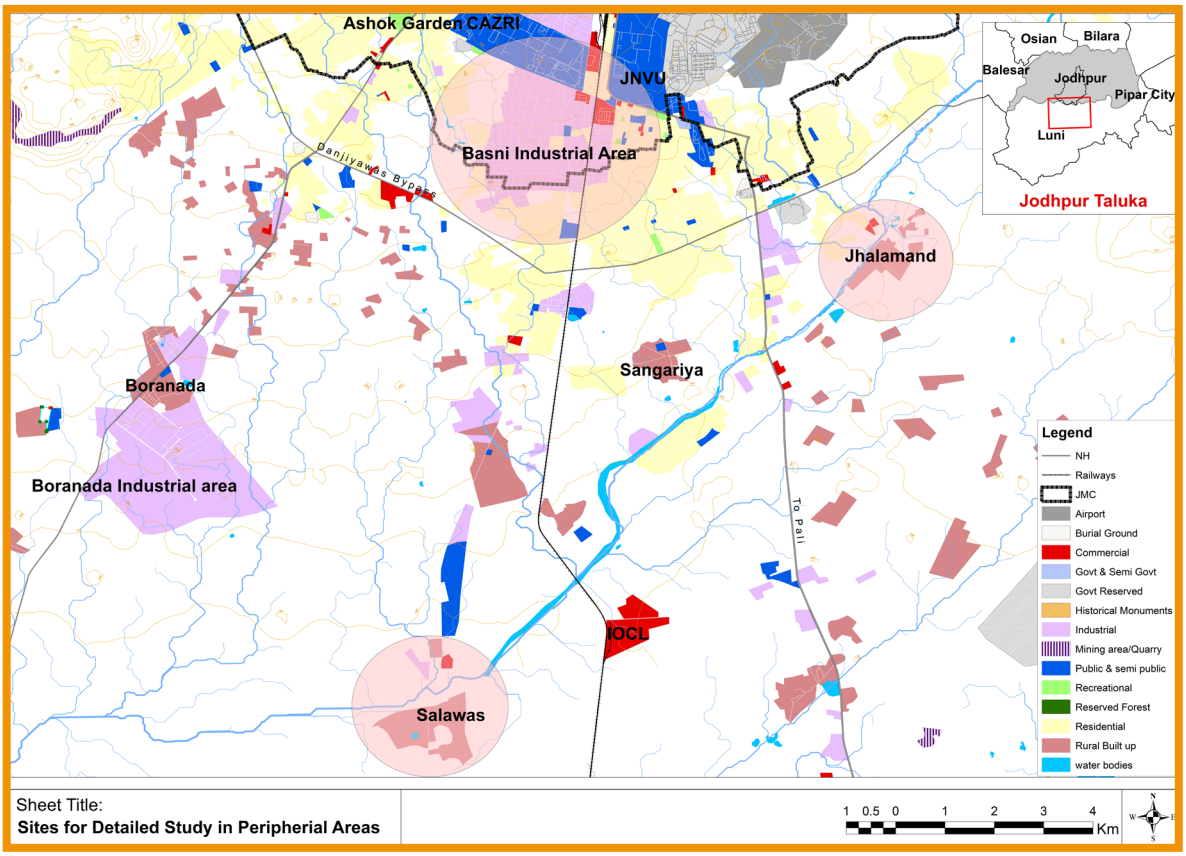

Figure 3 Sites for Detailed Study in Peripheral Areas
Source: (SPA Bhopal MPEP Second Semester, 2019)

point of industrial effluents from the city; 2) Basni, an industrial area located within the municipal boundary of city; 3) Jhalamund village, located along the Jojhari river close to the city sewage disposal site.

The core city was selected on account of i) the presence of traditional water bodies that are getting degraded; and ii) rising groundwater level resulting in 24 hours pumping of water to avoid flooding in basements of residences. The transect walks along with local experts, to know the ground conditions of traditional water bodies led to the selection of six locations: Brahmpuri; Toorji ka Jhalra and Gulab Sagar; Naya Talaab; Taapi Baori; Govind Baori; and Sujoti Gate areas as highlighted in Figure 4.

3.3 Survey methods

The qualitative data in the selected six locations in the city core and three locations in the periphery was collected by the research team of 18 members divided into six groups of three members. All the teams were trained together and briefed on the procedure of conducting interviews including the specific role of each of the members in the team. The task assigned to the team includes the observation, asking questions, taking photographs and recording audios and videos.

The total number of surveys conducted is 77 in number out of which 51 surveys are of city core area and 26 surveys of the peripheral area. Random sampling was adopted to select

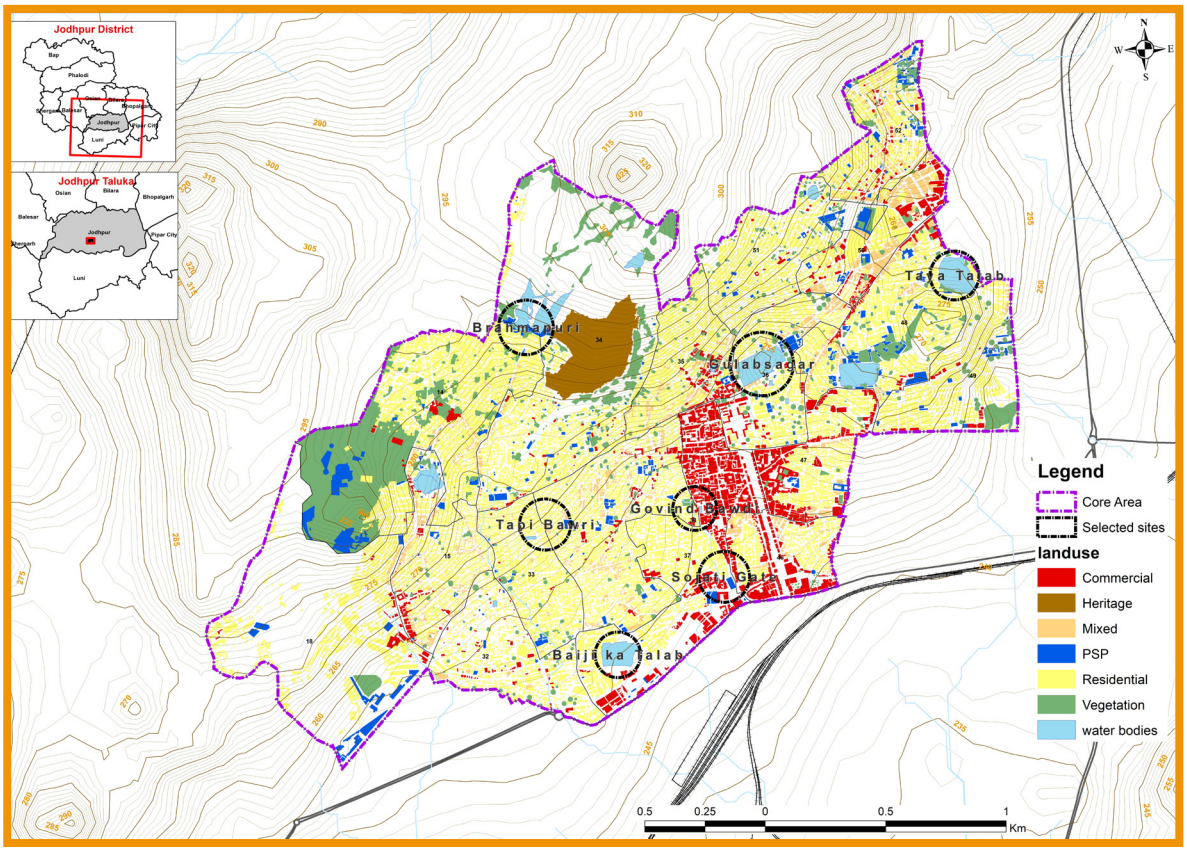

Figure 4 Selected sites in the core city area for detailed study
Source: (SPA Bhopal MPEP Second Semester, 2019)

Samples	City Core Area	City Peripheral Area	Jodhpur Study Area
Total no. of surveys	51 (Male = 36, Female-15)	26 (Male = 20, Female-06)	77 (Male = 55, Female-22)
Age Group: 10-24 years	04	02	06
Age Group: 25-50 years	27	12	39
Age Group: 51-60 years	06	10	16
Age Group: 61 & above	14	24	16

Table 1 Sample Population Description
Source: (SPA Bhopal MPEP Second Semester, 2019)

interviewees so as to collect responses from varied socio-economic and age groups as reported in Table 1.

4 Assessing Water Stress

4.1 Analysing growth pattern of the city

The changes in the growth pattern of Jodhpur city are mapped and analysed using indices NDBI and NDVI as these indices have a direct or indirect impact on the water system of the city. Landsat images for the years 2001, 2011 and 2018 images downloaded from the USGS website were used to compute NDBI and NDVI.

The decadal built-up growth of Jodhpur as shown in Figure 5 indicates that the city is sprawling towards south and south-west. The plateau and hills in north and north-west direction acts as barriers to growth towards these directions. The concentration of built-up within the Municipal Corporation area from 2001 to 2011 has increased from 53.55sq.km. to 68.28.km which further increased to 88.17 sq.km. in 2018.

The core area has become more compact over the period of time with built-up increasing from 74% of the total core area in 2011 to 81% in 2018. Encroachment over water bodies and reduction in vegetation due to unplanned development are few causes of overcrowding. The NDVI indicates loss of dense vegetation as shown in Figure 6 whereas sparse vegetation has increased in the area.

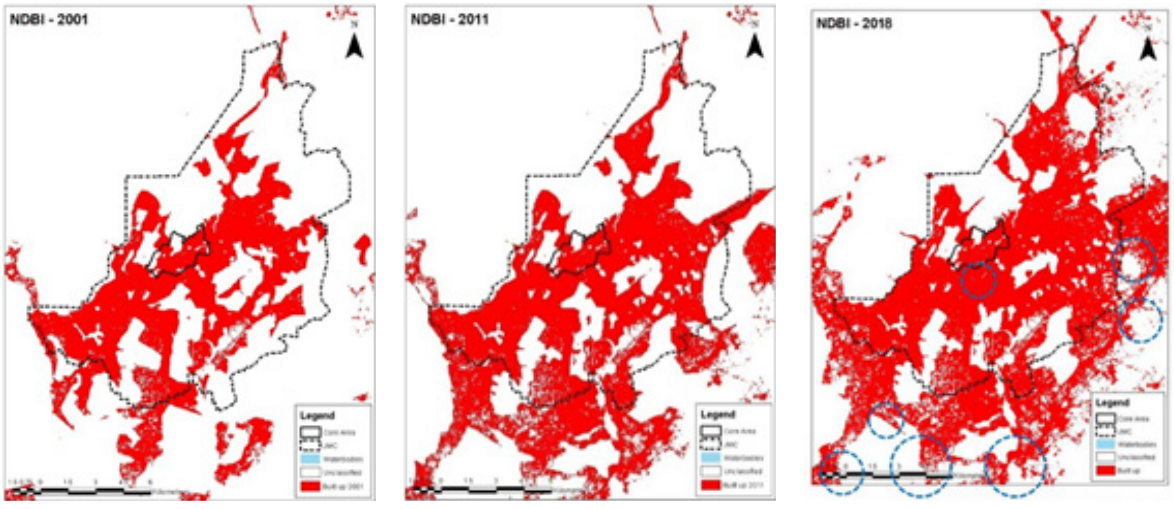

Figure 5 NDBI for the years 2001, 2011 and 2018
Source: (SPA Bhopal MPEP Second Semester, 2019)

4.2 Assessing water stress: respondents' perception

Textual data was generated after listening to all the recordings that were in audio or video format from the field survey. The transcripts generated were examined thoroughly to find out the as-pects that were relevant to the water stress. 97 aspects related to water stress were identified and clubbed into 23 factors on the basis of their characteristics. The responses of interviewees were then sorted and compiled in an excel sheet wherein the columns had responses related to the factors and rows represented each of the respondents. Further, these factors were grouped under (i) Causes (ii) Impacts (iii) Coping Mechanism (iv) Common Understanding and (v) Awareness, separately for core and periphery. The analysis of these 23 factors, helped in assessing people's perspective towards the water stress and how they are coping up with the stress.

The interviewees' responses under the identified factors are discussed in the following sections:

4.2.1 Causes of water stress

Construction in catchment areas of water bodies, encroachment on canals, disposal of wastes into the canals resulting in blockage and discontinuation of rainwater harvesting techniques are some of the reasons behind degradation. The traditional water systems in core areas have been losing their value due to non-functional water canals which once used to maintain the quality of water through circulation. Due to the disruption of the circulation of water and unused water bodies, the Baories are covered by algae in many areas. Respondents described the condition as follows:

"...water from Baori is not used. We used to draw water earlier, there was continuous inflow but since we are not withdrawing water anymore, it is unused and stagnant, not fit for consump-tion..."

"....it (Gulab Sagar) is not in good condition. Full of algae! Fishing was once done in Gulab Sagar, it is full of weeds now..."

Many respondents indicated that in the core area, the quality of water supplied for drinking has deteriorated over time. The respondents stated:

"We use RO (Reverse Osmosis water purifier) or alum in the drinking water. Earlier it wasn't required, water was clean."

The main reasons for water pollution are solid waste and sewage disposal into water bodies. Atti-tude towards Solid Waste Disposal is a grave concern. The survey highlighted the irresponsible behaviour of the residents in the vicinity of the water bodies. People could be seen disposing of household waste including food waste to feed the animals near the water bodies and roadside. The uncontrolled dumping of waste is leading to serious environmental and health problems. As described by residents:

"...government has made provisions for waste management; it is the people responsible for the poor conditions in the area. People go for fish feeding; how much will the fish consume? Hun-dreds of people take kilos of flour... water is getting degraded..."

"...whenever they cook at 1 or 2 pm they'd throw the garbage on the streets, nobody uses a dustbin. The person who collects the garbage comes around 8 am but these people keep their garbage out for collection at 11 am, so there is nobody to clean..."

The municipality official, on the other hand, said:

"...our work becomes difficult due to the lack of awareness among the residents. I have request-ed higher authorities to place volunteers on every point but nobody has listened... My duty ends at 2 pm, after which people come and throw garbage as they know there will be nobody to keep a check on them."

The combined system of stormwater and sewerage due to its inadequate capacity to carry the pumped out excess groundwater round the clock results in backflow. This sewerage water either waterlogs the low-lying areas or drains into water bodies. As per residents, the design of the sewer network is against the flow of gravity leading to waterlogging and overflow in many low-lying areas. The flooding was also attributed to haphazard development within the core city. Respondents also commented on sewage water being disposed into the ponds, leading to foul stench in the area.

"...it is a common knowledge here that the drainage system is faulty, which is leading to water-logging..."

"There are many cases of waterlogging as the drains are improperly laid and are choked. We all know that the drainage system is wrongly designed. Still, nobody has taken initiatives to cor-rect this."

"...as our house is situated in the low-lying area, flooding occurs. The level of the sewer line is high so water enters our house..."

In the water-scarce region of Jodhpur, inefficient stormwater management is also causing stress. As the areas get flooded even after short spells of rain.

Piped water supply has solved the problem of water scarcity in the core city area of Jodhpur. However, what was once considered a boon for the locals, has also become one of the causes of water stress in recent times. The respondents revealed that water is wasted regularly in washing cars and cleaning roads (in-front of the houses) contributing to the rise of the groundwater level.

"If you visit the old city early in the morning, you will see people washing their cars and women cleaning their houses with water."

In peripheral areas, the main cause of water stress is the brackishness of groundwater due to the infiltration of sewage water and industrial effluents. The water of the Jojhari river which re-ceives untreated liquid waste from industrial areas and sewage of Jodhpur city is also contami-nated.

"There were a lot of wells earlier, we used to grow a variety of vegetables like chillis, brinjals, tomatoes, lady-fingers, onions and more. Now the water of the river has all turned red, it has become dirty and the situation is the same as the water in the wells."

The water scarcity prevails in the areas outside the city where water is supplied once or twice a week during summer months. Due to this, the livelihood of the people is affected. To make up for this, residents depend heavily on private tankers and store the water. One of the respondents said:

„...We get water sometimes, once in 4 days for 1 hour, that too salty water, in summers once in 6-9 days..."

In Salawas, participants raised concerns over the degraded quality of Jojhari River and perceive the existence of the Common Effluent Treatment Plant (CETP) to be the reason for pollution.

"Since the wastewater of Jodhpur is released here, pollution will obviously occur. Earlier we used to fetch water from Natta Baori, now it can't be used because of the contamination."

In the Basni industrial area, industrial effluents get mixed up with sewage causing flooding dur-ing the rainy season.

People though are aware of contamination of both groundwater as well as surface water but are equally responsible for the degradation of water bodies. Due to a lack of efficient waste man-agement in the residential areas of Salawas, Basni and village Jhalamand, the household waste is either burnt or disposed into the river.

4.2.2 Impacts of Water Stress

Due to rising groundwater in the core city, people suffer losses in health and infrastructure. The issue arose in the past decade, with various researchers and reports attributing different reasons for the problem. The reason for increasing groundwater levels has been investigated multiple times by various institutes and government departments but there is no consensus in concluding the reason behind the same. The unused groundwater and high-water table are leading to the flooding of subterranean structures and basements which were designed to serve the inhabitants in the hot summer months. The authorities in their short-sightedness use energy to pump water every day from these water bodies and drain it to sewer lines. This water having contaminants is then disposed of to the redundant river basin thereby raising pertinent questions of resource management and resilience.

Weakening building structures is causing people especially the shop owners to shift from locations like Sojati Gate area, a commercial zone, to other parts of the city. It has adversely affected the livelihood. The basements and ground floors suffer damage due to dampness. The basements are full of water for year-round. The land values of properties are also getting affected. Respondents stressed the problem as follows:

"...due to this issue, if any disaster occurs in Jodhpur like an earthquake, buildings will collapse as the buildings have become very weak. Our lives are in acute danger"

"After we have emptied water from the basement, it gets filled again in two hours. We have been facing this problem for 8-10 years now. Earlier the pressure was quite low, not it gets filled even more quickly."

"We cannot rent the ground floor because of

dampness. Why would anyone take a room for rent with dampness all over the walls?"

People in the core city complained about health issues due to stagnant water. As per the respondents, the causes are the unkempt water bodies which act as breeding grounds of mosquitoes. The common diseases in the core due to stagnant water are mosquito-borne diseases, ty-phoid, and jaundice. A respondent in Naya Talab area quoted:

"...every new disease starts spreading from here. The Talab is so messy... there are mosquitoes everywhere..."

In peripheral areas too due to contaminated water people suffer from skin diseases. Vegetables grown in contaminated water are a major cause. The unavailability of health facilities further adds to this. A woman said:

"...skin diseases are common among children and elders. We use ointments and it gets better..."

Change in rainfall pattern has impacted the agriculture in peripheral areas as people have shifted from growing Wheat to Bajra, as Bajra consumes less water.

"Earlier it used to rain heavily, 15-20 years ago. Now, this is not the case. This has affected our agriculture production. Its God's will now..."

Due to water stress, livelihood gets affected. Delay in monsoon affects the Kharif crops in the fields, especially wheat. Rainfed vegetables also get hit due to irregularity in monsoon. Therefore, many farmers have shifted to daily wages labour work.

4.2.3 Coping Mechanism to Water Stress

The respondents in their interviews have mentioned coping mechanisms to water stress such as revival of traditional water bodies, water conservation practices and the usage of traditional wa-ter bodies as an alternate source. Dependency on Baori and Jhalra is limited to bathing or household chores. The wells are still in use for drinking water. A respondent said:

"We use water from the Baori for cleaning utensils and house and sometimes we even take baths in this Baori".

Although people are ignorant about water conservation some people still conserve water in their day to day affairs. Female quoted:

"...we don't wash clothes every day, we use the washing machine only when we have enough clothes to wash...."

"...After mopping, we use it for watering the plants and also after washing utensils we use it in the toilets for flushing...."

To resolve the rising groundwater problem government has taken initiative to pump the excess water out by installing pumps. Many respondents though are not satisfied with this unsustainable provision. A resident said:

"Government has started pumping the water in some areas, but now they are not working properly, only 2-3 pumps work"

With the persistent efforts of a French-born Irishman, some of the water bodies in the core city are now clean. Many respondents attributed the cleanliness of the water bodies to him. Later other NGOs like Mehrangarh Fort Trust and Urban Development Department also started initia-tives for conserving water bodies. These

have now become a recreational point for the people.

4.2.4 Common Understanding towards Water Stress

People are experiencing changes in climatic conditions and acknowledged that these changes are affecting their livelihood and health. Though respondents are aware of the ill effect of dumped garbage but did not show any empathy for bringing out behavioural changes in themselves. Ac-cording to one of the respondents:

"...people keep their houses clean, but are least concerned about their surroundings; they litter the place where they eat, whether it be the roads or water bodies..."

"...unless they start accepting and considering these assets as their own nothing will make any difference in their lives, environment or the water systems..."

The city is very rich in its cultural traditions that get reflected in their way of living and belief systems. One such cultural belief is the immersion of religious offerings like flowers, coconuts and other puja objects in water bodies. People could also be seen feeding fishes during morning and evening hours. The sentiment gets echoed in the following statement:

"...we provide food to animals in our locality...for us this is part of charity...no one can stop us from doing these things...feeding birds, cows, fishes, all this is charity..."

While the sentiments of other respondents had some sense of the adverse effect of these activi-ties.

"...whatever they get in the temple, the flowers offered to God or coconut, they put that in the water. Nobody thinks how such activities make Talab dirty, they don't understand this water is sacred, it belongs to God... but they don't realize it..."

But sometimes, these beliefs also contribute to protecting and conserving the natural environ-ment. Peepal tree is considered sacred by many. During the survey, an elderly man mentioned how he and his friends in the neighbourhood had protested against cutting of an old tree and how they had planted more trees along the road.

"...in my opinion we should plant as many trees as possible...I, with the help of my friends have planted about 15-20 Peepal trees along the road"

Despite the core area being inhabited by different religious communities, no communal divide was observed in the area. People share their resources and live in harmony in the areas sur-veyed. In the Brahmapuri area dominated by the Brahmin community, people of all castes and communities are allowed to withdraw water from Jetabera well, the water of which has medici-nal properties. However, the disparity in terms of sanitation conditions and the presence of tradi-tional water bodies is quite evident in areas inhabited by upper caste and lower caste.

People in periphery help each other during times of water scarcity. According to one of the women labourers in Jhalamand area, whenever there is no water supply, which is common in summer months, people in her neighbourhood share water for daily basic chores and other ne-cessities.

4.2.5 Awareness about Water Stress

The awareness of respondents about the water stress has been assessed through their knowledge related to climate change, causes of degradation of traditional water systems, conservation prac-

tices adopted, and the impact of poor solid waste management on water bodies. Residents are well aware of the importance of traditional water systems. The locals take initiatives to clean the Jhalra without any aid from the authorities. As per respondents:

"Earlier all the seasons were in balance, now a day's, summers are extended for longer peri-ods, monsoon period is shorter and sometimes it doesn't even rain"

"...people from the neighborhood keep the Jhalra clean, without any help from the authori-ties..."

Although some people are aware of the hazardous consequences of waste disposal in water bod-ies, yet many could be seen disposing the household waste near water bodies. The sanitation conditions are poor where streets (narrow) are inaccessible to garbage collection vehicle. How-ever, residents blame lack of awareness of proper disposal methods to be the cause of the issue.

"...people throw garbage wherever they feel like, nobody uses dustbins. People should be aware of their acts that might harm society."

In the periphery, all respondents of the Jhalamund area though knew that sewage from Jodhpur city is directly being disposed into the Jojhari river, yet the same water is used for irrigation and livestock rearing.

"People are using polluted water of Jojhari for farming, which causes diseases. Mosquitoes are prevalent everywhere, which causes malaria & dengue"

People are aware of the harmful effects of it on the crops being produced and its consequences

Strengths	Challenges	Opportunity	Threats
• Water quality • Water availability • Piped water supply • Recreational use of revived traditional water systems • Initiatives by NGO's/ others • Sense of community	• Lack of Government interventions • Behavioural aspects related to solid waste management • Degradation of traditional water systems • Rise in groundwater level • Co-existence of piped water supply with traditional water sys-tems • Lack of motivation for the conservation of traditional water systems • Waterlogging • Lack of community participation • Communal/caste disparity	• Reclamation of tradi-tional water systems • Strengthening the existing policies • Mainstreaming tradi-tional water systems using scientific tech-niques	• Rise in groundwater • Loss of built heritage • Loss of economy • Encroachments along with water bodies • Loss of traditional water systems • Property rates, land value affected- rise in groundwater

Table 2 Strength, Challenges, Opportunity, and Threats- Identified from Peoples' Responses
Source: Author

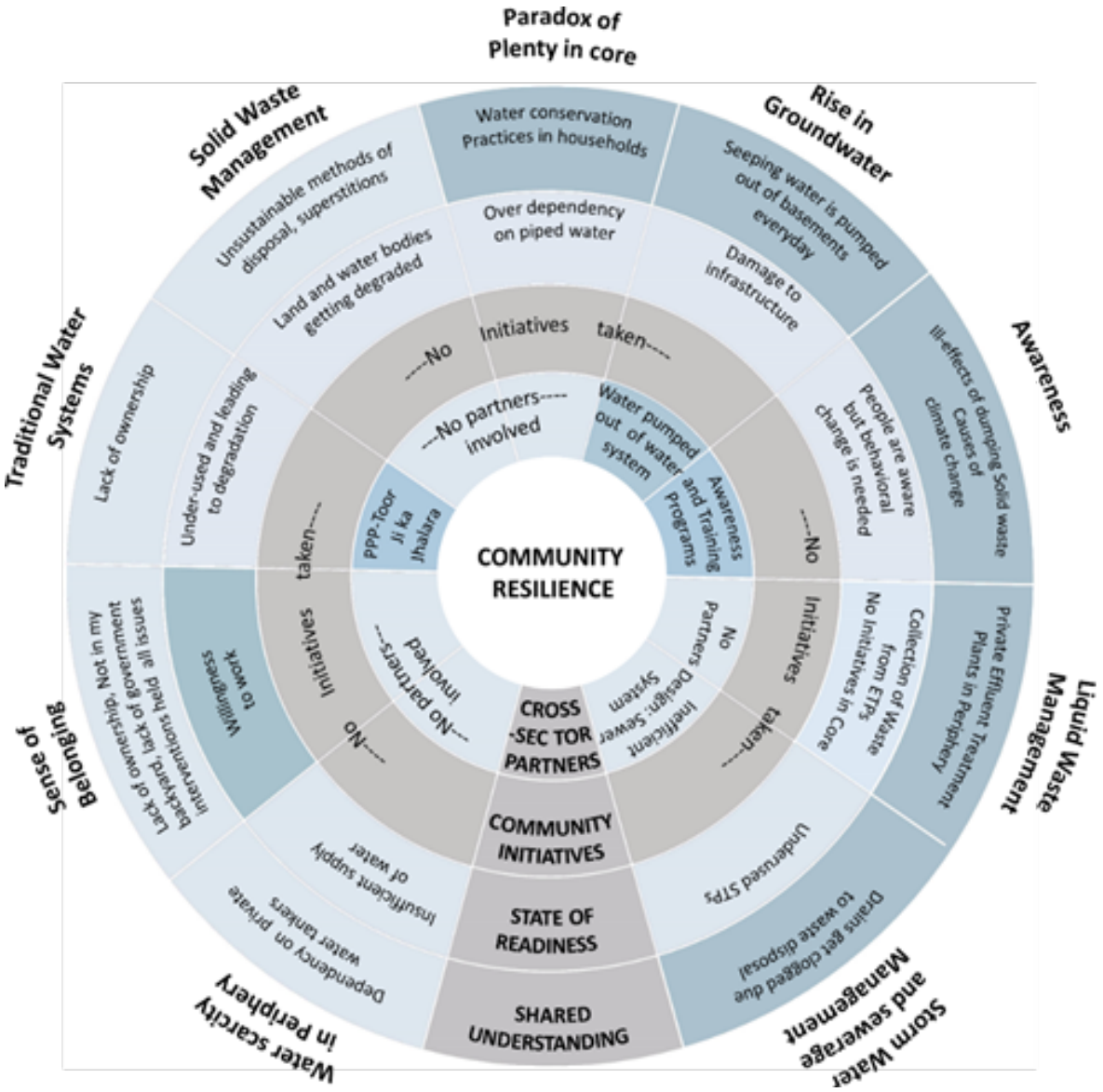

Figure 7 Defining Community resilience to water stress in the city of Jodhpur
Source: (SPA Bhopal MPEP Second Semester, 2019)

on the health of not just the area but the whole region. Since there is no alternative arrangement, they continue using the river water.

5 Discussion

The analysis of responses of the people, field observations and discussions with stakeholders resulted in the identification of strengths, challenges, and the opportunity for building resilience in the study areas (Table 2). This also led to identifying the challenges that have the potential of becoming threats. The challenges for building resilience to water stress can be broadly grouped under: i) Conservation of traditional water systems; ii) Regulating rising groundwater level; iii) Maintaining water quality in peripheral areas; iv) Addressing water scarcity in peripheral areas; v) Efficient solid waste management, and vi) Sewerage management.

Capitalizing on the strength and opportunities, a framework interlinking the four pillars (adapted from the BCR model of Milken Institute of Public Health) for enhancing community resilience to water stress is developed. The pillars are 'Cross-

Challenges	Institutional Barrier
Conservation of Traditional Water Resources	Considered as part of sub objectives and minor task in most of the policies and programs; major initiative towards conservation of such water systems are not considered as prime focus. In fact, district or city level intervention and program to revive them are hardly practiced.
Rise in Ground Water	Priority of GW departments is on sustainable use of resources but not on issues of rising ground water. The issue is faced in the core city which is not paid attention by the authorities nor mentioned in any of the initiative or policies.
Water Quality	Though polices and act takes water quality as prime factor of consideration but still on ground basis the pollution in river through discharge of industrial waste still continues which showcases that there is lack of continuous monitoring or evaluation on ground.
Water Security	Water scarcity also is considered as prime focus for city's policies and programs but the distribution of water is unequal in core and periphery. While there is abundance of water in core there is scarcity of water in the periphery.
Solid Waste Management	Municipal SWM is not effective to comply with the Norms of the MSW (Management & Handling) 2000 Rules. JMC adheres to the conventional approaches of collection and disposal of MSW.

Table 3 Institutional Barriers
Source: Author

sectoral partnerships', 'state of readiness', 'shared understanding' and 'community initiatives' as illustrated in Figure 7. The cross-sectoral partnership means partnership among government, civil society, NGO's and private sectors for resolving the concerns. Shared understanding in this context is how a concern or challenge or opportunities are being acknowledged by the community rather than an individual. How much a community is prepared or the adaptive capacity for addressing the upcoming challenges is 'state of readiness'.

The policies (state and district level) and applicable acts to the identified challenges are re-viewed. This is to understand their role in the implementation and regulation of interventions undertaken to resolve the challenges. The extent of involvement of various actors including NGOs and private institutions in addressing the water stress was also examined. Table 3 high-lights the institutional barriers with respect to each of the identified challenges of water stress.

The analysis revealed that there is a lack of

accountability and grievance redressal in the government system. Ignorance on the part of governing agencies and shortage of workforce are major issues of concern. There is a lack of local-level interventions for the conservation of traditional water system which is not considered as a prime focus in the cities' policies. Some NGOs, however, have taken initiatives to bridge the gap and mobilize public and private actors to com-bat water stress which in turn has also helped in enhancing the social-cohesion. The critical is-sues like rising groundwater levels have not been incorporated in any of the water policies at the state or district level. There exists a gap in continuous evaluation and monitoring of activities like the discharge of industrial effluents into rivers, solid waste management, sewerage management, etc. The disparity in the availability of water in the core and periphery also needs to be addressed. Therefore, a system that addresses issues based on local context is needed. Global issues like climate change and subsequent water stress have not been considered as local level concerns in order to address the vulnerable areas.

The proposed conceptual four pillars of Community and Institutional Resilience (CoIR) framework (Figure 8) integrates the challenges identified both through reviewing the institutional mechanism as well as result of field surveys that are: Conservation of traditional water system; Rising groundwater, Water quality; Water scarcity; Waste management; Community participation; and Governance. With the increase in 'cross-sector partnership', the 'state of readiness' can be improved while with the increase in 'shared understanding', 'community initiatives' can be enhanced. The maximum challenges are identified under the pillar of 'cross-sector partners' and 'community initiatives' which can be met through the

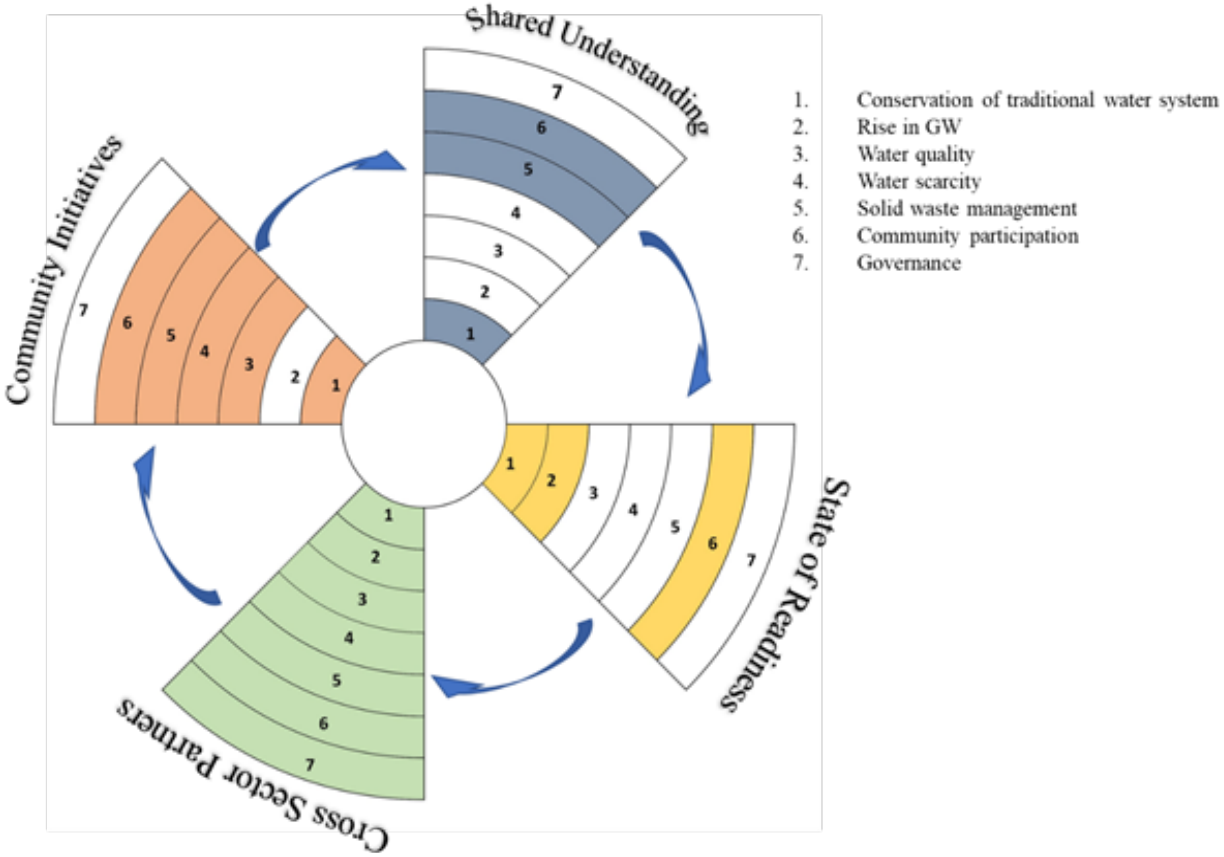

Figure 8 Conceptual CoIR Framework for Building Resilience of Jodhpur city
Source: (SPA Bhopal MPEP Second Semester, 2019)

existing strengths and opportunities of the study area.

The major significant common challenges found amongst the four pillars of CoIR are 'conservation of traditional water system' and 'community participation'. Both these challenges found under each pillar of the CoIR framework require the involvement of community and institutions to strengthen the lacking resilience. Solid waste management is another significant challenge which demands 'shared understanding' within the community to build the 'community initiatives' with the integration of cross-sector partnership. The pillar of 'cross-sector partners' plays a significant role in meeting all the identified challenges. For example- the challenge to 'rise in groundwater' can be best tackled with the help of 'cross-sector partners' which will improve 'the state of readiness' in terms of the existing system's capacity. The integration of 'cross-sector partners' and 'community initiatives' is found to be the best-suited solution to meet the challenge of 'water quality' and 'water scarcity' for enhancing resilience. The challenge of governance though less significant in the study area can be addressed through the pillar of cross-sector partners.

6 Conclusion

The study area is found to display features of water stress indicators viz. water availability, water quality, and accessibility. It was further observed that weak institutional and community resilience have aggravated the prevailing stresses. To bridge this gap and enhance resilience of community and institutions, actions under four pillars such as shared understanding, state of readiness, community initiatives and cross-sectoral partners have been identified from this qualitative study. The qualitative methods had helped in studying the population in relation to their natural setting to identify how the behaviour and experiences had shaped this relationship.

The following conclusions can be drawn with respect to the water stress in Jodhpur.

Lack of coordination amongst communities and institutions: The core city of Jodhpur has had a well-developed traditional water system that was designed to conserve water and make it available to the community. Since ancient times, these traditional water bodies have provided ecosystem services to the communities in Jodhpur, who are responsible for maintaining and pre-serving them. Unfortunately, these ecosystem services have been disturbed due to the ignorance of communities and institutions.

Co-production of water: The degraded water bodies need to be revived in order to augment the existing water supply. This will solve the issues that have come up because of their stagnation. As people have a sense of belongingness to these water bodies, this can be harnessed further for revival. Most of the wells as they belong to small communities or individuals, hence maintained and are being used for potable use. However, most of the Talaabs and Baories, except a few, are in a poor state due to waste disposal, pollution, stagnation or encroachment.

Rising Groundwater: Increase in groundwater level is another serious concern that needs to be addressed. Different studies have predicted various reasons for the rise in groundwater level based on a geological structure in Jodhpur. But through community interactions, it was inferred that as traditional water systems were not used, water seepage increased. For this, it is of utmost importance that the traditional water bodies are brought into use.

Role of NGOs: Over a period, many NGOs have

taken initiatives to revive these traditional water systems and protect these from further degradation. The Mehrangarh Fort is also attending to the issue, to some extent, by catering to certain water bodies like Gulabsagar. However, there is a need to accelerate this process by increasing awareness and improving understanding between the community and the institutions. The prevalent social cohesion should be harnessed for community-level efforts.

Adverse impact on health: Contrary to the core, peripheral areas face water scarcity owing to a limited supply of water. In these areas, the groundwater is brackish and hence, is unsuitable for irrigation. Issues like pollution from industries and the discharge of industrial effluents also need to be checked. The emissions from these industries have had an adverse impact on the health of people living in nearby areas.

Lack of accountability and grievance redressal: The review of the current institutional mechanism indicated certain limitations in governing bodies to address the causes of water stress. There is an absence of local-level implementation of policies for the conservation of the traditional water system as it is not considered as a prime focus area in municipal policies. A local-level critical issue like rising in groundwater too is not addressed in any of the water policies at the state/ district level. There is an absence of a robust system for continuous evaluation and monitoring of activities like disposal of industrial effluents to the river, solid waste management, sewerage management, etc. Therefore, a system is needed which addresses issues based on local context and a suitable monitoring mechanism.

Mainstreaming global concerns at the local level: The impact of national and global level issues like climate change should be considered in all the policies, guidelines and regulations at the local area level within the cities.

Strengthening the proposed four pillars of community resilience which are mutually dependent on each other using strengths and opportunities of the community becomes imperative in the context of Jodhpur city. Accordingly, a Community and Institutional Resilience (CoIR) frame-work is developed. For overall sustainable and resilient development, it is important to bring both community and institution together, so as to improve understanding to build resilience towards different stresses.

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