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# Case Study-10

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

**[N Sridharan; Rama U Pandey; Tania Berger]**

**2019**

Co-funded by the Erasmus+ program of the European Union



Contact: School of Planning and Architecture Bhopal
Email: dr.nsridharan@spabhopal.ac.in
Website: www.spabhopal.ac.in

Suggested Reference:

[Sridharan N; Pandey R U; Berger T (2019) Enhancing Institutional and Community Resilience to Climate Change Impacts in Jodhpur City: Heat Stress]. Report prepared in the BReUCom (Building Resilient Urban Communities) project, funded by the Erasmus+ Program of the European Union. www.breucom.eu

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

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**Abstract:** Climate change with its variations is leading to heat stress and is getting aggravated with time and India is no exception. The vulnerability due to exposure to heat stress varies just not as per the adaptive capacity of the individuals but also the way the built spaces interact with nature. Changing lifestyles along with the adoption of contemporary building materials and design components have been further adding to the stress. The arid and semi-arid climatic zones of India are traditionally heat-stressed zones and these are getting impacted the most due to changing climatic conditions. Communities in these places have been managing and coping up with the stress effectively but with changing lifestyles, finding it difficult to cope up. There is a need for remedial actions in designing and planning of built spaces at all scales of city planning to reduce the stress. Community engagement for understanding the challenges and possible measures to address these thus becomes all the more important to come up with implementable adaptive strategies. The capabilities and effectiveness of various institutions along with community engagement is noteworthy in improving heat resilience. Jodhpur, a historic city located in the semi-arid climatic zone, confronting heat stress due to worsening built fabric to contest heatwave conditions has been selected for enhancing urban resilience. Qualitative as well as geospatial methods are used to assess heat stress. Emphasis is given to the experiences of stakeholders in perceiving the stress as well as in documenting the coping mechanisms. The various institutional mechanisms relevant to addressing the identified challenges are reviewed. A conceptual framework is suggested for enhancing community and institutional resilience.

## 1 Heat stress in the urban environment

The societal impacts of climate change in the future will be larger than historically experienced even if, global warming is kept below 2°C by 2050 (Matthews, et al., 2017). The heatwave conditions will aggravate having deadly consequences on human health making the role of adaptation strategies very critical (Matthews, et al., 2017; Panda, et al., 2017; Murari, et al., 2015). The increased instances of a heatwave with each passing year is affecting India (Government of India, 2016). United Nations Agency also reported India as the most affected country by heat stress (CSE, 2019). The Heat Action Plans (HAP) guidelines were therefore prepared by National Disaster Management Authority (NDMA) in 2016 for cities all across

Figure 1 The Blue city as viewed from Mehrangarh fort. Source: Author

India. The focus of HAP though initially was on early warning, inter-agency coordination, capacity building of healthcare professionals, and building public awareness. The scope now has expanded to addressing concerns of vulnerable groups and implementing adaptive measures (NRDC International, 2019). The vulnerability of the poor across countries to heat stress is a well-researched topic, mainly on the premise that those exposed to high temperatures during summer are susceptible to heat-related implications. The variations to heat stress exposure among the vulnerable population can be explored further for effective policy formulation (Sandhoefner, 2015). Many cities located in low latitude, not just India across the globe have already adopted the HAPs but they do not capture the complexity of the policies, plans, and regulations intertwined with governance system (Mahlkow & Donner, 2017) at a local area level. Emphasis on City plans developed as per local context has been asserted by many researchers to deal with heat stress. The role of community engagement for understanding the challenges and possible measures to address these thus becomes all the more important to come up with implementable adaptive strategies. The capabilities and effectiveness of various institutions in improving heat resilience cannot be ignored while formulating adaptation strategies. The results of a pilot project undertaken by World Resources Institute (WRI) in Indonesia for enhancing urban resilience indicate that for cities to increase resilience in vulnerable urban communities, efforts should reflect communities' specific needs and engage individuals both in the identification and implementation of climate-resilience measures on the ground (WRI, 2019).

Ecosystems in semi-arid regions appear to be undergoing various processes of degradation, aggravating the impacts of climate change in the region. Local warming in semi-arid regions is likely to be greater than the average global warming in the coming decades (Souza, et al., 2015). This means that the already-hot semi-arid regions will be exposed to additional pressures of heat stress in the form of longer heatwaves and a greater number of extremely

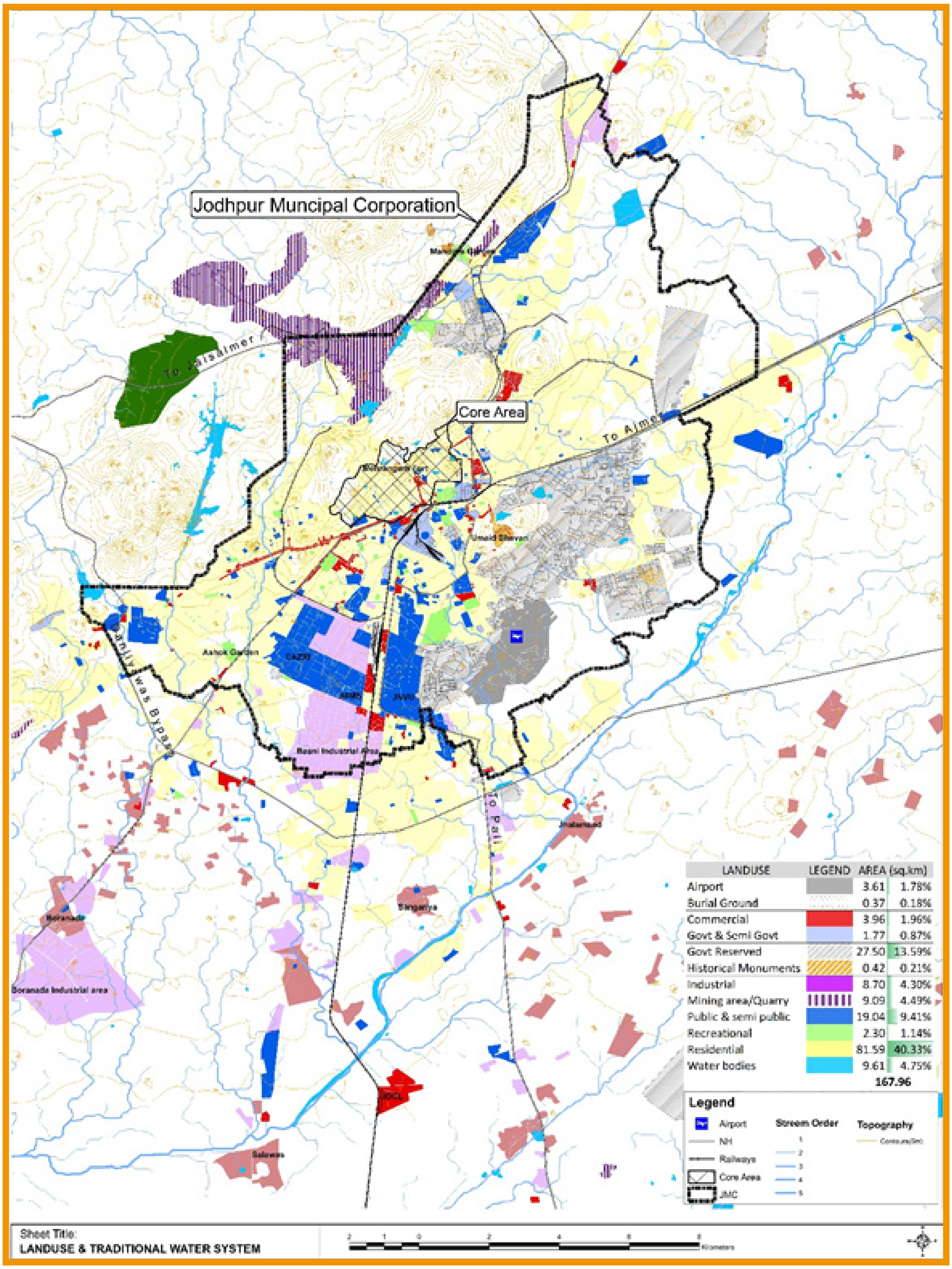



Figure 2 Core city area, municipal corporation area and existing land use pattern of Jodhpur city
Source: (SPA Bhopal MPEP Third Semester, 2019)

hot days. The existing vulnerabilities of semi-arid communities due to high levels of poverty, inequality, and rapidly changing socio-economic, governance, and developmental contexts, shall be exacerbated further by heat stress. This shall adversely affect people's livelihood, health, and well-being. Since human health is highly sensitive to the thermal environment (McGregor, et al., 2015), extreme heat events can increase morbidity and mortality as well as reduce work productivity.

Therefore, with rising global temperatures, semi-arid regions are experiencing additional social, economic, and environmental pressures. To address these issues, future development must take into account these climate-induced stresses.

## 2 City Selection

The semi-arid regions of India are expected to become warmer in the next 50 years. The average summer monsoon rainfall has decreased by 0.01-1.40 mm/year and the mean daily temperature has increased marginally faster than the national average (0.02 °C/year) (ASSAR, 2015). Jodhpur, located in the semi-arid region of Rajasthan has been selected for assessing the community's perception of heat stress. Jodhpur is the second-largest city of Rajasthan and has a population density of 13,438 persons per sq. km, which is the highest in the state.

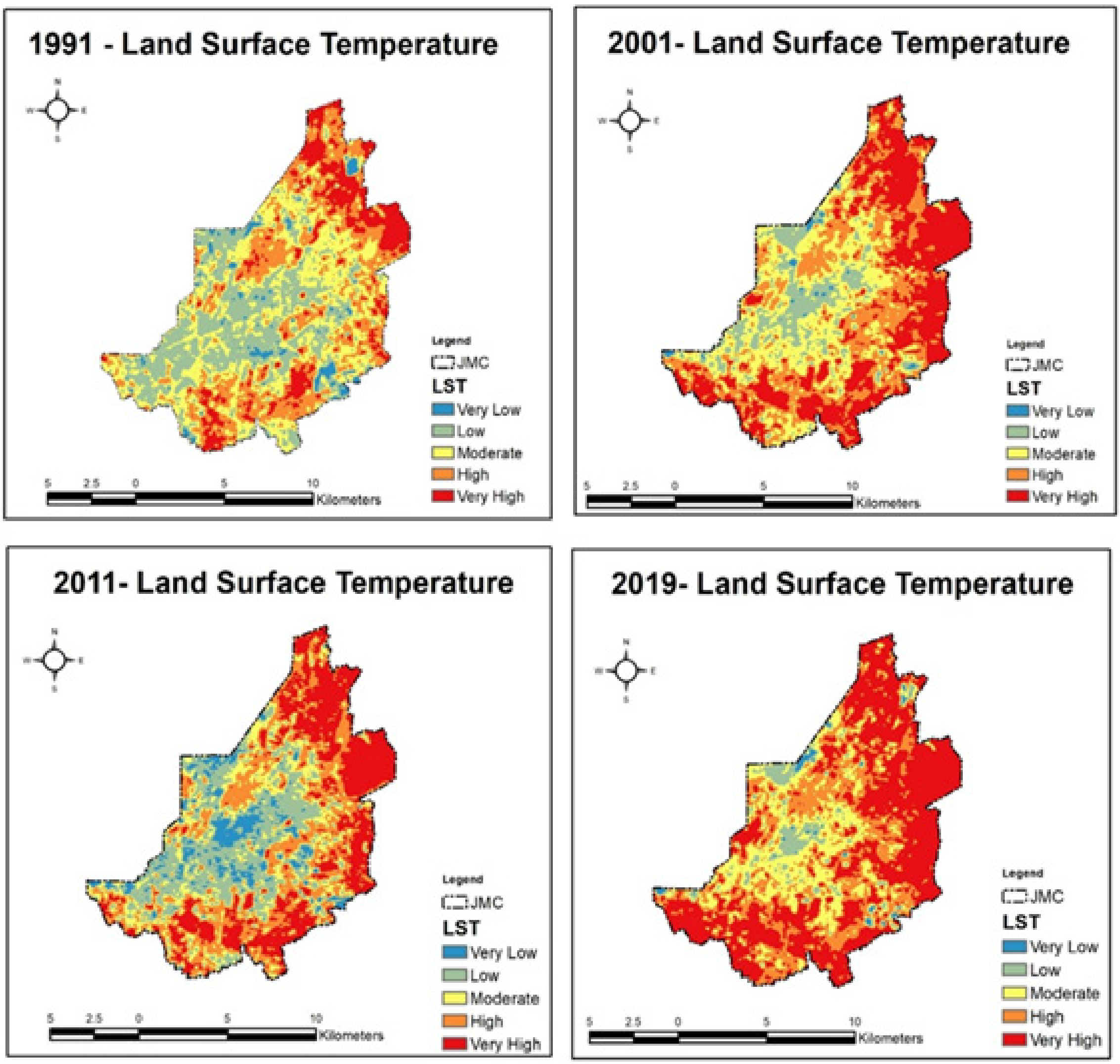
Developed in the foothills of Mehrangarh Fort, the core city is known as 'blue city' (Figure 1) because of the light blue painted houses in the core city area around the Mehrangarh Fort.

The city has grown and spatially spread out in the fort surroundings since its establishment in 1459. The blue colour of the houses, portraying the traditional construction techniques, help to cope the high temperature in the region. Jodhpur has three distinct built environment characteristics reflecting various phases of development: (i). The core city area developed during the patronage of Kings of Jodhpur - compact and traditional construction techniques have been used to cope with heat stress. (ii). Outside the core city boundary-the built environment is as per the City Development Plan, and (iii). Sparse development - prevalent in peripheral areas of the city. The existing land use pattern with distinct core city and municipal corporation boundaries of Jodhpur city is shown in Figure 2.

There is a recent shift to the new building materials in the city. Further, the changing settlement structure resulted in the decline of the coping capacity. From the city core to the peripheral wards, there is an apparent transformation particularly in the proportion and layout of open spaces, built fabric including usage of material and construction technology.

### 2.1 Heat Stress in Jodhpur

Over a period of time, the local community has always been attempting to overcome the high heat stress. However , the recent changes in the lifestyle and the tranformation of built environment seem to have apparently contributed to aggravating the stress. The vulnerability to heat in the city is now exacerbating because of the impacts of climate change, which is predicted to worsen more in the future. The city faces heatwave every year and drought condition in every 2 to 3 years (Poonia & Rao, 2013), which has adversely affected people's health and livelihood. Heatwaves as per Indian Meteorological Department (IMD) is acknowledged when an area for more than five consecutive days experiences prolonged




| LST - Jodhpur City | | | | |
|---|---|---|---|---|
| LST | 1991 (Area in Sq.Km) | 2001(Area in Sq.Km) | 2011(Area in Sq.Km) | 2019(Area in Sq.Km) |
| Very Low | 4.3 | 10.8 | 1.4 | 1.2 |
| Low | 42.8 | 39.5 | 24.6 | 14.0 |
| Moderate | 50.9 | 28.0 | 44.3 | 40.3 |
| High | 45.4 | 45.6 | 42.3 | 49.5 |
| VeryHigh | 24.2 | 43.6 | 54.9 | 62.5 |
| TOTAL | 167.5 | 167.5 | 167.5 | 167.5 |

Figure 3 Temporal Variations in Land Surface Temperature of Jodhpur City. Source: Authors.

heat. The daily maximum temperature during heat waves gets 5°C higher than the average maximum temperature. In the summer of 2019, the city experienced heatwaves condition for a prolonged period in May and June wherein as per local newspaper 16 people died within two days and affected the health of many people (Mishra, 2019).

A 100-year trend of 1901-2000 is compared statistically with the recent 35 years average maximum and minimum temperature of 1979-2013 (IMD, n.d.). This comparison shows a significant increase in the average maximum and minimum temperatures for the months of June, July, August, and September. The minimum temperature, however, has decreased for the months of April and May. The Mann-Kendall Test applied for testing the presence of monotonic increase or decrease in temperature trends in the past 35 years (1979-2013) shows a significant increase in the maximum temperature for the month of March at 99% confidence level whereas at 95% for the months of June, November, and December. However, the minimum temperatures do not show any significant change. The mean daily maximum temperature is the highest (41.4°C) in May (IMD, n.d.).

Over the years, there has been consistent rise of temperatures. The city has been witnessing the heat stress. In order to assess the rising temperatures, the LANDSAT OLI 8 imagery of May 2019 were used for determining Land Surface Temperature (LST) for the years 1991, 2001, 2011, and 2019 (Figure 3). The analysis revealed that the low surface temperature (ranging from 34°C to 37°C) areas reduced from 42.8 sq. km to 14 sq.km. whereas very high temperature (40°C-44°C) increased from 24.2 sq. km. in 1991 to 62.5 sq.km in 2019. This increase in surface areas of higher temperatures in last three decades indicates the increased exposure to heat in Jodhpur city.

## 2.2 Traditional Built Environment and Practices to Resist Heat

The core city area of Jodhpur has an organic built form (Figure 4) that reflects the physiographic constraints, climatic conditions, and the culture of the place. This organic built form acts as a shield against heat stress. The topography and the climatic constraints resulted in the development of a densely built city. The identified typical character of the place (Figure 5) like courtyard-houses, carved stone façades, *Jharokhas*[1], *Jaalis*[2], meandering streets, open *Chowks*[3], community spaces, and water structures in the core area help in coping with the high temperatures (Upadhyaya, 2015). The irregular pattern of streets helps in diverting the wind pattern in the city. Almost every house has a courtyard which helps in cutting down the heat. The water bodies aid in keeping the climate cool, and act as a node for social and cultural activities.

In the traditional building layout, buildings usually have a fewer openings, as the courtyard acts as the main source for ventilation. The building envelope is made up of sandstone, thick roof tiles, and blue paint on the facade to resist heat. Seemingly, the blue colour is a result of abundantly available indigo, copper sulphate, and limestone deposits, which helps the dwellings to maintain cool temperatures during harsh summers. It is interesting to note that traditionally, the Brahmin community used the colour considering the sacredness associated with it (Marcello Balzani, 2019).

The core city follows the traditional hierarchy of open spaces suited to arid climatic conditions in

1 *Jharokhas* = Ventilators

2 *Jaalis* = Screens

3 *Chowks* = Courtyards

Figure 4 Organic character of core city. Source: Author

Figure 5 Traditional house in Brahmapuri with courtyard and Narrow Streets. Source: Author

Figure 7 Chabutras’ and Pyaaus’. Source: Author


Figure 7 Chabutras' and Pyaaus'. Source: Author

the form of *Chourahas*[4], *Verandahs*[5], and *Chowks* in individual residencies. The *Chourahas* are marked either by landmarks such as temples or by shady trees with *Chabutras*[6] (Raised Platform) to sit and drinking *Pyaaus*[7] (water fountains) as shown in Figure 6 and Figure 7. These open spaces are very important for not just protection from heat but also for healthy social networking. These intermittent open *Chowks* act as breathers to the organically laid streets. The presence of abundant water bodies keeps the climate cooler and act as a node to cultural activities (Mukhopadhyay, 2019).

Although still prevalent, traditional techniques are being fast replaced by the newer ones. The old and elegant *Jharokhas* have been replaced by windows, stone walls with brick-mortar, and blue paint with claddings as is evident from Figure 8. The houses no more have a common courtyard and the social gathering spaces are now fast diminishing out of sight.

## 2.3 Influence of Cultural Practices and Change in Lifestyle on Heat Stress

While a lot has been done for the conservation of Mehrangarh Fort, the core city within the boundary wall lies neglected on the foothill. One of the many reasons for this neglect can be attributed to the changing lifestyle of the city inhabitants. Many traditional buildings either lie in disrepair or being demolished and renovated (Figure 8) as they no more serve their purpose. It is a great cause for concern to note that these building even include some old structures of heritage value with unique traditional architetural style.

It was found that a majority of residents opted to shift to the city peripheral areas, which are relatively modern in nature. Although the city inhabitants value the heritage buildings, the availability of urban infrastructure such as education, healthcare and transport facilities in the peripheral areas seem to be the main reason for this shift. It therefore becomes imperative for the urban local body to take necessary policy

4 *Chourahas* = Public Squares

5 *Verandahs* = Semi-open space in front of the house

6 *Chabutras* = Raised Platform

7 *Pyaaus* = Water Fountains

Figure 8 Changes in built structures. Source: Author

Figure 9 Transition spaces between the public and private realms. Source: Author

Figure 10 Changing Skyline and transformation of Built Fabric within Core City. Source: Author

measures so as to protect and rennovate the traditional establishments.

The city provides many spaces of interaction between the users and the built component. The transition of roads into open spaces (Figure 10) integrated with the local lifestyles of the people is a good example. Initially created as a response to the unbearable summer sun, the city evolved around these spaces, with individual communities marking the surrounding areas. With the change in family structures from joint families to nuclear ones with diverse backgrounds, such spaces still act as icebreakers and instill a sense of neighbourhood among the residents. This phenomenon has resulted in the deterioration of the quality of these spaces and further reduced the sense of ownership affecting the city as a whole.

The transition spaces between the public and private realms, marked by raised plinths, acted as porticoes towards the internal spaces (Figure 9). Such hierarchy of spaces can also be seen in the streets, where shop fronts have raised plinths to not only accommodate people in harsh weather but also to cool the interiors of the structures. Thus these *Chabutras* act as a refuge and transition space between the public passage and individual existence (Marcello Balzani, 2019). These spaces have not gained much regard in the design and planning of new commercial areas or streetscapes, where the structures look abrupt without any transition or thresholds.

Jodhpur, a major tourist destination, is falling prey to the western notions and theories based on the built form, undermining the local culture and context. The perspective of the people towards the historic city has changed and as such, the blue colour of the city is also under threat of extinction. The values and knowledge associated with the ancient structures and traditional construction methods seem to have lost in time. Moreover, the stone masonry, thick walls with lime plaster, and blue colour that predominantly protected against the scorching sun have no more contemporary value. The heights of the structures and houses have risen in the city (Figure 10). The newer floors are added to the houses to accommodate the increased residents or the tourists.

# 3 The framework of the study

## 3.1 Methodology

The qualitative aspects of changing lifestyle, cultural values and their role in the transformation of built spaces are analysed. The study further explores the influence of transforming built spaces and changing climatic conditions in aggravating heat stress as experienced by the community. Qualitative research methods are employed to capture the perception of people for the causes of heat stress, their concerns related to it, and coping mechanism to deal with the stress. The role of multilevel actors in facilitating the conducive environment to mitigate heat stress is assessed. The challenges in enhancing the resilience and the relevant institutional barriers are identified. An in-depth analysis is conducted for understanding the strength of the community, salient features of existing institutions, and the cross-sectoral actors engaged with the community. Linking the four pillars of community resilience viz: i) community initiatives; ii) cross-sectoral partners; iii) shared understanding; iv) state of readiness, a conceptual framework is suggested for building community and institutional resilience.

## 3.2 Research Methods

The perception of stakeholders was collected through interviews, discussions, and observations. The research of Gale et al. (2013) highlighted that the framework analysis method is the most suitable as compared to other qualitative research methods such as phenomenology, ethnography, discourse analysis, and grounded theory; for analyzing systematically the data collected through qualitative surveys. The framework analysis method was therefore selected for analysing the data collected during the field visit.

Quantitative methods are used to know the changing climatic conditions. The significanct changes in temperature is tested using the Mann-Kendall test. The changes in the number of days with prolonged heat in the last two decades is analysed using trend analysis. Geospatial techniques such as Shannon Entropy is used to understand the growth pattern of built-up spaces. Landsat 8 images downloaded for May (for the years 1991; 2001; 2011; 2019) from USGS Earth Explorer website are used as the primary data source for analysing temporal changes in Land Surface Temperature (LST).

## 3.3 Selection of Detailed Study Areas

Jodhpur city has witnessed land use/ land cover (LU/LC) modifications in the form of built-up areas, impervious covers, pavements as well as a massive reduction of the vegetative area. Shannon's Entropy analysis indicates (Figure 11) the major growth of built-up spaces towards SSW, NEE, and SWW direction. The concentration of built-up has gradually increased due to an increase in anthropogenic activities. The LST analysis (Figure 3) affirmed the major changes in surface temperature both in peripheral as well as in the core areas. Different past researches and studies have shown that built up and bare soil areas have maximum temperatures. To counter the heat, green cover is required, but there is a lack of green spaces in the core area as is evident (Figure 12) from the Normalized Differentiated Vegetative Index (NDVI) computed for February in 1991, 2001, 2011 and 2018. The dense green cover in peripheral areas is also getting affected due to prevalent mining activities as well as water scarcity. The land cover changes from dense forest to the plantation and open forest as getting highlighted from temporal (1991-2018) NDVI analysis. The vegetation cover has reduced from 15.19% in the year 1991 to 8.99% in the year 2018.

Hence, perception studies were carried out in the two identified study areas : (i) the core city with compact organic built-up spaces having traditional building layouts and techniques; and (ii) peripheral areas confronting land use and land cover changes. The field study was conducted from July 30, 2019, to August 10, 2019.

The reconnaissance survey of the core city led to the selection of six locations (highlighted in Figure 13) based on built-up area characteristics.

***Brahmpuri area:*** The majority of the houses are more than 100 years old and built with traditional construction techniques exhibiting central courtyards and Jharokhas. As streets are narrow the built structures not only provide shading on to the streets but also the houses across the street. With all the built structures painted in blue limestone, the area depicts the characteristics of Jodhpur as a 'blue city' in all its glory. Ranisar and Padmasar are specifically responsible for keeping the area cool in hot summer afternoons, with *Peepal* trees or *Ficus religiosa* at major junctions and space to sit under the shade.

***Tapi Baori:*** Although most houses are of an old construct, the area does not preserve the blue vista as in the case of Brahmapuri. Most of the structures showcase varying hues. The narrow streets and dense built-up is dotted with *Peepal* trees, although with numbers going down over the years.

***Govind Baori:*** Most of the construction in the

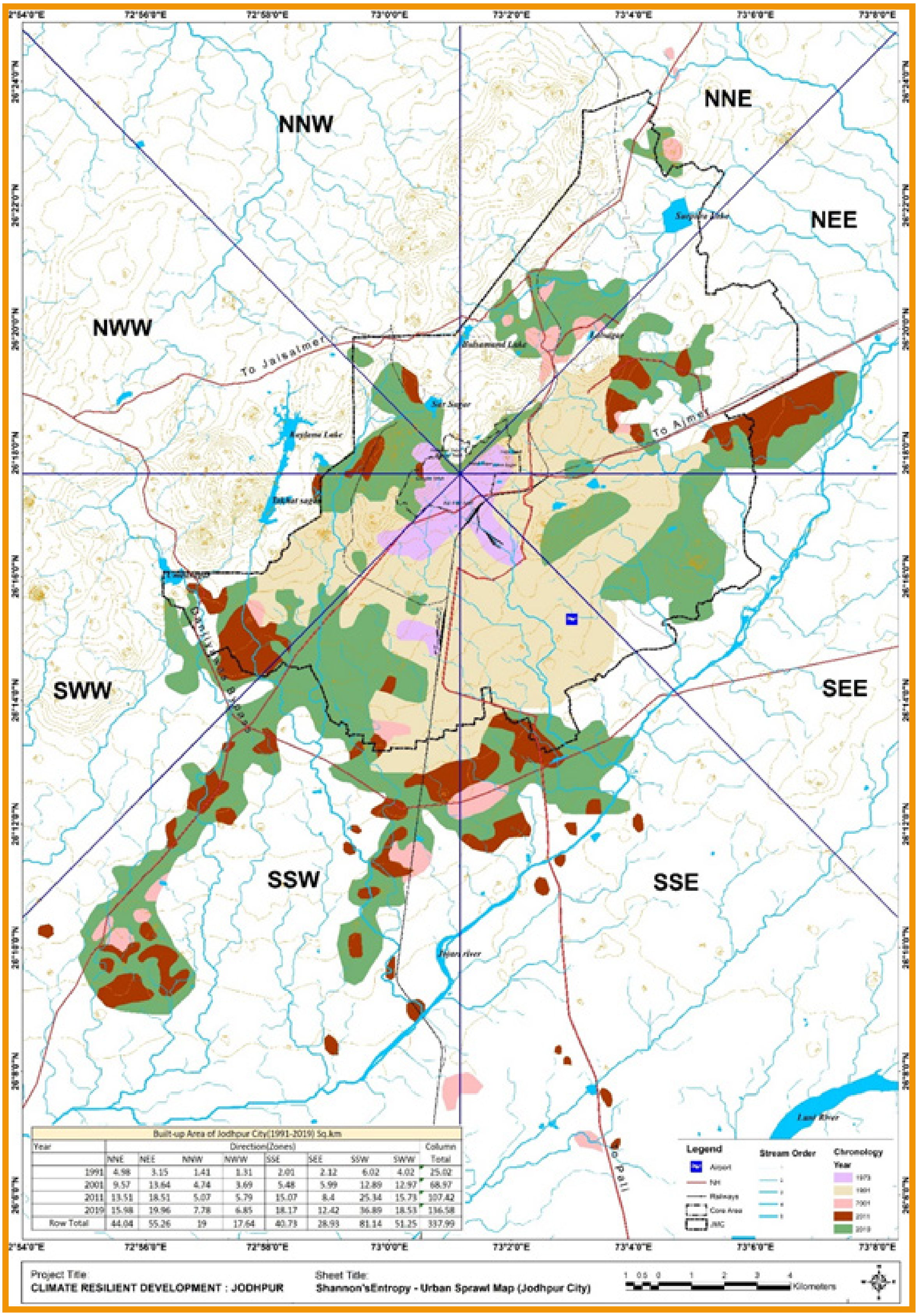
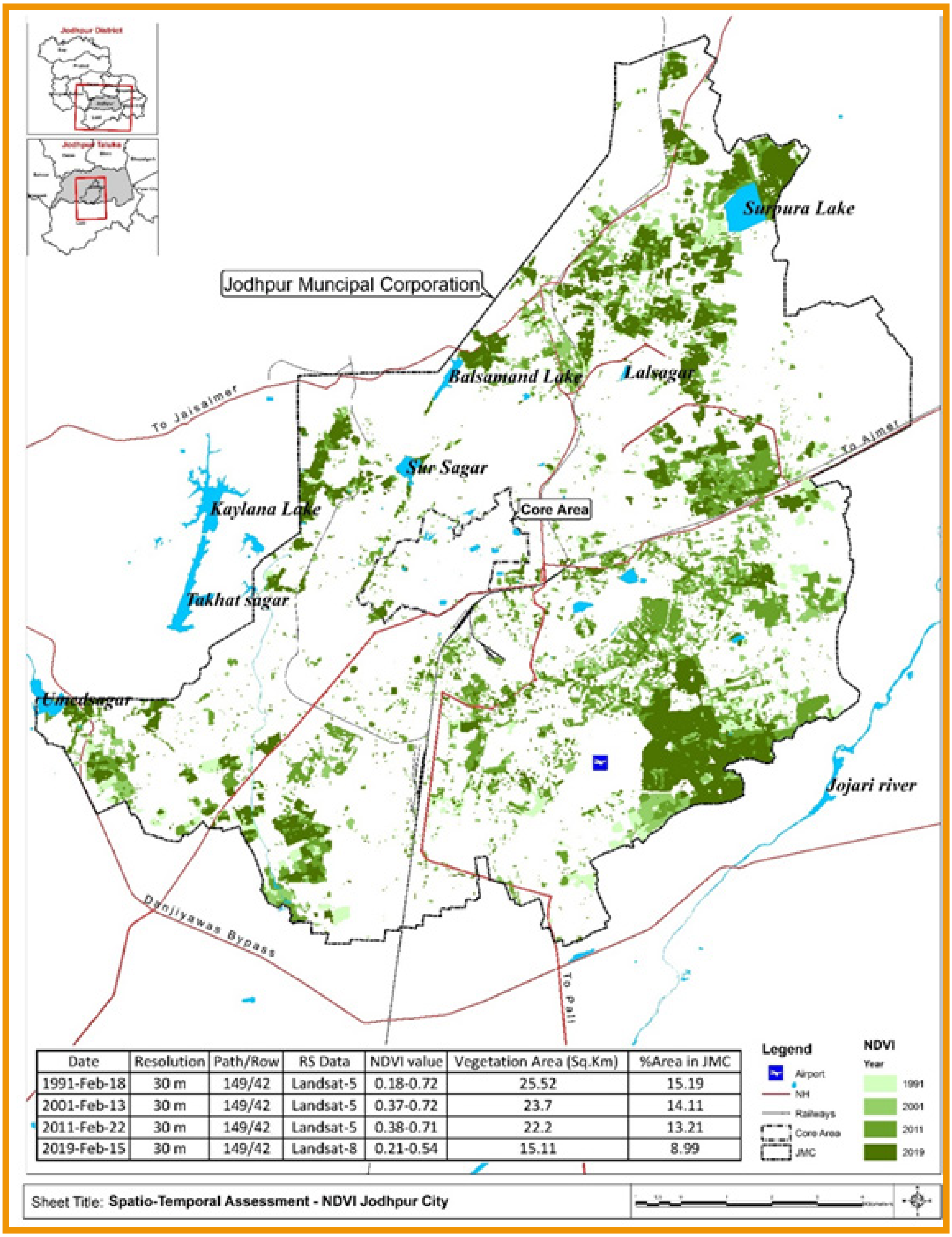



Figure 11 Growth pattern of built-up spaces from 1973 to 2015.
Source: (SPA Bhopal MPEP Third Semester, 2019)




| Date | Resolution | Path/Row | RS Data | NDVI value | Vegetation Area (Sq.Km) | %Area in JMC |
|---|---|---|---|---|---|---|
| 1991-Feb-18 | 30 m | 149/42 | Landsat-5 | 0.18-0.72 | 25.52 | 15.19 |
| 2001-Feb-13 | 30 m | 149/42 | Landsat-5 | 0.37-0.72 | 23.7 | 14.11 |
| 2011-Feb-22 | 30 m | 149/42 | Landsat-5 | 0.38-0.71 | 22.2 | 13.21 |
| 2019-Feb-15 | 30 m | 149/42 | Landsat-8 | 0.21-0.54 | 15.11 | 8.99 |

Figure 12 Temporal changes in vegetation
Source: (SPA Bhopal MPEP Third Semester, 2019)

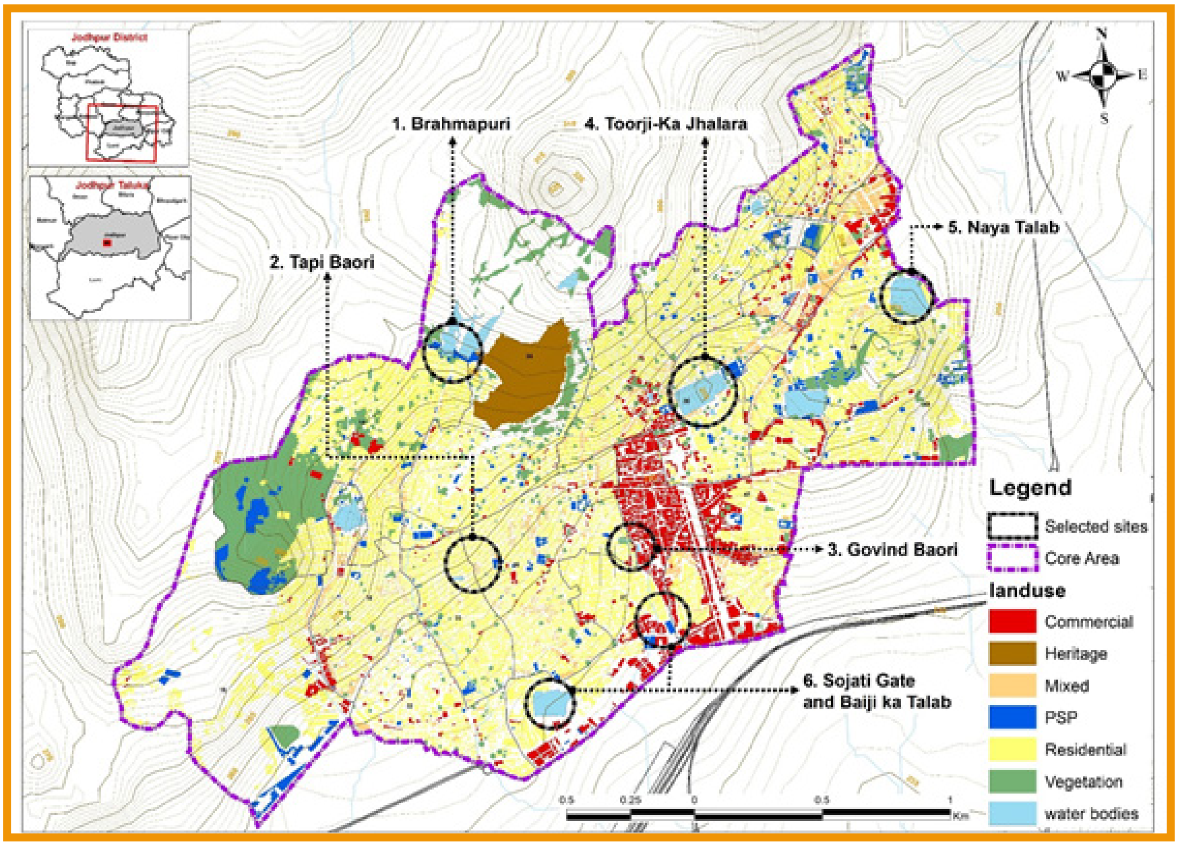



Figure 13 Core city of Jodhpur showing selected locations for Interviews
Source: (SPA Bhopal MPEP Third Semester, 2019)

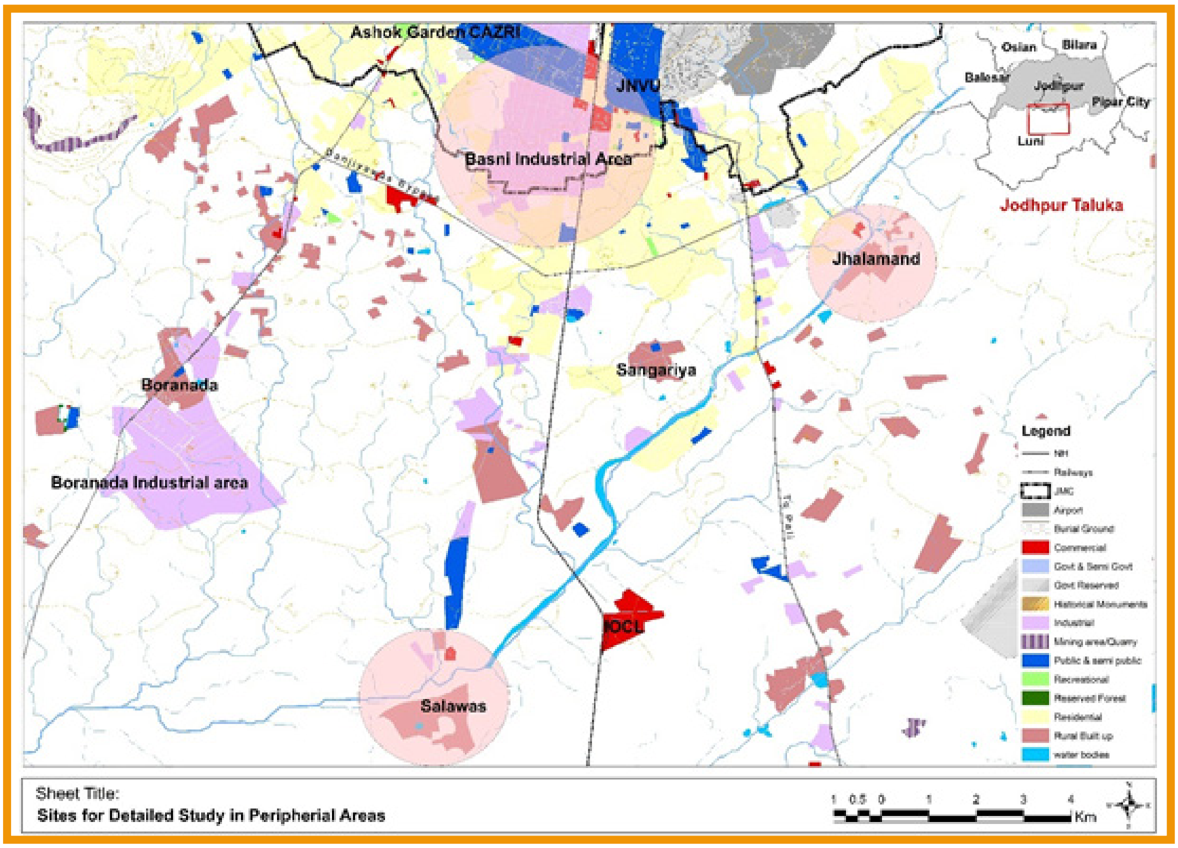



Figure 14 Peripheral areas of Jodhpur city showing selected locations for Interviews
Source: (SPA Bhopal MPEP Third Semester, 2019)

area is traditional with a network of dense and narrow streets. The use of air conditioners was evident. During a reconnaissance survey, the residents attributed the increased use of air conditioners, cemented roads, and motor vehicles for increasing instances of heat stress in the area.

***Toorji Ka Jhalara:*** The built-up structures of the area has a mix of traditional and new construction. The newer structures are predominantly constructed with bricks and concrete, while the traditional ones with stone masonry, which provide thermal comfort both in the summers and the winters. The area is kept cool by Gulab Sagar while the restored Toorji Ka Jhalara now serves as a retreat for the passers-by to sit around and enjoy the cool breeze.

***Naya Talab:*** The area has a mix of traditional and new construction. However, it lacks in vegetation cover, with sparse and dispersed trees in the open lands. Naya Talab, the water body is not well-maintained, with wastewater flowing into it which inturn is leading to mosquitobreeding.

***Sojati Gate and Baiji ka Talab:*** An area with mixed land use characteristics having shops lined along both sides of the road. It also serves as a commercial hub with a backdrop of residential areas. This area has a good mix of traditional and newer construction types. It was also observed that a majority of the shops still have un-used basements due to rising groundwater levels.

The three areas in the city periphery were selected for conducting interviews as shown in Figure 14 are: 1) Salawas village showing urban transformation both in terms of built fabric as well as a lifestyle; 2) Basni, an industrial area located within the municipal boundary of the city and responsible for air pollution in the vicinity; 3) Jhalamund village, also showing characteristics of urban transformation.

## 3.4 Survey Methods

The six research teams with three members in each team, were briefed on the procedure of conducting interviews including the specific role. Each team was assigned with the task of collecting information through semi structured questionnaires, observation formats and audio-visual documentation. The qualitative data was collected from selected six locations in the city core area and three locations in the periphery. The surveys were conducted within a limited time of 10 days during the monsoon season when the average temperature was around 36°C. During the survey, heatwave conditions were not felt. A total number of 77 surveys were conducted. Out of which 51 surveys were from the city core area and 26 surveys from the peripheral areas. Random sampling was adopted to select interviewees to collect responses from varied socio-economic and age groups. The samples included 55 males and 22 females. The maximum number of respondents (51%) are in the age group 25-50 years and 41% are of more than 50 years of age. The least number (8%) of respondents are in the category of 10-24 years of age.

# 4 Assessing Heat Stress

Transcripts were generated for all the recordings in audio-visual format collected through interviews of stakeholders. The recordings were in the local language i.e. Hindi. Hence, these were translated into English. Further the translated scripts were thoroughly proof-read to identify 45 relevant aspects related to the heat stress. These were further grouped into 16 factors under five categories namely (i) Causes (ii) Impacts (iii) Coping Mechanism (iv) Shared Understanding and (v) Awareness.

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 the respondent. The compilation was done separately for the core and the peripheral areas. The analysis of these factors helped in assessing people‘s perspective towards heat stress and how they are coping up with stress.

The interviewees‘ responses under the five categories are discussed in the following sections:

## 4.1 Causes of the Heat Stress

Respondents attributed the increased use of air conditioners, concrete roads, smoke from industries, and increased use of vehicles for the rise in temperature. They also related air pollution to heat stress. Air pollution along with high temperature severely affects human health and is a cause of concern. In the core city, the congestion due to the increase in vehicular traffic is degrading the air quality. The air pollution in peripheral areas is due to the presence of industries in the neighbourhood. The responses indicate how pollution from industries is affecting the day-to-day life and health of people. Therefore, there is a need to monitor the compliance of pollution control standards by industries.

The modern design and construction techniques of buildings don‘t follow the traditional techniques, *Jharokas* have been replaced with big windows, stone wall with brick-mortar, blue paint with tile cladding and courtyards are gradually disappearing from the houses. The respondents in the core city emphasized that the use of Reinforced Cement Concrete in buildings has increased in the last 15-20 years. A majority of the respondents were interested in the maximum utilisation of the available land, and were not in favour of having open courtyards.

Ramphant felling of trees is one of the reasons for decrease in the green cover and increased temperatures. This increase in temperatures could be felt both in the core and the peripheral areas of the city. At the same time, changing life styles of the city inhabitants cannot be ignored and can be corroborated with the increased temperatures.

## 4.2 Impacts

According to the respondents, one of the major causes of concern is the the most ill impact of heat stress on their health. Dehydration and heat stroke are common among the vulnerable population during the summer. Among them, the most affected are the children and elderly persons. In particular, people living in temporary houses such as settlements near the Sojati Gate area were severely affected by the heatstroke. The rise in vector-borne diseases is also reported from both city core and peripheral study areas due to prolonged summer months.

The responses reveal that loss of dense vegetation is seemingly affecting the biodiversity. There has been a substantial reduction in the fauna . The animal count in the city has significantly reduced. The respondents re-confirmed attributing the loss of animal habitat due to the rise in the temperatures.

A shift from agriculture practice to alternate occupations in the peripheral areas of the city has been reportedby the respondents of peripheral areas, particularly by the women. The reason for this change can be attributed to the reduced yield due to variations in the micro climatic conditions.

In comparison to the core city area, the respondents of the periphery were more vocal about the health issues as a major concern due to heat stress. Higher exposure to heat, due to sparse development in peripheral areas as compared to compact development of core city, may be the reason for health impacts. Lack of traditional systems of construction and planning could also be one of the causes of higher exposure to heat.

## 4.3 Coping Mechanism

The traditional building techniques adopted in the core city area reduce to some extent the exposure of residents to heat stress. *Brahmapuri* area in Core city, well known for its blue coloured traditional houses, had adopted this aspect as one of the ways of coping with the heat. According to respondents, the blue colour as also elaborated in section 2.2 keeps their house cooler but highlighted that people are no more using this technique for cooling their houses.

Most people prefer to stay inside to cope up with the heat during peak summertime. Respondents informed that school timings are usully staggered for reducing exposure of students to harsh heat. Residents mostly complete their work by noon and prefer to remain inside during the rest of the day. As people prefer to sit outside for socializing so sprinkle water on roads in front of their houses to make the surrounding air cooler. People choose to use Air Conditioner or Desert Coolers as per their affordability. Chemicals are also being applied to the rooftops for reflecting the heat. Changes in eating habits like less consumption of spicy food, more water, and dairy products during the summer months are also highlighted by the residents.

The importance of trees for their cooling effects is also highlighted. A couple of residents pointed out that the shaded area under the old Banyan tree is four to five degrees cooler than the other open areas in the vicinity.

Respondents also mentioned the initiatives taken by the Government such as the provision of temporary shelters to the poor and sprinkling of water on roads. On the other hand, the residents, as well as private agencies, set up *'pyau-ghar'* (drinking water fountains) for the public.

## 4.4 Shared Understanding

The community participation in coping up with heat stress in the core area is quite robust. Many drinking-water fountains have been set-up by the locals. Also, on occasions, people set up temporary drinking water facilities during summer, for the passers-by in the market place or on roads. An elderly resident in the market area said that as there was no provision made for drinking water supply by the concerned authorities, the local residents usually contribute and collectively make necessary provisions for drinking water facilities on streets.

Social gathering / cohesion is quite a habitual phenomenon in the peripheral areas, as the elderly and middle-aged persons most frequently spend their leisure time under *Peepal* or *Banyan* trees during hot summer hours. Residents usually spend their leisure time in casual interactions / discussions and sometimes play card games. These casual interactions are instrumental in increasing the sense of binding of the community.

## 4.5 Awareness

Air conditioners and increased use of active cooling mechanisms apparently are the key contributors  to heat stress.

The sparse vegetation and reduced forest cover have drastically determined the the rainfall patterns.

Respondents of the core city area unanimously pointed out that increased ownership of automobiles is causing a rise in temperature. Some also blamed concrete roads for the cause. Although contemporary construction techniques are being used for new structures, few participants stressed that the integration of traditional methods can reduce the temperature.

Despite the advantages of traditional constructions techniques, particularly with respect to heat control, rarely these techniques are being applied in the contemporary built forms.

# 5 Discussion

The heat stress is getting aggravated both in the core and periphery of Jodhpur. Changing lifestyle, the increased use of automobiles, increased consumption of electricity, and air pollution is adding to the changes in microclimatic conditions. The reduction in green spaces in the periphery due to urban sprawl and the transformation of rural lifestyle has led to heat stress.

The visible impact of heat stress is on reduction in vegetation leading to biodiversity loss which in turn can be linked to growing haphazard urbanization in both the areas. The health of people is getting affected by increased heat stress.  In peripheral areas people are shifting their occupation as the water scarcity due to heat stress is not sufficing the demand for agricultural needs. The reduction in yield is forcing the farmers to change their livelihood patterns. People have changed their eating habits and stay inside during the day to cope with heat stress which they face on a day-to-day basis. The importance of old shade-providing trees as a refuge during the summer months is highlighted by almost all the respondents. Various Government and NGO led initiatives are also helping people to cope with the heat stress. People are also aware of various causes leading to heat stress. They know the benefits of compact planning and traditional construction techniques but those practices are getting lost to newer materials and techniques.

## 5.1 Community Resilience

The stakeholder's responses were further analysed for identifying strengths, challenges, opportunities, and threats (listed in Table 1) for building community resilience in both core city areas and peripheral areas.

The identified factors of heat stress from the transcripts are further analysed concerning four pillars of community resilience namely: 'shared understanding', 'state of readiness', 'community initiatives', and 'cross-sector partners', adapted from BCR model of Milken Institute of Public Health (Ellis & Dietz, 2017). The factors categorised (Table 1) under the strengths, weaknesses, opportunities, and threats in the previous section were divided among these four pillars (Table 2) to highlight the interlinkages among the pillars. This further helps in identifying the gaps to address the heat stress issues for strengthening resilience.

| | Core City Area | Peripheral Area |
|---|---|---|
| **Strength** | • Compact Layout<br>• Traditional knowledge of building design, materials, and construction techniques<br>• Community initiatives to cope up heat stress<br>• Sense of community | • Narrow lanes<br>• Social Cohesiveness<br>• Traditional knowledge and craft<br>• Awareness about changes in climatic conditions |
| **Challenges** | • Health issues<br>• Urban renewal<br>• Mainstreaming spatial interventions to address heat stress in local area planning<br>• Behavioural changes in consumption pattern | • Health Issues<br>• Rural to urban transformation<br>• Land use and land cover change<br>• Mainstreaming spatial interventions to address heat stress in existing regulations<br>• Behavioural changes in consumption pattern |
| **Opportunities** | • Strengthening of existing policies for the inclusion of local challenges in land use planning | • Residents willingness to work<br>• More built-up areas yet to come |
| **Threats** | • Usage of construction material not conducive to the local climate<br>• High-rise buildings | • Contamination of groundwater and Jojari River<br>• Food insecurity due to dying agricultural practices<br>• Health of Community |

Table 1 Strengths, Challenges, Opportunities, and Threats for Building Resilience

The matrix as in Table 2 highlighted that though 'shared understanding' is there for all the factors of heat stress but robust measures are needed. The strengthening of the other two pillars 'cross-sector partnerships', and 'communitive initiatives' which are interdependent would certainly improve the first pillar of 'shared understanding'. The efforts towards enhancing 'state of readiness' would further improve community resilience.

## 5.2 Institutional Resilience

The analysis of stakeholder's perception indicated a lack of dedication and accountability in Government agencies, lack of grievance redressal in the government system, ignorance on part of governing agencies for common goods, and shortage of workforce from the authorities as major concerns in the study region. The provisions in existing policy documents and applicable acts concerning the identified

| Community Resilience Pillars | Identified Factors of Heat Stress | | | | | | |
|---|---|---|---|---|---|---|---|
| | Traditional Construction Techniques | Health | Reduced Green Cover | Coping Mechanism | Biodiversity Loss | Behaviour | Awareness |
| **Shared Understanding** | Considering traditional techniques as an asset to cope with the heat | Dietary Habits adopted | The plantation was done individually by a few residents | Air-conditioners/ Water-coolers used all day long | Food provision for animals | Water bodies used for recreational purposes | Changing lifestyle leading to heat stress |
| **State of** | Re-visiting building bye-laws for building upcoming development | Addressing conditions leading to poor health such as fatigue, vomiting, dehydration, and headache | Changes in microclimate due to lack of trees | The revival of traditional construction techniques | Responsible urbanisation to reduce the loss of dense forest | Constructive use of superstitious beliefs | Willingness to work |
| **Community Initiatives** | No initiatives | No initiatives | Plantation drive | Public drinking water fountains | No initiatives | No initiatives | No initiatives |
| **Cross-Sector Partners** | No initiatives | No initiatives | No initiatives | Sprinkling water on roads | No initiatives | No initiatives | No initiatives |

Table 2 Addressing Heat Stress Through Community Resilience Pillars. Source: Author

heat stress factors are reviewed. The role of government departments, the involvement of NGOs, and other private institutions for addressing heat stress are examined to understand the barriers in building institutional resilience. The identified institutional barriers corresponding to the heat stress factor are listed in Table 3. The policies fail to address local area-level concerns and lacks implementation mechanisms to reach out to vulnerable areas. The climate-resilient heat action plan of Rajasthan state focuses on rural communities as there is no HAP yet prepared for cities. Loss of biodiversity in the city because of declining green cover has also not been addressed. There are no policies that include spatial planning mitigation measures for addressing health issues arising out of an impact of heat stress. Building bye-laws too do not consider increasing heat keeping in mind the future implications of the same at the local level.

### 5.3 Building Community and Institutional Resilience- A Conceptual Framework

The integration of traditional knowledge for designing built and unbuilt spaces with new scientific knowledge is required to build the resilience of Jodhpur city towards heat stress. This will not only address the causes but also the challenges arising out of the Heat Stress. Heat stress factors identified through experiential investigation supported by geospatial techniques and secondary information for the city of Jodhpur are variations in climatic conditions; Change in lifestyle; Lack of integration of Traditional building techniques with modern techniques; Green cover loss; Community participation; and Governance. All these heat stress factors are dynamic and interlinked with each other. Addressing one factor such as green cover loss through community participation and governance would help in improving the bio-diversity as well as microclimatic conditions for improved resilience to heat stress. The traditional knowledge that exists in the form of building technologies; building materials; building layouts; traditional water systems; indigenous vegetation; and traditional water systems, etc. if gets blended with science and new technologies through provisions in various formal and informal institutions for spatial planning would help in building the resilience of the city. Figure 15 presents a conceptual framework highlighting the important links between various components of community and institutional resilience to heat stress.

Available strengths and opportunities of Jodhpur city (as identified in Table 1) through the four pillars of Community Resilience are used to meet the challenges of heat stress. Therefore, strengthening these four pillars which are mutually dependent on each other becomes imperative in the context of Jodhpur city.

## 6 Conclusion

Climate change along with urban expansion associated with new building technologies are threatening the traditional knowledge and the communities. The industrialization and unsystematic urban planning have increased the city heat stress resulting in additional burden on communities to cope up with it. The increasing built-up areas and decreasing green cover, if not addressed, may evolve into a threat in the coming years. The major threat due to rising temperature and heat relates to health issues in Jodhpur. It requires to be addressed through progressive adaptation strategies, involving the community and effective governance. There is a need to prioritize action plans for addressing local level causes of heat stress at the time of policy formulation. This is important to address the concerns of vulnerable areas and to resolve issues like loss of green spaces in the city. Evaluation and monitoring of actions for ground-level activities should also ensure that various stakeholders are accountable for their actions.

Increasing heat is not considered a factor, having future implications, at a local level for developing building bye-laws and development control regulations. The use of local material and adaptive construction techniques is not being emphasised in such regulations. Successful convergence of various government schemes is needed through the collaboration for building resilience.

Traditional knowledge as we see in a semi-arid, historic city like Jodhpur can capitalize to cope with climate change and adapt to resilience against heat stress. Our experiments through qualitative and geo-spatial techniques on communities and institutions show how the communities are capitalizing the traditional knowledge along with modern technologies to address and adapt to climate change and heat stress. This convergence in traditional knowledge and coping up mechanisms an illustration to nurture community resilience in the cities.

## 7 Acknowledgement

We thank the students of third semester of Master of Planning (Environmental Planning), batch MPEP 2018 for their contribution to survey during July 31, 2019 and August 10, 2019. Authors also acknowledge Mr. Mudhukar Kuchvaram for his Geo-Spatial analysis work and Ms. Arsh Saluja for compilation of data.

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