Assessing Double Injustice of Peri-urban Water Resources around Bangalore

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Assessing Double Injustice of Peri-urban Water Resources around Bangalore

Undertaken by
Public Affairs Centre (PAC), Bangalore

Supported by
Environment Management and Policy Research Institute

ISBN 978-81-88816-95-8

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Cover Design: Arvind Lakshmisha

Acknowledgement

This path breaking study is the first step towards a larger initiative and could not be completed without support from the Environment Management and Policy Research Institute (EMPRI), Bangalore. We are indebted to them for funding this study, and take this opportunity to thank

Ms. Ritu Kakkar, IFS, Director General for the interest, guidance and kind support provided at every stage of the study to enrich study findings and ensure a successful completion of this study.

Ms. Saswati Mishra, IFS, Director for the support and direction by providing valuable inputs to enrich the study and its findings.

Mr. Vinaya Kumar, IFS, Director for the constant support and guidance throughout the study period.

Dr. O K Rema Devi, Consultant, for the continual support and encouragement during the study period.

Ms. Chitra P, Research Associate for her proactive support to help complete study successfully.

Special thanks to the community and members of Manchnayakanahalli Gram Panchayat for sharing their time and perceptions on water security in their villages.

Our sincere thanks to our field partner, SACRED who helped gather data from the field and contributed greatly in completing the study.

We are grateful to Ms. Ashwini V, from PAC for her support in conducting the training of Field Partners and accompanying us to the field during the training.

Special thanks to Ms. Anjana Ramkumar, from National University of Singapore and Ms. Bhargavi Nagendra, Program Officer PAC for helping us complete the study by conducting interviews with Toyota Kirloskar, Wonderla and Industry association to understand water security from industry perspectives.

Our thanks to the Lab team in EMPRI for accompanying us to the field to collect water samples and also for the quick analysis provided and making the study a success.

Our heartfelt thanks to T M Vijay Bhaskar, IAS, Additional Chief Secretary for his valuable comments and suggestions provided during his interaction at the stakeholder consultation workshop. Additionally, we would like to thank to all the respondents, for taking time out and sharing their experience and perception at the stakeholder consultation which enriched the study.

Thanks to all the participants of the stakeholder consultation who helped enrich the study and its findings.

Special thanks, to Mr. R Suresh, Director, Public Affairs Centre, for his continual support and playing a key role at various stages in the completion of this study.

Executive Summary

According to the 2011 Census, for the first time since Independence in 1947, the absolute increase in population was more in urban areas than in rural areas. In 2011, the rural–urban distribution stood at 68.84 and 31.16 per cent respectively. The level of urbanisation increased from 27.81 per cent in the 2001 Census to 31.16 per cent in the 2011 Census, and the proportion of rural population declined from 72.19 per cent in 2001 to 68.84 per cent in 2011 (Chandramouli, 2011). What is more surprising is that the number of towns increased from 5,161 in 2001 to 7,935 in 2011, adding 2,774 'new' towns. Out of the 2,774 new towns, there has been an increase of 242 statutory towns and 2,532 census towns since 2001. Many of these towns are part of Urban Agglomerations (UAs) and the rest are independent towns. The total number of UAs/towns, which constitutes the urban frame, is 6,166 in India according to the 2011 Census (Census of India, 2011a, b). These trends show that India is becoming increasingly urbanised. The latest figures corroborate the fact that due to various socio-economic factors, like population pressure and poverty, the urban regions have seen a large influx of people from rural areas, and this has led to the rapid growth of new urban centres.

Urbanisation is a prominent vehicle of development in the global south. Studies of development and its related issues have thus traditionally categorised space into urban and rural, with each category being prescribed certain characteristics. Over the past decade, a new amalgamated space that straddles the boundaries of both these categories has been drawing the attention of scholars. Known as the 'Peri-Urban Interface' (PUI), this area is defined as 'zone of (dynamic) transition or interaction between urban and rural areas; usually used in the context of rapidly urbanizing poor countries' (Simon, 2008: 2).

The consequence of increasing urbanisation is an unprecedented pressure on the urban infrastructure and resources. Access to water in urban India at present is already severely constrained. Most Indian cities have formal water supply for only a few hours a day and only in limited areas. So, where is the water to meet the remaining requirements going to come from? As India is becoming increasingly urbanised, the municipal corporations are not able to cope with the rising water demand for various reasons. For much of India's 'water history', the focus has been on large-scale surface-water projects to provide irrigation, whilst neglecting sources within the city and in the peri-urban areas.

Narain (2011) in his analysis of water issues in peri-urban areas highlights that the problem is not merely one of *scarcity* but that of *security*. He identifies three domains over which conflicts to water resources take place – quantity of water, quality of water and access to water sources. This study assess water security in peri-urban areas based on the approach of Climate Change Scorecard, an approach developed by Public Affairs Centre (PAC) which is based on citizen science and collective citizen action has been applied in this study. This approach tries to answer two fundamental questions

- *How can world's citizens, who have a vital stake in identifying a global solution to the present climate crisis, become actors in the effort to resolve it*? and
- *How can social concerns of citizens and communities be mobilised to help forge a collective will and develop the knowledge to educate the public and governments on the urgency and the need for climate protection?*

The study consisted of two phases: an exploratory phase, an initial phase where primary visioning exercises are undertaken. This phase consisted of identification of study areas and scoping visits to the field to understand the on-ground conditions. The second phase is the analytical phase which included household surveys to assess and identify household perceptions of drinking water security. Furthermore, 240 Fuzzy cognitive maps were developed with the aid of local communities to assess their perceptions of how urbanisation coupled with changing climate has impacted water security in peri-urban areas. These 240 maps were then condensed into three maps one for urbanisation, variation in rainfall and the last for increasing temperature. Neural network modelling was undertaken to identify and generate scenarios to improve water security. It was analysed that water security in the study areas were affected mainly due to urbanisation and industrialisation which has rendered these areas water insecure due to increased pollution and over exploitation of water bodies (surface and groundwater). This is exacerbated due to changing climate, which has an impact on health and financial conditions of the local population. Policy options were generated with various assumptions such as the increase in population, stringent enforcement of pollution control norms, increasing forest cover and rejuvenation of surface water bodies. These assumptions were based on the issues identified and based on the interviews with gram panchayat members and household surveys it was opined that there is need for increased awareness among the stakeholders, in addition to concerted efforts for continued dialogue between them.

The study highlighted that urbanisation has changed the lifestyle of this once quaint agrarian gram panchayat. Urbanisation has created a job market in nearby industries and also increased the conversion and sale of agrarian land for commercial and residential purposes thereby, increasing their financial/economic conditions. It was found that this development has increased access to modern infrastructure facilities such as access to schools and speciality hospitals. It was found that development had resulted in the neglect of natural resources including water sources.. Though the gram panchayat is blessed with adequate water sources, they are contaminated and not suitable for consumption. This impact has been aggravated due to climate change mainly variation in rainfall and increase in temperature, which has resulted in drying up of surface water bodies, which have been encroached in places as well. Lack of adequate water has also resulted in shift from agriculture to labour based livelihoods in the villages. Agriculture, though practiced in small scale has been the result for change in cropping pattern and at some places sewage water is used for irrigating agricultural lands. It was also highlighted that local industries have established, drinking water purifiers as a part of their CSR activities in the gram panchayat which are a one of the major sources for drinking.

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1. Introduction

Most cities in India are facing severe water `scarcity'. The problems and concerns of city water supply pertain to quantity and quality, equity – across different segments and different sections of population, poor sanitation, ineffective and obsolete wastewater management practices and lack of long-term vision, planning and motivation. At the same time cities continue to expand at a rapid rate and eat into resources (such as land and water) available in peri-urban areas. While land in peri-urban areas is grabbed for urban housing, industrial establishments and for dumping urban wastes (both solid and liquid) very little is ploughed back by way of developing these areas. Urbanisation process cannot be blind. It should ensure sustainable use of natural resources, in particular land and water – more so groundwater.

Indeed, very little attention is paid to investigate the role of urbanisation coupled with the impacts of climate change on water security in these peri-urban areas. The available water sources are exploited in an unplanned and unregulated manner resulting in ecological degradation. The surface and groundwater and land use should be an integral part of the urban and peri-urban development. In India, not only that water is never a part of the urban planning, the peri-urban issues are completely ignored and given the least importance in the overall planning process. This has resulted in serious livelihood problems in these areas. Furthermore, such unconcerned and unplanned urban expansions have triggered off conflicts between urban and peri-urban interests.

Resource scarcity is certainly one of the reasons for such conflicts; but resource scarcity is not just the consequence of hydro-geological factors but most often it is manmade (Janakaranjan, 2004). Regardless of causes, the consequences imply that water supply (both quantity and quality) are very much part of the concerns such as urban water environment, water supply and sanitations. Secondly, as indicated earlier, the looming threat of serious conflicts in resource sharing between cities and their peri-urban and rural areas is something which needs due attention. This question is of growing importance in the ongoing context of Indian urbanisation. Keeping these two elements, this paper highlights the water resource dimension in the sphere of unplanned urbanisation and changing climate.

The 2011 Census of India reported an annual growth rate of the urban population of 2.76 per cent, which is almost the same (2.73 per cent) as reported in 2001. The urban population of India stands at 377 million, with 31.16 per cent of the total population living in urban locations. The 2011 Census shows that India's urban population grew by 90.99 million during 2001–2011. This is more than the absolute increase of 90.47 million in the rural population over this period. In percentage terms, the urban population grew by 31.8 per cent, which was 2.6 times the corresponding decadal rise of 12.18 per cent for the rural population. The 12.18 per cent rural population growth during 2001–2011 represents a sharp dip from the 18.09 per cent increase over the period 1991–2001, whereas the growth rate for the urban population has seen a marginal rise from 31.47 to 31.8 per cent over these two periods. Therefore, the absolute increase in the urban population was more than the increase in the rural population in India.

According to the 2011 Census, for the first time since Independence in 1947, the absolute increase in population was more in urban areas than in rural areas. In 2011, the rural–urban distribution stood at 68.84 and 31.16 per cent respectively. The level of urbanisation increased from 27.81 per cent in the 2001 Census to 31.16 per cent in the 2011 Census, and the proportion of rural population declined from 72.19 per cent in 2001 to 68.84 per cent in 2011 (Chandramouli, 2011). What is more surprising is that the number of towns increased from 5,161 in 2001 to 7,935 in 2011, adding 2,774 'new' towns1. Out of the 2,774 new towns, there has been an increase of 242 statutory towns and 2,532 census towns since 2001. Many of these towns are part of Urban Agglomerations (UAs) and the rest are independent towns. The total number of UAs/towns, which constitutes the urban frame, is 6,166 in India according to the 2011 Census (Census of India, 2011a, b). These trends show that India is becoming increasingly urbanised. The latest figures corroborate the fact that due to various socio-economic factors, like population pressure and poverty, the urban regions have seen a large influx of people from rural areas, and this has led to the rapid growth of new urban centres.

So how is urban India accessing its water resources? The consequence of increasing urbanisation is an unprecedented pressure on the urban infrastructure and resources. Access to water in urban India at present is already severely constrained. Most Indian cities have formal water supply for only a few hours a day and only in limited areas. So, where is the water to meet the remaining requirements going to come from? As India is becoming increasingly urbanised, the municipal corporations are not able to cope with the rising water demand for various reasons. For much of India's 'water history', the focus has been on large-scale surface-water projects to provide irrigation, whilst neglecting sources within the city and in the peri-urban areas. Over time, an enormous informal groundwater market has risen in several cities to bridge the demand–supply gap. Water for these informal water markets is often sourced from the peri-urban regions, which are usually richer in surface water and groundwater.

The peri-urban areas are witnessing change in two ways. First, they cater for the rising urban economic class that is ready to pay for a constant water supply through the sale of water fuelled by an informal water-tanker economy. Second, periurban areas and their citizens are at the receiving end of the wastewater produced by cities, and suffer the consequences in the form of polluted rivers, industrial and domestic waste and a damaged urban ecosystem. This study documents, the perceptions of peri-urban communities on water security in view of these changes, through the case study of areas located around Bengaluru.

1.1 Community participation in Planning Adaptation

The current and projected impacts of climate change make the understanding of environmental and social vulnerability of peri-urban areas and the planning of adaptations important to achieve international goals and national policy initiatives. Social, political, economic, demographic and environmental changes occurring at local to national scales compound these global changes and increase the vulnerability of communities. Adaptation has become essential, especially the manner in which adaptation occurs can be proactive or reactive, and results can be beneficial or detrimental for communities and local environments. Largely due to current and projected impacts of climate change, there has been a significant research focus on analyzing vulnerability (Adger 2006; Eakin and Luers 2006; Ford et al. 2006; Smit and Wandel 2006; Turner et al. 2003) and an international program and policy focus on planning adaptations (IPCC 2014; McCarthy and IPCC 2001; Parry and IPCC 2007). Vulnerability refers to the susceptibility of an entity, such as an individual, group, sector, community or country, to an endogenous change, stressor or threat and the ability of the entity to recover from that threat (Smit and Wandel 2006). Analysis of community vulnerability requires an understanding of (a) the types and magnitude of changes to which communities are exposed (often called ‘‘exposures’’ or ‘‘stressors’’), (b) the susceptibility of a community to change (‘‘sensitivity’’) and (c) the ability of the community to adapt to change through managing risks, learning and devising effective response strategies (‘‘adaptive capacity’’) (Marshall et al. 2010; Smit and Wandel 2006).

An adaptation is a proactive response strategy that seeks to reduce the vulnerability of a community to a change. Adaptations can include mitigations to reduce sensitivity, actions to increase adaptive capacity or actions to reduce impacts (Smit and Wandel 2006). Effective adaptation planning requires recognizing and planning for the numerous different changes that are occurring simultaneously— i.e., taking into account multiple biophysical and socioeconomic stressors (Bennett et al. 2015a, b; Bunce et al. 2010; O'Brien and Leichenko 2000; Tuler et al. 2008)—and considering impacts on both social and ecological components of social–ecological systems (Turner et al. 2003). The term social–ecological refers to the integration of humans and nature in complex adaptive systems (Berkes and Folke 1998).

Numerous methods have been used to assess vulnerability and different processes have been applied to plan adaptations. Many vulnerability assessments have been designed and applied by outside researchers or experts with little local engagement and, some argue, with limited applicability or impact (Ensor and Berger 2009; Moser 2010). There has been an increasing emphasis on incorporating both scientific and local knowledge and using participatory methods and community-based approaches (Ensor and Berger 2009; Leary et al. 2008, 2009). The notion is to produce vulnerability assessments and adaptation plans that are useful and implementable. Different international governmental organizations and NGOs have produced different processes for adaptation planning (e.g., CARE 2009; IISD 2012; Marshall et al. 2010; USAID 2009; Wongbusarakum and Loper 2011). During the past decade, both academics and organizations have been engaging more with ‘‘futures’’ planning methodologies—such as visioning, backcasting and scenario planning (Birkmann et al. 2013; CARE 2011; Evans et al. 2006; Palacios-Agundez et al. 2013; Peterson et al. 2003; Plieninger et al. 2013; Rawluk and Godber 2011; Robinson et al. 2011; Schmidt et al. 2013; Sheppard et al. 2011; Swart et al. 2004; Wesche and Armitage 2014)—in planning adaptations for communities and ecosystems. Yet there remains significant scope for modification and application of these futures planning processes to different contexts and local scales, for integration of vulnerability analysis with adaptation planning to produce applicable results, for incorporation and consideration of multiple interacting and combined socioeconomic and biophysical stressors, and for reflection on the potentials and shortcomings of applying these methods in order to improve future practice. On this last point, it is problematic for researchers and practitioners that there are often few stepwise descriptions of methods with critical and honest reflections on research process and outcomes.

There is also a need for development of and reflection on participatory and nontechnical scenario planning methods that can be applied in a short time frame and with a limited budget by on-the-ground organizations and practitioners that work closely with local communities.

This study focuses on citizen-centred scenario planning as a practical and potentially powerful tool for local-scale vulnerability analysis and adaptation planning in coastal communities and social–ecological systems within the context of multiple interacting socioeconomic and biophysical changes or stressors. Community-based scenario planning proved to have significant potential as an anticipatory action research process for incorporating multiple stressors into vulnerability analysis and adaptation planning

Our approach is based on the principles of constructive engagement and to move research away from top-down, extractive information gathering towards participatory, bottom-up and inclusive knowledge generation. Climate Change Score Cards (CCSC) will be used to develop community based scenarios based on scores provided by all/major actors in improving resilience to water security in peri-urban areas.

1.2 Fuzzy Cognitive Maps – An Introduction

In this study climate change scorecard approach was modified to include the fuzzy cognitive mapping method. Fuzzy cognitive maps are models of how a system operates based on defined variables and the causal links between these variables. These variables can be measurable physical quantities such as amount of precipitation or complex aggregate and abstract ideas such as people's welfare. The person making the fuzzy cognitive maps decides what the important variables are that affect the system and then draws the causal relationships among the variables indicating the relative strength and sign of the relationships among variables with a number between -1 and 1. Once the maps are drawn, their structures are analysed using graph theory and their outcomes determined through fuzzy cognitive mapping computations.

Fuzzy cognitive maps have their roots in graph theory. Euler formulated the first graph theory in 1736 (Biggs and others 1976). Since then mathematicians have extensively developed graph theory, but Harary and others (1965) presented the theory of directed graphs (digraphs) for studying the structural properties of the empirical world. Signed digraphs have been used by anthropologists to represent different social structures in human society (Hage and Harary 1983). Axelrod (1976) first used signed digraphs to represent the assertions of informants. He adopted the term “cognitive map” [first used by Tolman (1948)] for these graphed causal relationships among variables as defined and described by people. Cognitive mapping has been used to look at decision-making and conceptions of complex social systems (Axelrod 1976, Bauer 1975, Bougon and others 1977, Brown 1992, Carley and Palmquist 1992, Cossette and Audet 1992, Klein and Cooper 1982, Malone 1975, Montazemi and Conrath 1986, Nakamura and others 1982, Rappaport 1979, Roberts 1973). Kosko (1986) coined the term fuzzy cognitive map when he modified Axelrod’s cognitive maps by applying fuzzy causal functions with real numbers in [-1, 1] to the connections. Kosko (1987) was also the first to determine the outcome of a FCM, as well as to model the effect of different policy options. FCMs have been used to model a variety of things such as the physiology of food appetite (Taber and Siegel 1987), political developments (Taber 1991), electrical circuits (Styblinski and Meyer 1988), a dolphin virtual world (Dickerson and Kosko 1994), organizational behaviour and job satisfaction (Craiger and others 1996), economics and demographics of nations (Schneider and others 1998). In the field of environmental management, we know of only three studies that have used FCMs. Radomski and Goeman (1996) used FCMs to suggest ways to improve decision-making in sports-fisheries management. Hobbs and others (2002) used FCMs as a tool for defining management objectives for the Lake Erie ecosystem. Ozesmi (1999a) first used FCMs to represent an ecosystem as told by different stakeholders. This research describes the use of FCMs for contrasting stakeholder perceptions and shows how this information can be used to develop a participatory management plan.

2. Literature Review

Urbanisation is a prominent vehicle of development in the global south. Studies of development and its related issues have thus traditionally categorised space into urban and rural, with each category being prescribed certain characteristics. Over the past decade, a new amalgamated space that straddles the boundaries of both these categories has been drawing the attention of scholars. Known as the 'Peri-Urban Interface' (PUI), this area is defined as 'zone of (dynamic) transition or interaction between urban and rural areas; usually used in the context of rapidly urbanizing poor countries' (Simon, 2008: 2).

The PUI is, to a large extent a result of continued urbanisation. In her overview of peri-urban areas in India, Shaw (1999) describes the areal spread of the country's four largest cities. She highlights that this urban expansion results in increasingly complex interactions with the surrounding rural lands, with gradual changes in land-use (Shaw, 1999). The resultant peri-urban area thus contains a mix of urban and rural functions. Most notably, agricultural and forested land is converted into residential, industrial, commercial and recreational spaces, often accompanied by select infrastructure such as roads and power stations (Simon, 2008). Accompanying such changes in land use is a shift in the livelihoods of peri-urban dwellers from agriculture to other secondary services. While the above is a spatial description of the PUI, Narain and Nischal (2007) argue that the term is more indicative of a process, where the PUI refers to a two-way flow of goods, services and natural resources between the rural and the urban. Such a bi-directional flow gives rise to unique characteristics of the area and correspondingly, results in unique environmental problems that emerge in peri-urban areas.

2.1 Problems in Peri-urban Areas

The urbanisation of rural spaces often occurs rapidly without the corresponding development of environmental services such as piped water supply and wastewater treatment plants (Shaw, 2005). Transition from agricultural to non-agricultural land uses subsequently results in the imposition of negative environmental externalities such as land, water and air pollution (Simon, 2008). Further, the accumulation of solid and liquid wastes from industrial and residential developments in the PUI results in severe sanitation issues– The additional waste generated poses a big problem given the absence of waste management infrastructure (Janakarajan et al, 2007). This problem of waste accumulation is further exacerbated by the flow of waste from the urban core to peri-urban areas. Given the accessibility of Peri-Urban areas from the city and the free availability of open spaces, peri-urban areas often become dumping grounds for urban waste (Prakash, 2014). Such unregulated waste disposal results in severe environmental and health issues for peri-urban populations and also contaminates the land and water resources that households depend on for their livelihoods and sustenance (Simon, 2008).

In addition to waste-related problems, there is also increased pressure on water in peri-urban areas. Urbanisation of previously rural space inherently increases demand for water due to a larger population and the additional industrial consumption (Lakshmi & Jakarajan, 2005).

Compounding on this shift is the flow of water, particularly drinking water, from peri-urban to urban areas. Such a flow is driven by two primary reasons – The first is the continued densification of cities which increases water demand and the second is the depletion of sources that had originally been supplying water to the cities (Ahmed & Sohail, 2013). The availability and access of water for peri-urban residents then becomes contested due to the combined pressures of increased peri-urban demand, increased urban demand as well as the contamination of peri-urban water sources by improper waste management.

2.2 Water Security in Peri-Urban Areas

Narain (2011) in his analysis of water issues in peri-urban areas highlights that the problem is not merely one of *scarcity* but that of *security*. He identifies three domains over which conflicts to water resources take place – quantity of water, quality of water and access to water sources (Narain, 2011). These three categories also emerge in Allen et al's (2006) investigation into a group of people termed as the 'peri-urban water poor'. The defining features of this group include 'informal/illegal access to water, access to poor-quality water and insufficient access to water' (Allen et al, 2009: 11). Water security can thus be understood to be consisting of these three dimensions, each of which is examined in the next section.

According to the United Nations, water security is defined as 'the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability' (UN-Water, 2013). The access to potable water and sanitation is considered a basic human right and yet billions do not have easy access to these services. It is estimated that approximately 1.8 billion people use a water source that has faecal contamination and approximately 40% of the world's population suffers from water scarcity (UN, 2015). The UN's Sustainable Development Goal 6 addresses this shortcoming by aiming to provide clean water and sanitation to all by 2030. While such a water crisis is a common phenomenon across developing countries, India has the largest population of 76 million people who do not have access to clean water – a much larger proportion of the country's population is faced with water scarcity and is forced to make do with irregular access to water (Wateraid, 2016). Residents in peri-urban areas largely fall into this second category and have to negotiate with water insecurity that is driven by several factors unique to the peri-urban space.

2.2.1 Quantity of Water

The quantity of water available to peri-urban households decreases due to increased water demand from industrial/residential developments and the supply of water to urban areas. The latter is particularly threatening due to the extensive scale of operation. For instance, Janakarajan et al (2008) call attention to the fact that the Metro water board transports more than 6000 tanker loads of water each day to Chennai city from its peri-urban areas. Similarly, in his study on the peri-urban areas of Hyderabad, Prakash (2014) highlights how the city's peri-urban residents have lost out to the wealthier urban middle class populations and are deprived of sufficient water. In addition to the extraction of water by tankers, peri-urban water supplies are also attractive for mineral water companies who extract groundwater, purify and sell them, further increasing the pressure on peri-urban water supply (Janakarajan et al, 2011). For instance, there are presently 200 bottling companies operating in the areas around Chennai City and the fact that they do not pay licensing fees results in unregulated over-exploitation of groundwater (Janakarajan et al, 2011).

The increase in pressure of groundwater resources is most evident when one examines the state of bore wells in India - In May 2016, 4000 bore wells in and around Bengaluru went dry, possibly due to overexploitation (Deccan Herald, 2016). Bore wells are also being dug deeper into the ground as water resources closer to the surface are being drained – 6000 year old water was drawn from a bore well 1,400 feet deep in Hyderabad, illustrating just how deep bore wells are being dug at present (Deccan Chronicle, 2016). Most states in India have laws that regulate construction of bore wells – permission has to be sought from local governments before individuals or corporations construct bore wells, there are restrictions on the depth of bore wells that can be constructed and additional bore wells are not allowed to be built in areas where groundwater is scarce. However, due to poor capacity of enforcing agencies new bore wells continue to be constructed, often at higher depths (Deccan Herald, 2016).

Indeed, the continued and rapid exploitation of peri-urban water resources not only reduce the absolute quantity of water available to households but it also affects the regenerative capacity of groundwater systems. The high demand for water from the urban core results in unregulated water harvesting, where water is extracted at much higher rates than that of replenishment. For example, in his analysis of peri-urban water security in Gurgoan, Narain (2011) comments on the lowering of the water table in the region over the past decade – in some cases up to 300% lower than the initial levels. The lowering of the water table also makes it harder for low-income households dependent on groundwater as they lack the resources to extract water from greater depths – this is a serious issue considering that most peri-urban areas lack piped water supply (Narain, 2011). In some areas of Chennai, water harvesting is taking place at such an unsustainable rate that in some areas of Chennai, ground water has dried up completely (Janakarajan, 2005).

In addition to such urban drivers of water shortage, climate variability has also been reported to lead to a reduction in the quantity of available water. For instance, in their study of the Orangi Township in Karachi, Ahmed & Sohail (2013) mention how poor rainfall over a continuous 10 year period led to a severe water shortage in the region which had previously had ample supply of water. Such climate related drawbacks, further exacerbate water shortage in peri-urban areas.

2.2.2 Quality of Water

Water security is also threatened by the deteriorating quality of water sources in peri-urban areas. Industrialisation on urban fringes results in the dumping of industrial effluents or chemical discharges into groundwater or water bodies (Dahiya, 2007) – Such a state is largely attributable to the lack of industrial regulations in peri-urban areas, where effective environmental governance is present in negligible amounts (Simon, 2008). Several scholars even suggest that it is precisely this lack of stringent regulations in the peri-urban area that drives the movement of such polluting industries away from the urban core (Shaw, 2005). Further, sewage from the increased population load in peri-urban areas also leads to water pollution when it is released into water bodies without treatment (Shaw, 2005) – This occurs primarily due to the lack of sanitation infrastructure. In addition, peri-urban populations dependent on rivers flowing downstream through the urban core receive heavily contaminated water due to the improper disposable of residential and industrial wastes (Simon, 2008). Depending on the extent of contamination, peri-urban households may resort to buying water from other sources such as mineral water companies. However, it is not uncommon for low income households to consume water of poor quality due to the lack of alternatives (Simon, 2008).

2.2.3 Access to water

In several instances, the poor purchasing power of peri-urban residents' results in them not having regular water supply. For example, in their analysis of Hyderabad's peri-urban areas, Arha et al (2014) draw from a survey done in 2003 to highlight discrepancies between Hyderabad's low income peri-urban households who are supplied water on alternate days for a few hours and the quantity of water supplied to IT companies and other corporate bodies in the area. The low frequency of water supply is often an issue of inconvenience for peri-urban households.

In some instances, peri-urban dwellers lose all access to their traditional sources of water. The accessibility of peri-urban areas to the economic market results in water bodies being lost to other purposes, inhibiting access to households. For example, the filling up of water bodies for urban acquisition is a common phenomenon across India (Narain, 2010), which displaces communities that have traditionally been using the source. At times, even if water bodies are not eradicated, their management is transferred to corporate bodies, making them inaccessible to the public. In their analysis of the peri-urban interface in Shahpur Khurd, Narain and Nischal (2007) note that three ponds in the village traditionally used by residents are now auctioned off by the village panchayat to fisheries contractors. Such emerging market relations further threaten the water security of peri-urban dwellers.

2.2.4 Issues of Governance around water security

Behind several considerations of water security mentioned above, is the issue of governance – There is a general consensus between scholars that the lack of proper governance is the main driver of water insecurity in peri-urban areas. Shaw (2005), for example, highlights that peri-urban areas 'generally lack the institutional capacities and governance structures' to respond to the changes happening in their area. A key reason for this lack of governance capacity is that peri-urban areas often fall through the cracks when it comes to authorities as cities are managed by municipalities and while villages are managed by panchayats – which body has authority over which sectors of the peri-urban space often varies from state to state (Prakash, 2014). Jurisdictional ambiguity, lack of cooperation and the absence of coordination among the various governmental bodies often results in peri-urban issues not being addressed effectively (Prakash, 2014).

It should be noted that while effective governance is impeded in peri-urban areas due to the reasons mentioned above, market based solutions do not preserve the water security of peri-urban residents either (Allen et al, 2006). This is attributable to the low purchasing power of peri-urban residents, which do not provide sufficient incentive for the private companies to meet their water needs (Allen et al, 2006). It is given this dual failure of both the state and the market that several scholars have resorted to calling for greater community involvement and initiative in addressing issues of water security. For instance, in analysing the plight of a peri-urban community in Chennai, Shaw (2005) proposes 'looking beyond dependence on government and attemplting to solve problems through community or local involvement'.

Such citizen participation is considered ideal for it allows householders, as key stakeholders in the issue of water insecurity, to identify and prioritize the problems to be addressed, set the agenda for action and assess the efficiency of the measures taken to address the problems (Swedish Water House, 2007). A more ground-up approach then reduces the dependency of these communities on local government bodies and is expected to result in more effective solutions that benefit the community. Ideally, such participatory initiatives should be inclusive and be carried out at a sufficiently small scale to ensure that subgroups that vary in economic and social status are not marginalised (Swedish Water House, 2007). Integral to such citizen empowerment is the presence of civil society organisations that enable and facilitate communities in identifying and addressing problems of water security (Dahiya, 2003).

2.3. Investigating peri-urban water security around Bangalore

Before one can try to address water security however, it is essential to first identify how water security is being compromised in any given area. While this review has considered the current literature on water security in peri-urban areas, each peri-urban locality faces a unique set of challenges that need to be addressed. As Allen (2013) highlights, environmental management of peri-urban areas needs to be designed to address the 'specific environment, social, economic and institutional aspects' of the targeted locality (Allen, 2003:1). While literature on peri-urban areas in India is already scant, it is predominantly focused on Delhi, Hyderabad and Chennai. A primary study conducted on the peri-urban areas of Bangalore will thus be useful in identifying the drivers and conditions of water-security, specific to the peri-urban areas of Bangalore city.

In line with the rationale that a participatory approach may be the most effective in peri-urban areas, it is ideal to gather information on water security from peri-urban residents themselves. Having such a stake-holder centric design in identifying issues around water security pre-empts any participatory action that can be taken by the residents in addressing these issues - Understanding their perspective on water security is the foundation upon which solutions to address them can be devised. PAC's proposed study will thus aim to extract stakeholder perspectives on water security in peri-urban areas. Given that water security is majorly influenced by urbanisation, along with stressors of climate variability, stake-holder's perspectives will be analysed with specific relation to both these variables. Such an approach is well suited given that vulnerability to water insecurity is a combined product of both these stressors, with each interacting synergistically with the other to create patterns of insecurity unique to each locality (Narain, 2010).

3. Study Area Descriptions

Manchanayakanahalli gram panchayat located in Ramanagar district of Karnataka was selected as the study area (Shown in the Map below). The gram panchayat was selected due to its proximity to Bengaluru and the Bidadi Industrial Estate located in its periphery. Seven villages namely, Manchanayakanahalli, Shanamangala, Hejjala, Talakuppe, Billakempanahalli, Lakshmisagara and Inorapalya, which fall within the jurisdiction of the gram panchayat, were studied. The villages support a combined total of 2489 households, comprising 9905 individuals. Each village has a literacy rate of between 72% and 61%. The working population of each village is 45% on average. While all of the villages have employment in agriculture and non-agricultural sectors, the distribution between the two vary for each village. With the exception of Hejjala and Lakshmisagara, all other villages have a few individuals involved in household industries.

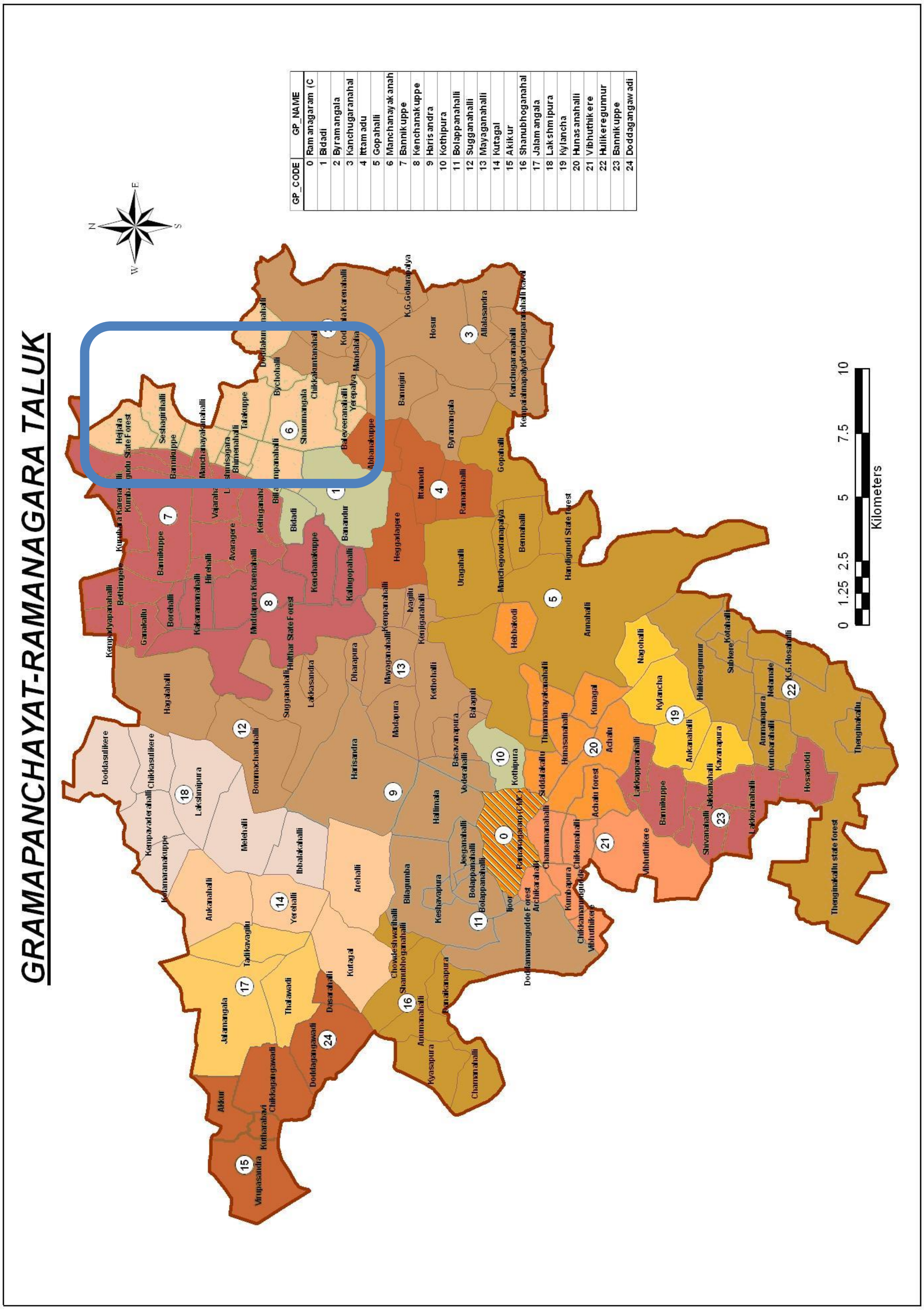
It is extremely important to possess comprehensive and documented information about the socio-economic aspects of the villages because it provides the basis of analysis. But, it is essential to know the demographic profile of the study area before any analysis. Therefore, a brief documentation of the demography, socio-economic condition and employment profile of the concerned villages is provided below.

As per the requirement of the study, the above villages were classified as big, medium and small based on their population based on the available data from the Census of India, 2011. It may be mentioned here that since the village Inorapalya has a very low population, the census does not provides separate data for this village and hence, categorised as a hamlet. It could be roughly assumed that the features of the other villages will be similar to Inorapalya taking our field interactions into consideration. The same was verified during our scoping visits to the Inorpalya.

The demographics show that on an average the male population consists of 52.2% of the total population which is more than the female population (47.8%). The rate of literacy among the male members is more than the female members with an average of 15% gender gap in literacy across all the villages. An average of 44.8% of the population constitute the working population group in the villages with a break up of 63.7% male and 24.1% female. A significant difference in the distribution of the percentage of working people owing to gender across the villages was observed.

Occupational patterns in the study villages were classified similar to census of India such as, Cultivators, agricultural labourers, household industries, main and marginal industrial workers and others. While all of the villages still continue to be engaged in agriculture, employment in non-agricultural sectors is on the rise and currently constitutes a higher share of employment. Census, 2011 data classifies almost 96% of the working population as main workers who are working in the industrial area located close by.

One of the striking features revealed by the categorized data on employment is that besides being classified as rural areas by the census, the average percentage of persons engaged in cultivation and farm-wage in all the villages is very low. Thus, it can be concluded that the population in these villages are engaged in non-farm labour and in the service industries. Except in case of Shanamangala and Talakuppe, where 58% and 73% of the labour force is still involved in agriculture sector respectively. There is relatively less number of households in the villages who are dependent on household industries. As is seen from the census 2011 employment data, a higher percentage of the population is engaged in non-agricultural activities as their main livelihood. This can be described an urban characteristic, as urban areas as defined by the Indian census is an area with more than 70 per cent of the population engaged in non-agricultural activities. The question therefore, arises that whether these areas should still be considered and administered as rural or should they be treated as urban areas. This interface which is developed due to an area being classified as rural but possessing urban characteristics can be defined as peri-urban interface as is mentioned in section 2.



Source: Ramanagara Zilla Panchayat(http://ramanagara.nic.in/maps/rmgtaluk.jpg)

4. Methodology

Over the last two decades Public Affairs Centre (PAC) has envisioned good governance through the use of citizen-centred tool to improve accountability namely, Citizen Report Cards (CRC) and CRC+. In these times of changing climate, Public Affairs Centre with its expertise to "*undertake and support research based on citizen science and facilitate collective citizen action through development of dialogue platforms and capacity building activities"* has developed several social accountability tools to answer the fundamental questions of

- *How can world's citizens, who have a vital stake in identifying a global solution to the present climate crisis, become actors in the effort to resolve it*? and
- *How can social concerns of citizens and communities be mobilised to help forge a collective will and develop the knowledge to educate the public and governments on the urgency and the need for climate protection?*

To answer these questions the Environmental Governance Group has developed an approach which helps PAC to "*move research away from top-down, extractive information gathering towards participatory, bottom-up and inclusive knowledge generation"*. Based on this approach Environmental Governance Group has developed the Climate Change Score Cards (CCSC).

CCSC considers three important dimensions; People, Climate and Governance. CCSC is a tool which supports communities with evidence and rationale to prioritize issues on planning adaptation to climate and environmental degradation. The tool provides a platform for dialogue with relevant decision makers based on the knowledge generated and helps in evidence based policy decisions. The holistic approach of assessing vulnerability to climate change and formulating adaptation methods is founded principles of constructive engagement. CCSC is an attempt to move research away from top-down, extractive information gathering towards participatory, bottom-up and inclusive knowledge generation.

CCSC has been pilot tested along 170 villages along the east coast of India and Cauvery delta regions, where the tool has led to identification of local level vulnerability in addition to documenting autonomous adaptation practices. PAC has trained organisations and individuals on climate change and the need for social accountability in this sector at the local level. PAC has also created policy dialogue platforms at the taluk and district level for successfully incorporating people's voices in policy spheres. These serve as knowledge sharing platforms between communities and experts.

4.1 Climate Change Score Card

Climate change score card (CCSC), is an adaptation of the community score card (CSC), a well-known social accountability tool (Sekhar and Nair 2008c, NRHM 2000). CSC consolidates peoples' opinion and facilitates an informed dialogue between communities and the local governance structures. Conventionally, a CSC aims to bridge the dialogue between two main actors: the people and the state. In the case of climate change there are not two, but three important dimensions: the people, the state and the environment. To account for this, systematic integration of information on local governance and local climate science and livelihoods will be made in the CCSC. The tool will support communities to prioritize issues and provide a platform for dialogue with relevant decision makers.

The climate change score card is undertaken in three distinct phases:

4.1.1 Exploratory Phase

This phase is the initial phase where primary visioning exercises are undertaken. This phase consisted of identification of study areas and scoping visits to the field to understand the on-ground conditions.

The primary visioning exercises undertaken in this phase included a household questionnaire based survey was conducted to assess the water security of households to drinking water in their villages. The survey involved a sample size of 475 households from nineteen villages near Bidadi town, out of which eight were from Manchanayakanahalli gram panchayat, Ramanagara taluk. The villages were chosen based on the definition of peri-urban areas, mentioned in section 2. During the course of the study some of the study villages were incorporated into the Bidadi town municipality, which rendered them inappropriate to be considered under the study definition. Hence, 10 villages had to be dropped from the study and the study focussed on the following eight villages in Manchanayakanahalli gram panchayat in Ramanagara taluk. The villages chosen for the study are as mentioned in Table 1.

Table 1: List of villages studied in Manchanayakanahalli Gram Panchayat

Sl. No	Village
1	Manchanayakanahalli
2	Shanumangala
3	Hejjala
4	Talakuppe
5	Bilikempanahalli
6	Lakshmisagara
7	Bheemanahalli
8	Inorapalya

Furthermore, fuzzy cognitive maps were undertaken to develop qualitative models of the system, consisting of variables and the causal relationships between different variables within the system. The system here refers to the impact of climate change (variations in rainfall and increase in temperature) and urbanisation on water security.

Fuzzy Cognitive maps can be described as a qualitative model of how a given system operates. The map is based on defined variables and the causal relationships between these variables. These variables can be physical quantities that can be measured, such as amount of precipitation or percent vegetation cover, or complex aggregate and abstract ideas, such as political forces or aesthetics. The person drawing the cognitive map decides what the important variables are which affect a system and then draws causal relationships among these variables indicating the relative strength of the relationships with a number between −1 and 1. The directions of the causal relationships are indicated with arrowheads. Cognitive maps are especially applicable and useful tools for modelling complex relationships among variables. Cognitive maps of various stakeholders can be examined and compared as to their similarities and differences, which were discussed and agreed upon. In addition the effects of different policy options can easily be modelled. Maps can also be made with local people, who often have quite a detailed understanding of the ecosystem (Özesmi, 1999a,b). Their input can be important for decision-making and for the public to accept the chosen solutions.

For the purpose of this study 240 maps were drawn among various stakeholders. The stakeholders were chosen based on the demographics of the study villages which included agricultural labourers, livestock herders, industrial labourers and farmers. Table 2 provides the details of the number of maps drawn per village, and the classifications of maps between men and women groups in the villages. It can be seen that out of the 10 groups involved in each village nearly 6 were womens' groups as it was identified that women are the major group involved in livelihood activities.

4.1.2 Analytical Phase

The second phase of the study which involved assessing the vulnerability of the local communities based on the data collected in the exploratory phase. The household surveys were assessed to identify household vulnerability to water resources. Fuzzy cognitive maps were utilised to assess the vulnerability of communities to climate change and urbanisation and simulate different policy options through neural network computations.

The steps involved in analysing the fuzzy cognitive maps are as follows:

- Adequacy of the sample size
- Coding the cognitive maps into adjacency matrices
- Augmenting individual cognitive maps and then adding them together to form stakeholder social cognitive maps
- Analysing the structure of individual and social cognitive maps using graph theoretical indices

- Analysing the differences and similarities in variables among stakeholder groups
- Analyses of outcomes of cognitive maps using neural network computation

The study, apart from gathering primary data from field surveys and fuzzy cognitive maps, used climate data (rainfall, diurnal temperature range, cloud cover, potential evapotranspiration, and reference crop evapotranspiration and vapour pressure) available from secondary sources. Indian Meteorological Department provides climate data at a district level and hence, the same was used when assessing rainfall variation and increase in temperature in the study area.

4.1.2.2 Fuzzy Cognitive Maps

In this study 240 interviews were conducted with stakeholder belonging to four different categories (livelihood groups): farmers (1 men's group and 2 women's group), livestock herders (1 men's group and 1women's group), agricultural labourers (1 men's group and 1 women's group) and industrial labourers (1 men's group and 2 women's group). In total 90 people participated in drawing 240 maps (Table 2). Each group drew three maps identifying the impact of increase in temperature, variation in rainfall and urbanisation on water security in their respective villages.

Before drawing cognitive maps with stakeholders, the moderator drew his own cognitive maps of impact of temperature, rainfall and urbanisation on water security in Manchanayakanahalli gram panchayat. Thus, the moderator was aware of his map and realized his biases while drawing maps with the stakeholders. It is recommended that this exercise be done before conducting interviews in any cognitive mapping research (O¨ zesmi 1999a).

Table 2: Stakeholder Categories for developing fuzzy cognitive maps

Categories	No. of Groups		Total Number of Maps
	Men	Women	
Agricultural Labourers	1	1	6
Livestock Herders	1	2	9
Industrial Labourers	1	1	6
Farmers	1	2	9
Total per village	**4**	**6**	**30**

During the interviews the first two steps of textual analysis for drawing cognitive maps as described by Carley and Palmquist (1992) were used. The interviews were begun by explaining why the research was being conducted. The location, date, time and duration, and the names of the participants, their gender, and occupation were noted. Then the FCM process was explained by showing the interviewees an unrelated map. After the interviewees understood the process of creating a FCM, they were asked: "When I mention increase in temperature and water availability what are the factors, things, variables that come to your mind?" This question was also written at the top of a large piece of paper that was used for drawing their map. If it was not clear what was meant by a variable, questions were asked to clarify but not to direct the interviewee to an answer. Non-interference was the goal.

The variables listed by the interviewees were drawn the variables in the center of the paper. The interviews were asked to draw lines between the variables to represent their relationships. They were asked to label the lines with arrows to indicate their directions, to give them signs of positive or negative, and strengths of high (1), or moderate (0.5). For example, if the interviewee thought that temperature decreased surface water availability substantially, they would draw a line with the arrow pointing from temperature to surface water and give the connection a value of -1. If the interviewees seemed to be confused or not focused on the mapping, they were asked non-directional questions such as: “Are there any variable that affect this variable or does this variable affect any other variables?” The process continued until the interviewees felt that their maps were complete and they had nothing more to add. The reaction of the interviewees when drawing their cognitive maps varied from great enthusiasm to neutrality. In this study none of the interviewees refused to be part of the group to draw a map, and all maps that were started were completed.

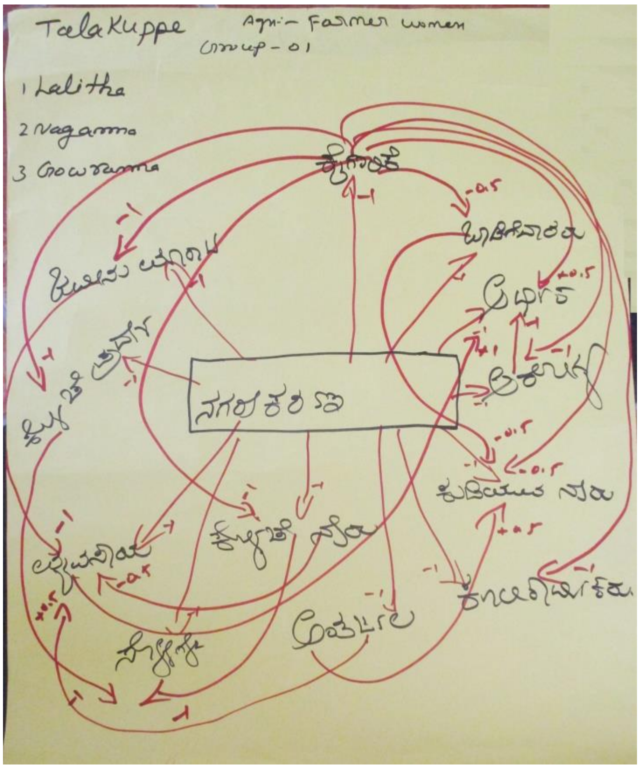


Figure 1: Example of a FCM drawn by community member

After the interviews, the FCMs were transformed according to graph theory into adjacency matrices in the form A(D) _ [aij] (Harary and others 1965). The variables vi (e.g., surface water) were listed on the vertical axis and vj (e.g., crop production) on the horizontal axis to form a square matrix. Matrix entries were made based on the cognitive map. For example, -1 was entered for aij if there was a causal decrease from vi to vj (e.g., reduction in surface water decreased crop production).

As FCMs can be quite complex, graph theory indices provide a way to analyse their structure. First the number of variables (N) and the number of connections in a map are determined. Indexes can be calculated after counting the number of different types of variables. The variable types are defined by their outdegree [*od(vi)*] and indegree [*id(vi)*]. Outdegree is the row sum of absolute values of a variable in the adjacency matrix and shows the cumulative strengths of connections (*aij*) exiting the variable:

$$od(vi) = \sum_{k-1}^{N} aik$$

Indegree is the column sum of absolute values of a variable and shows the cumulative strength of variables entering the unit:

$$id(vi) = \sum_{k-1}^{N} aik$$

Transmitter variables (forcing functions) have a positive outdegree and zero indegree. Receiver variables (utility variables) have a zero outdegree and a positive indegree. Ordinary variables have both positive outdegree and indegree (Bougon and others 1977, Eden and others 1992, Harary and others 1965).

The contribution of a variable in a cognitive map can be understood by calculating its centrality (*c*), whether it is a transmitter, receiver or ordinary variable. The centrality of a variable is the summation of its indegree and outdegree (Harary and others 1965):

$$Ci = td(vi) = od(vi) + id(vi)$$

The complexity index of a map is the ratio of receiver to transmitter variables (*R/T*). Maps with a large number of receiver variables are seen to be complex because they consider many outcomes and implications that are a result of the system (Eden and others 1992).

However a large number of transmitter variables indicate thinking with top down influences, a "formal hierarchical system" (Simon 1996, p. 185) and a map where causal arguments are not well elaborated (Eden and others 1992). Complex maps will have large complexity ratios because they define more utility outcomes and less controlling forcing functions.

4.1.2.3 Condensed Cognitive Maps

The square matrices of the individual stakeholder maps were combined into stakeholder group cognitive maps by adding the augmented matrices (Kosko 1988). Each stakeholder map was given an equal weight. Then these group maps were condensed. Condensation is a way to simplify fuzzy cognitive maps, as they can be quite complex with many variables and connections. In condensation, groups of variables connected by lines, called sub graphs, are replaced by a single unit (Harary and others 1965). The connections of variables within sub graphs with other sub graphs are maintained when replacing groups of variables. This grouping and replacing is also called aggregation. Variables can be combined by qualitative or quantitative aggregation.

For example, Nakamura and others (1982) used qualitative aggregation to condense 152 variables coded from 5 documents into 16 categories. This study used qualitative aggregation to combine variables into categories that were represented by a larger encompassing variable. For example, this study combines variables such as household finances, price rise, loan and low income into the category of economic conditions. After condensing the maps, they were drawn with connections showing the weight and sign of the causal relationship.

Finally, all the individual stakeholder maps are combined into one social cognitive map, where each stakeholder map was given an equal weight, by adding all of the augmented matrices (Kosko 1988). The outcome of the map can then be determined by using matrix algebra where a vector of initial states of variables (In) is multiplied with the adjacency matrix A of the social cognitive map. Usually a threshold function or a transformation by a bounded monotonic increasing function is applied to the result of the matrix multiplication, In * A, at each time step (Kosko 1987, 1992).

5. Findings and Discussions

This section details the results of the study including the time series data analysis, results drawn from the Climate Change Score Cards which consists of household survey conducted on drinking water conducted in 475 households and the results of fuzzy cognitive maps (240 maps) drawn by the communities on water security to increase in temperature and variation in rainfall in addition to urbanisation. In addition to these, the section also highlights the vulnerability of the eight selected villages, which are considered for the study.

5.1 Time Series Analysis of Climate Data (1901-2002)

The data for the climatic parameters such as rainfall (a_rainfall), vapour pressure (a_vp), number of wet days, potential evapotranspiration, and cloud cover, diurnal temperature range and reference crop evapotranspiration are considered for analysis. The data for these variables have been obtained from the Indian Meteorological Department for the years 1901 to 2002. The data collected was for the Bangalore Rural District, as Bidadi and surrounding areas were part of this till 2003. Figure 2 shows the summary statistics of the variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
a_rainfall	102	834.1735	161.3686	492.745	1237.162
a_vp	102	20.73234	.2318385	20.027	21.445
a_wd	102	4.066627	.3314034	3.256	4.858
a_peva	102	6.11002	.0253412	6.013	6.174
a_cc	102	47.31979	1.060133	44.377	51.277
a_dtr	102	10.66883	.0016832	10.652	10.669
a_rcep	102	4.555539	.0344509	4.483	4.66
a_temp	102	24.44989	.3194438	23.775	25.41

Figure 2: Summary Statistic of climate data 1901-2002

Time series regression analyses of the variables are shown in Figures 2. The Figure shows the regression analysis of average temperature on climate data available, it can be seen that as vapour pressure and reference crop evapotranspiration increases, the average annual temperature also increases. Furthermore, temperature is found to decrease with an increase in potential evapotranspiration and an increase in cloud cover. It can be seen that all the variables considered are significant at 95 % CI and the effect of the variable reference crop evapotranspiration is significant at 99% CI. From Figure 2, it can be seen that the variables potential evapotranspiration (90%) and cloud cover (99%) have a significant impact on the rainfall in the region, as against any other climate variables. Further, it can be concluded from that a slight increase in diurnal temperature range has a huge negative impact on rainfall in the region. Reference crop evapotranspiration can also be attributed to having a negative impact on rainfall.

	(1) a_rainfall	(2) a_temp
a_temp	75.46	
	(0.14)	
a_vp	152.9	0.0627*
	(0.91)	(2.02)
a_peva	14827.5**	-2.194*
	(3.21)	(-2.58)
a_cc	314.3***	-0.0386*
	(3.55)	(-2.35)
a_dtr	-13228.4	
	(-1.41)	
a_rcep	-9279.9	9.980***
	(-1.56)	(19.78)
_cons	73756.6	-7.081
	(0.74)	(-1.80)
N	102	102

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Figure 3: Regression analysis of Temperature and Rainfall with various climate parameters

5.2 Drinking water Security

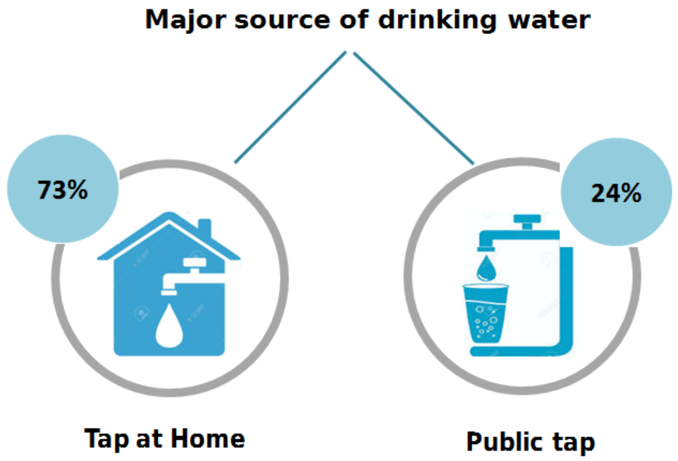
This subsection deals with the findings and discussion on analysis of the results from the household survey undertaken in the study villages. 475 household surveys were undertaken with the help of our field partners. The questionnaire used in this study was an extraction of the questionnaire used to assess the service delivery of Bangalore Water Supply and Sewerage Board (BWSSB). It consisted of four parts, general information; demographic information; water usage pattern; and coping strategies by the communities to overcome any issues with the available drinking water.

Analysing drinking water security through the lens: availability, access, quality and usage pattern is a useful interdisciplinary framework. An understanding of people's perceptions on water availability, quality is very important to assess ones water security. This analysis is very important, as this helps understand the issues of water security at the household level, due to rapid unplanned urbanisation and in the time of changing climate on each, and of the relationships between them, is vital for policy, project and programme development.

Household survey on drinking water was one of the major components of the study. Broadly, the survey questionnaire covered information on availability and usage of drinking water sources, access, adequacy, frequency, and quality of drinking water supplied. The survey also tried to assess the coping mechanisms adopted by local communities to tackle insecurity and/or inconsistency faced regarding the parameters studied.

Source of Drinking Water Supply

The survey findings revealed that most of the households possess a tap at home (73 per cent) which is the main source of drinking water. Apart from this, public taps were the next major source of drinking water as reported by nearly 24 per cent of the respondents. This is followed by use of mini water supply scheme (3 per cent) and hand pumps (1 per cent) act as the main source of water for the respondents.



Availability of Drinking Water – Sources and Time

Most of the households surveyed had an easy access to drinking water sources, with a majority having a tap at home (75 per cent). Other households, which did not have a tap at home, had access to a public tap (27 per cent), or a mini water supply scheme (33 per cent). 6 per cent of the households surveyed purchased water through tanker supply at a cost incurred on household budgets. Though majority of the households in the villages of Lakshmisagara, shanamangala, Billekempanahalli and Inorapalya, mentioned the availability of mini water supply scheme, it did not serve as their main source of drinking water as they depended on public taps or water supplied to their homes. 19 per cent of households in the village of Lakshmisagara, identified mini water supply systems as their main drinking water source, which is the only exception among all the other households and villages. Hence, we can conclude that availability of drinking water is not a major issue in the gram panchayat as 95 per cent of the respondents have access to water sources within less than half a kilometer from their homes.

Apart from this, the survey asked questions regarding the number of hours water is supplied to those households that responded to having a tap at home or which used public taps as a major source of drinking water. 67 per cent of the households revealed that drinking water was supplied for 2-3 hours a day whereas 14 per cent answered they receive water for up to 4-5 hours a day, while only 7.5 per cent of the houses report getting water for more than 5 hours. The village of Inorapalya was the only exception where every household surveyed reported to receiving water once in twice a day for every two days. The survey highlights that all the households (100 per cent) are satisfied with the timings of the drinking water supply and its adequacy; be it tap water or public tap. On the contrary, 58 per cent of the respondents purchase mineral water for drinking purposes from water vendors.

More than 50 per cent of all respondents who reported to having a tap at home reported to having sump tank, overhead tank and water pump in their house. Similarly only 20 per cent of the households who mentioned to use public tap have the above mentioned infrastructure.

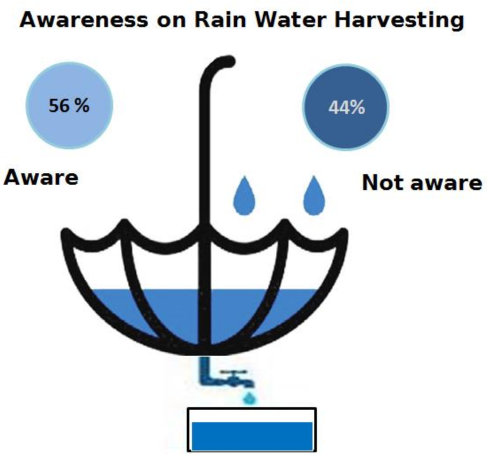
Quality of Water Supply

When questioned about the quality of water supplied, it was observed that 10 per cent of the households receive salty water; about 21 per cent receive tasteless water and nearly 68 per cent reported to receiving sweet water. However 14 per cent and 43 per cent of the households in Manchanayakanahalli and Talakuppe reported to receive salty drinking water respectively. Furthermore, 12 per cent of households in Machanayakanhalli and 11 per cent of households in Talakuppe and Billekempanahalli reported to be receiving muddy water.

The findings from this analysis resulted in collection of drinking water samples, from the villages of Lakshmisagara, Manchanayakanahalli and Talakuppe, as these were the villages where the quality of water was not up to the standards in addition to depending on other sources such as water vendors.

Awareness on Rainwater Harvesting

It was highlighted by the survey that there is a lack of awareness among the households regarding measures that can be adopted by households to improve both surface and groundwater sources. Only 44 per cent of the households mentioned to have gathered some information about rainwater harvesting from television and other sources of media.



Thus, it can be concluded that water insecurity in these areas is likely to be more a function of high demand and poor management and maintenance of water bodies rather than absolute scarcity of water. Improving, water sources through modern techniques and rejuvenation of water bodies may have a considerable impact on overall water and livelihood security.

5.3 Water Sample Analysis

The findings from the household survey, in terms of quality of water highlighted the supply of salty water which raised questions on quality of water used by the communities for drinking, and other household usage. Thus, seven samples were collected from three villages namely, Manchanayakanahalli, Talakuppe and Lakshmisagara. The water samples included water from drinking water sources, groundwater and water supplied through public tap by the Gram Panchayat.

Three samples were drawn from the villages of Manchanayakanahalli, two of which are from groundwater sources (MH (A) and MH (B)) and one sample was from the Reverse Osmosis plant which serves as the source of drinking water (MH(C)). Furthermore, samples from public tap in Tallakuppe (TK (A)) and Laksmisagara (LS (A)), in addition to water from hand pump (TK (B)) were also collected. Another sample was collected from a Reverse Osmosis plant (GP (A)), which serves as a major drinking water source in these two villages was also collected.

The samples were analysed by the Water Testing Lab at EMPRI, and the findings of the analysis are as in Table 3 and 4. Based on the analysis, we can mention that even though most of the water samples are well within the agreeable range as mentioned in the BIS Standards, there are few exceptions. These exceptions are seen mainly in terms of colour (slightly cloudy); turbidity, as seen in one of the sample which was higher than the agreeable limit but within the permissible limits; and P^H, mainly seen in the water samples from the RO plants, highlighting that the water supplied is acidic in nature; in addition to this, an analysis of the odour of water samples shows that two samples including a sample from the RO plant to be slightly muddy or earthy in addition to presence of metal in one of the water sample collected from a household in Talakuppe.

Table 3: Water Sample Analysis of Ground Water

Sl. No	Description			Sample Code					BIS Stand. Agreeable Limit	BIS Stand. Permissible Limit
	Parameter	**Unit**	**Measurement Methods**	**MH (A)**	**MH (B)**	**TK (A)**	**TK (B)**	**LS (A)**		
1	Colour	-	Visual	Colourless	Colourless	Slightly Cloudy**	Colourless	Colourless	Agreeable	Agreeable
2	Odour	-	Manual	No Odour	Slightly Earthy **	No Odour	Metal Corrode **	No Odour	Agreeable	Agreeable
3	P^H	-	P^H meter	6.70	7.97	7.02	7.10	7.31	6.5-8.5	No Relaxation
4	Turbidity	NTU	Nephelo Turbidity Meter	0.39	0.43	1.24**	0.34	0.40	Max. 1	5
5	TDS	Mg/l	TDS Meter	220	180	192	190	190	Max. 500	2000
6	Free Residual Chlorine	mg/l	Colorimetric Method	NA	0.6	0.4	0.5	NA	Min. 0.2	1

Table 4: Water Sample Analysis of Water from Reverse Osmosis Plants

Sl. No	Description			Sample Code		BIS Stand. Agreeable Limit	BIS Stand. Permissible Limit
	Parameter	**Unit**	**Measurement Methods**	**MH (C)**	**GP (A)**		
1	Colour	-	Visual	Slightly	Colourless	Agreeable	Agreeable

				Cloudy**			
2	Odour	-	Manual	Slightly Muddy**	No Odour	Agreeable	Agreeable
3	p^H	-	p^H meter	6.10**	5.53**	6.5-8.5	No Relaxation
4	Turbidity	NTU	Nephelo Turbidity Meter	0.54	0.48	Max. 1	5
5	TDS	Mg/l	TDS Meter	120	80	Max. 500	2000
6	Free Residual Chlorine	mg/l	Colorimetric Method	0.5	0.6	Min. 0.2	1
7	Microbial Analysis	CFU	Membrane Filtration Method			Shall not be detectable in any 100ml sample	

5.4 Fuzzy Cognitive Maps

This section deals with the assessment and analysis of the fuzzy cognitive maps drawn by stakeholders. For the study 240 maps were drawn with stakeholders belonging to various livelihood groups. The maps were drawn based on three factors (temperature, rainfall and urbanisation) that affect water security in the region. The maps drawn by stakeholders were then coded into adjacency matrices and condensed into a single cognitive map from 240 maps, one for temperature, one map for rainfall and one on urbanisation.

5.4.1 Urbanisation and water security

It was highlighted during scoping visit to the study area and the data from census 2011, that the gram panchayat, though classified as rural, does not hold true to its definition, as over 70 per cent of the population are engaged in activities other than agriculture. Hence, it was decided to assess the impact of this unplanned expansion and conversion from rural to urban on water availability, quality and security in the area. Fuzzy cognitive maps were drawn by stakeholders (Table 5) totalling to 10 maps per village. These maps were then aggregated to 70 maps from the 7 study villages. The maps were then converted to individual matrices and condensed to form a single socio-economic matrix for the gram panchayat. An example of the same is shown in Table 5.

Table 5: Example of condensed matrix developed from 70 individual cognitive maps (Urbanisation)

	Urbanization	Agriculture	Health	Financial conditions	Drinking water	Surface water	Ground water
Urbanization	0.00	-0.76	-0.31	0.81	-0.28	-0.35	-0.11
Agriculture	0.00	0.00	0.04	0.32	0.00	0.00	0.00
Health	0.00	0.00	0.00	-0.16	0.00	0.00	0.00
Financial conditions	0.00	-0.15	0.00	0.00	-0.02	0.00	0.00
Drinking water	0.00	0.00	-0.09	-0.03	0.00	0.00	0.00
Surface water	0.00	0.05	0.00	0.00	0.04	0.00	0.07
Ground water	0.00	-0.01	0.00	0.00	0.08	0.00	0.00

The matrix provided above is a condensed matrix of 70 individual matrices drawn by ten stakeholders groups from the seven study villages. These condensed matrices were normalised to ensure the scores were limited to the range -1 to 1 as is shown in Table 5. This matrix was then analysed to identify some of the most influential elements responsible for the current state of water security and identify how to improve the present conditions. Figure 3 & 4 highlights that industries and pollution, including garbage and sewage disposal from urban areas have a high influence on the socio-economic conditions of the communities. In addition to this, these variables also have a high influence on surface water sources including drinking water. Furthermore, urbanisation has also affected the health of local communities and has had a negative impact on agriculture. This has led to an increase in land conversions and sale resulting in improved economic conditions. Spill-overs from ever urbanising Bangalore, though has improved the economic conditions and improved infrastructure facilities such as schools, hospitals, job opportunities in the study villages, it has resulted in decreasing water availability and accessibility in addition to contamination of water from urban sewage rendering the peri-urban communities vulnerable to these negative changes and increasing water insecurity.

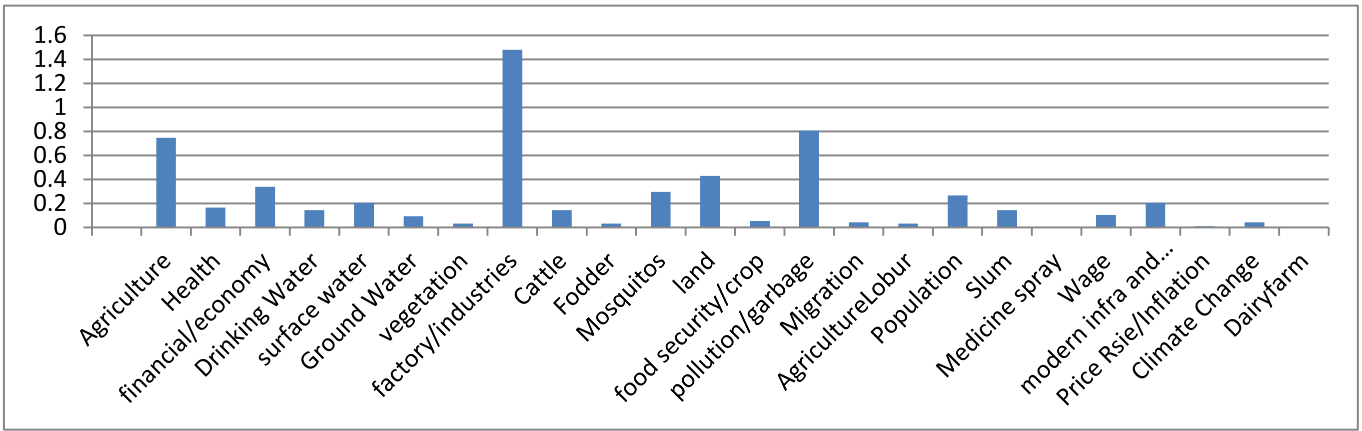


Figure 4: Graph showing the variables which have influence on other (Urbanisation)

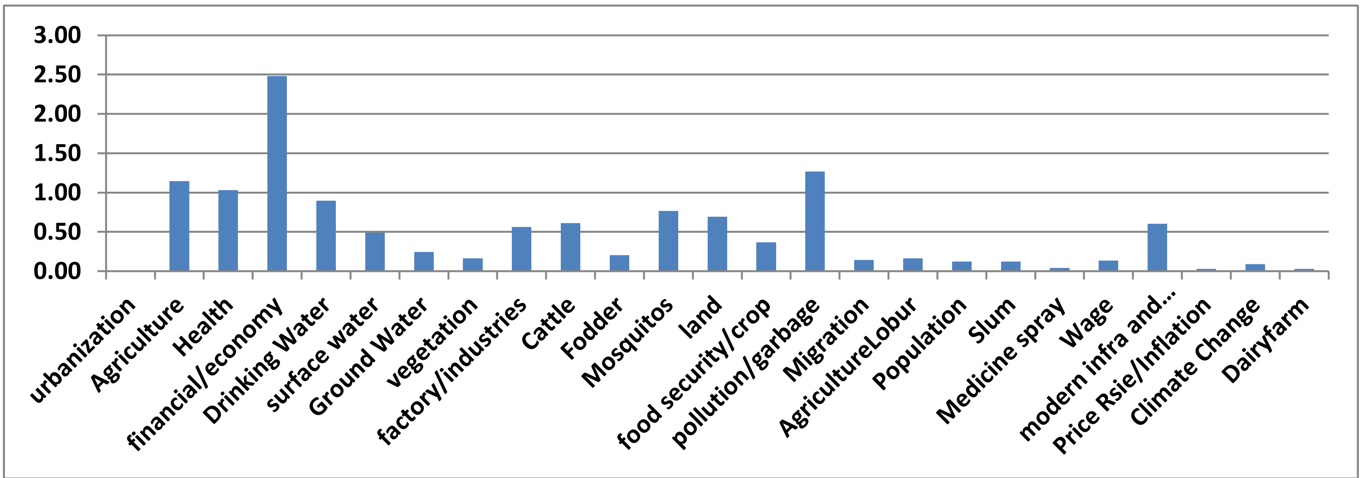


Figure 5: Graph showing the variables which are highly impacted due to urbanisation

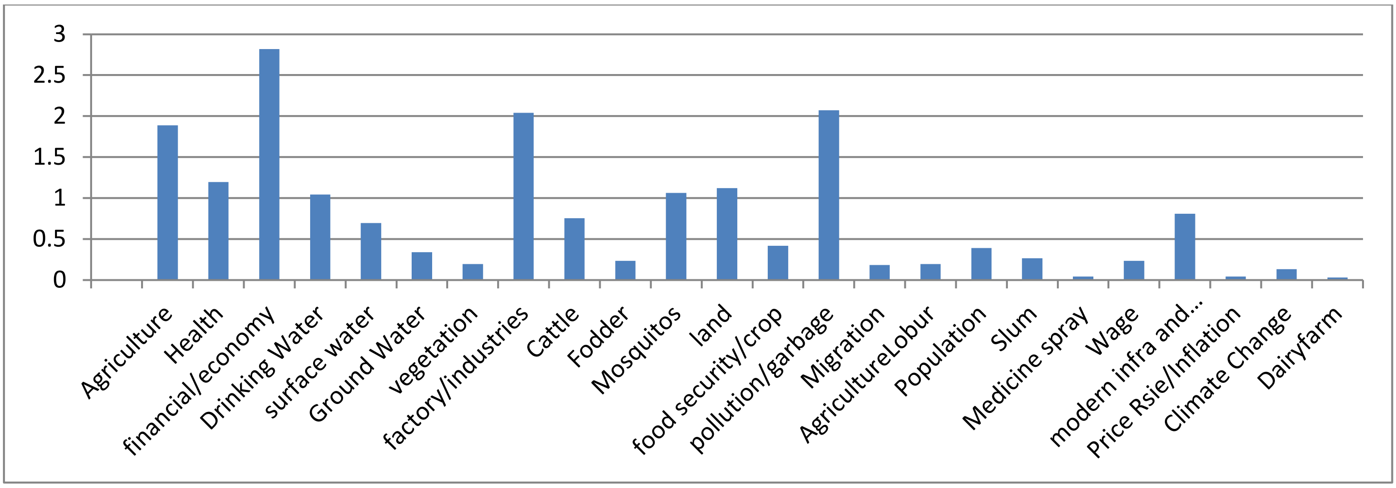


Figure 6: Graph showing the variables based on their influence on all other variables (Urbanisation)

The cognitive interpretation diagram (CID) for urbanisation is shown in Figure 6, The CID is drawn based on the condensed stakeholder maps, ten maps from each of the seven villages accounting for 70 maps in total. The size of the bubbles indicates the influence of the variables. The positive causal relation is shown in black and the negative relationship is highlighted in red links. It can be seen from Figure 6 that urbanisation has resulted in increased financial conditions of the communities, and provided increase access to modern infrastructure has a negative influence on drinking water, groundwater and surface water sources in addition to health of the local communities. It can also be seen that urbanisation has increased pollution, which has a negative effect on agriculture livelihoods pushing people to work as industrial labourers and conversion of agriculture land to commercial and industrial purposes.

Though urbanisation has increased financial capabilities, the communities are spending much more to collect drinking water, and on health related problems, which negates the income generated due to urbanisation. This has also resulted in migration among the youngsters to cities and nearby towns.

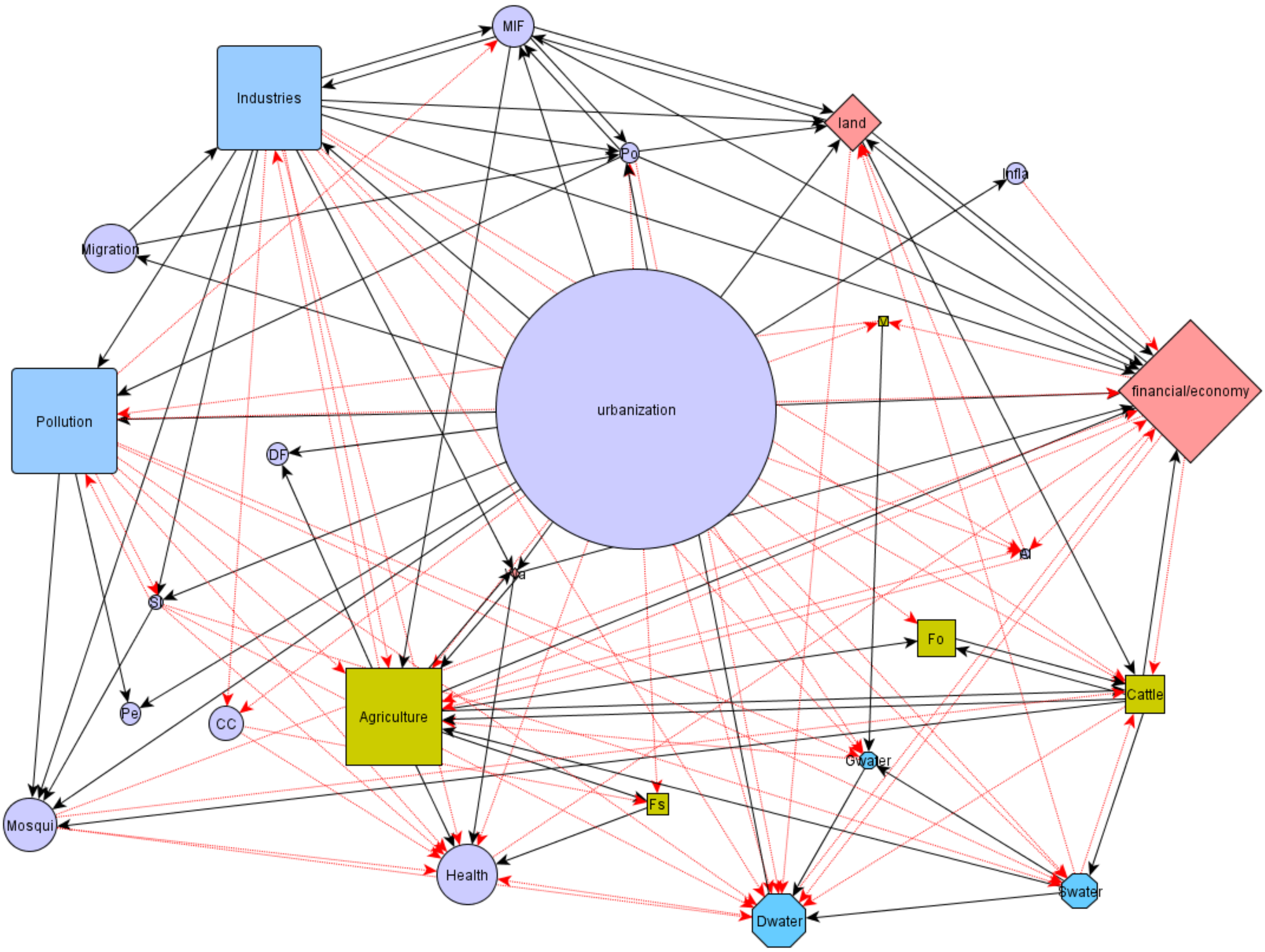


Figure 7: Cognitive Interpretation Diagram (CID) for Urbanisation drawn from condensing 70 individual maps

Models were run to ask 'what-if' questions and was run to determine what state the system will go to under different conditions or if different policy options are implemented. These calculations were made on the condensed cognitive map resulting from the addition of seventy individual cognitive maps. The models were run in a way as to increase water security through enforcement of stringent pollution control norms, reduction in slum population through provision of better housing and other facilities and improving vegetation and agriculture practices. One of the models runs assumed that population in the area would increase moderately, whereas another model was run assuming the current trend in population will remain same.

In the policy option run, the improvement of water security was prioritized. Through the policy option simulations, it is possible to determine which policies and combination of policies would increase water security according to people perceptions. In the scenario analysis, FCMs indicate the direction in which the system will move given certain changes in the driving variables. Given an initial state of the system (Table 6) two scenarios were imagined in our model: first, (Table 7) agricultural patterns, food security was improved by 50 per cent and pollution was reduced by 50 per cent through existing norms and policies. The model also assumed that, the sale of land will increase and there would be an increase of slums by 50 per cent. This model predicted a strong positive change in drinking and surface water sources, and a moderate positive change in vegetation and forest cover in the area. The model also predicted a strong positive improvement in the health of the local population which can be attributed to reduced pollution and also a reduction in mosquitoes which was perceived by all the respondents to be one of the major factors for decreasing health conditions, apart from contaminated drinking water. Though pollution was reduced by 50 per cent, the model predicted a weak negative change in the number of industries and/or industrial establishments affected. This provides a positive outlook, that there is a need for stringent enforcement of effluent laws and a need for establishment of sewage treatment plants for treating urban sewage which is dumped in water sources along the area.

Second model (Table 8), was run under the assumption that pollution will be reduced by 100 per cent and there will be reduction in the slum population by 50 per cent. This was coupled with increase in provision of modern infrastructure facilities and an increase in vegetation and tree cover moderately. The model also assumed sale of land and industries will continue to operate as business as usual scenario. The predictions from this model as well show a strong positive change in drinking water availability and accessibility, where as moderate positive change in surface and groundwater sources. As this model assumed pollution will be reduced 100 per cent, the industries will be affected negatively though the effect is moderate, which will lead to a slight decrease in the economic conditions of the local population.

Table 6: Example Calculation of Steady State for the FCM (Urbanisation)

	Urbanization	Agriculture	Health	Financial conditions	Drinking water	Surface water	Ground water
Urbanization	0.00	-0.76	-0.31	0.81	-0.28	-0.35	-0.11
Agriculture	0.00	0.00	0.04	0.32	0.00	0.00	0.00
Health	0.00	0.00	0.00	-0.16	0.00	0.00	0.00
Financial conditions	0.00	-0.15	0.00	0.00	-0.02	0.00	0.00
Drinking water	0.00	0.00	-0.09	-0.03	0.00	0.00	0.00
Surface water	0.00	0.05	0.00	0.00	0.04	0.00	0.07
Ground water	0.00	-0.01	0.00	0.00	0.08	0.00	0.00

FCM Simulation

Initial State Vector	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
	0.731059	0.510203	0.548318	0.953033	0.585875	0.629626	0.714709
	0.675038	0.439796	0.474150	0.922424	0.513628	0.567752	0.655219
	0.662630	0.434452	0.465457	0.911867	0.503508	0.558742	0.642519
	0.659851	0.436088	0.465864	0.908944	0.503112	0.558006	0.639907
	0.659227	0.437212	0.466625	0.908216	0.503570	0.558182	0.639405
	0.659087	0.437663	0.466979	0.908044	0.503827	0.558311	0.639320
	0.659055	0.437816	0.467107	0.908006	0.503927	0.558363	0.639308
	0.659048	0.437863	0.467148	0.907997	0.503961	0.558380	0.639308
	0.659047	0.437877	0.467161	0.907995	0.503971	0.558386	0.639309
	0.659046	0.437881	0.467164	0.907995	0.503974	0.558387	0.639309
Steady State Vector	0.659046	0.437883	0.467166	0.907995	0.503975	0.558388	0.639309
	0.659046	0.437883	0.467166	0.907995	0.503975	0.558388	0.639309
	0.659046	0.437883	0.467166	0.907995	0.503975	0.558388	0.639309

Table 7: Results of the first simulated scenario (urbanisation)

Positive Changes	Strength (+)	Negative Changes	Strength (-)
Health	Strong Change	Industries	Weak Change
Drinking water	Strong Change	Mosquitos	Strong Change
Surface water	Strong Change	Pesticides	Moderate Change
Ground water	Moderate Change		
Vegetation	Moderate Change		
Cattle	Moderate Change		

Fodder	Moderate Change		
Agriculture Labour	Moderate Change		
Population	Weak Change		
Wage	Weak Change		
Infrastructure and facilities	Moderate Change		
Climate Change	Very Weak Change		
Dairy farm	Weak Change		

Table 8: Results of the second simulated scenario (urbanisation)

Positive Changes	Strength (+)	Negative Changes	Strength (-)
Agriculture	Moderate Change	Financial conditions	Moderate Change
Financial conditions	Strong Change	Industries	Moderate Change
Drinking Water	Strong Change	Mosquitos	Strong Change
surface water	Moderate Change		
Ground Water	Moderate Change		
Cattle	Weak Change		
Fodder	Weak Change		
food security/crop	Very Weak Change		
Wage	Very Weak Change		
Climate Change	Very Weak Change		
Dairy farm	Very Weak Change		

5.4.2 Variation in Rainfall and water security

Although water security in peri-urban areas affected by urbanisation and its spill over effects; climate (rainfall and temperature) has a major role in ensuring water security in the areas. This led us to analyse available secondary data which is described in section 5.1. The time series analysis confirms with the community experiences which show an increase in variation of rainfall patterns and increase in temperature in study areas, which is in line with the forecasts by the IPCC AR 5 reports.

Thus, stakeholders were asked open ended questions on both rainfall and temperature. This sub section deals with rainfall and communities were asked open ended questions such as 'according to you, has rainfall patterns changed in the past five years?' and 'how has this change affected water availability and accessibility in your area?' The stakeholders were asked to identify variables, which affected water security and these were listed on the paper. Once the variables were listed causal relationships were identified and relative scoring was provided by the stakeholders. The scores provided were 0 (no impact), 0.5 (moderate impact) and 1 (high impact). These maps were then transformed into matrices which are shown in Table 9.

Table 9: Example of condensed matrix developed from 70 individual Cognitive Maps (Rainfall)

	Rainfall difference	Agriculture	Health	Financial Conditions	Drinking Water	Surface Water Sources	Ground Water
Rainfall difference	0.00	-0.86	-0.39	-0.49	-0.79	-0.81	-0.81
Agriculture	0.00	0.00	0.06	0.31	0.00	0.00	0.00
Health	0.00	0.00	0.00	-0.11	0.00	0.00	0.00
Financial Conditions	0.00	0.00	-0.04	0.00	0.00	0.00	0.00
Drinking Water	0.00	0.00	-0.08	-0.06	0.00	-0.05	0.00
Surface Water Sources	0.00	0.02	0.00	0.00	0.07	0.00	0.17
Ground Water	0.00	0.02	0.00	0.01	0.04	0.00	0.02

Seventy matrices were condensed into a single matrix which was normalised to ensure the scores were limited to the range -1 to 1. The condensed map was then analysed to identify the variable types and most influential variables which impact water security. Analysing the map on the effects of rainfall on water security it was found that variables such as agriculture, industries, cattle, drought and excess have higher outdegree values indicating that these variables have a higher forcing function on other variables (Figure 8). Similarly when looking at Figure 9 it can be seen that variation in rainfall impacts financial conditions, agriculture, health, drinking water, surface water and groundwater in addition to cattle and food security. This helps us identify the centrality of the variables which are shown in Figure 10. Centrality of the variables provides us with the importance of the variables on the whole structure of the cognitive map. From the Figure 9 we can clearly see that apart from rainfall, health, financial conditions of the local communities, in addition to surface and ground water sources and drinking water, followed by food security are variables that are influenced and impact other variables. Thus, this gives us an idea on issues that need to be improved to enhance water security in Bidadi, in view of variation in rainfall.

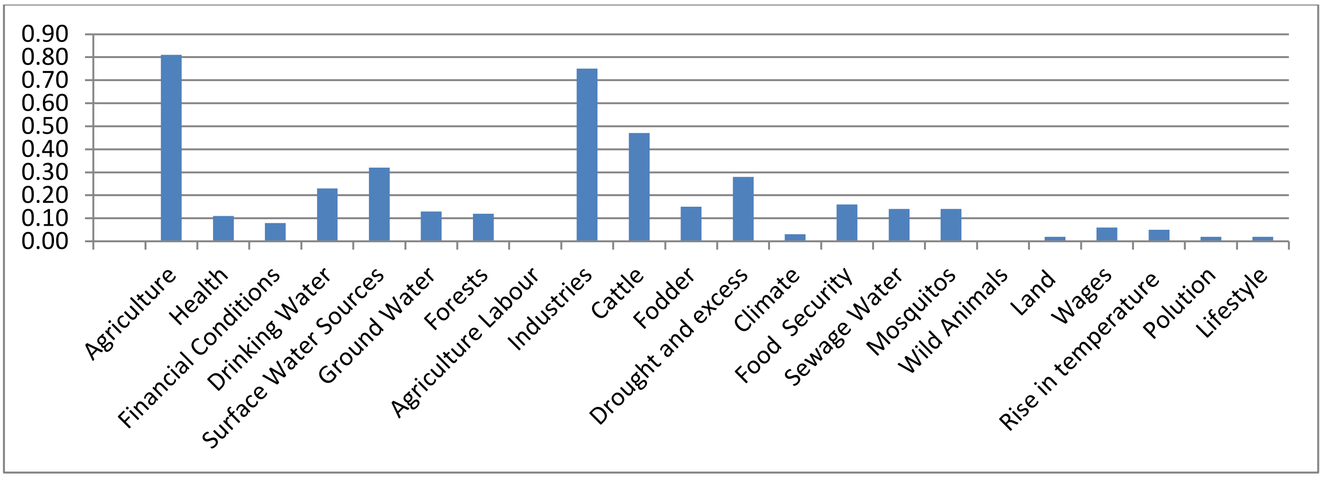


Figure 8: Graph showing the variables which have influence on other (Rainfall)

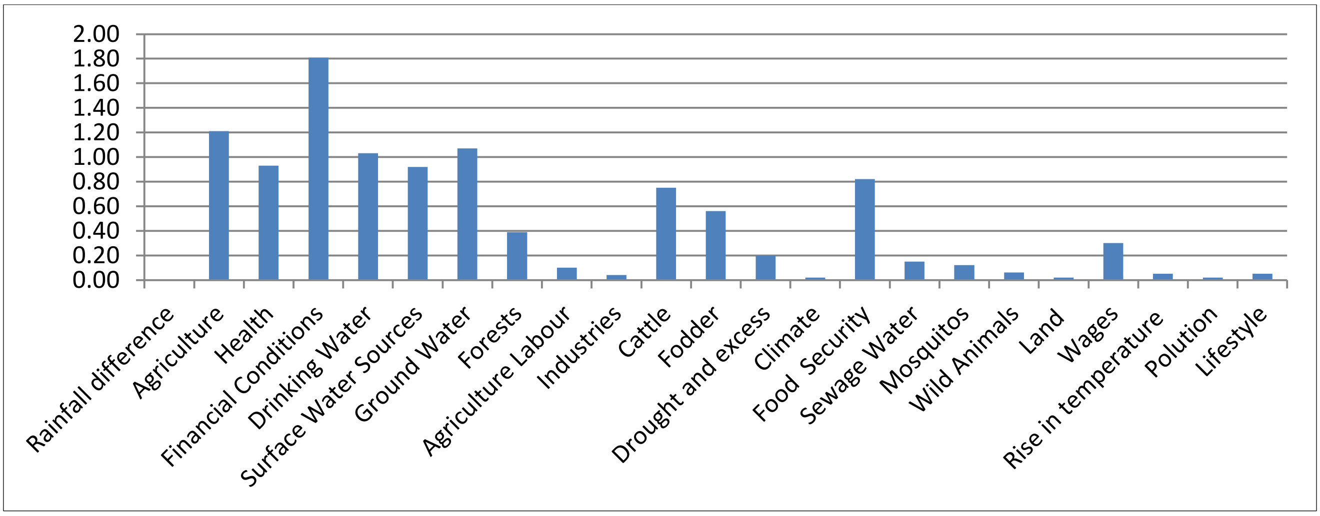


Figure 9: Graph showing the variables which are highly impacted due to increase in Rainfall

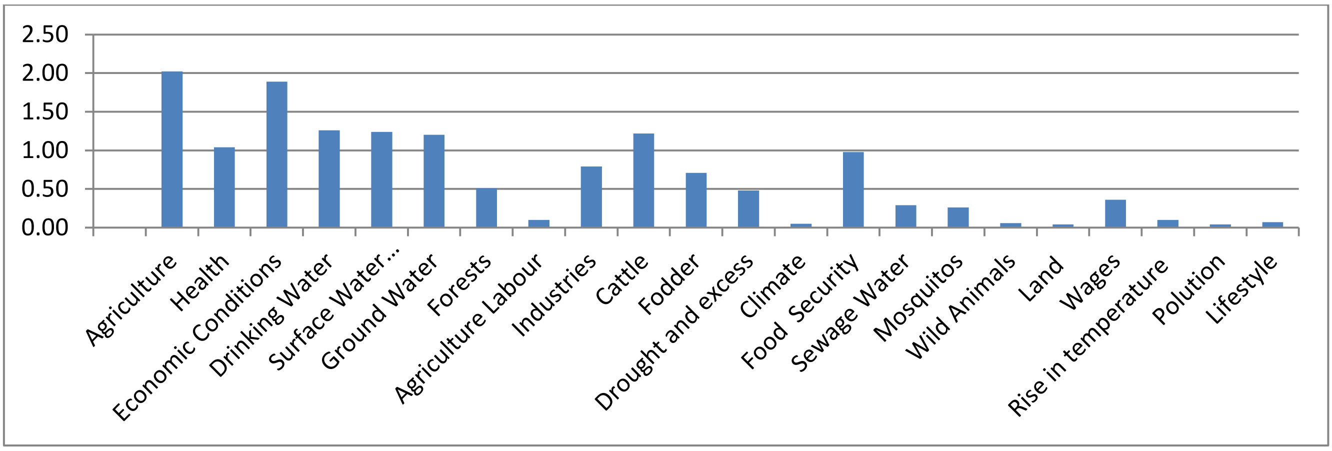


Figure 10: Graph showing the variables based on their influence on all other variables (Rainfall)

The cognitive interpretation diagram (CID) for rainfall was drawn based on the seventy individual stakeholder maps condensed into a single map. The size of the bubbles indicates the influence of the variables. The positive causal relation is shown in green and the negative relationship is highlighted in red links. It can be seen from Figure 11 that variation in rainfall has a negative influence on all the variables, including surface and ground water, community health, agriculture and food security. This also provides us with an understanding that local communities perceive variation in rainfall to have an impact not only on their lives and livelihoods but also on water security.

Models were run to ask ‘what-if’ questions and was run to determine what state the system will go to under different conditions or if different policy options are implemented. These calculations were made on the condensed cognitive map resulting from the addition of seventy individual cognitive maps. The models were run in a way as to increase water security and reduce the impact of variation in rainfall through afforestation and reforestation programmes in addition to stringent pollution and sewage management in the areas.

In the policy option run, the improvement of water sources (surface, drinking and groundwater) was considered to be a priority. Through the policy option simulations, it is possible to determine which policies and combination of policies would increase water security according to people perceptions. In the scenario analyses, FCMs indicate the direction in which the system will move given certain changes in the driving variables. Given an initial state of the system (Table 10) two scenarios were imagined in our model: first (Table 11), surface water sources was improved through removal of encroachments on water bodies, rejuvenation of surface water bodies in addition to increasing forest cover, which is assumed to cool the micro-climate. This was coupled with ensuring at least partial treatment of sewage water and reduction in pollution by implementation of existing laws and norms. The resulting model predicted a strong positive improvement (change) in drinking water quality and availability in addition to improving health conditions. Furthermore, this model predicted a moderate change in the quantity and quality of groundwater and an increase in agricultural activities in the region.

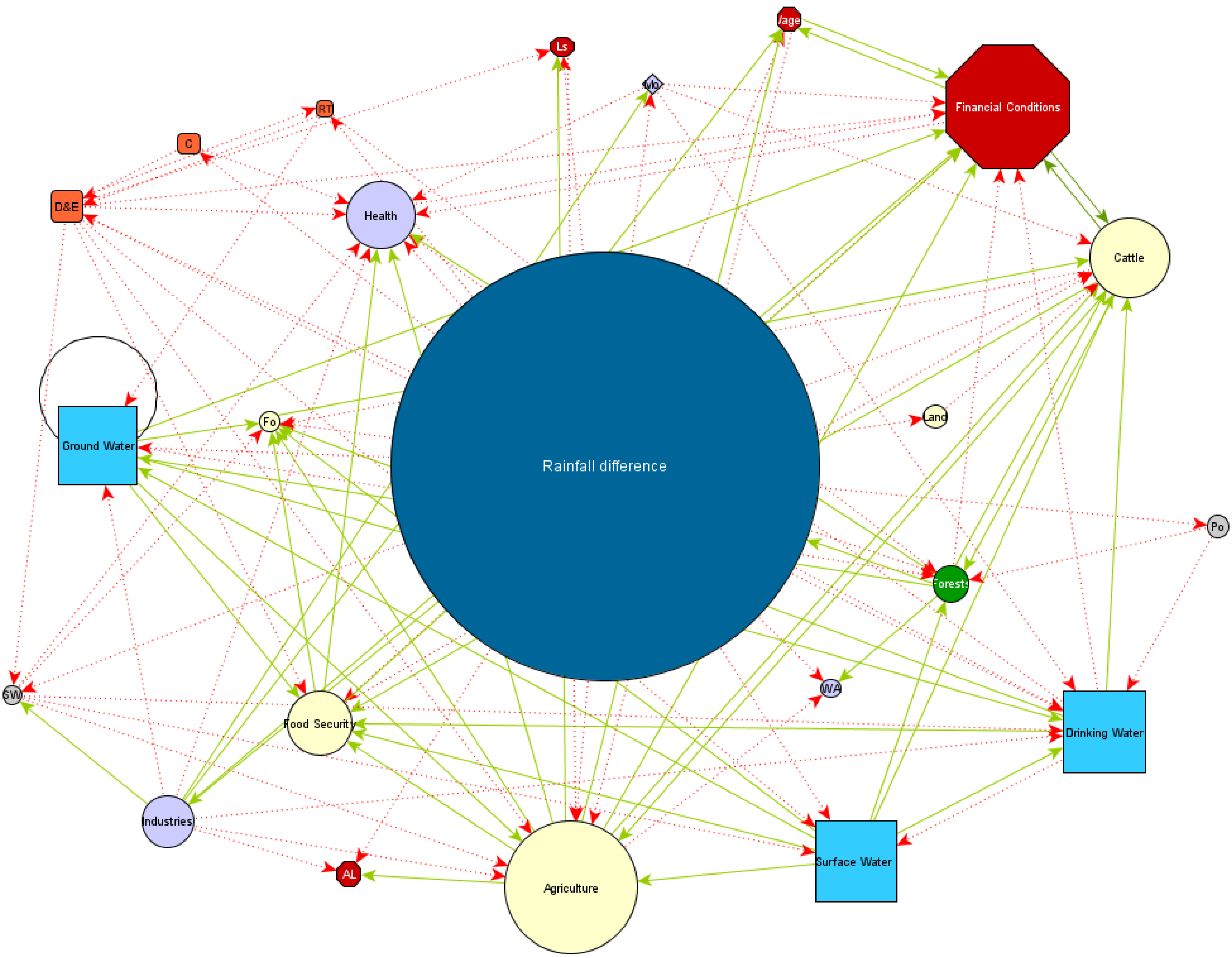


Figure 11: Cognitive interpretation diagram (CID) of the condensed Rainfall map from the stakeholder groups (Rainfall)

The second model described in Table 12, was run under the assumption that, sewage water will be completely treated in addition to stringent pollution curbing mechanisms being implemented. The model also assumed that in addition to rejuvenation of surface water bodies, there will be an increase in effective management of water through rainwater harvesting schemes and an increase in the forest cover. Based on the assumptions, the model predicted a very strong positive change in drinking water and groundwater sources. Furthermore, there is strong positive change on availability of fodder helping in the current occupation of dairy farming and also the health of the local population.

Table 10: Example Calculation of Steady State for the FCM (Rainfall)

	Rainfall difference	Agriculture	Health	Financial Conditions	Drinking Water	Surface Water Sources	Ground Water
Rainfall difference	0.00	-0.86	-0.39	-0.49	-0.79	-0.81	-0.81
Agriculture	0.00	0.00	0.06	0.31	0.00	0.00	0.00
Health	0.00	0.00	0.00	-0.11	0.00	0.00	0.00
Financial Conditions	0.00	0.00	-0.04	0.00	0.00	0.00	0.00
Drinking Water	0.00	0.00	-0.08	-0.06	0.00	-0.05	0.00
Surface Water Sources	0.00	0.02	0.00	0.00	0.07	0.00	0.17
Ground Water	0.00	0.02	0.00	0.01	0.04	0.00	0.02
FCM Simulation							
Initial State Vector	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
	0.731059	0.571996	0.601088	0.787513	0.547358	0.519989	0.591459
	0.675038	0.508602	0.541506	0.726790	0.483908	0.464670	0.522595
	0.662630	0.502442	0.534827	0.710439	0.479283	0.463834	0.514158
	0.659851	0.503256	0.534996	0.706477	0.480871	0.466351	0.514531
	0.659227	0.504045	0.535456	0.705628	0.481949	0.467550	0.515311
	0.659087	0.504390	0.535666	0.705479	0.482389	0.467967	0.515692
	0.659055	0.504515	0.535740	0.705464	0.482542	0.468095	0.515837
	0.659048	0.504556	0.535764	0.705467	0.482590	0.468131	0.515886
	0.659047	0.504569	0.535771	0.705471	0.482605	0.468141	0.515901
	0.659046	0.504573	0.535773	0.705472	0.482610	0.468144	0.515906
	0.659046	0.504574	0.535774	0.705473	0.482611	0.468144	0.515907
	0.659046	0.504575	0.535774	0.705473	0.482611	0.468144	0.515908
Steady State	0.659046	0.504575	0.535774	0.705473	0.482612	0.468144	0.515908

	0.659046	0.504575	0.535774	0.705473	0.482612	0.468144	0.515908
	0.659046	0.504575	0.535774	0.705473	0.482612	0.468144	0.515908
	0.659046	0.504575	0.535774	0.705473	0.482612	0.468144	0.515908

Table 11: Results of the first simulated scenario (Rainfall)

Positive Changes	Strength (+)	Negative Changes	Strength (-)
Agriculture	Moderate Change	Financial Conditions	Weak Change
Health	Strong Change		
Drinking Water	Strong Change	Cattle	Weak Change
Ground Water	Moderate Change	Lifestyle	Very Weak Change
Agriculture Labour	Very Weak Change		
Fodder	Moderate Change		
Food Security	Weak Change		
Wages	Weak Change		

Table 12: Results of the second simulated scenario (Rainfall)

Positive Changes	Strength (+)	Negative Changes	Strength (-)
Agriculture	Moderate Change	Financial Conditions	Moderate Change
Health	Strong Change		
Drinking Water	Strong Change		
Ground Water	Strong Change		
Agriculture Labour	Very Weak Change		
Cattle	Moderate Change		
Fodder	Strong Change		
Wages	Weak Change		
Lifestyle	Very Weak Change		

5.4.3 Temperature and water security

As is seen from section 5.1, temperature in the region is on an increasing trend, which is in line with the forecasts by the IPCC AR 5 reports. Hence, stakeholder were asked open ended questions such as 'according to you, has temperature increased in the past five years?' and 'how has this temperature increase affected your water availability and accessibility?' The stakeholders were asked to identify variables, which affected water security and these variables were listed on the paper. Once the variables were listed causal relationships were identified and relative scoring was provided by the stakeholders. The scores provided were 0 (no impact), 0.5 (moderate impact) and 1 (high impact). These maps were then transformed into matrices which are shown in Table 13.

Table 13: Example of condensed matrix developed from 70 individual cognitive maps (Temperature)

	Temperature	Agriculture	Health	Economic Condition	Drinking Water	Surface water	Ground Water
Temperature	0	-0.69	-0.52	-0.27	-0.7	-0.85	-0.68
Agriculture	0	0	0.05	0.49	0	0	0
Health	0	0	0	-0.26	0	0	0
Economic Condition	0	-0.02	0.02	0.01	0	0	0
Drinking Water	0	0.02	0.07	-0.05	0	0	0
Surface Water	0	0.2	0	0	0.03	0.01	0.32
Ground Water	0	0.12	0	0	0.17	0.06	0

The matrices were added and normalised to ensure the scores were limited to the range -1 to 1. These were then analysed to identify the variable types and most central variables. Analysing the map on the impact of temperature on water security it was found that variables such as temperature followed by agriculture, surface water, and ground water have higher outdegree values indicating that these variables have a forcing function on other variables (Figure 12). Similarly when looking at Figure 13 it can be seen that temperature has an impact on agriculture, economic conditions, drinking water, surface water and groundwater in addition to cattle and food security. This helps us identify the centrality of the variables which are shown in Figure 14. Centrality of the variables provides us with the importance of the variables on the whole structure of the cognitive map. From the Figure 13 we can clearly see that temperature has a high influence on all other parameters and with a higher impact on health, economic conditions of the local communities, in addition to surface and ground water sources. It can be highlighted that the above mentioned variables have a high influence on other variables.

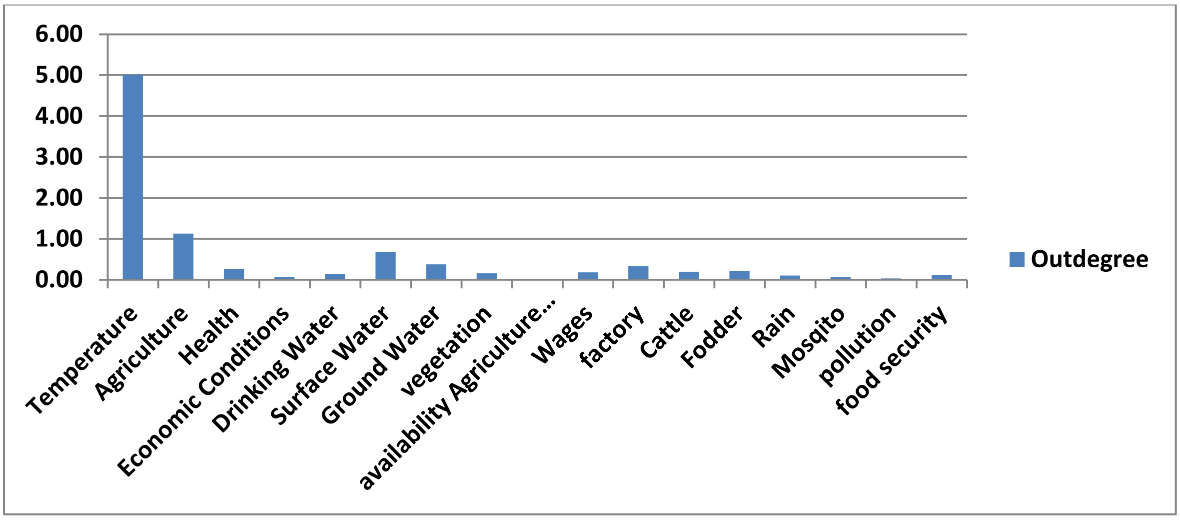


Figure 12: Graph showing the variables which have influence on other (Temperature)

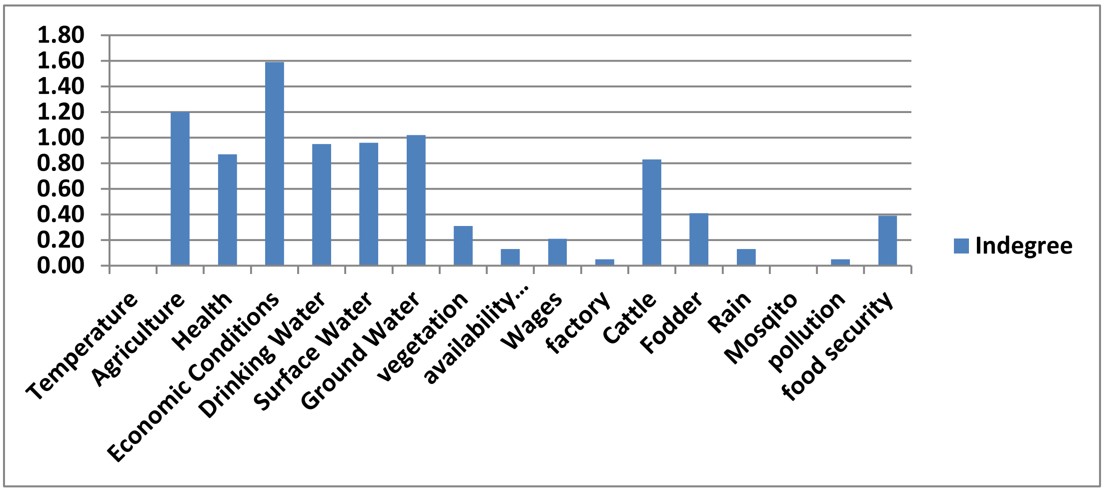


Figure 13: Graph showing the variables which are highly impacted due to increase in temperature

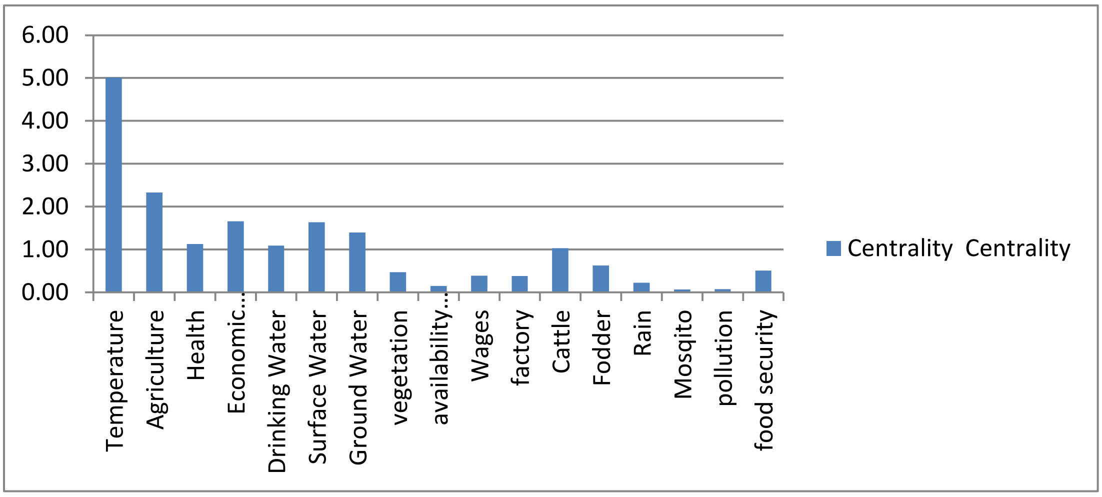


Figure 14: Graph showing the variables based on their influence on all other variables (Temperature)

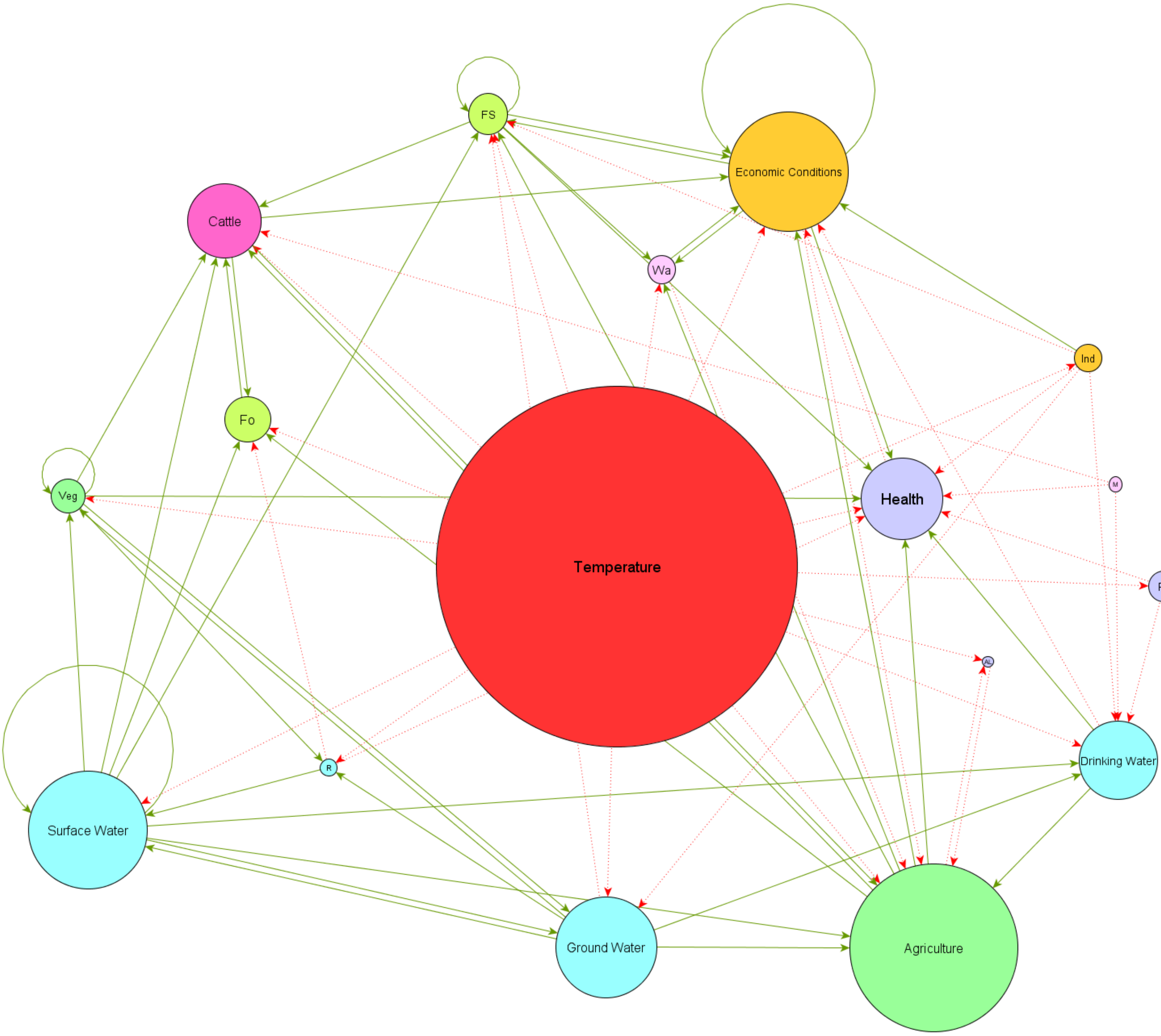


Figure 15: Cognitive interpretation diagram (CID) of the condensed temperature map from the stakeholder groups (Temperature)

The cognitive interpretation diagram (CID) for temperature, drawn based on the condensed stakeholder maps, ten maps from each of the seven villages accounting for 70 maps in total. The size of the bubbles indicates the influence of the variables. The positive causal relation is shown in green and the negative relationship is highlighted in red. It can be seen from Figure 15 that temperature has a negative influence on all the variables, including surface (-0.85) and ground water (-0.68), health (-0.52) and economic conditions (-0.27) of the local communities. This also provides us with an understanding that local communities are feeling the impact of temperature on their lives and livelihoods.

Furthermore, it can be seen from the map that that variables of economic conditions, surface water and food security have a positive self-loop. This indicates that if we improve the above variables it will result in an overall improvement of the water security of the local communities. It can be further noticed that industries have a positive impact on the local economic conditions; it has a negative impact on food security, ground water, drinking water availability and thus the overall health of the gram panchayat. It can also be mentioned here that pollution including emissions from industries, though a low influencing variable has a negative impact on drinking water and health in the gram panchayat.

The negative impact on ground water can be attributed to be the cause for reduction in quality and availability of drinking water in the panchayat, as ground water is the main source of water which is supplied by the panchayat. Over extraction of ground water has also affected the availability of surface water and vice versa, in form of encroachment and drying up of lakes and wells in the region. Due to over extraction and contamination of groundwater the depth has increased from 400 feet to nearly 800 – 1200 feet. This can also be attributed to an increase in contaminants and a decline in water quality. Local communities complained about formation of a white layer on the water if stored overnight.

Models were run to ask 'what-if' questions and was run to determine what state the system will go to under different conditions or if different policy options are implemented. These calculations were made on the condensed cognitive map resulting from the addition of all the maps. In the policy option run, the improvement of surface water sources is at high level. The difference between improvement of surface sources of water and steady state is calculated.

Through the policy option simulations, it is possible to determine which policies and combination of policies would increase water security according to community perceptions. In the scenario analyses, FCMs indicate the direction in which the system will move given certain changes in the driving variables. Given an initial state of the system two scenarios were imagined in our model: firstly, surface water sources were improved from 0.5 to 1, comparing these scenarios improving surface water sources has a high possibility of improving the ground water situation and a medium possibility of improving the drinking water conditions. Furthermore, this is shown to have a high positive change on agriculture resulting in moderate possibility of positive change in availability of fodder and vegetation thus, improving the quality of life for cattle (Table 15).

Table 14: Example Calculation of Steady State for the FCM

	Temperature	Agriculture	Health	Economic Conditions	Drinking Water	Surface Water	Ground Water
Temperature	0.00	-0.69	-0.52	-0.27	-0.70	-0.85	-0.68
Agriculture	0.00	0.00	0.05	0.49	0.00	0.00	0.00
Health	0.00	0.00	0.00	-0.26	0.00	0.00	0.00
Economic Conditions	0.00	-0.02	0.02	0.01	0.00	0.00	0.00
Drinking Water	0.00	0.02	0.07	-0.05	0.00	0.00	0.00
Surface Water	0.00	0.20	0.00	0.00	0.03	0.01	0.32
Ground Water	0.00	0.12	0.00	0.00	0.17	0.06	0.00
FCM Simulation							
Initial State Vector	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
	0.731059	0.668188	0.651355	0.738850	0.621284	0.564636	1.000000
	0.675038	0.610238	0.590519	0.674859	0.573699	0.509471	1.000000
	0.662630	0.602101	0.580951	0.658400	0.571521	0.506887	1.000000
	0.659851	0.601893	0.579981	0.654350	0.573154	0.508750	1.000000
	0.659227	0.602359	0.580112	0.653445	0.574057	0.509785	1.000000
	0.659087	0.602619	0.580244	0.653275	0.574394	0.510173	1.000000
	0.659055	0.602724	0.580304	0.653256	0.574505	0.510300	1.000000
	0.659048	0.602761	0.580326	0.653260	0.574538	0.510338	1.000000
	0.659047	0.602773	0.580334	0.653264	0.574548	0.510349	1.000000
	0.659046	0.602777	0.580336	0.653266	0.574550	0.510352	1.000000
	0.659046	0.602778	0.580337	0.653266	0.574551	0.510353	1.000000
Steady State	0.659046	0.602779	0.580337	0.653267	0.574551	0.510353	1.000000
	0.659046	0.602779	0.580337	0.653267	0.574551	0.510353	1.000000
	0.659046	0.602779	0.580337	0.653267	0.574551	0.510353	1.000000

Table 15: Results of the first simulated scenario (Temperature)

Positive Changes	Strength (+)	Negative Changes	Strength (-)
Agriculture	Strong Change	Temperature	Very Weak Change
Health	Weak Change	Availability Agriculture Labour	Weak Change
Economic Conditions	Moderate Change	Industry	Very Weak Change
Drinking Water	Moderate Change	Mosquito	Very Weak Change
Ground Water	Strong Change	Pollution	Very Weak Change
vegetation	Moderate Change		

Wages	Strong Change		
Cattle	Moderate Change		
Fodder	Strong Change		
Rain	Weak Change		
Food Security	Moderate Change		

Second, (Table 16) we improved the ground water scenario from 0.5 to 1 and reduced the influence of industries from 1 to 0.5. Comparing the steady state scenario and the second scenario it was found that there is a strong positive change in the availability of drinking water with moderate changes in surface water and increase in vegetation. This scenario will negatively affect the economic conditions of the communities as the influence of industries has been reduced.

Table 16: Results of the second simulated scenario (Temperature)

Positive Changes	Strength (+)	Negative Changes	Strength (-)
Agriculture	Strong Change	Economic Conditions	Strong Change
Health	Moderate Change	Availability of Agriculture Labour	Weak Change
Drinking Water	Strong Change	Mosquito	Very Weak Change
Surface Water	Moderate Change	Pollution	Very Weak Change
vegetation	Moderate Change		
Wages	Weak Change		
Cattle	Weak Change		
Fodder	Weak Change		
Rain	Moderate Change		
Food security	Moderate Change		

5.5 Interviews with Stakeholders

As part of this study, interviews were conducted with key industries and Gram Panchayat members in Bidadi. The following section outlines the key findings from the stakeholder interviews. A detailed assessment of each interview is presented in the subsequent sections.

The two industries surveyed in this study, (Toyota Kirloskar Motor and Wonderla Amusement Park) are implementing sustainability initiatives to recycle, reuse and reduce their water consumption – These initiatives are carried out with the help of technologies such as wastewater treatment plants and rainwater harvesting systems. Such recycling of wastewater also results in more environmentally responsible disposal of industrial waste. Industries surveyed ensure that the final sludge produced is compliant with ISO regulations before using them as compost for horticulture on their premise. Such practices reduce possibility of groundwater contamination and also allow the industries to minimise their raw water usage.

It was emergent from the interviews with industry representatives that water sustainability initiatives require significant financial capital. It was highlighted that smaller industries may lack such capital and subsequently may not have the means to have such initiatives. For example, it was mentioned that smaller industries lack sewage treatment plants, which could possibly result in improper disposal of industrial waste. Water management in smaller industries should be investigated further to this end.

Corporate Social Responsibility (CSR) Initiatives taken by the surveyed industries are directly beneficial to surrounding communities. The most relevant CSR project to this study is the water purification plants that have been built to provide drinking water to the surrounding villages. The direct benefits of this initiative was emergent in the interview with the Gram Panchayat (GP) members who highlighted that the water purification plants serve as the main source of drinking water for the villagers. The CSR initiatives are thus reducing the vulnerability of peri-urban residents to water insecurity. More details on the water purification plants can be found in section 1.3.

Currently, the Manchanayakanahalli GP is managing to meet the water demand of its households, with groundwater as their primary source. The rapid urbanisation taking place in and around the Bidadi Industrial Area has resulted in increased commoditization of several entities, including water. The increased population in the area along with industrial demands have increased the pressure on groundwater resources and incentivised private sale of water. A detailed description of the effects of urbanisation on water availability can be found in section 3.3.

With regards to water security in the future, the GP members express concern over the possibility of water scarcity. They have started taking pre-emptive measures such as building check damns, bunds and recharge pits. In addition, they are also exploring how to maximise rainwater collection in catchment areas. The implementation of rain water harvesting systems at a household level is an additional avenue that is yet to be explored. Awareness of rain water harvesting is currently low among villagers – Increasing awareness on this issue and implementing cost-effective solutions to maximise rain water usage is promising as a strategy to enhance water security in the area.

An overarching issue that connects all stakeholders interviewed is the unsustainable rate of groundwater extraction. The water table in the area has decreased from approximately 450 feet ten years ago to around 850 feet at present. This indicates that current rates of water extraction far exceed the recharge capacity of the bore wells. Considering that all stakeholders in the area draw water from a common aquifer, the decisions of individual stakeholders impact the entire community in the area. Given the current lack of formal regulations against excessive water extraction, policy intervention may be necessary to ensure sustainable water management. The section below provides the details on perception of water security and CSR activities undertaken by local industries.

5.5.1 Toyota Kirloskar Motor Pte Ltd

Toyota Kirloskar Motor (TKM) started operation as an Auto manufacturer in the Bidadi Industrial Area in 1999. The company began with a single plant, before expanding to include a second production plant in 2010. The TKM site currently occupies a land area of 432 acres and a combined production capacity of up to 310,000 units per annum currently. TKM employs approximately 10,000 individuals in its Bidadi plant. The plant is certified with ISO4001 and is also compliant with the Global Environmental Management System of the Toyota Group of companies.

Water Supply and Wastewater Management

Prior to the construction of the second plant, TKM was utilising water sourced from Cauvery river and supplied by the Bangalore Water Supply and Sewerage Board (BWSSB) - this water was being used to fulfil hundred percent of its water requirement. In 2008, when the second production plant was conceived, it was designed to contain Common Effluent Treatment Plants (CETP). These plants allowed for the recycling of wastewater originating from production in both TKM plants as well as the wastewater produced from domestic usage (cooking, cleaning, washing, water usage in toilets etc) on the TKM site. Each CETP contains a Membrane Bioreactor (MBR) and Reverse Osmosis (RO) system through which waste water is run through. RO reject water is used as nutrient to maintain on-site horticulture.

Immediately after the recycling plant went into operation, 60% of water input for the entire site was recycled wastewater and 40% of water was drawn from the BWSSB water supply. The 40% of water usage drawn from pipes was primarily for domestic usage. This percentage has been reducing over the past years with non-drinking/non-cooking domestic uses being supplemented with recycled water and rainwater (elaborated below). As of 2016, 60% of the total recycled water is used for auto-production while the other 40% is channelled into domestic purposes (TKM Sustainability Report, 2016). The recycling efficiency of TKM is currently at 65%.

The wastewater treatment process consequently yields solid sludge along with the treated water. Wastewater treatment in TKM produces two types of sludge – Bio-sludge from domestic wastewater and Chemical sludge from wastewater produced in the manufacturing process. Bio-sludge is used as the raw input for vermin-composting after which the product fed back as compost for on-site gardening initiatives. Such compost is also used for any afforestation initiatives that TKM undertakes. Chemical sludge on the other hand is disposed via co-processing in the production of cement. Chemical sludge is treated at the sludge drying yard at TKM and is transported to a partner company to be co-processed. In this way, there is zero discharge of waste into the environment beyond the borders of TKM.

In 2014, TKM also put in place a rain water harvesting pond with a storage capacity of 25,000 cubic metres. The rain water collected and stored in the pond is then used as a supplementary water source. Such a practice serves to reduce dependence on water provided by BWSSB and instead increases the self-sufficiency of the TKM plant. As of 2016, the harvested rainwater is used in the production process as well as for domestic purposes, with the exception of drinking and cooking. The rainwater collected is sent to the CETP for treatment before being utilised for either of these purposes. The amount of water collected through rainwater harvesting varies between the monsoon and dry seasons. During monsoon months, the water collected exceeds storage capacity at times.

Figure 16: Rain Water Harvesting Pond built by TKM

In light of such excess water availability, TKM is exploring ways to store excess water for use during drier periods. For example, by increasing the height of the walls surrounding the rain water harvesting pond, TKM has increased storage capacity of the pond from its initial amount. The company is also targeting to increase storage capacity such that 100% of production requirements can be fulfilled by recycled water and rain water alone. Further, TKM is also exploring potential technologies that would allow for the rain water collected to be used for drinking and cooking purposes. In addition, the company is also investigating if and how such excess water can be made useful to the community.

In addition to the above sources of water, TKM also has bore wells within its premise. Groundwater is accessed only in the event of emergency and water is currently extracted from a depth of 12-15m. The extracted groundwater is then run through the CETP plant before being used as inputs in production or domestic consumption. It was also highlighted that groundwater extracted from bore wells have higher levels of TDS than the standard BWSSB water, necessitating treatment before usage. Extraction of groundwater is carried out contingent on considerations of water levels in the bore well and its recharge capacity.

Corporate Social Responsibility (CSR) Initiatives

As part of its corporate ethos, TKM considers the local community and society to be one of its key stakeholders. In line with this, the company has been involved in a range of CSR initiatives ranging from the provision of school supplies to needy children to road safety awareness programmes. Of particular relevance to this project's focus on water security is TKM's initiative in setting up water purification units in surrounding villages. Given that groundwater in TKM's surrounding regions is not potable due to contaminants, the company partnered with the Gram Panchayats and local NGOs to establish large scale community based water purification units at Byramangala, Ittamadu, Bidadi and Manchanayakanahalli. Every unit hosts a six step filtration process featuring Reverse Osmosis Technology and exposure to UV rays. Each unit has a purification capacity of a 1000 litres per hour and meets the needs of 40,000 people across 42 villages (TKM Sustainability Report, 2016).

Figure 17: A photograph of one of the water purification units built as part of Toyota's CSR

Perspectives on Water Management

TKM believes that water is a shared resource and must be used with care. Such a belief is translated into action through its sustainability initiatives such as recycling and rain water harvesting as detailed above. In addition, TKM has also been reducing the water-intensity of its production process. For instance, total water usage per vehicle has reduced from 4.72 m^3 in

2012-2013 to 3.49 m^3 in 2014-2015. TKM eventually aims to be Water Plus (production of net water rather than consumption) and hopes to provide water for community needs.

It was highlighted that such sustainability initiatives and operations come with their own costs to the company, at least in the short run. For example, TKM spends approximately 125Rs per cubic metre for waste water recycling. As highlighted by a TKM representative, it is precisely this cost that potentially deters other companies, especially smaller companies who may not have enough capital, from adopting similar water management systems. It was also highlighted during the interview that the government had allocated land for a waste treatment plant that could be used by smaller industries. It was suggested that the development of such initiatives should be facilitated by governments and civil society organisations in order to bring about more sustainable practices among smaller industries.

5.5.2 Wonderla Amusement Park

Wonderla Holidays operate three parks in Kochi, Hyderabad and Bangalore. The Wonderla Amusement park in Bangalore is located in Bidadi and it has a water park within its premise. Wonderla spans approximately 82 acres and has been in operation since 2005. The amusement park was first certified with ISO140001 in 2009 and was recertified last year.

Water Consumption and Wastewater Management

There are three main categories of water consumption in Wonderla – water for pools, water for the restaurants operating within the amusement park and water for use in restrooms. All three streams are separated at all times and the wastewater originating from each of the three uses pass through discrete treatment channels. Wonderla has had a wastewater recycling plant within its premise since the park's opening.

Recycled water is mainly used to fill the pools in the water park. Wonderla's water treatment process consists of physical, biological and chemical treatments. The physical treatment is done in a grit chamber that allows for the segregation and disposal of solids after which the biological treatment is carried out via aeration that will eliminate any remaining Biochemical Oxygen Demand (BOD). Following that, chemical treatment is carried out for all wastewater (except from sewage) with alum and sodium hypochlorite. The water is subsequently treated with Reverse Osmosis. Wastewater from all three sources (pools, restaurants and toilets) is then cycled back to the pools once treated with RO technology. Wonderla has four Reverse Osmosis plants in total – One handles exclusively pool water while the other three handle drinking water. Water in pools is monitored in relation to 7 parameters as prescribed by ISO standards and water is continuously cycled between the pools and the water treatment plants.

Water that is rejected by the RO process is then combined with sewage water and used as a source of nutrient for horticulture in Wonderla's premise. The sludge produced from the wastewater treatment is also fed back as compost for gardening. Sludge analysis is done once a year to ensure compliance with ISO standards. In this way, Wonderla operates as a zero discharge facility, where all the waste generated on the premise is recycled.

In addition to the above, Wonderla also has rainwater harvesting systems. Rainwater is collected in two ways. The first is via roof water collection systems which are installed on the roofs of all buildings in the park – water collected into these systems drain into two storage tanks in the premise. Each of these tanks has a storage capacity of 10 lakh litres. The second method of rainwater harvesting is via three surface water collection ponds. One of these three ponds is manmade while the other two are natural lakes which are used to store water. The manmade pond is the primary catchment area, with a storage capacity of 1 crore litres while the other two secondary ponds can store approximately 30-40 lakh litres of water each. All the rainwater collected is then subject to water treatment and is primarily used as drinking water. During monsoon season, rainwater collected is sufficient to fulfil 20% of the drinking water requirements of the premise.

Figure 18: The primary surface water collection pond at Wonderla

The main source of water for drinking in Wonderla is groundwater. There are 12 bore wells located within Wonderla's premise and groundwater is used primarily to supply restaurants with water. Groundwater is supplemented with rain water during the monsoon season as mentioned earlier. During the dry months, groundwater is the only source of drinking water. Water extracted from bore wells is run through a sand filter and the RO plant before being consumed. The depth at each bore well varies across the premise and bore well readings for the yields are taken every month. Bore well recharge is done as and when necessary based on these readings. The total water consumption at Wonderla, for pool, restaurant and toilets, comes up to 4 lakh litres a day – This amount includes recycled water, rain water harvested and groundwater extracted.

Corporate Social Responsibility (CSR) Initiatives

Wonderla has engaged in a range of CSR activities ranging from the construction of toilets to the provision of school supplied for underprivileged children. Of particular relevance to this project is Wonderla’s contribution in the construction of an RO treatment plant that provides clean drinking water to surrounding villages.

5.5.3 Gram Panchayat Members of Manchanayakanahalli

The Manchanayakanahalli panchayat is located in the Ramnagara district of Karnataka. The panchayat contains a population of approximately 20,000 individuals and is located in close proximity to the Bidadi Industrial Area. Agriculture is the main source of livelihoods for households in the Panchayat.

Water Supply to Manchnayakanahalli

The main source of drinking water for the panchayats is from a water purification plant. The plant was established in a joint effort between the Gram Panchayat and the Bidadi Industrial Area Welfare Association. The land and bore well for the purification plant was provided by the Panchayat while the construction and maintenance of the plant is undertaken by the industries. The plant uses Reverse Osmosis to make groundwater potable. Water is then sold to villagers through tankers at a rate of 5Rs/25 Litres. A present, several bore wells are used purely to supply drinking water and more than 10 water purification plants have been built over the past 5-6 years. 90% of the panchayats population consumes the water provided by the purification plant while the other 10% consume bottled mineral water.

The levels of fluoride in the groundwater are too high for direct drinking consumption, necessitating water treatment as described above. Due to the high fluoride levels, the government of Karnataka has declared that the groundwater is not safe to be consumed. Fluoride levels in the groundwater are reported to have been increasing over the past 5-6 years and concentration is checked twice yearly by the state authorities. With the exception of 2-3 bore wells which have directly potable water, water from all other bore wells has to be treated before consumption.

For all other non-drinking water uses, groundwater is used directly without any treatment. Water is pumped from several bore wells around the villages which are stored in overhead tanks/sump tanks of households. The water stored in the tanks is then directed to household pipes for use by the residents. Depending on the total water demand across the panchayats, water is supplied in pipes once a day, with the duration of supply ranging from one to two hours. Payment for groundwater is collected as part of a yearly utilities tax comprising payment for water and sanitation among other things – Utilities are taxed at a rate of Rs 100-Rs 200 per household. The panchayats plans to introduce a per-metre billing system for water consumption as well. The pipes connecting the bore wells, overhead tanks and household taps are maintained every 6 months by the Gram Panchayat.

Perceptions of Water security

From the perspective of the Gram Panchayat members, the availability of water in the region is generally sufficient in meeting the demand of villagers both for drinking and for other purposes. As an approximate quantification, they mentioned that the current amount of water meets the needs of approximately 80% of the total water demand in the panchayat. At the same time, the Gram Panchayat members highlighted that they were keeping a check on how industries are disposing their wastewater, given its potential to disrupt the water supply of the villagers.

Figure 19: Interviews with the Gram Panchayat Members at the Manchanayakanahalli Gram Panchayat Office

A key point articulated by the Gram Panchayat members was the rapid change experienced in the locality over the past 10 or so years. The proximity of the Manchanayakanahalli panchayat to Bangalore and the consequent development of the Bidadi Industrial Area has led to massive commercialisation of its surrounding villages. The members of the Gram panchayat see these changes as inevitable and they also see opportunities for their own growth in such urbanisation. At the same time, the unplanned nature of the industrial development has also resulted in indirect consequences for the villages in the panchayat. For example, while people were formerly engaging in subsistence agriculture, crop production is now carried out for profits. The price of land in the region has increased drastically as well. Such commercialisation also has several implications on water security.

Firstly, there is increased pressure on water resources due to increased infrastructure demands and immigration into the locality – both of which are driven by the industrial development. This is cited as one reason for the mild water scarcity in the region. It was also highlighted that it is difficult to control industrial consumption of water and hence the price of water also increases. While most industries in the area use piped water supplied by the KIADB for their production processes, groundwater is used for external purposes such as during the initial construction. Another effect of such commercialisation is the sale of water by individual households, whereby water from private bore wells is sold to tankers that supply water elsewhere. The high price of water incentivises such sales and also leads to increased extraction of water from bore wells – Such unsustainable practices lower the groundwater reserves. Although the Gram Panchayat members are aware of this and its negative impact on the entire community, they highlighted that there was no mechanism with which groundwater extraction could be regulated. The only condition that needs to be fulfilled is that bore wells are located at least 800m away from one another. At times, private entities even resort to violence to defend their rights to unlimited groundwater extraction from bore wells.

The amount of groundwater available has indeed decreased over the past decade. While water was available at a depth of 450 Feet ten years ago, it is now being extracted from a depth of 800-900 Feet. It was highlighted that in some bore wells, there is no water available even at a depth of a 1000 feet. In addition, around 4 to 5 bore wells have also completely dried up. Groundwater recharge is thus one of the main concerns of the Gram Panchayat with regards to water security. Further, seasonal variations in the amount of groundwater are also a cause for concern, especially during the dry months where water levels will be lower.

Given these trends, the Gram Panchayat members recognise that in future, water supply will be scarce. Several initiatives have been introduced to address this issue. Firstly, the panchayat is using the Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA) to carry out work on farms that will allow for better water management – Examples include the construction of check dams and bunds as precautionary measures against water insecurity. Further, recharge pits have also been built to sustain groundwater supply. Secondly, the panchayat is also increase awareness on reducing water wastage, in partnership with Non-Governmental Organisations. In particular, minimising rain water wastage is an issue of focus and efforts are being made to maximise rainwater collection in catchment areas. As part of such an agenda, rain water harvesting systems are being explored for potential use in the villages.

6. Limitations and Further Scope

This study tries to provide a participatory and inclusive way to assess local perceptions based on user needs. One of the main limitations of this study is that, models were developed based only on community perspectives. To ensure an efficient and robust policy option, there is a need to map the impacts based on experiences of all the stakeholders. This includes the gram panchayat members, the industrial associations, and household industries. Though, the study team was not able to draw maps with these various stakeholders, short interviews were conducted with these members to at least gather their ideas and understanding of water security. The interviews themselves have been used to identify policy options that can be implemented with stakeholder interactions and coordination.

Secondly, this study is based on perceptions of population which might be biased. The study team has taken utmost care to limit the influence of external biases on respondents while developing the cognitive maps. The team were trained not to influence the respondents, in any way while drawing the map as the questions asked were open ended and the variables listed were themselves identified by the community.

There is a need to expand this study to understand community needs and requirements before any intervention can be implemented. Thus, the team feels that there is a need to expand this study into peri-urban regions around Bengaluru. There is a also a need to involve industry associations and panchayat members for developing separate fuzzy cognitive maps which will help generate a holistic understanding of the current situation of water security. This will also enable ownership among stakeholders and lead to concerted efforts by all to improve their surrounding environment and common property resource base.

7. Conclusions

Currently, the Manchanayakanahalli GP is managing to meet the water demand of its households, with groundwater as their primary source. The rapid urbanisation taking place in and around the Bidadi Industrial Area has resulted in increased commoditization of several entities, including water. The increased population in the area along with industrial demands have increased the pressure on groundwater resources and incentivised private sale of water. The models developed using FCM, provide only directions that policy options need to be taken and are not conclusions in themselves.

The study highlighted that urbanisation has changed the lifestyle of this once quaint agrarian gram panchayat. Urbanisation has created a job market in nearby industries and also increased the conversion and sale of agrarian land for commercial and residential purposes thereby, increasing their financial/economic conditions. It can also be said that this development has increased access to modern infrastructure facilities such as access to schools and speciality hospitals. Even with all this development, it was found that natural resources including water are neglected. It was found that effluents and pollution from nearby industries and sewage from the city have impacted water (both surface and ground) sources in a large way.

It was identified from household water survey that the households are not aware of the benefits of rainwater harvesting mechanisms. Whereas the gram panchayat understood the need for rainwater harvesting structures, they are still unable to educate and implement the ideas due to various reasons. The GP has plans to undertake large scale awareness programs in the coming months.

Though the gram panchayat is blessed with adequate water sources, they are contaminated and not suitable for consumption. This impact has been aggravated due to climate change mainly variation in rainfall and increase in temperature, which has resulted in drying up of surface water bodies, which have been encroached in places as well. Lack of adequate water has also resulted in shift from agriculture to labour based livelihoods in the villages. Agriculture, though practiced in small scale has been the result for change in cropping pattern and at some places sewage water is used for irrigating agricultural lands. It was also highlighted that local industries have established, drinking water purifiers as a part of their CSR activities in the gram panchayat which are a one of the major sources for drinking.

As was mentioned during our interviews, members of gram panchayat believe that, apart from water management policies there is a need for large scale rainwater harvesting systems to be put in place, if water security is to be improved. This cannot be achieved by the gram panchayat alone and needs support from various stakeholders, including industries located in the region. Water security in Manchanayakanahalli can be improved only when stakeholder's perspectives are analysed with specific relation to both urbanisation and climate change. Such an approach is well suited given that vulnerability to water insecurity is a combined product of both these stressors, each interacting synergistically with the other to create patterns of insecurity.

8. Policy Engagement and Communication

As a part of the study, the findings were shared with Mr. T M Vijay Bhaskar, IAS, Additional Chief Secretary to the Department of Ecology, Forests and Environment Government of Karnataka (GoK), on 1st October 2016. Furthermore, the study methodology and findings were review and shared with experts from government departments, academia, practitioners and researchers through a stakeholder consultation that was held on 14th October 2016 at EMPRI. This section provides an overview of the comments, suggestions and inputs provided by the above mentioned stakeholders.

The inputs provided by Mr. T M Vijay Bhaskar, IAS, Additional Chief Secretary to the Department of Ecology, Forests and Environment GoK are as follows

- There is a need for similar studies in the peri-urban areas of North Bangalore namely, Doddaballapura and Devenahalli as these areas are highly water scarce
- Government agencies such as Bangalore Water Supply and Sewerage Board, Karnataka Industrial Area Development Board, Bangalore Development Authority, Bangalore Metropolitan Region Development Agency have prepared master plans regarding water resources and security in and around Bangalore. There is a need to look at these plans and reports as these are some of the major stakeholders
- Regarding sewage and effluent treatment plants, it was mentioned to us that BWSSB has already initiated the process of tendering for sewage treatment plants in the region. It was also highlighted that the current capacity of the V-valley treatment plant has been increased from the current 180 MLD to 280 MLD, but is not completely utilised. There was also a mention that the industries have expressed concern and have asked the government to supply recycled water to them through separate pipes. The government is currently not providing recycled water as there are no separate pipelines and is an expensive proposition

Figure 20: Presenting the Study Finding to Mr TM Vijay Bhaskar, IAS Additional Chief Secretary, Department of Ecology, Forests and Environment Government of Karnataka

- Water quality is a major issue in the region, even water from the purification plants were found to have a low P^H value. Regarding this, he suggested the need for a detailed mapping and analysis of location, number and maintenance of the purification plants. Regarding the current status of the plants, He also suggested that we need to inform the gram panchayat to mix raw water with treated water to improve the P^H value
- Mr. Vijay Bhaskar has asked EMPRI to write to KUIDFC and the KIADB to set common effluent treatment plant in the Bidadi Industrial area to treat effluents from industries from the region. He has also asked EMPRI to write to department of Rural Development, Karnataka to help spread and create awareness on rainwater harvesting (RWH) at the Gram Panchayat level and also to write regarding creation of RWH structures and rejuvenation of existing tanks and lakes under the MGNREGA

The inputs from the stakeholder consultation held on 14th October 2016, where experts from TERI, ARGHYAM, CSTEP and EMPRI in addition to Manchanayakanahalli Gram Panchayat President and community members including members of SACRED were present. The stakeholder consultation provided a platform the community to share their experiences from the ground with the experts regarding water security in their area. The consultation raised questions and clarifications regarding the CCSC methodology followed and threw light on the further scope for the study.

The workshop started with a welcome speech by Smt. Ritu Kakkar (Director General of EMPRI) where, she stressed the importance of the urgent natural resource management issues that need to be addressed in peri-urban areas. Mr. Suresh, Director of Public Affairs Centre, gave an introduction of the working of Public Affairs Centre, its social accountability tools and a brief overview of the organization. Mr. Jangal gave an account the experiences and projects undertaken by the Environmental Governance Group within Public Affairs Centre.

This was followed by an overview of the study area, Manchanayakanahalli, by Ms. Mary Philomena, Director SACRED. She also highlighted the changes the gram panchayat had undergone due to urbanisation and the issues of water security that they are facing presently due to in migration and change in land use. This was followed by a presentation by Ms. Nanda Prabha, Member, Manachanayakanahalli gram panchayat, who mapped the various factors impacting the water issues, especially those related to drinking water and ground water. She mentioned about the land use changes, real estate business and its impact, private water vendors and most importantly the awareness levels among the citizens in that Gram Panchayat.

Figure 21: Inaugural session of the Stakeholder Consultation

Figure 23: Mr. R Suresh introducing PAC to the participants

Figure 22: Figure 22: Ms. Ritu Kakkar, IFS, DG EMPRI welcoming the experts

Figure 24: Mr Jangal, PAC introducing Environment Governance Group

The project team presented the methodology and the findings to the experts and community members present and some of the suggestions and comments based on the findings are as below:

- Climate Change Scorecards provides an innovative way to gather local experiences to a global issue such as climate change. The use of fuzzy cognitive maps to identify causal relationship between variables is novel way of capturing community experiences and perceptions of water security to urbanisation and climate change
- There is a need for mapping policies and institutions which are responsible for water resources; both at the supply and demand side
- It was mentioned that aspects of sanitation on water security, especially in light of the current push under the Swaach Bharat Mission need to be studied

- Mapping of sewage and effluent flows need to be undertaken to identify the source of pollution and contamination. As there are chances that water bodies are contaminated due to inefficient and improper treatment mechanisms in the panchayat itself
- There was discussion on how owners of private bore wells sell water to tankers illegally and this needs to be addressed if we are to ensure water security in the region
- Regarding the V-valley treatment plant, it was discussed if expansion of the plant alone will help solve the issue of sewage treatment or should there be other means through which treatment can be undertaken
- It was highlighted that there was a need to
- With regard to water accessibility and change in agriculture patterns, it was highlighted that there was a need to look at the agriculture statistics over the years to see how water availability has impacted agricultural practices in the region
- It was also suggested to create awareness among the community an dGP members on water quality and rain water harvesting

Figure 25: Participants at the Stakeholder Consultation

Figure 26: Ms. Nanda Prabha, GP member speaking about water security in Manchanayakanahalli

Figure 27: Project Team presenting the findings

9. Recommendation

Based on the study undertaken and the conclusions in Section 7, the project team would like to propose the following recommendations to improve and enhance water security in Manchanayakanahalli Gram Panchayat.

- As expressed by industries, there is a need for common effluent treatment plant in Bidadi Industrial area within the industrial area
- The capacity of Vrishabhavathi valley sewage treatment plant located within the study area needs to be expanded from its current 180 MLD. The plant also needs to be upgraded from secondary trickling filter mechanism to a tertiary treatment plant. There is a need for up-gradation of the plant as reports have identified that the plant does not function efficiently and has had no positive impact on effluent discharge on river water quality.
- This highlights the need establishment of smaller decentralised treatment plants along the river basin to ensure efficient treatment and water quality. The water supplied should be graded which can be used for various activities (agriculture, industrial purposes etc.) thus, reducing the current dependence on groundwater.
- There is a strong need for coordination and interaction between the gram panchayat members and industry representatives to improve water security. This will ensure that the industries which have a huge stake in the area and the gram panchayat work together to help undertake water conservation and awareness programs in addition to implementing rain water harvesting as a part of their CSR activity.
- Training programmes on awareness and benefits of rainwater harvesting mechanisms among the community is strongly recommended. Furthermore, surface water bodies such as lakes, tanks and the Vrishabhavathi River itself needs to be improved through effective water management policies and programmes. Lake rejuvenation, aquatic weed and algae control measures have to be undertaken in addition to encroachments of lakebeds to be reclaimed through annual lake management programmes.

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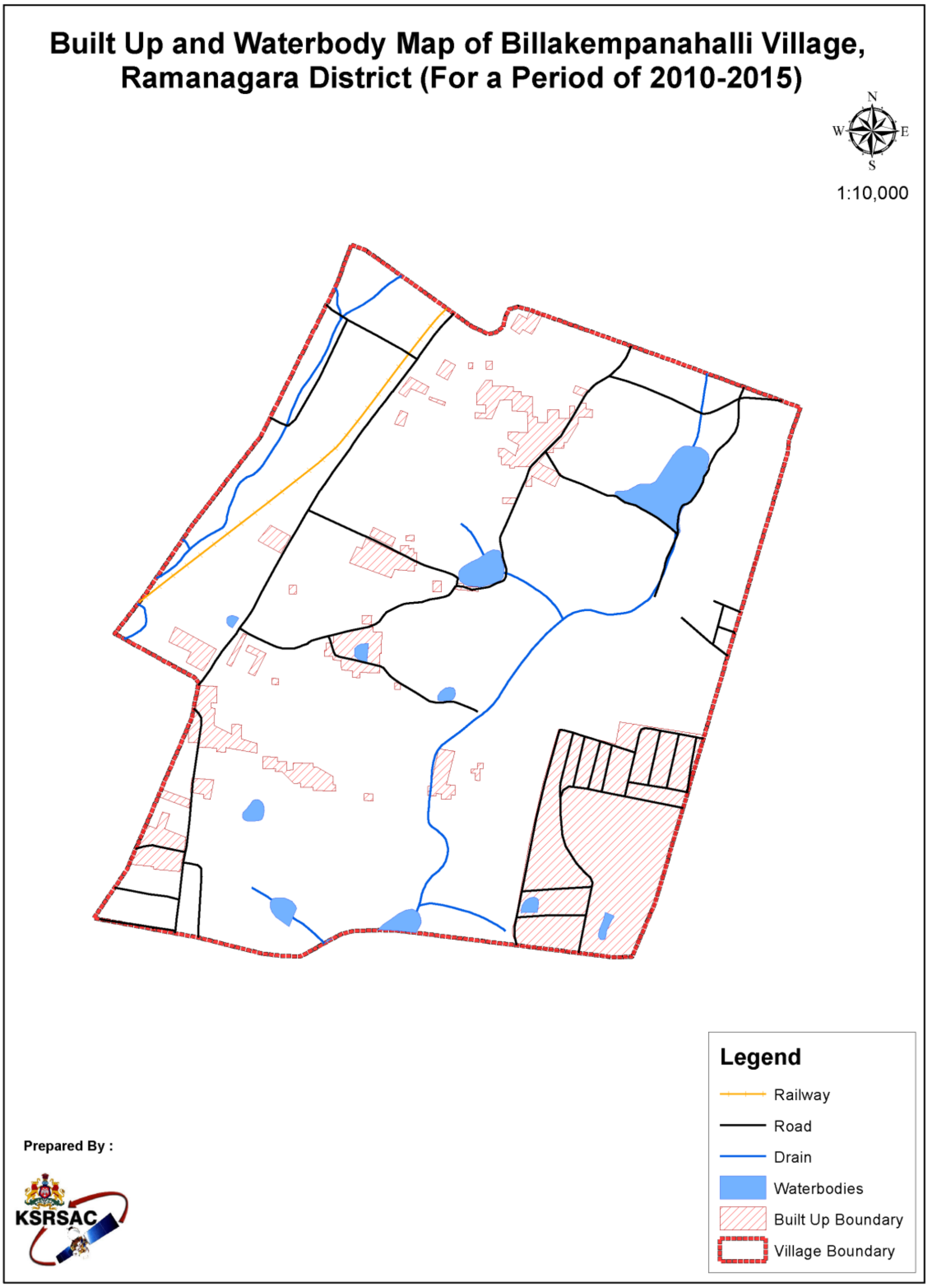
Annexure 1


Built Up and Waterbody Map of Billakempanahalli Village, Ramanagara District (For a Period of 2010-2015)
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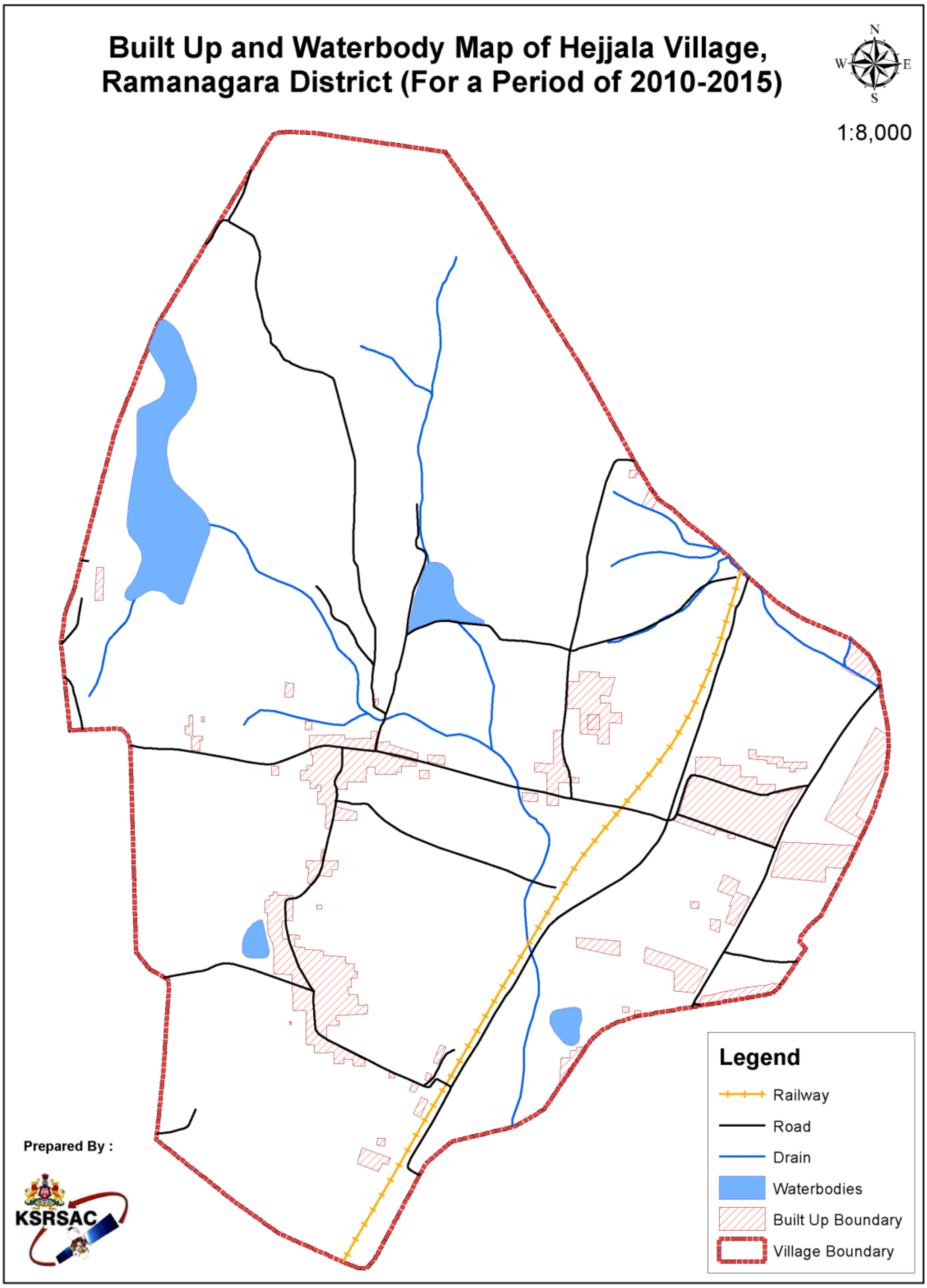

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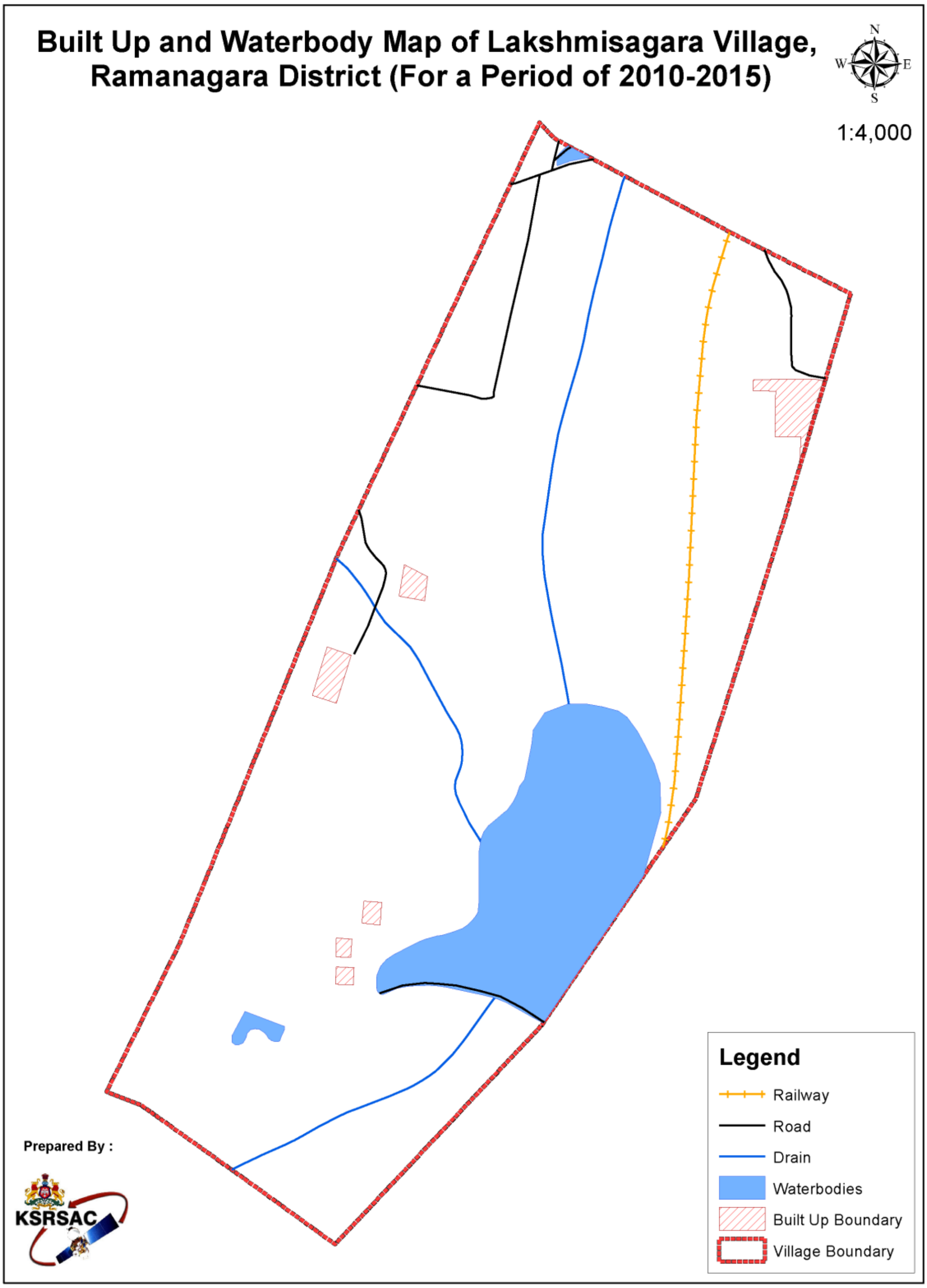
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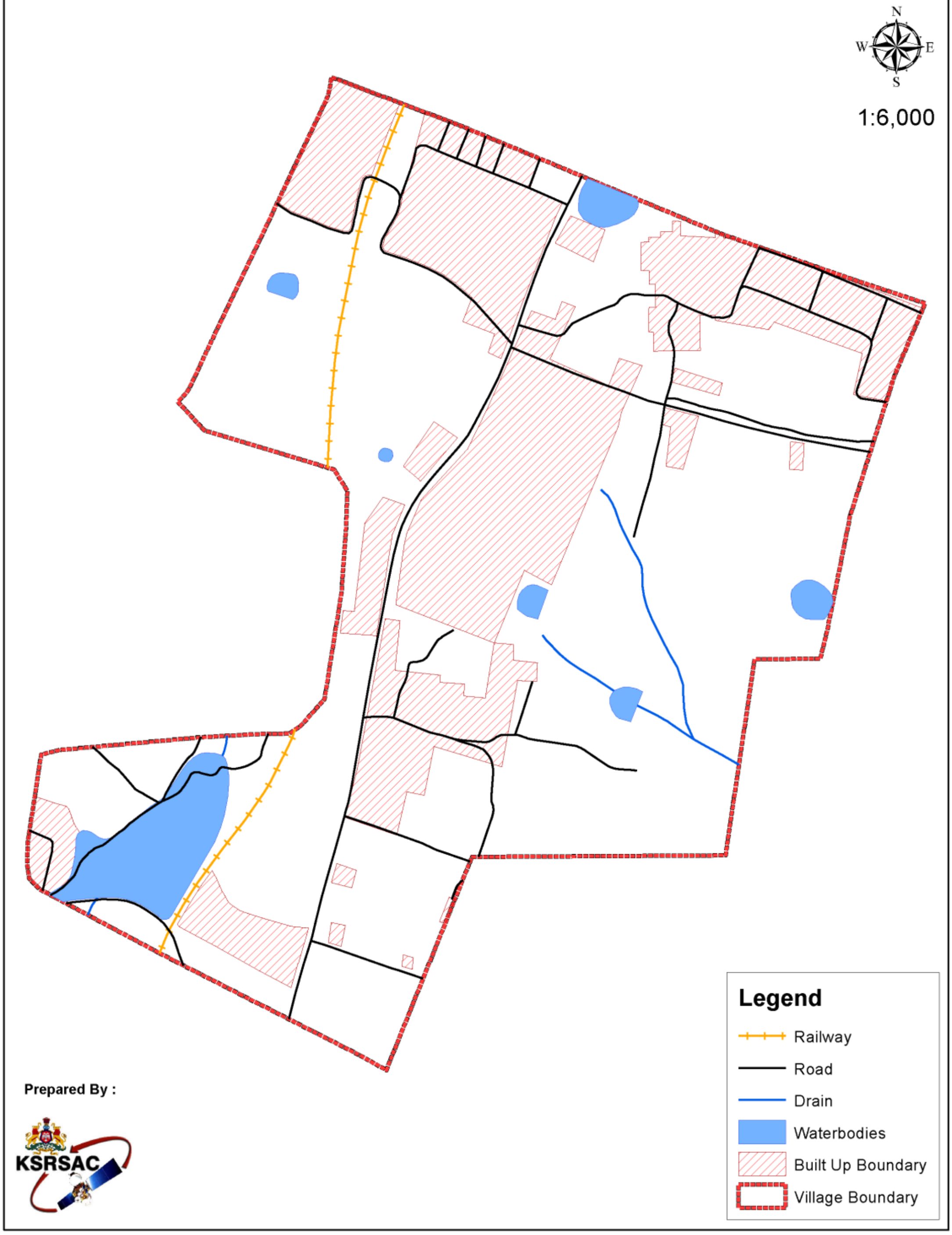
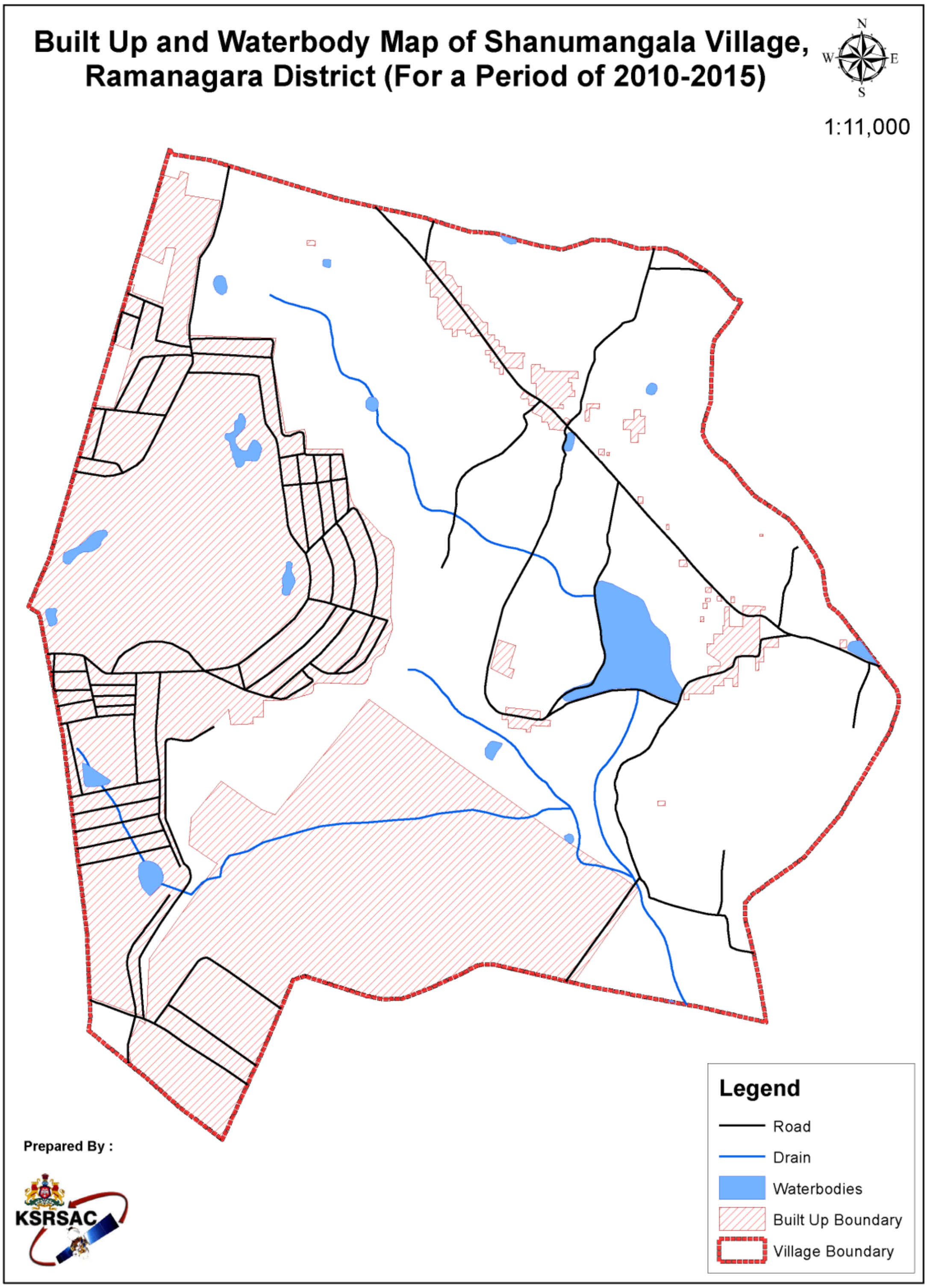
Built Up and Waterbody Map of Manchanayakanahalli Village, Ramanagara District (For a Period of 2010-2015)

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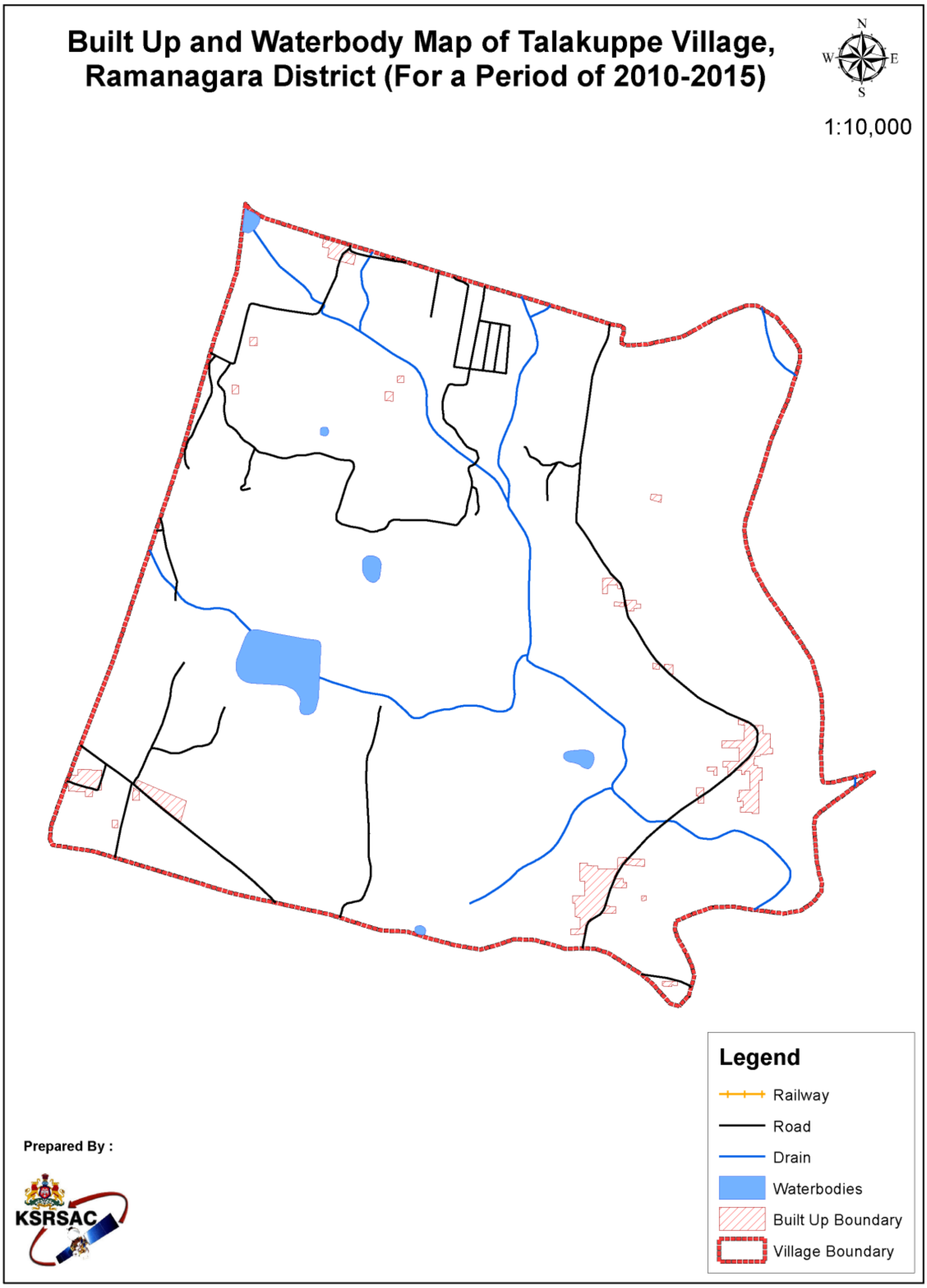
Built Up and Waterbody Map of Talakuppe Village, Ramanagara District (For a Period of 2010-2015)



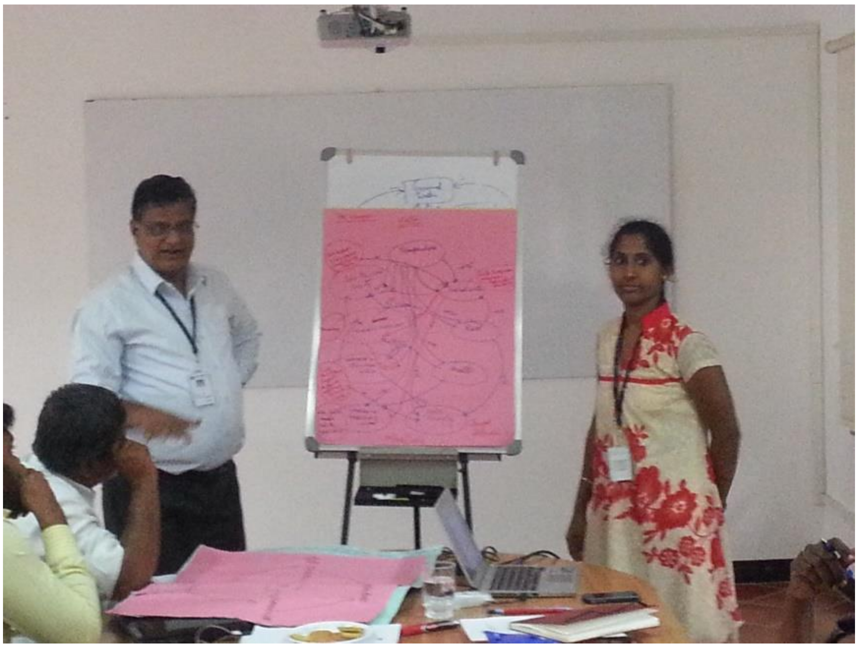


Figure 28: Training of Field Partners at PAC

Figure 29: On field training for Developing FCM in Manchanayakanahalli

Figure 30: Developing FCM based on Interactions with community members, Manchanayakanahalli

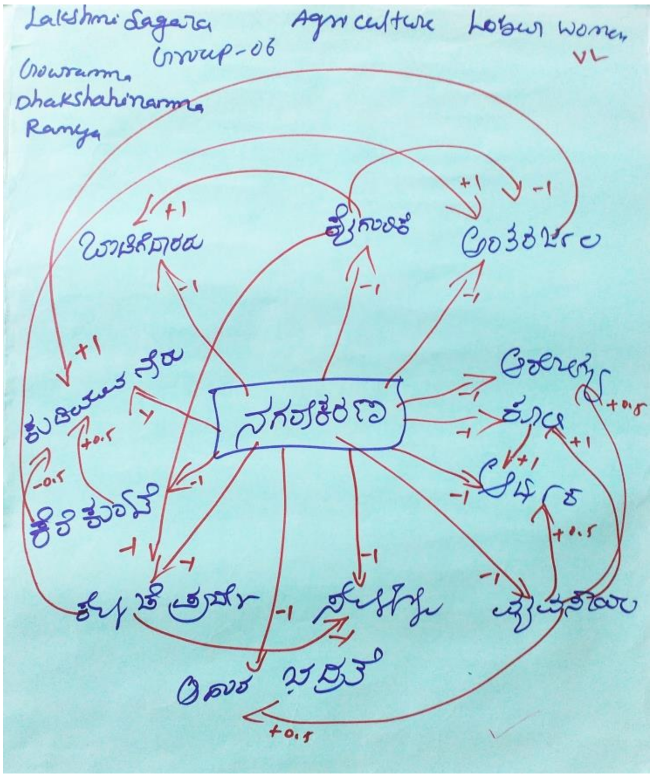
Figure 31: Collection of drinking water samples for analysis

Figure 32: Collection of water sample from mini-water supply system

Figure 33: Drinking water purifiers located in Manchanayakanahalli

Figure 34: Dried lake bed in Manchanayakanahalli Gram Panchayat

Figure 35: Polluted Vrishabhavathi River flows through the panchayat



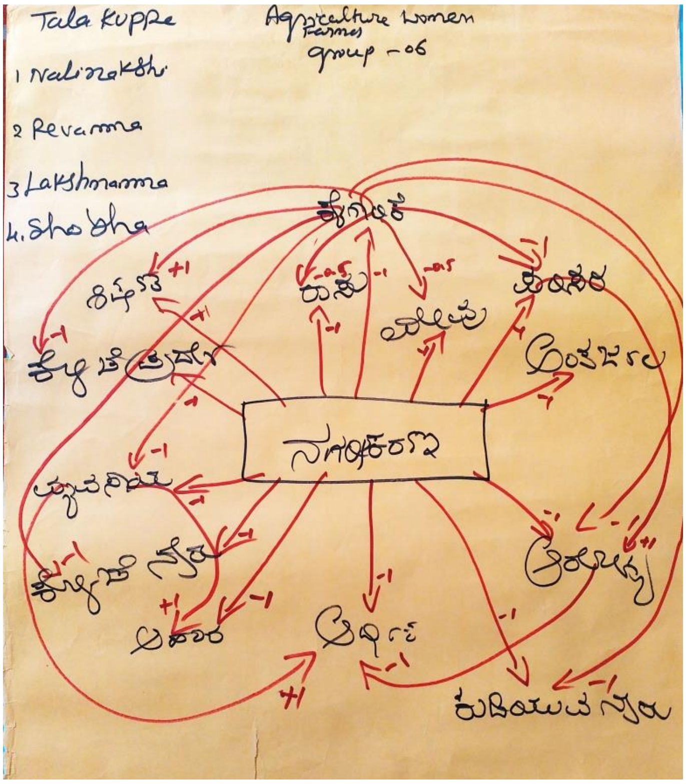
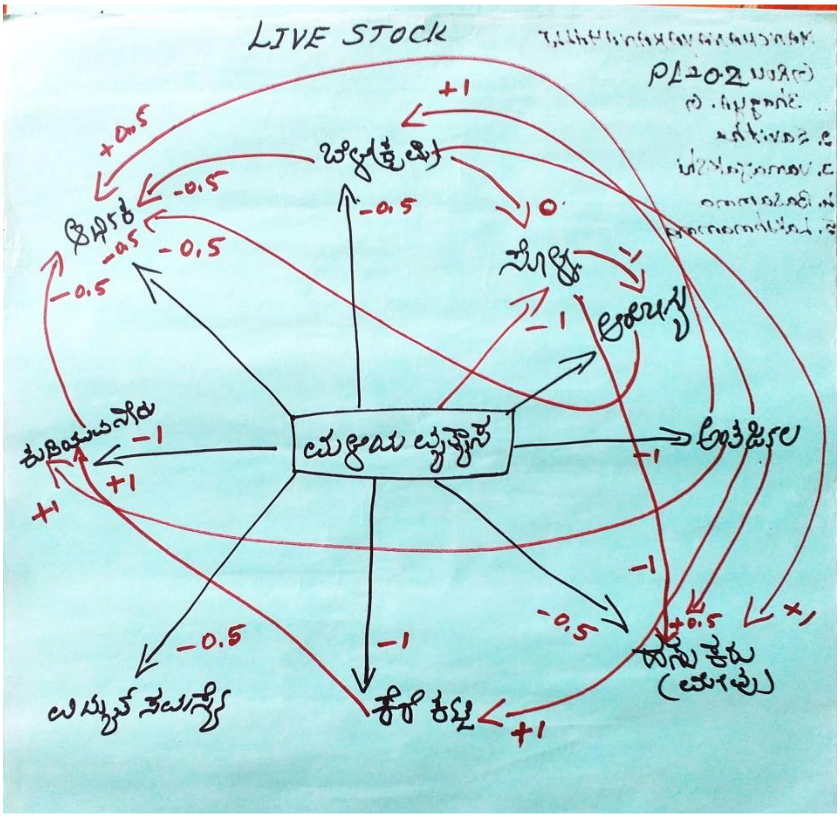


Figure 36: Stakeholder maps on urbanisation and water security



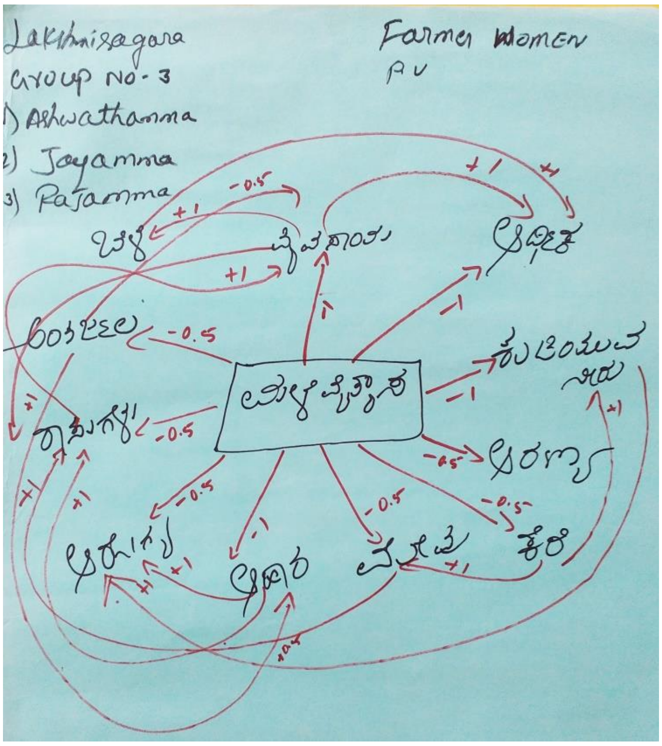


Figure 37: Stakeholder maps on rainfall variation and water security

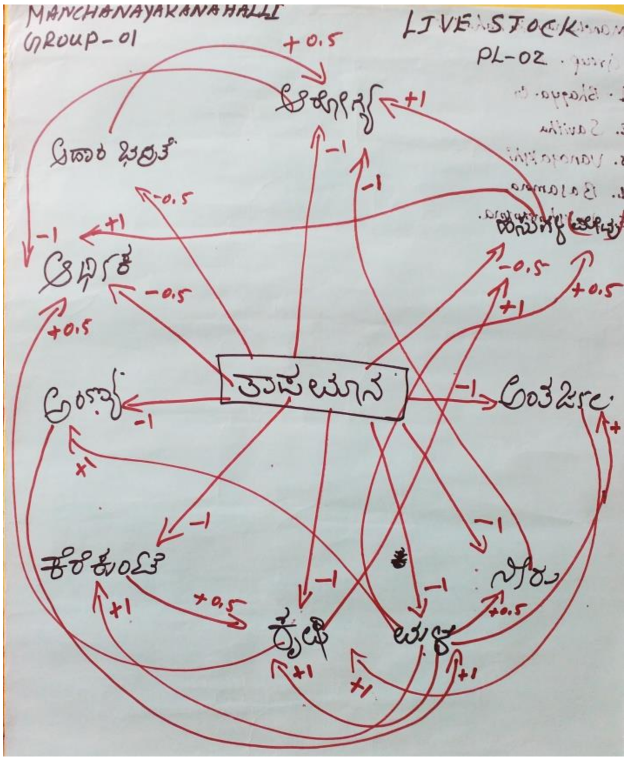


Figure 38: Stakeholder map on temperature and water security

Figure 39: Group Picture from the Stakeholder Consultation

Figure 40: EMPRI Climate Change Team and PAC Environment Governance Team

Annexure 2

Schedule No: | | | | |

ವಿವರಪಟ್ಟಿ ಸಂಖ್ಯೆ

Assessing Stakeholder Perception on Water Security in Peri-urban Areas: Developing Citizen Centered Scenarios

QUESTIONNAIRE

ಪ್ರಶ್ನಾವಳಿ

1. General Household Survey

1.ಸಾಮಾನ್ಯ ಕೌಟುಂಬಿಕ ಸಮೀಕ್ಷೆ

INSTRUCTION*:* Introduce yourself and speak to respondent, fill appropriate boxes properly and circle with proper codes carefully.

ಪರಿಚಯ: ನಿಮ್ಮನ್ನು ನೀವು ಪರಿಚಯ ಮಾಡಿಕೊಳ್ಳಿ ಮತ್ತು ರೆಸ್ಪಾಂಡೆಂಟೊಂದಿಗೆ ಮಾತನಾಡಿ, ಸೂಕ್ತವಾದ ಬಾಕ್ಸ್‌ಗಳಲ್ಲಿ ತುಂಬಿ ಮತ್ತು ಸೂಕ್ತವಾದ ಕೋಡ್‌ಗಳೊಂದಿಗೆ ಜಾಗರೂಕತೆಯಿಂದ ಗುರುತು ಮಾಡಿ

INTRODUCTION: Namaskar, I am ………………………….. from Public Affairs Centre (PAC). We are currently trying to know your experiences with water supply which will help us to assess the stakeholder perception on water security in peri-urban areas you are free to keep out your name in this questionnaire though we would like to assure you that the information collected would be collated and presented collectively. Could I please talk to you for a few minutes in this regard?

A. General Information

ಸಾಮಾನ್ಯ ಮಾಹಿತಿ

1.	Date of Interview ಸಂದರ್ಶನದ ತಾರೀಖು	dd/mm/yy
2.	Starting time of interview ಸಂದರ್ಶನ ಪ್ರಾರಂಭಿಸಿದ ಸಮಯ	___________am/pm
3.	Name of the Village ಜಾಗದ ಹೆಸರು	________________

B. Demographic Profile Of The Respondent

ರೆಸ್ಪಾಂಡೆಂಟ್‌ನ ಜನಾಂಗಸ್ಥಿತಿ ಅಧ್ಯಯನ

1	What is the name of the respondent? ರೆಸ್ಪಾಂಡೆಂಟ್‌ನ ಹೆಸರೇನು?		
2	What is the age of the respondent in completed years? ರೆಸ್ಪಾಂಡೆಂಟ್‌ನ ಪೂರ್ಣವಾದ ವಯಸ್ಸು ತುಂಬಿದ ವರ್ಷಗಳಲ್ಲಿ ಎಷ್ಟು?	________________ Years ವರ್ಷಗಳು	
3	What is the gender of the respondent? ರೆಸ್ಪಾಂಡೆಂಟ್‌ನ ಲಿಂಗವೇನು?	Male ಗಂಡು Female ಹೆಣ್ಣು	1 2

C. Water Usage Pattern

ಬಳಕೆಯ ವಿಧಾನ

1	Which of the drinking water sources are **available** near your house? (Multiple Response) ಇವುಗಳಲ್ಲಿ ಕುಡಿಯುವ ನೀರಿನ ಯಾವ ಮೂಲಗಳು ನಿಮ್ಮ ಮನೆಯ ಬಳಿ ಲಭ್ಯವಿದೆ? (ಒಂದಕ್ಕಿಂತ ಹೆಚ್ಚು ಉತ್ತರ)	Tap at home ಮನೆಯಲ್ಲಿ ಕೊಳಾಯಿ	1
		Public Tap ಸಾರ್ವಜನಿಕ ಕೊಳಾಯಿ	2
		Public Hand Pump/bore well ಸಾರ್ವಜನಿಕ ಹ್ಯಾಂಡ್ ಪಂಪ್/ಬೋರ್‌ವೆಲ್	3
		Public Mini Water Supply Scheme ಸಾರ್ವಜನಿಕ ಕಿರು ನೀರು ಸರಬರಾಜು ಯೋಜನೆ	4
		Tanker supply (free of cost) ಟ್ಯಾಂಕರ್ ಸರಬರಾಜು (ಉಚಿತವಾಗಿ)	5
		Tanker supply (at cost) ಟ್ಯಾಂಕರ್ ಸರಬರಾಜು (ಬೆಲೆ ನೀಡಿ)	6
		Open well ಬಾವಿ	7
		Others ಇತರೆ	8
2	Which of the sources do you **use**? (Multiple Response) ನೀವು ಇವುಗಳಲ್ಲಿ ಯಾವ ಮೂಲಗಳನ್ನು ಉಪಯೋಗಿಸುತ್ತೀರಿ? (ಒಂದಕ್ಕಿಂತ ಹೆಚ್ಚು ಉತ್ತರ)	Tap at home ಮನೆಯಲ್ಲಿ ಕೊಳಾಯಿ	1
		Public Tap ಸಾರ್ವಜನಿಕ ಕೊಳಾಯಿ	2
		Public Hand Pump/bore well ಸಾರ್ವಜನಿಕ ಹ್ಯಾಂಡ್ ಪಂಪ್/ಬೋರ್‌ವೆಲ್	3
		Public Mini Water Supply Scheme ಸಾರ್ವಜನಿಕ ಕಿರು ನೀರು ಸರಬರಾಜು ಯೋಜನೆ	4
		Tanker supply (free of cost) ಟ್ಯಾಂಕರ್ ಸರಬರಾಜು (ಉಚಿತವಾಗಿ)	5
		Tanker supply (at cost) ಟ್ಯಾಂಕರ್ ಸರಬರಾಜು (ಬೆಲೆ ನೀಡಿ)	6
		Open well ಬಾವಿ	7
		Others ಇತರೆ	8

3	Which is your **main source**? (single response) ನಿಮ್ಮ ನೀರಿನ ಪ್ರಮುಖ ಮೂಲ ಯಾವುದು? (ಒಂದೇ ಉತ್ತರ)	Tap at home * ಮನೆಯಲ್ಲಿ ಕೊಳಾಯಿ *	1
		Public Tap ಸಾರ್ವಜನಿಕ ಕೊಳಾಯಿ	2
		Public Hand Pump/bore well ಸಾರ್ವಜನಿಕ ಹ್ಯಾಂಡ್ ಪಂಪ್/ಬೋರ್‌ವೆಲ್	3
		Public Mini Water Supply Scheme ಸಾರ್ವಜನಿಕ ಕಿರು ನೀರು ಸರಬರಾಜು ಯೋಜನೆ	4
		Tanker supply (free of cost) ಟ್ಯಾಂಕರ್ ಸರಬರಾಜು (ಉಚಿತವಾಗಿ)	5
		Tanker supply (at cost) ಟ್ಯಾಂಕರ್ ಸರಬರಾಜು (ಬೆಲೆ ನೀಡಿ)	6
		Open well ಬಾವಿ	7
		Others ಇತರೆ	8

***If the respondent has a 'Tap at home' then go to question 9**

D: Fill the grid by using given codes (for the main source only)

ಕೊಟ್ಟಿರುವ ಕೋಡ್‌ಗಳನ್ನು ಉಪಯೋಗಿಸಿ ಗ್ರಿಡ್ ಭರ್ತಿ ಮಾಡಿ (ಪ್ರಮುಖ ಮೂಲಕ್ಕೆ ಮಾತ್ರ)

	Quality of Service ಸೇವೆಯ ಗುಣಮಟ್ಟ	**Tap at home** ಮನೆಯಲ್ಲಿ ಕೊಳಾಯಿ	**Public sources** ಸಾರ್ವಜನಿಕ ಮೂಲಗಳು				
			Open well ಬಾವಿ	**Public tap** ಸಾರ್ವಜನಿಕ ಕೊಳಾಯಿ	**Hand pump/Bore well** ಹ್ಯಾಂಡ್ ಪಂಪ್/ಬೋರ್‌ವೆಲ್	**Mini water supply** ಕಿರು ನೀರು ಸರಬರಾಜು	**Others** ಇತರೆ
4	What is the distance you have to cover for fetching water? ನೀರು ತರಲು ನೀವು ಎಷ್ಟು ದೂರ ಹೋಗಬೇಕು? <= ½ km(ಕಿ.ಮೀ) 1 ½ –1 km (ಕಿ.ಮೀ) 2 > 1Km (ಕಿ.ಮೀ) 3						

	Quality of Service ಸೇವೆಯ ಗುಣಮಟ್ಟ	Tap at home ಮನೆಯಲ್ಲಿ ಕೊಳಾಯಿ	Public sources ಸಾರ್ವಜನಿಕ ಮೂಲಗಳು				
			Open well ಬಾವಿ	**Public tap** ಸಾರ್ವಜನಿಕ ಕೊಳಾಯಿ	**Hand pump/Bore well** ಹ್ಯಾಂಡ್ ಪಂಪ್/ಬೋರ್‌ವೆಲ್	**Mini water supply** ಕಿರು ನೀರು ಸರಬರಾಜು	**Others** ಇತರೆ
5	Is there a platform around the public source? ಆ ಸಾರ್ವಜನಿಕ ಮೂಲದ ಬಳಿ ಕಟ್ಟೆ ಇದೆಯೇ? Yes 1 ಹೌದು No 2 **Go to 7** ಇಲ್ಲ 7ಕ್ಕೆ ಹೋಗಿ						
6	Is the platform clean? ಕಟ್ಟೆಯು ಸ್ವಚ್ಛವಾಗಿದೆಯೇ? Yes 1 ಹೌದು No 2 ಇಲ್ಲ						
7	Is there a queue? ಸಾಲಾಗಿ ನಿಲ್ಲ ಬೇಕಾಗುತ್ತದೆಯೇ? Yes 1 ಹೌದು No 2 **Go to 9** ಇಲ್ಲ 9ಕ್ಕೆ ಹೋಗಿ						
8	How long do you have to wait for your turn? (Min) ನಿಮ್ಮ ಸರದಿ ಬರಲು ನೀವು ಎಷ್ಟು ಹೊತ್ತು ಕಾಯಬೇಕಾಗುತ್ತದೆ?(ಕನಿಷ್ಠ)						
9	How frequently do you get water supply? ನಿಮಗೆ ನೀರು ಸರಬರಾಜು ಎಷ್ಟು ಬಾರಿ ಆಗುತ್ತದೆ? Once a day 1 (ದಿನಕ್ಕೊಮ್ಮೆ) Once in 2 days 2 (2 ದಿನಗಳಿಗೊಮ್ಮೆ)						

	Quality of Service ಸೇವೆಯ ಗುಣಮಟ್ಟ	Tap at home ಮನೆಯಲ್ಲಿ ಕೊಳಾಯಿ	Public sources ಸಾರ್ವಜನಿಕ ಮೂಲಗಳು				
			Open well ಬಾವಿ	Public tap ಸಾರ್ವಜನಿಕ ಕೊಳಾಯಿ	Hand pump/Bore well ಹ್ಯಾಂಡ್ ಪಂಪ್/ಬೋರ್‌ವೆಲ್	Mini water supply ಕಿರು ನೀರು ಸರಬರಾಜು	Others ಇತರೆ
	Once in 3 days 3 (3 ದಿನಗಳಿಗೊಮ್ಮೆ) Once in 4-5 days 4 (4–5 ದಿನಗಳಿಗೊಮ್ಮೆ) Less often 5 (ಕಡಿಮೆ ಬಾರಿ)						
10	On the day of supply, what time period do you get water during ನೀರು ಸರಬರಾಜಿನ ದಿನ, ಯಾವ ಸಮಯದಲ್ಲಿ ನೀರು ಸಿಗುತ್ತದೆ? Mid night (12.00 - 4.00 AM) 1 ಮಧ್ಯರಾತ್ರಿ Early morning (4.00 – 7.00 AM) 2 ಬೆಳಗಿನ ಜಾವ Morning (7.00 AM – 12.00 Noon) 3 ಬೆಳಿಗ್ಗೆ Afternoon (12.00 Noon - 4.00 PM) 4 ಮಧ್ಯಾಹ್ನ Evening (4.00 - 7.00 PM) 5 ಸಾಯಂಕಾಲ Night (7.00 to 10.00 PM) 6 ರಾತ್ರಿ Late night (10.00 – 12.00 AM) 7 ಸರೋರಾತ್ರಿ						
11	Is the timings of water supply convenient? ನೀರು ಸರಬರಾಜಿನ ಸಮಯ ಅನುಕೂಲಕರವಾಗಿದೆಯೇ? Yes 1 **Go to 13** ಹೌದು 13ಕ್ಕೆ ಹೋಗಿ						

	Quality of Service ಸೇವೆಯ ಗುಣಮಟ್ಟ	Tap at home ಮನೆಯಲ್ಲಿ ಕೊಳಾಯಿ	Public sources ಸಾರ್ವಜನಿಕ ಮೂಲಗಳು				
			Open well ಬಾವಿ	Public tap ಸಾರ್ವಜನಿಕ ಕೊಳಾಯಿ	Hand pump/Bore well ಹ್ಯಾಂಡ್ ಪಂಪ್/ಬೋರ್‌ವೆಲ್	Mini water supply ಕಿರು ನೀರು ಸರಬರಾಜು	Others ಇತರೆ
	No 2 ಇಲ್ಲ						
12	What is the most convenient timing for you to get water supply? ನೀರು ಸರಬರಾಜು ಪಡೆಯಲು ನಿಮಗೆ ಅತ್ಯಂತ ಅನುಕೂಲಕರ ಸಮಯ ಯಾವುದು? Mid night (12.00 - 4.00 AM) 1 ಮಧ್ಯರಾತ್ರಿ Early morning (4.00 – 7.00 AM) 2 ಬೆಳಗಿನ ಜಾವ Morning (7.00 AM – 12.00 Noon) 3 ಬೆಳಿಗ್ಗೆ Afternoon (12.00 Noon - 4.00 PM) 4 ಮಧ್ಯಾಹ್ನ Evening (4.00 - 7.00 PM) 5 ಸಾಯಂಕಾಲ Night (7.00 to 10.00 PM) 6 ರಾತ್ರಿ Late night (10.00 – 12.00 AM) 7 ಸರೋರಾತ್ರಿ						

<table>
<tr><th rowspan="2"></th><th rowspan="2">Quality of Service
ಸೇವೆಯ ಗುಣಮಟ್ಟ</th><th rowspan="2">Tap at home
ಮನೆಯಲ್ಲಿ ಕೊಳಾಯಿ</th><th colspan="5">Public sources
ಸಾರ್ವಜನಿಕ ಮೂಲಗಳು</th></tr>
<tr><th>Open well
ಬಾವಿ</th><th>Public tap
ಸಾರ್ವಜನಿಕ ಕೊಳಾಯಿ</th><th>Hand pump/Bore well
ಹ್ಯಾಂಡ್ ಪಂಪ್/ಬೋರ್‌ವೆಲ್</th><th>Mini water supply
ಕಿರು ನೀರು ಸರಬರಾಜು</th><th>Others
ಇತರೆ</th></tr>
<tr><td>13</td><td>On the day of supply, for how many hours do you get water?
ನೀರು ಸರಬರಾಜಿನ ದಿನ, ಎಷ್ಟು ಗಂಟೆಗಳ ಕಾಲ ನೀರು ಬರುತ್ತದೆ?

One hour 1
ಒಂದು ಗಂಟೆ

two to three hours 2
ಎರಡರಿಂದ ಮೂರು ಗಂಟೆಗಳು

four to five hours 3
ನಾಲ್ಕರಿಂದ ಐದು ಗಂಟೆಗಳು

More than five hours 4
ಐದು ಗಂಟೆಗಳಿಗಿಂತಲೂ ಹೆಚ್ಚು</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>14</td><td>On the day of supply, what is the pressure of water supply?
ನೀರು ಸರಬರಾಜಿನ ದಿನ, ನೀರಿನ ರಭಸ ಹೇಗಿರುತ್ತದೆ?
High 1
ಹೆಚ್ಚು

Medium 2
ಮಧ್ಯಮ

Low 3
ಕಡಿಮೆ</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>15</td><td>Is the frequency of water supply sufficient for your needs?
ನಿಮ್ಮ ದಿನದ ಅವಶ್ಯಕತೆಗೆ ಸಾಕಾಗುವಷ್ಟು ನೀರು ಆಗಿಂದಾಗ್ಗೆ ಸರಬರಾಜು ಆಗುತ್ತಿದೆಯೇ?

Yes 1 Go to 17
ಹೌದು 13ಕ್ಕೆ ಹೋಗಿ

No 2
ಇಲ್ಲ</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>16</td><td>How often would you like to get water?
ಎಷ್ಟು ಸಾರಿ ನೀರು ಸರಬರಾಜು ಆಗಬೇಕೆಂದು ನೀವು ಇಷ್ಟಪಡುತ್ತೀರಿ?</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

	Quality of Service ಸೇವೆಯ ಗುಣಮಟ್ಟ	Tap at home ಮನೆಯಲ್ಲಿ ಕೊಳಾಯಿ	Public sources ಸಾರ್ವಜನಿಕ ಮೂಲಗಳು				
			Open well ಬಾವಿ	Public tap ಸಾರ್ವಜನಿಕ ಕೊಳಾಯಿ	Hand pump/Bore well ಹ್ಯಾಂಡ್ ಪಂಪ್/ಬೋರ್‌ವೆಲ್	Mini water supply ಕಿರು ನೀರು ಸರಬರಾಜು	Others ಇತರೆ
	All Day (24 hours) 1 ದಿನವಿಡೀ (24 ಗಂಟೆಗಳು) More than once in a day 2 ದಿನದಲ್ಲಿ ಒಂದು ಬಾರಿಗಿಂತ ಹೆಚ್ಚು Once a day 3 ದಿನಕ್ಕೊಂದು ಬಾರಿ At least once in 2 days 4 ಕನಿಷ್ಠ 2ದಿನಗಳಿಗೊಮ್ಮೆ						
17	Is the quantity of water adequate for your daily needs? ನೀರಿನ ಪ್ರಮಾಣವು ನಿಮ್ಮ ನಿತ್ಯದ ಅವಶ್ಯಕತೆಗೆ ಸಾಕಾಗುತ್ತದೆಯೇ? Yes 1 Go to 19 ಹೌದು 19ಕ್ಕೆ ಹೋಗಿ No 2 ಇಲ್ಲ						
18	How do you manage for your daily needs? ನಿಮ್ಮ ನಿತ್ಯದ ಅವಶ್ಯಕತೆಗಳನ್ನು ಹೇಗೆ ನಿಭಾಯಿಸುತ್ತೀರಿ? Purchase from outside 1 ಹೊರಗಿನಿಂದ ಖರೀದಿಸುವುದು Purchase / borrow from neighbours 2 ನೆರೆಹೊರೆಯವರಿಂದ ಖರೀದಿಸುವುದು/ಎರವಲು ಪಡೆಯುವುದು Others 3 ಇತರೆ						
19	Quality of water supplied ಸರಬರಾಜು ಮಾಡಿದ ನೀರಿನ ಗುಣಮಟ್ಟ						
a	Colour : Clear 1 Muddy 2 ಬಣ್ಣ : ತಿಳಿ 1 ಮಣ್ಣು 2						

	Quality of Service ಸೇವೆಯ ಗುಣಮಟ್ಟ	Tap at home ಮನೆಯಲ್ಲಿ ಕೊಳಾಯಿ	Public sources ಸಾರ್ವಜನಿಕ ಮೂಲಗಳು				
			Open well ಬಾವಿ	Public tap ಸಾರ್ವಜನಿಕ ಕೊಳಾಯಿ	Hand pump/Bore well ಹ್ಯಾಂಡ್ ಪಂಪ್/ಬೋರ್‌ವೆಲ್	Mini water supply ಕಿರು ನೀರು ಸರಬರಾಜು	Others ಇತರೆ
b	Odour: Odourless 1 Foul smell 2 ವಾಸನೆ: ವಾಸನೆರಹಿತ 1 ದುರ್ವಾಸನೆ 2						
c	Taste: Sweet 1 Salty 2 Tasteless 3 ರುಚಿ: ಸಿಹಿ 1 ಉಪ್ಪು 2 ರುಚಿ ಇಲ್ಲ 3						

D. Coping Strategies
ನಿಭಾಯಿಸುವ ವಿಧಗಳು

21	Do you purchase mineral water for drinking purposes? ನೀವು ಕುಡಿಯುವ ನೀರಿಗಾಗಿ ಮಿನರಲ್ ವಾಟರ್ ಖರೀದಿಸುತ್ತೀರಾ?	Yes 1 No 2 ಹೌದು ಇಲ್ಲ
22	Do you purchase water from? ನೀವು ನೀರನ್ನು ಎಲ್ಲಿಂದ ಖರೀದಿಸುತ್ತೀರಾ?	Yes ಹೌದು 1 / No ಇಲ್ಲ 2 Tankers ಟ್ಯಾಂಕರ್‌ಗಳು 1 2 Water venders ನೀರು ಮಾರಾಟಗಾರರು 1 2 Neighbors ನೆರೆಹೊರೆ 1 2
23	Do you have the following in your house? (Multiple response) ಇವುಗಳು ನಿಮ್ಮ ಮನೆಯಲ್ಲಿ ಇವೆಯೇ? (ಒಂದಕ್ಕಿಂತ ಹೆಚ್ಚು ಉತ್ತರ)	Water Purifier ವಾಟರ್ ಪ್ಯೂರಿಫೈಯರ್ 1 Bore well ಬೋರ್‌ವೆಲ್ 2 Sump tank ಸಂಪ್ ಟ್ಯಾಂಕ್ 3 Overhead tank ಓವರ್‌ಹೆಡ್ ಟ್ಯಾಂಕ್ 4 Pump/ motor for overhead tank ಪಂಪ್/ಓವರ್‌ಹೆಡ್ ಟ್ಯಾಂಕ್‌ಗಾಗಿ ಮೋಟಾರ್ 5 Open well ಮನೆಯಲ್ಲಿ ಬಾವಿ 6

		Others 7 ಇತರೆ
24	Are you aware of rainwater harvesting? ನಿಮಗೆ ಮಳೆ ನೀರಿನ ಕೊಯಿಲಿನ ಬಗ್ಗೆ ತಿಳಿದಿದೆಯೇ?	Yes 1 No 2 ಹೌದು ಇಲ್ಲ **if 'yes' answer 25, 26 and 27**
25	What were your sources of information regarding rainwater harvesting? (Multiple response) ನಿಮಗೆ ಮಳೆ ನೀರಿನ ಕೊಯಿಲಿನ ಬಗ್ಗೆ ತಿಳಿದುಬಂದ ಮೂಲಗಳು ಯಾವುವು? (ಒಂದಕ್ಕಿಂತ ಹೆಚ್ಚು ಉತ್ತರ)	Newspaper / magazines 1 ವಾರ್ತಾಪತ್ರಿಕೆ/ಮ್ಯಾಗಜೀನ್ Television / radio 2 ದೂರದರ್ಶನ/ರೇಡಿಯೋ Advertisements 3 ಜಲ ಮಂಡಳಿಯ ಜಾಹಿರಾತು School text books/clubs 4 ಶಾಲಾ ಪಠ್ಯ ಪುಸ್ತಕ/ಕ್ಲಬ್‌ಗಳು Others 5 ಇತರೆ
26	Does your house have rainwater harvesting system? ನಿಮ್ಮ ಮನೆಯಲ್ಲಿ ಮಳೆ ನೀರು ಕೊಯಿಲಿನ ವ್ಯವಸ್ಥೆ ಇದೆಯೇ?	Yes 1 ಹೌದು No 2 ಇಲ್ಲ
27	When was the system installed? ಪದ್ಧತಿಯನ್ನು ಯಾವಾಗ ಅಳವಡಿಸಲಾಯಿತು?	Less than six months 1 ಆರು ತಿಂಗಳಿಗಿಂತ ಕಡಿಮೆ Six months to one year 2 ಆರು ತಿಂಗಳಿಂದ ಒಂದು ವರ್ಷ More than one year 3 ಒಂದು ವರ್ಷಕ್ಕಿಂತ ಹೆಚ್ಚು

F. Descriptive Questions
ವಿವರಣಾತ್ಮಕ ಪ್ರಶ್ನೆಗಳು

a. Is there a difference in the roles of men, women and children (boys and girls) in managing household water resource?
ಕುಡಿಯುವ ನೀರಿನ ನಿರ್ವಹಣೆಯಲ್ಲಿ ಗಂಡಸರ, ಹೆಂಗಸರ ಮತ್ತು ಮಕ್ಕಳ (ಹುಡುಗರು ಮತ್ತು ಹುಡುಗಿಯರು) ಪಾತ್ರವೇನು?

b. What is the role of service providers in providing drinking water to the community?
ಸಮುದಾಯಕ್ಕೆ ಒದಗಿಸುವ ಕುಡಿಯುವ ನೀರಿನ ಸರಬರಾಜಿನಲ್ಲಿ ಸೇವೆಯನ್ನು ಒದಗಿಸುವವರ ಪಾತ್ರವೇನು?