Impact of LULC change on the health of urban stream: a case of Bhukhi kaas

Thesis submitted in

partial Fulfillment for

the Award of the Degree of

Master of Urban and Regional Planning

by

Bhumi Nadarapa

Second semester, MURP II – 2020-21

Primary guide: Prof. Bindu Bhatt

Secondary guide: Neha Sarwate

Master of Urban and Regional Planning (MURP) Program

Department of Architecture

Faculty of Technology and Engineering

The Maharaja Sayajirao University of Baroda

D. N. Hall, Pratap Gunj, Vadodara, Gujarat, India

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CERTIFICATE

Impact of LULC change on the health of urban stream: a case of Bhukhi kaas

The contents presented in this Thesis represent my original work and it has not been submitted for the award of any other Degree or Diploma anywhere else.

Bhumi Nadarapa

This Thesis is submitted in partial fulfillment of the requirements for the Degree of Master of Urban and Regional Planning
at the Department of Architecture
Faculty of Technology and Engineering
The Maharaja Sayajirao University, Vadodara, Gujarat, India.
The present work has been carried out under our supervision and guidance and it meets the standard for awarding the above stated degree.

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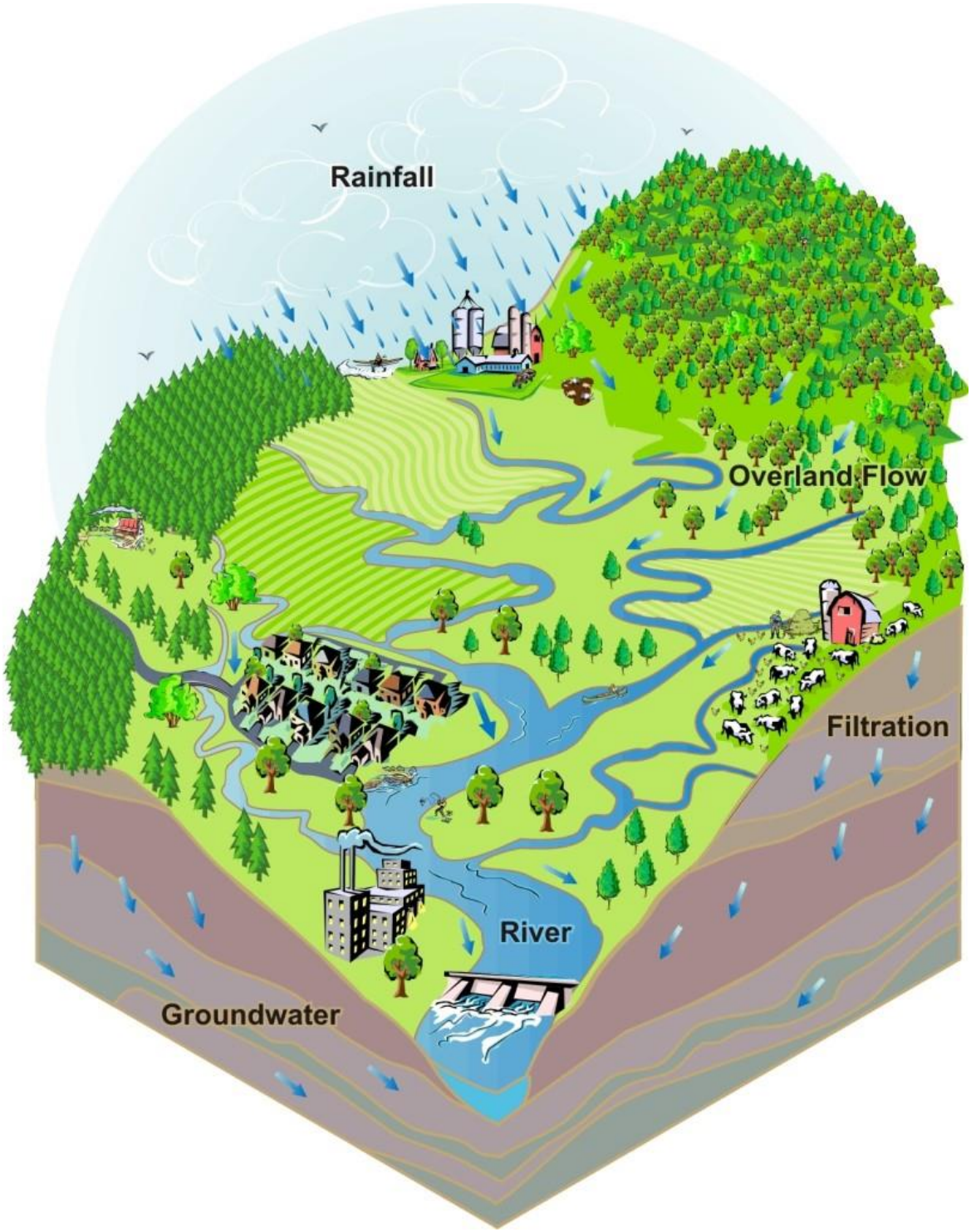
Watershed planning



Source: https://www.lswc.ca/watershed_planning

ABSTRACT

Streams are an important part of any ecosystem as it supports variety of habitats and biodiversity therefore its assessment, preservation and management are extremely necessary. Bhukhi kaas is a stormwater drainage channel that originates from Chhani lake, passing through the MSU campus draining into Vishwamitri river near Kalaghoda Circle, Vadodara. Total length of the stream is 7.5 kilometers out of which 2.2 kilometers falls under The Maharaja Sayajirao University of Baroda's campus. The stream supports large amount of biodiversity but due to excessive anthropogenic interference the overall quality of the stream is being degraded. The present study focuses on impact of landuse landcover changes on health of urban stream using remote sensing and GIS which includes use of high-resolution Google Earth images and satellite images to map landuse landcover change over the watershed of Bhukhi kaas from the year 1990 to 2020. Health of stream is defined by riparian vegetation and catchment connectivity. The spatial mapping was done using the process of satellite image processing, followed by supervised classification using ArcGIS 10.3. Apart from this, i interviewed the experts to assess change in riparian vegetation and spatial analysis of catchment connectivity. Also conducted google form survey to know local people's perception about the kaas. Overall, the study provides a comparative study on changing land use pattern in the buffer zone to provide effective control strategies and limiting point-source waste discharge in urban areas.

My study indicates that urban landuse was key factor affecting riparian vegetation. Research finding provided useful information in identifying pollution sources and understanding LULC with river water quality as references to policy maker for proper management of Land Use area.

Resultant LULC and overlay maps indicate a significant shift from Other (35.1%) to Built-up. By degradation of natural factors are putting ecosystem at risk. This study envisages to facilitate policy makers, planners and other associated development workers to adopt the best suitable land-use management option for the Watershed.

Keyword: urban (micro) watershed, landuse landcover (LULC) change, health of stream, catchment, riparian vegetation

DEDICATION

This thesis is dedicated to my parents Nayana Nadapara and Pravin Nadapara who have given me the opportunity of an education from the Maharaja Sayajirao University of Baroda and support throughout my life.

This thesis is dedicated to my husband who have always stood by me and dealt with all of my absence from many occasions with a smile.

This thesis is dedicated to my professors Bindu Bhatt and Neha Sarwate who have been my guides and philosophers.

I dedicate this thesis to my best friend who has always helped me and believed that I could do it.

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Finally, I would like to thank my family, friends and all those who helped me throughout my thesis work.

Thanking you,

Bhumi Nadapara.

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GLOSSARY

Riparian Of, inhabiting, or situated on the bank of a river.

Riparian vegetation - Hydrophytic vegetation growing in the immediate vicinity of a lake or river close enough so that its annual evapotranspiration represents a factor in the lake or river regimen.

Riparian zone of direct interaction between terrestrial and aquatic environments Vegetation, hydrology, and topography all determine the type, magnitude, and direction of functional relationships. The direction of riparian interactions refers to the notion that the terrestrial system may affect the aquatic or vice versa.

Catchment: An area drained by a river and all its tributaries; also referred to as a drainage basin, river basin or, in North America, as watershed. The morphological parameters of the river basin, such as area, shape, slope, perimeter, drainage density, soil permeability etc. may be used to explain observed variations in hydrological phenomena and then employed in predictive equations for sites without formal hydrometric networks.

Culvert **-** An engineered structure which takes a water course underground through a bridge or for longer distances in urban areas.

An **urban stream** is a formerly natural waterway that flows through a heavily populated area. Urban streams are often polluted by urban runoff and combined sewer outflows.

(Source: https://medwet.org/aboutwetlands/wetland-terminology/)

ABBREVIATIONS

LULC	Land use Land cover
NPS	Non Point Source
USGS	United States Geological Survey
RS	Remote sensing
GIS	Geographic Information System
DEM	Digital Elevation Model
SWAT	Soil and Water Assessment Tool
MSU	Maharaja Sayajirao University
VMC	Vadodara Municipal Corporation
GES	Gujarat Ecological Society

CHAPTER 1

INTRODUCTION

Water is the basic requirement of any living organism on Earth and is a prime life-sustaining natural resource. The river, lakes, streams are freshwater sources on the Earth. It plays an essential role in our daily life and a city's shape. Freshwater systems sustain people, strengthen agricultural production, industrial process, urban development, culture, recreation and other biotas that depend on them, and yet we are consistently reminded that these systems are in crisis.

Water is an essential element of human life. In every period of history, ancient civilization grew near freshwater resources such as streams, lakes, rivers, etc. Land use is mainly dependent on the availability of freshwater sources. Generally, the freshwater resource can be considered the center of the city's evolution. In history, people lived in harmony with nature and respected its order and logic. Later the concept of nature is extended to include the enjoyment of nature, pleasure, cultural and spiritual meaning, and its influence on the quality of life. Later on, it is used for economic, transportation, industries, etc. Nowadays, water is affected by the creation of cities (urbanization) as well. As freshwater courses, rivers and streams have a long-standing relationship to urbanization since the ancient civilizations.

Another development later was the scientific understanding of the environmental impact on public health due to documentation of environmentally sensitive diseases. This study helps to understand the relationship between human impact on the environment, health, and well-being of society. In the 18th century, the industrial revolution began when agricultural societies became more industrialized and urban. Rapidly expanding cities, railroad development, and the industrial sector led to an

environmental crisis by destroying nature and polluting water, soil, and air. The development of sewer systems and wastewater from industries was disposed of in waterbody, creating many environmental problems in urban areas and downstream areas. As it has been observed, rivers have been standing as the lifeline of cities. However, past practices after industrialization have polluted them and covered them up. They became marginalized waterscapes from urban life. For example, the scenes as river water quality deterioration and emerging bad-smelling rivers have been seen in developed cities (Gul Simsek, 2012). Later we see a concern for the environment comes into the picture of the conservation movement of the late 18th century, growing out of a concern for damage and loss of resources such as land and water as a result of development and misuse in the European nations. Later on, the planners, authorities, stakeholders, and local people are concerned about conserving natural resources with land-use planning in the urban area.

Therefore, ecological and environmental planning comes into practice in Europe and the united nations. Conservation and land-use planning in the 1900s in the united states adopted an ecological perspective in which uses were assigned to land according to its landscape pattern, environmental sensitivity, and suitability as a human habitat. The application of conservation of environment was first applied to community development by Ian Mc Harg, who promoted the concept of ecological planning to balance between land use and environment. Nevertheless, virtually every landscape has been settled in some fashion, such that a whit of original landscape scarcely remains (Marsh, 2005). This transformation story is revealed through the various countries in the world apart from India. The planning profession in India is not paying attention to its rich and vast environment.

By the industrial development particularly, An India is becoming increasingly urbanized. The movement of people from farms to cities began thousands of years ago, accelerated in the 20th century, and

continues into the 21st century. In India, according to the 1901 census, it was 11.4%, increasing to 28.53% by the 2001 census, and is currently 31.1% in 2011 census. We can see that urbanisation is increasing gradually. The future of the world is urban, and the problem of cities and their environment must be addressed. While the urban population is growing and climate change has been lived, the effects of urbanization on water systems (river, lake, stream) are increasing. The current problems with urban rivers, in general, are closely concerned with achieving eco-efficiency of the urban water system and rivers (Gul Simsek, 2012). Water resources are also under extreme pressure today in the whole world (Gul Simsek, 2012)

India is classified as an emerging and developing country (EDC) that is experiencing rapid economic development. This is leading to social, cultural, and environmental changes. Some researchers stated that economic development is the cause of environmental issues. It has been suggested that India's growing population is a primary cause for the degradation of the environment. Nevertheless, the developed countries such as Japan, United States, European countries have similar density like us still they are enjoying a better quality of the environment. India, as a developing country more focused on economic development and neglected environmental issues, which is a long-term effect on the health of society. Now it is a high time to stop environmental degradation and conserve it for the future generation. India faces the "worst water crisis" in groundwater scarcity in terms of groundwater depletion and contamination, and polluted surface water affects India's health, economy, environment, and food supply. The water resource is plenty in amount. The problems are not scarcity but rather inefficient use and bureaucratic policies (water scarcity in india, n.d.).

After being neglected for decades, since the second half of the 20th century, more attention given to the sustainability of resources; awareness has grown of the vital role of urban rivers as a resource for

humans and a lifeline for cities. As a result of the problems associated with urban rivers cannot be isolated from the water system. In challenging economic times, it is vital to re-invest in our cities' infrastructure and environmental improvement. Aiming to create sustainable cities, there is a concentration on the development of many transformation projects, including urban waters. The resulting problems have given rise to the activities, which reflect the growing interest in them and their management. Besides, water is significant for economic and socio-cultural reasons as well as a scarce natural resource. But nowadays, river connection among cities, societies, cultures, and environments unclear (ali, 2017). The process of evaluating water-related interventions and projects is critical in the context of sustainable planning. One of the city's major problems, especially in third-world nations, is 'dead rivers' or 'forgotten rivers' which become sources of pollution and disease, forming a dead path, fragmenting communities, degrading biodiversity, with urban encroachment, the absence of a healthy environment and the loss of community aesthetic value (ali, 2017). People also face their back toward the river due to the degradation of a river system. We value land more than water, neglecting our local water bodies, which have either gone dry or encroached. We are only considered the top layer as land and ignored the base layer of the natural system as hydrology (water system), geology, geomorphology in land-use planning. Natural system layers are equally crucial for planning.

Therefore, the restoration and conservation of rivers are of utmost importance for sustaining humanity and ecology through India's present and future generations. The national mission for clean Ganga Committed and Focussed Approach River rejuvenation efforts in India have often focused on large rivers as a whole but have failed. Not only is the river too large to be observed and monitored comprehensively, but the anthropogenic factors affecting the river are also often too diverse and unevenly distributed across the river basin. The task becomes much

simpler when the effort to reverse the degradation process focuses on the smaller urban and semi-urban tributaries/drains, especially those perennial or can be easily made perennial. It can be easily converted to perennial water bodies by supplying them with treated wastewater around the year. The multiple benefits accruing from such rejuvenation – economic, environmental, aesthetic, and cultural are also immediate, and they impact large population groups, which can have a cascading effect on river rejuvenation initiatives in the rest of the basin. This is essentially a bottom-up approach (building a right pyramid) that ensures the stability of the restoration process as opposed to the top-down process (inverted pyramid), which often leaves vast chinks of deformity that makes the entire river system vulnerable to degeneration (River Restoration and Conservation, 2019). Large rivers are formed by the coming together of smaller order – the tributaries – like the tertiary, secondary, primary order stream. The lower order tributaries are therefore of crucial importance in maintaining the health of rivers. They feed not only water, nutrients, and sediments but also significant biodiversity into higher-order tributaries and the river's main stem. It is not surprising. Therefore, that river degradation often begins in the smaller tributaries, especially those flowing through or near urban settlements (River Restoration and Conservation, 2019).

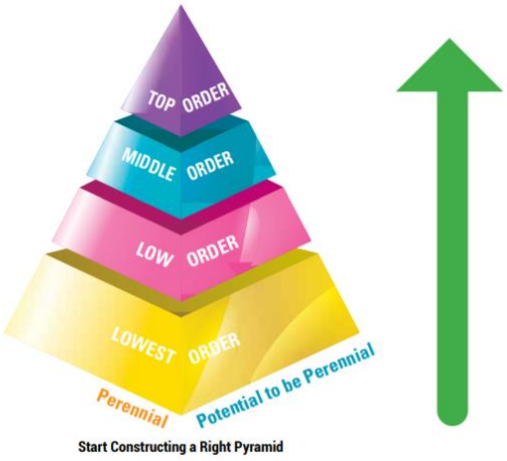


FIGURE 1: RIVER RESTORATION PYRAMID

source: River Restoration and Conservation, 2019

CHAPTER 2

LITERATURE REVIEW

2.1 THE WATERSHED CONCEPT:

Overland flow moves only a short distance on the ground before it gathers into minute threads of water. These threads further merge into one another to form rivulets which further merge to form streams and finally end in a river formation. This system of channels, characterized by streams linked together like branches of trees, is called a drainage network. The area feeding water to a drainage network is a drainage basin or a watershed (Marsh, 2005). These smaller streams are formed at higher elevations to mean sea level, collect rainwater gained through precipitation and pass them to streams at a lower elevation from mean sea level to meet the headstream of the river finally and eventually to an ocean (in case of a river watershed). This whole area thus constitutes the watershed of a river. A watershed is a topographically delineated area that is drained by a water system. A watershed is also a hydrological response unit, a biophysical unit, and a holistic ecosystem in terms of the materials, energy, and information that flow through it (Guangyu Wang, 2016).

2.2 WATERSHED BASED LAND-USE ANALYSIS

Watershed and land-use are interdependent. Land-use changes are significant issues in the century and urbanization is considered a dominant factor for land-use change which increased surface runoff, impervious surface, and non-pollutant source (NPS). Furthermore, it causes urban flooding and degradation of water quality, natural environment, and biodiversity, affecting the change in landscape patterns. Watershed-level planning is inherently concerned with land-use issues and their impact on watershed areas, such as the stream's health and

aquatic biodiversity. Watershed has been used as physical, economic, social, environmental, and political units to plan and implement land management practices.

In the united states, the use of watershed as planning units originated from defining the best hydrological planning unit for land, water, and ecosystem management, then defining governmental boundaries based on watersheds, and finally delineating the boundaries of planning based on watersheds. For example, in New York, a watershed management agreement was signed in 1997 to protect water quality and quantity of drinking water while promoting environmental sustainability compatible with economic development.

Japan has based planning for ecosystems, cultural landscapes, and disaster prevention on the watershed-based planning in the master plans for parks and open spaces in some municipalities. Therefore, the watershed can be considered a planning unit for urban and regional planning through its boundaries that do not necessarily coincide with the administrative boundaries. In watershed-based research, the study of land use is the most prominent issue. Many studies have focused on the influence and impact of land-use practices on the health of the watershed. There is a need to develop watershed as a planning unit in India to conserve and manage water resources for future generations in the way of ecological planning approach.

2.3 IMPACT OF LULC CHANGE ON SURFACE WATER SYSTEM

Land Use Land Cover (LULC) refers to two separate terminologies that are often used interchangeably (A. Butt, 2015) (Kumar, 2015). Land Cover can be defined as the physical characteristics of the Earth's surface, including vegetation, water, soil, and other physical features created through human activities like settlements. At the same time, Land-use refers to land used by humans for habitats concerning socio-economic activities. LULC patterns depend on human usage in terms of natural and

socio-economic development through space and time. Land Use changes can affect the Land Cover and vice versa. In most cases, Shifting into possibility negative impact through the Land-use perspective for social activities is affecting Land Cover to change, especially in biodiversity, water, and earth radiation, trace gas emission, and other processes that come together to affect the climate and biosphere (A. Butt, 2015) (M. S. Boori and V. Vozenilek, 2014).

Increasing human population growth, directly and indirectly, contributes to LULC changes, especially from the perspective of demand and supply for the built-up area, agricultural activities, and water resources. As per the gradient settings of any particular stream, each part of the land is an essential element of the watershed through which water drains to its lower point along with influential nutrients, chemicals, debris, etc. Therefore, a typical watershed that comprises multiple forms of land uses/land covers (LULC) might influence the hydrological characteristics of watersheds (Haque, 2013).

Land use and land cover change (LULCC) assessment help identify the extent of human influence on the natural environment.

Many researchers considered it a necessary process that affects natural settings and socioeconomic conditions at local, regional, and global levels (A. Butt, 2015) (Wubie, 2016). Hence, information about LULC is increasingly needed to manage the environment as well as lining conditions effectively. Planners, resource managers, scientists, and decision-makers from local, state, regional, local government, and private corporations use this information for various purposes.

Aquatic ecosystems provide a wide array of such services, including freshwater for agricultural, industrial, municipal uses, transportation corridors, food, opportunities for recreation and aesthetic enjoyment, spiritual activities, and waste disposal.

As human populations have grown, their effects on aquatic ecosystems have increased (Postel 1996, 2000; Vitousek et al. 1997; Sala et al. 2000). Freshwater ecosystems are particularly vulnerable because human populations are concentrated near freshwater resources.

As rural lands surrounding urban areas are converted to urban land uses, nearby freshwater systems will experience increased stresses with various consequences for biodiversity and ecosystem processes (McDonnell and Pickett 1990; Sala et al. 2000; Paul and Meyer 2001).

Ecologists pay considerable attention to the land-use change impacts predominantly concerning its effects on biodiversity and aquatic ecosystems (Turner et al., 2001).

Land use and land cover changes, associated with human activities and natural factors, compromise many ecosystem services in a watershed (C.L., 2007). For example, forestland converted to agricultural or urban land may have increased soil erosion, surface runoff, and urban flooding.

Riparian edge is reducing as urbanization is increasing. Boundary walls and paved areas replaced riparian vegetation. Riparian vegetation is habitats for many aquatic animal and birds which need to be protected and preserved with the development process. Riparian edge helps to keep low water temperature by providing shading on the stream, maintaining a micro-climatic zone along the riverbanks by providing fresh and clean air, and reducing the urban heat island effect, reducing the nutrient load from surface runoff in a stream. It is used for recreational purposes and spiritual activities.

Changes in land use and land cover interact with anthropogenic and natural drivers to affect the water quality and quantity of surface and groundwater in watersheds. Deforestation, agricultural activities, and urbanization generally modify land surface characteristics and landscape pattern, alter runoff volume, reduce groundwater recharge, increase the transfer of pollutants, change water temperature, generate pollution,

increase algal production, and decrease concentrations of dissolved oxygen in water bodies. Water quality is affected by point source pollution such as wastewater treatment facilities and non-point source pollution such as impervious surface runoff, agricultural runoff. Understanding non-point source pollution requires an understanding of how particular land covers influence water quality within a watershed.

Thus, the assessment of land use patterns and their chances at the watershed level is crucial to the planning and managing of water resources and land use of the particular watershed. Change analysis of Earth's surface features is essential for understanding interactions and relationships between human activities and the natural system. This understanding is necessary for improved resource management and improved decision making (A. Seif, 2012).

Various studies have been conducted all over the world regarding the change analysis of watersheds through different methods. They are essential to developing effective management strategies for watersheds worldwide (Ashraf, 2013) (Gajbhiye, 2012). Changes in land cover/land use in the watershed area, including urbanization and deforestation, continuously affect the water availability and the nature and extent of surface and subsurface water interactions, thus influencing watershed ecosystems and their services.

Therefore, LULC information at the watershed level is vital for selecting, planning, monitoring, and managing water resources so that the changes in Land Use meet the increasing demand for human needs and welfare without compromising water quality.

Various research studies have been conducted about the change analysis of watersheds, which are essential in developing effective management strategies to protect water resources (Kumar, 2015) (Ashraf, 2013). Watershed management is necessary because a watershed is not only a hydrological unit (P. Singh, 2014). and plays an integral part in

socioecological perspective by providing economic, food, and social security and provision of life support services to residents (A. Fernald, 2012). LULC changes in the watershed area for urbanization and deforestation will continuously negatively impact water quality the nature of a watershed ecosystem. Hence, understanding the spatial and temporal variations that occur in a watershed over time and an explanation of the interaction between hydrological components of the watershed will allow better water conservation strategies to be formulated (Ashraf, 2013).

2.4 THE HEALTH OF RIVER

A 'healthy' river has retained its biodiversity and ecosystem integrity (Nick Bond, 2012). River health is a concept that incorporates both ecological and human values. The symbols of the healthy river should be acceptable water quality natural banks of the river and a supportive ecosystem when the river's social functions and natural functions achieve in a balanced manner. In broad terms, a healthy river can sustain its ecological integrity. Thus, these streams integrate a wide variety of processes occurring in their watersheds. Hence, the streams' physical, chemical, and biological characteristics can serve as an essential indicator and regulator of the overall health of a water system (McDowell, 2009).

The concept of river health is an integration of physical, chemical, and biological factors that maintain the structure and function of the river's natural ecosystem. River health indicators should indicate the river's natural function status, including the riverbank, water quality, river ecosystem, and runoff. The concept of river health assessment (RHA) came about as an attempt to measure the health of the river. For a long, these studies have focused only on the water quality which included physiochemical properties of the water. It only identified those situations where the plant and animal life in the river at risk but did not provide any facts about the actual damage done. RHA uses six thematic components as indicators of river health- health of the catchment (CH), floodplain

(FPH), river channel (RCH), flow (FH), water quality (QH), and biotic health (BH) (Shah, 2016).

A catchment or watershed is an area of land where water collects when it rains. The catchment health is assessed through factors like LULC change of the catchment for planning and management of water quality and connectivity. This indicator helps assess the impact of human activities that can disturb the river's catchment area.

Floodplain assessment of the impact of vegetation on the floodplains the characteristic of the river banks such as its stability or its soil erosion, shape and slope of the banks, average runoff, encroachment on the bank, the impact of activities such as the use of chemical and pesticide in agriculture, sewage wastewater and impervious surface runoff from an urban area, etc. flood plain health provides information about the changes and the impacts due to flood dynamics.

River channel health provides facts concerning the ecology and the biotic condition of the river, length and breadth of the river channel, the longitudinal connectivity, and condition of plants and animals in the river, etc. Flow health comprises information on the kind, frequency, magnitude, and duration of the river flow and the impact of water extraction such as tube well on the river's natural flow. Water quality health is measured by assessing the water quality index of the river water. It includes dissolved oxygen, pH, temperature, salinity, and nutrients (Nitrogen and Phosphorus). They also include measures of toxicants such as insecticides, herbicides, and metals. Biotic health contains indicators such as the aquatic organisms present in the river that are influenced by the changing condition of the river, health, and population of flora and fauna, their habitats such as fish or macroinvertebrate diversity, benthic algal growth, linkages between the river and its catchment, the dynamic of the water flow and the transformation of nutrients (Shah, 2016).

Many research papers indicate that the correlation and regression analysis indicated that water quality was significantly related to vegetated coverage. Researchers significance that it is important to consider river health concerning the society, economy, and culture. River health assessment needs to be a community-driven process. Participatory river protection, together with local awareness at the community level, can play a significant role in river conservation (Shah, 2016).

Remote sensing has been widely used to classify and map LULC changes with different techniques and data sets, such as Landsat images that provide a better classification of different landscape components at a large scale (Loveland, 2012). Recently several change detection techniques have been developed that make use of remote sensing images. Among these Unsupervised classifications or clustering, Supervised classification, Hybrid classification, and Fuzzy classification are the most commonly applied techniques used in classification (Lu et al., 2004; Rundquist et al., 2001; Zhang et al., 2000). Although various classification techniques have been proposed, supervised classification methods are considered favorable for change detection analysis. Researchers have recently applied supervised classification for several LULC change detection for several research aims and purposes.

Watershed is an essential factor in planning our settlements along the river course to maintain the river systems. Studies state that the water quality of watersheds was most strongly affected by Landuse. Therefore, understanding LU patterns and watershed relationships is helpful for effective landscape planning to protect the water system. Comparative studies founded that LULC change has significant impacts on the health of the river in terms of water quality, riparian edge, aquatic ecosystem. Despite the many studies that have described the general relationship between land use and health of stream: that relationship is not fully understood. Many studied were done on a significant river basin.

Nevertheless, a few studied of LULC's impact on the health of urban or micro-watersheds in India. LULC impact is a long-term effect and differs according to the local climate and context of a case. Urban (micro) watershed is equally important to support urban ecology for its services, including freshwater for agricultural, industrial, and municipal uses, food, opportunities for recreation and aesthetic enjoyment, spiritual activities, and waste disposal. The change influences the urban river in the urban watershed. For the restoration of an urban river, the urban watershed is important to take into consideration while planning. This importance is not conveyed through the plans and the planning process in the Indian context. The government policy and development plans must consider issues of urban(micro) watersheds for sustainable cities. In India, city Planning is done from only a socio-economic point of view and ignoring natural systems. At the regional, state, and county levels, the government plans for significant rivers, which are also not integrated with urban planning. Many private firms and NGOs are practicing ecological planning as long-term planning in India. However, the government must incorporate ecological planning approach in the development process, which affects significant planning decisions because, in India, major planning decisions are taken by the government rather than experts in the field. Mr. yale stated that "planning needs to be done scientifically, not politically" (Yale, 2020).

I studied the LULC change impact on the health of streams in the urban (micro) watershed.

This study is carried out using the remote sensing application on google earth images to differentiate LULC changes in the urban watershed are than integrated into GIS. I compared LULC change and its impact on the health of urban (micro) watershed in terms of water quality, riparian vegetation, soil erosion as indicators for the health of the stream. The study demonstrates the crucial role of Geospatial technology in LU/LC mapping and monitoring for the use of planners/decisions makers. This

primary data will provide a solid foundation for the design and implementation of environmental policies and for institutional analyses. The results will also be useful for land use planning recommendations.

A case of Bhukhi Kaas - the urban watershed area was selected for change detection because of being subjected to urbanization, decreasing riparian edges, and cutting of trees. The rapid urban development taking place in the study area has led to environmental problems as well, encompassing fragmentation of aquatic habitats, active water and soil erosion, and water pollution due to solid waste dumping and domestic sewage discharge, influent from a sewage treatment plant. Since no previous data is available about the Bhukhi stream, this will act as primary data for future studies. Since the Bhukhi stream is a tributary of the Vishwamitri river, it will play a crucial role in the upcoming Vishwamitri project. From literature reviews, it is also clear that development is an inevitable process which causes both negative and positive impact on the environment.

2.5 RESEARCH QUESTION

What is the impact of LULC changes on health of urban stream - Bhukhi kaas as a case?

2.6 GOAL, AIM AND OBJECTIVES

Goal: To determine the role of LULC change on health of urban stream

Aim: To determine the role of LULC change on health of urban stream

Objective:

1. Delineating urban stream watershed
2. Detecting chronological LULC change in urban (micro) watershed from 1980 to 2020.
3. Examine the impact of LULC change on riparian vegetation 2000-2020
4. Assess the change in catchment connectivity with LULC change

2.7 SCOPE AND LIMITATION:

Scope:

To determine the impact the LULC change impact on downstream from the Chhani lake up to kalaghoda.

Limitation:

- I studied riparian vegetation in urban area only because of time constraint.
- Density of vegetation is an important indicator. But there is no appropriate data to process and analyze my study area. We need less than 30 meters resolution images for this study. Because of unavailability of data in public realm I have used limited data for my study. The detail study of Density of vegetation needs to be done in future as research thesis.

CHAPTER 3

RESEARCH DESIGN AND METHODS

3.1 STUDY AREA

The study will focus on the urban(micro) watershed of Bhukhi Kaas. Its influence to be considered in the planning and implementation through its impact on the health of stream in urban (micro) watersheds.

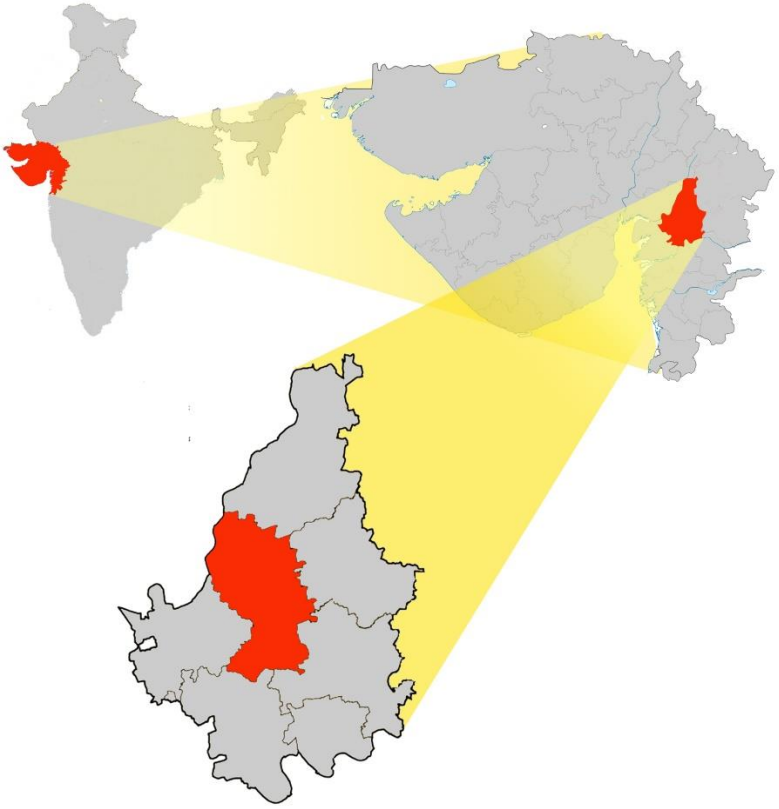


FIGURE 2: LOCATION OF STUDY AREA

The study area, Bhukhi Kaas watershed, is located in the north of Vadodara city in Gujarat. Geographically it lies in between 22°21' N and 22°18' North and 73°10' and 73°11' East of Vadodara city. The stream originates from Chhani lake, and it drains into the Vishwamitri river at Kalaghoda circle. It is a stormwater drainage channel and a 1st order

stream of the Vishwamitri river. The catchment areas are approximate 139 km² that flows through Chhani, Sama, Nizampura, Pratapgunj areas. The stream is about 7.5 km out of which 2.2 kilometres falls under the Maharaja Sayajirao University campus, and is underground for 1.5 kms. The stream's route is highly meandering due to its natural structure. It has varying widths due to the banks' concretization in a densely populated area. The stream is naturally carrying stormwater during the monsoon from its upper watershed, which was dominantly agricultural land-use in the past. The scenario is changed due to urban areas in the Bhukhi Kaas urban(micro) watershed. It is converted into Nala due to domestic wastewater and solid waste. This all disturbs the aesthetic and environmental value of the stream. It also has various major and minor inlets present at the buffer zone, entering into its channel. Human activities like constructing a compound wall, covering or culverting stream with concrete, and presence of slums near the stream also affect its riparian vegetation. The stream supports significant biodiversity, including an immense green cover on the banks, and altogether supporting many birds, mammals, reptiles, molluscans, macroinvertebrates, etc. (Environmental science dept., 2020).

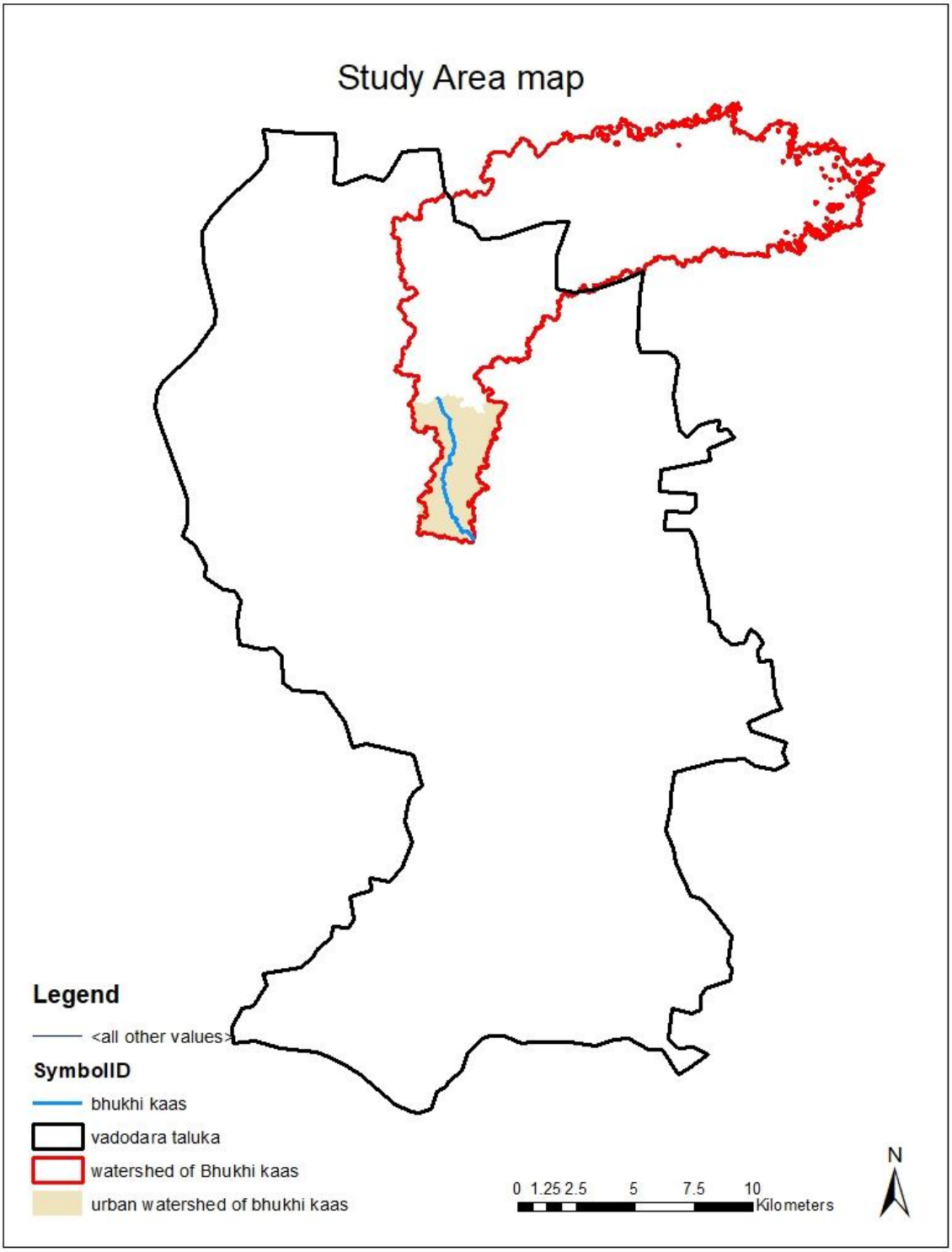


FIGURE 3: STUDY AREA - BHUKHI WATERSHED

3.2 METHODS AND TOOLS:

3.2.1 Research Design:

The research study undertaken was exploratory in nature as it assessed the change of variation on riparian vegetation and catchment area over the period of 40 years and how it plays a vital role in health of urban stream. It included collection of data, analyses and its presentation accordingly. It serves as a tool for initial research that provided a hypothetical or theoretical idea of the research problem. Exploratory research was flexible and provided the initial groundwork for future research. Exploratory research required me to investigate different sources such as published secondary data, observation of research items, and opinions of experts (C.R.Kothari, 2004) .

This research was based on primary (Personal Interview and E-Survey) and secondary (Spatial mapping) data collection. In this research, two types of data were used i.e. Quantitative data and qualitative data.

3.2.2 Data collection method for Qualitative data

One of the Data collection methods for the research was to "Ask" in which personal interviews on the online platform or telephonic responses of experts in the field of Botany, Environmental Science, Geography, Zoology Department of the Maharaja Sayajirao University of Baroda was taken to understand the causative factors and questionnaires are also used. Another data collection method was content analysis consisting of analysing documentary materials such as books, magazines, newspapers, research papers, and all other verbal materials, which can be either spoken or printed and digital. This part was qualitative analysis concern which reflecting the general message of the existing documents.

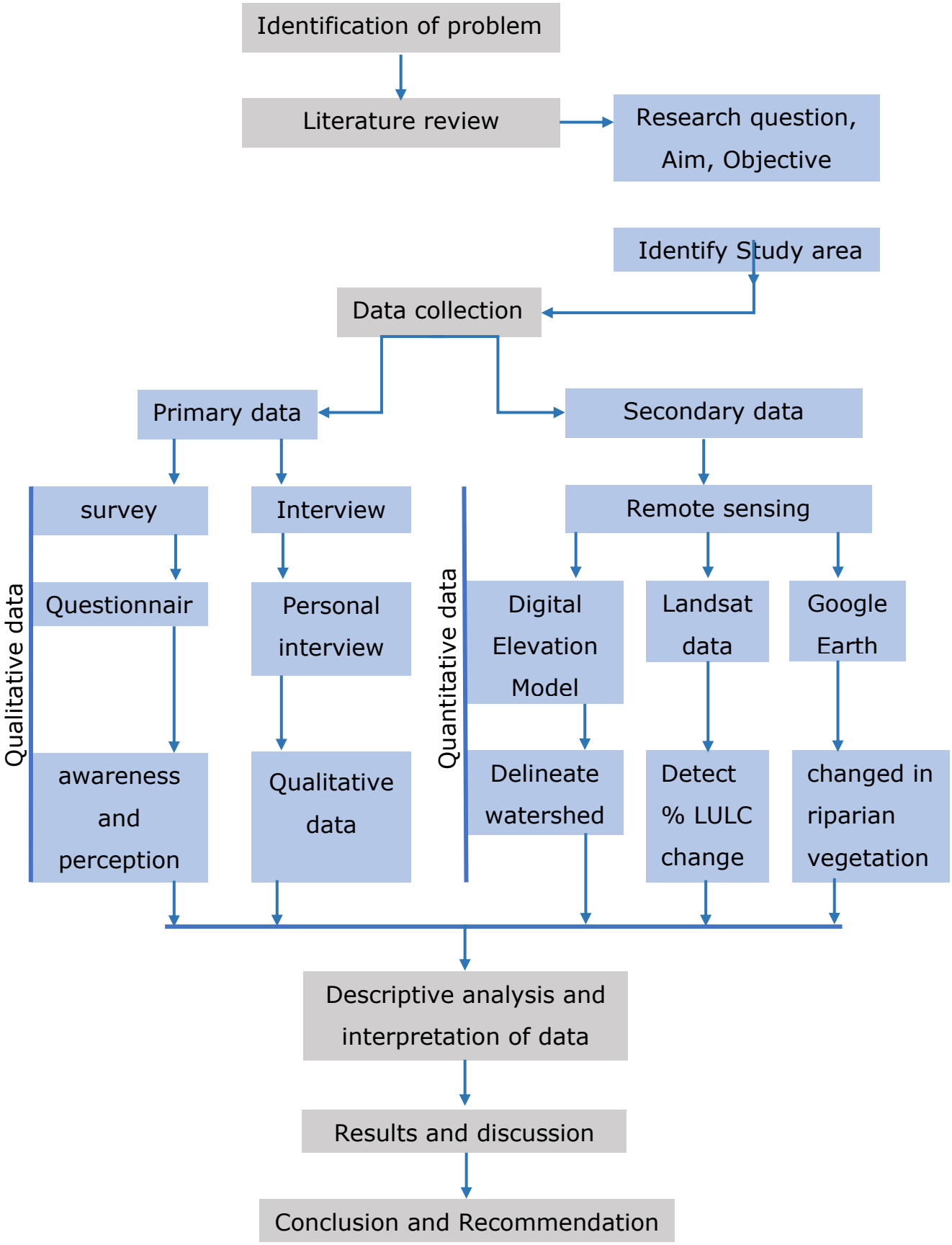


FIGURE 4: METHODOLOGY FLOW CHART

3.2.3 Data collection method for quantitative data

Quantitative data from satellite images for the last four decades consisting of multi-spectral data acquired by Landsat satellite provided by The United States Geological Survey (USGS) Earth Explorer (https://earthexplorer.usgs.gov/) were used for visual image interpretation and detecting LULCC. During image selection, cloud and unwanted shade-free imagery was set as criteria as their presence could substantially reduce the accuracy of the classification work.

Quantitative data for riparian vegetation was provided by rasterization of google earth images. images of the post-monsoon season particularly for the month of December (2000,2010,2020) along the whole study area selected.

3.3.4 Delineating watershed

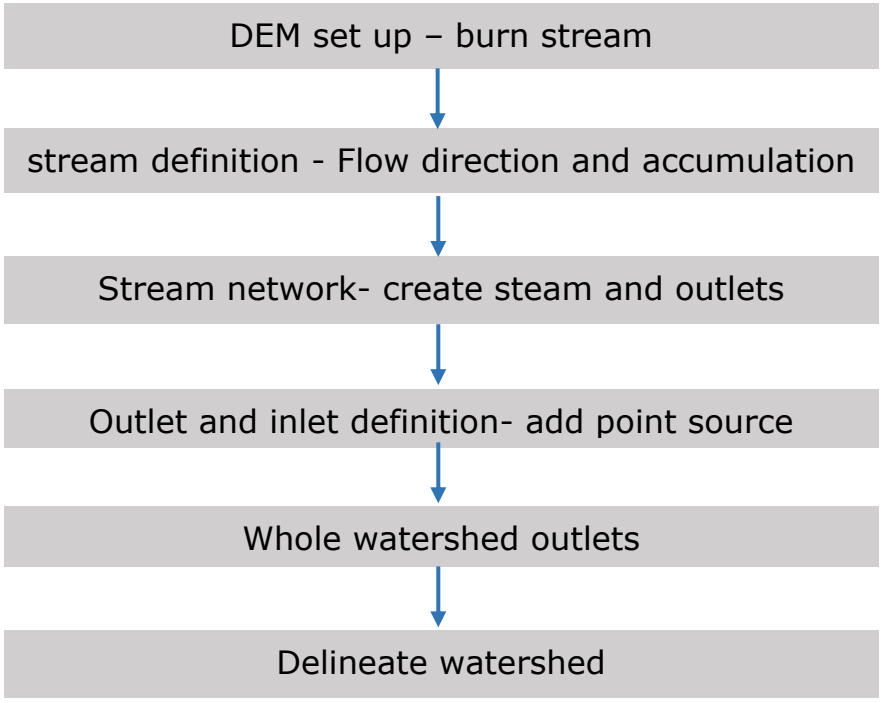


FIGURE 5: AUTOMATIC WATERSHED DELINEATION PROCESS IN SWAT MODEL

Watershed delineation means creating a boundary that represents the contributing area for a control point or outlet. Several software applications are available that provide automated watershed delineation

tools. Most of these tools only require a DEM as input. Besides, a stream network shape-file can also be used for automated watershed delineation in Soil and Water Assessment Tool (SWAT) model. In this research, ASTER GDEM of the study area with 30-meter spatial resolution was used for watershed delineation. The process flow diagram followed for watershed delineation is shown in fig.5.

3.3.5 Remote Sensing Data - Image Pre-processing and LULC Classification.

Remote sensing (RS) and Geographic Information System (GIS) are two effective tools for detecting and analysing land cover and its changes over a certain period through integrating spatial and temporal windows of the study area. It helps to understand current landscape along with changing patterns and evaluate past management decisions as well as predict possible effects of their current decisions before their implementation (NOAA, 2015). During image selection, cloud and unwanted shade free imagery were excluded from selection criteria as their presence could substantially reduce the accuracy of the classification work. Also, I have tried to use imageries of same month along the whole study period.

All satellite data were studied by assigning per-pixel signatures and differentiating the watershed into four classes on the bases of the specific Digital Number (DN) value of different landscape elements. For each of the predetermined land cover/use type, training samples were selected by delimiting polygons around representative sites. Spectral signatures for the respective land cover types derived from the satellite imagery were recorded by using the pixels enclosed by these polygons. A satisfactory spectral signature is the one ensuring that there is 'minimal confusion' among the land covers to be mapped (Gao and Liu, 2010). After that maximum likelihood algorithm was used for supervised classification of the images. It is the type of image classification which is mainly controlled by the analyst as the analyst selects the pixels that are representative of the desired classes.

The remote sensing imaginary for download from USGS Earth explore of the selected research area. Landsat 8 images for 2020 underwent spatial sharpening using the panchromatic bands which resulted in images with a 15m resolution. Meanwhile, Landsat 5 TM images for 1990 and Landsat 7 TM images for 2000 and 2010 year were obtained in an original 30m resolution. The image was displayed in color infrared using a band combination of 4, 3, and 2 for Landsat 5 TM and Landsat 7 and 5, 4, and 3 for Landsat 8 (Table 1). Maximum likelihood supervised classification was performed with study area based on delineated classes of vegetation, built-up areas, waterbody, and other (Table 2) using ArcMap 10.3.

TABLE 1: SATELLITE DATA SPECIFICATION

Data	Sensor identifier	Path/row	Year of acquisition	Band / Colour	Resolution (m)
Landsat 5	TM	148/045	09-03-1990	4,3,2 /color infrared	30
Landsat 7	ETM	148/044	23-11-2000	4,3,2 /color infrared	30
Landsat 7	ETM	148/044	05-12-2010	4,3,2 /color infrared	30
Landsat 8	OLI_TIRS	148/044	24-12-2020	5,4,3/color infrared	30

Based on the landscape of this area, LULC change assessment is done on the following four categories, namely- Built-up (all land covered by infrastructure), Water body (all areas of surface water), Vegetation (area covered with vegetation, Agricultural land), and other (non-forested and

non-agricultural land, barren land). Classes delineated on the basis of supervised classification as below:

TABLE 2: CLASSES DELINEATED ON THE BASIS OF SUPERVISED CLASSIFICATION

Class Name	Description
Built-up	Areas designated as residential, commercial, industrial zone, roads, transportation
Waterbody	Rivers, lakes, ponds, Reservoirs as well as areas that are water logged and swampy during the rainy season and dry during the dry season.
Vegetation	Areas covered by trees both natural and planted, Crop field and fallow lands
other	All land areas that are exposed soil and barren area influenced by human.

3.3.6 Impact of LULC change on riparian vegetation and catchment connectivity

The quantitative data is collected and processed by using Google earth images and AutoCAD software. Riparian vegetation area was in the form of raster used from google earth images. The qualitative data to examine riparian vegetation and catchment connectivity is collected through personal interviews of experts in field of Botany, Environmental science, Geography and Zoology in MSU. Whereas, extensive data is collected through E-survey (Google forms) to assess knowledge awareness and perception of the residents. The questionnaire for both expert interviews and E-survey is attached in the appendix i and ii respectively.

Sampling design:

Snowball sampling has been used to collect data from the respondents who are local and national experts in Allied field. A total of 14 respondents had participated in the research.

As for sampling design, snowball sampling has been used to collect data from the respondents who are available for the research. A total of 50 respondents had participated in the research.

Data processing:

The collected primary data was classified and tabulated. Thereafter the data was presented in the form of tables, charts and as the case may be. The collected data was analysed with the help of descriptive statistical tools.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 BHUKHI WATERSHED

The watershed of Bhukhi encompasses an area of 13900Ha (139 sqkm). Over the years, this watershed was subjected to considerable LULC changes. The resultant LULC maps of 1990, 2000, 2010 and 2020 are shown in Figs. 6-9 and the summary of the derived map is presented in Table 3.

4.2 SPATIAL MAPPING ASSESSMENT

4.2.1 LULC scenario of Bhukhi watershed, 1990

In 1990, the watershed area was mostly covered with green vegetation (56%). Characteristically, green vegetation plays an important role in the hydrological characteristics of a watershed by infiltrating most part of the falling rain in the monsoon and minimizing both surface runoff and soil erosion. It will also reduce flood intensity at low land watershed (Haque, 2013). The second dominant land cover in the watershed was barren (36%). At that time, settlements 8% of the area while, nearly 1% of this total watershed area was occupied by waterbodies (Table 3).

4.2.2 LULC scenario of Bhukhi watershed, 2000

In 2000, the extent of vegetation cover was 58%. Built-up and vegetation also increased at that time whereas immense declination was seen in case of other land. Table 3 depicts that built-up occupied 10% of total land cover and both other class and water body represent 31% and 1% of total land area respectively.

4.2.3 LULC scenario of Bhukhi watershed, 2010

In 2010, massive change has been observed in case of built-up and other. In this study, it is found that present vegetation cover of Bhukhi watershed is 60%. In this study, it is found that present built-up of Bhukhi watershed is 19% which is almost equal to other coverage (18%). Again, vegetation cover put pressure on land use and water system (Green, 2009). Now, water bodies represent 3% of the total watershed areas.

TABLE 3: CATEGORY WISE LANDUSE DISTRIBUTION OF BHUKHI WATERSHED (1990-2020)

Land use category	Land use in 1990		Land use in 2000		Land use in 2010		Land use in 2020	
	Area (Ha)	(%)	Area (Ha)	(%)	Area (Ha)	(%)	Area (Ha)	(%)
Built-up	1113	8	1392	10	2644	19	3340	24
Waterbody	139	1	139	1	418	3	278	2
Vegetation	7794	56.4	8072	58	8350	60	8490	61
other	4732	34.6	4315	31	2505	18	1809	13
Total	13918	100		100		100		100

4.2.4 LULC scenario of Bhukhi watershed, 2020

In 2020, the extent of vegetation cover was 61%. Built-up and vegetation also increased at that time whereas immense declination was seen in case of other class. Table 3 depicts that built-up occupied 24% of total land cover and both other and water body represent 18% and 2% of total land area respectively.

4.2.5 Temporal Change (1990 - 2020)

Between 1990 and 2020, a major decline with respect to area coverage was observed in other class whereas area of built-up increased (Tables 3). Other land class shrank by 21.6%. Other class retained only 1809 ha in

2020. Manjusar – Savli (phase I-II) GIDC was proposed in 1995. This industrial estate spread over of 800 ha and Vadodara White Oil Terminal was established between 1990 to 2000 near Sama-Savli road. Both industrial areas proposed on other land class which concerted from barren to built-up. Besides, water class retained only 278 ha of the total 418 ha in 2020. It was mainly replaced by vegetation and then followed by built-up in 2020. Vegetation is progressively increased (5%) in last three decades. Out of 7794 ha that was vegetation area in 1990, 8490 ha was vegetation area in 2020. It has increased because of Narmada canal which led to increase in agricultural practises. At the same time built-up increased (16%) from 1113 ha in 1990 to 3340 ha in 2020.

4.3 IMPACT OF LULC CHANGE ON RIPARIAN VEGETATION

4.3.1 Quantitative analysis from Google earth.

Below fig. 18-20 show the stream condition in three categories, first one is natural condition shown in fig.10-12, second is channelization (culverts) shown in fig.13 and 15 and last one is the condition covered with slab (underground) which is shown in fig. 14. In year 2000, Bhukhi kaas was in natural state having 4.78 km of total length, 2.49 km of channelization (culverts) and 0.3 km concrete slab cover. In year 2010, it was in natural state having 4.78 km total length, 2.49 km of channelization (culverts) and 0.3km concrete slab cover. In year 2020, Bhukhi kaas was in natural state having 4.44 km of total length, 1.58 km of channelization (culverts) and 1.54 km concrete slab cover.

TABLE 4: RIPARIAN VEGETATION COVER AND KAAS CONDITION FROM 2000 TO 2020

Sr. No.	year	Riparian vegetation	Natural state	Channelization (culverts)	Covered with concrete slab
1	2000	245.78 sqkm	4.78 km	2.49 km	0.3 km
2	2010	249.4 sqkm	4.78 km	2.49 km	0.3 km
3	2020	257.8 sqkm	4.44 km	1.58 km	1.54 km

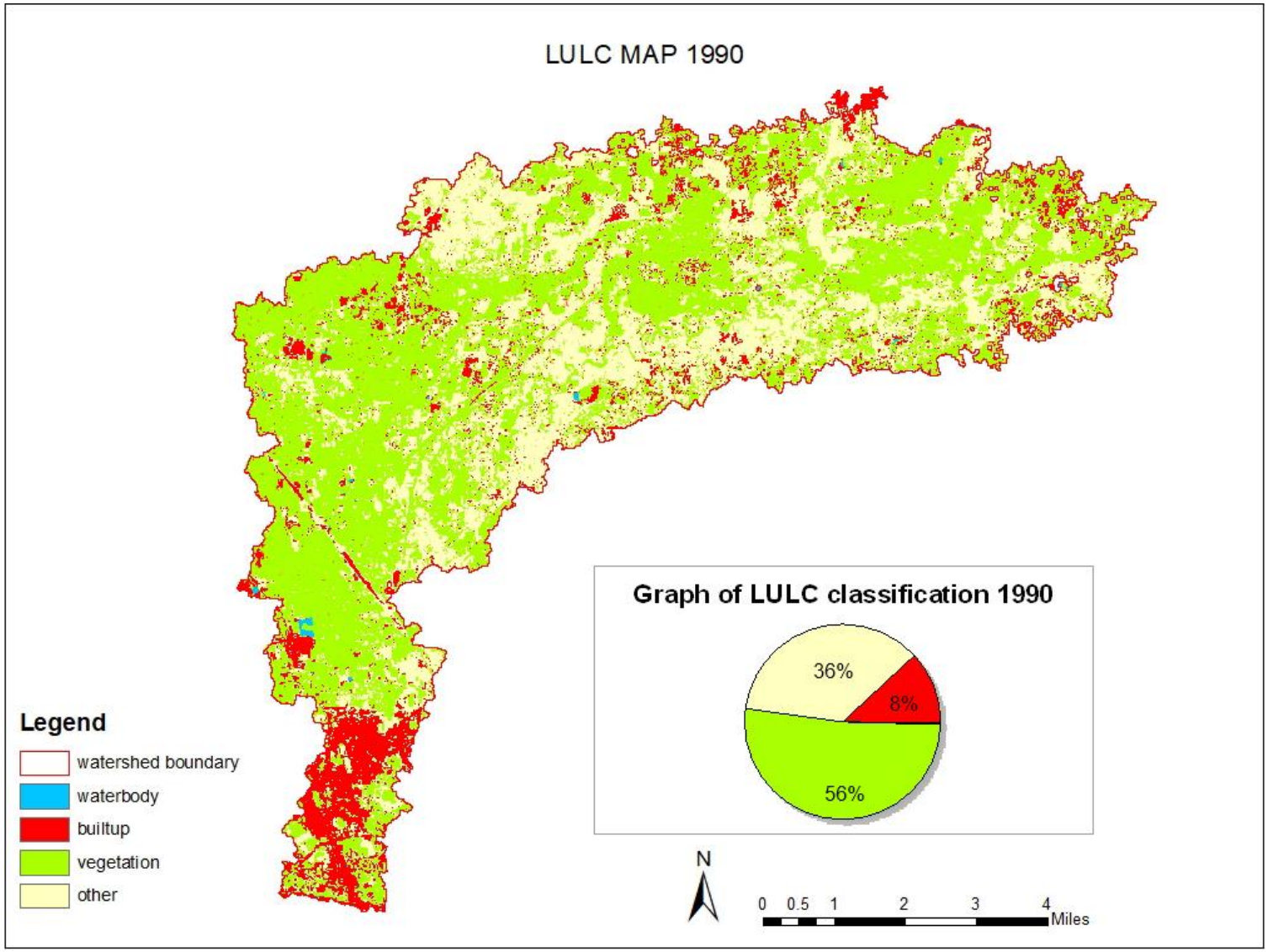


FIGURE 6: LANDUSE LANDCOVER MAP 1990

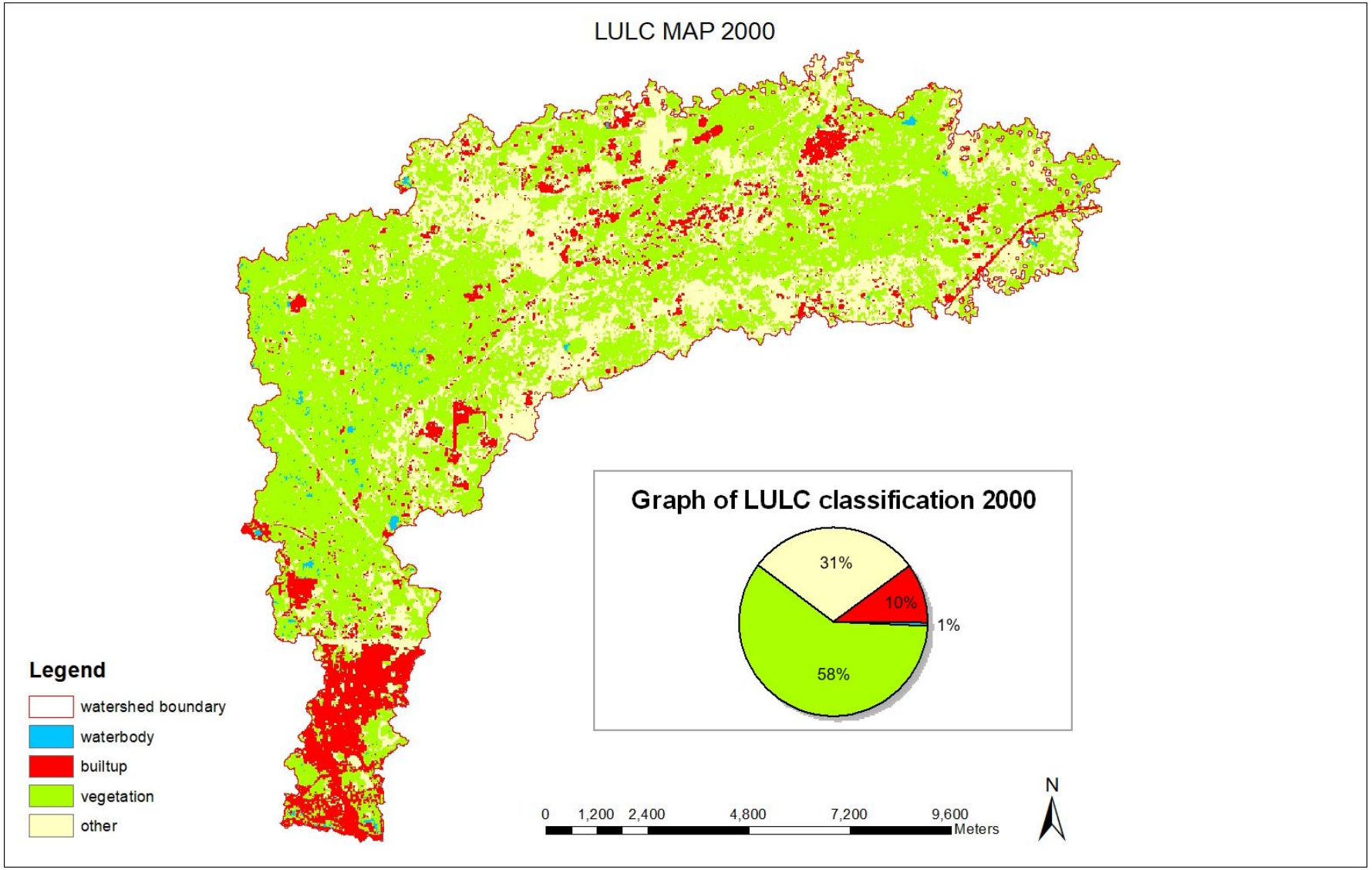


FIGURE 7: LANDUSE LANDCOVER MAP 2000

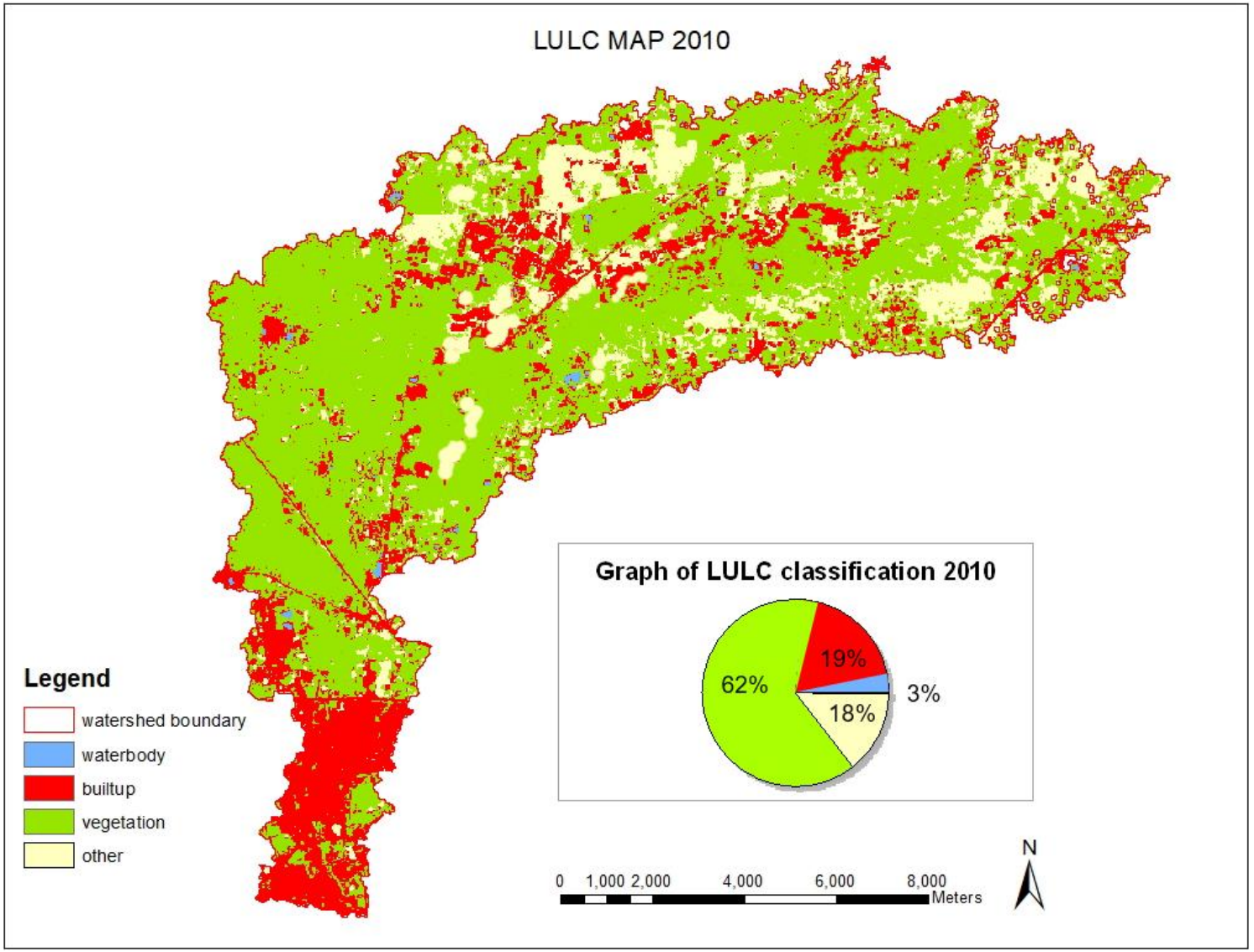


FIGURE 8: LANDUSE LANDCOVER MAP 2010

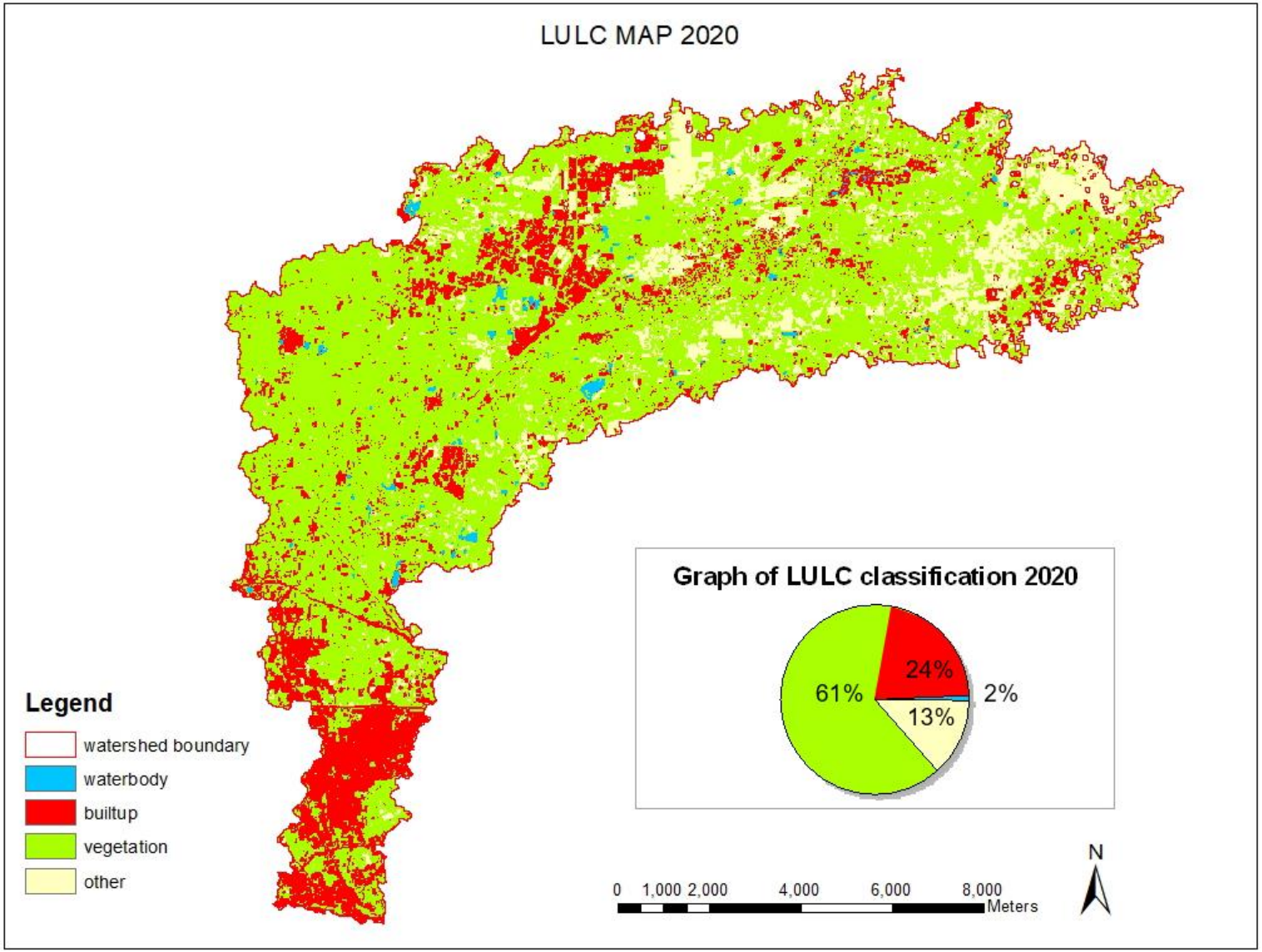


FIGURE 9: LANDUSE LANDCOVER MAP 2020

Above table 4 shows the riparian vegetation area in square kilometer and Bhukhi kaas condition in three categories in year 2000, 2010, 2020 from data extracted from google earth.

From the table 4 we could see that Bhukhi was transformed between 2010 to 2020 from natural state to channel which in turn was covered with concrete slab. Natural state of the stream is reduced from 4.78 to 4.44 km and channel is decreased from 2.49 km to 1.58 km because it is covered with concrete slab and so, covered part of kaas is increased from 0.3 km to 1.54 km. Apart from that we could see that riparian vegetation cover is increased from 2000 to 2020. In 2000, 2010 and 2020, it was 245.75 sqkm, 249.4 sqkm and 257.8 sqkm respectively. It is increased from year 2000 to 2020, because in 2000 "Vaho Vishwamitri" drive was conducted and clean whole the vegetation along the kaas. From google earth, I could only calculate canopy cover, so I also did ground truthing and found that the vegetation is grown on debris. Apart from that I also found that there is increase in invasive species as shown in fig 10-17.

FIGURE 10: PLACE WHERE BHUKHI ORIGINATE FROM CHHANI LAKE (A)

FIGURE 11: NEAR ADA TALAV IN NATURAL STATE (B)

FIGURE 12: NEAR NARMADA CANAL, CARRIES WASTE WATER AND DEBRIS ON BANKS (C)

FIGURE 13: CHANNELIZATION IN BHUKHI KAAS NEAR SAMA (D)

FIGURE 14: COVERED WITH CONCRETE SLAB IN NIZAMPURA AREA (E)

FIGURE 15: CHANNELIZATION IN BHUKHI NEAR NIZAMPURA (F)

FIGURE 16: NEAR BOY'S HOSTEL IN PRATAPGUNJ AREA (G)

FIGURE 17: NEAR BRIDGE IN MSU CAMPUS (H)

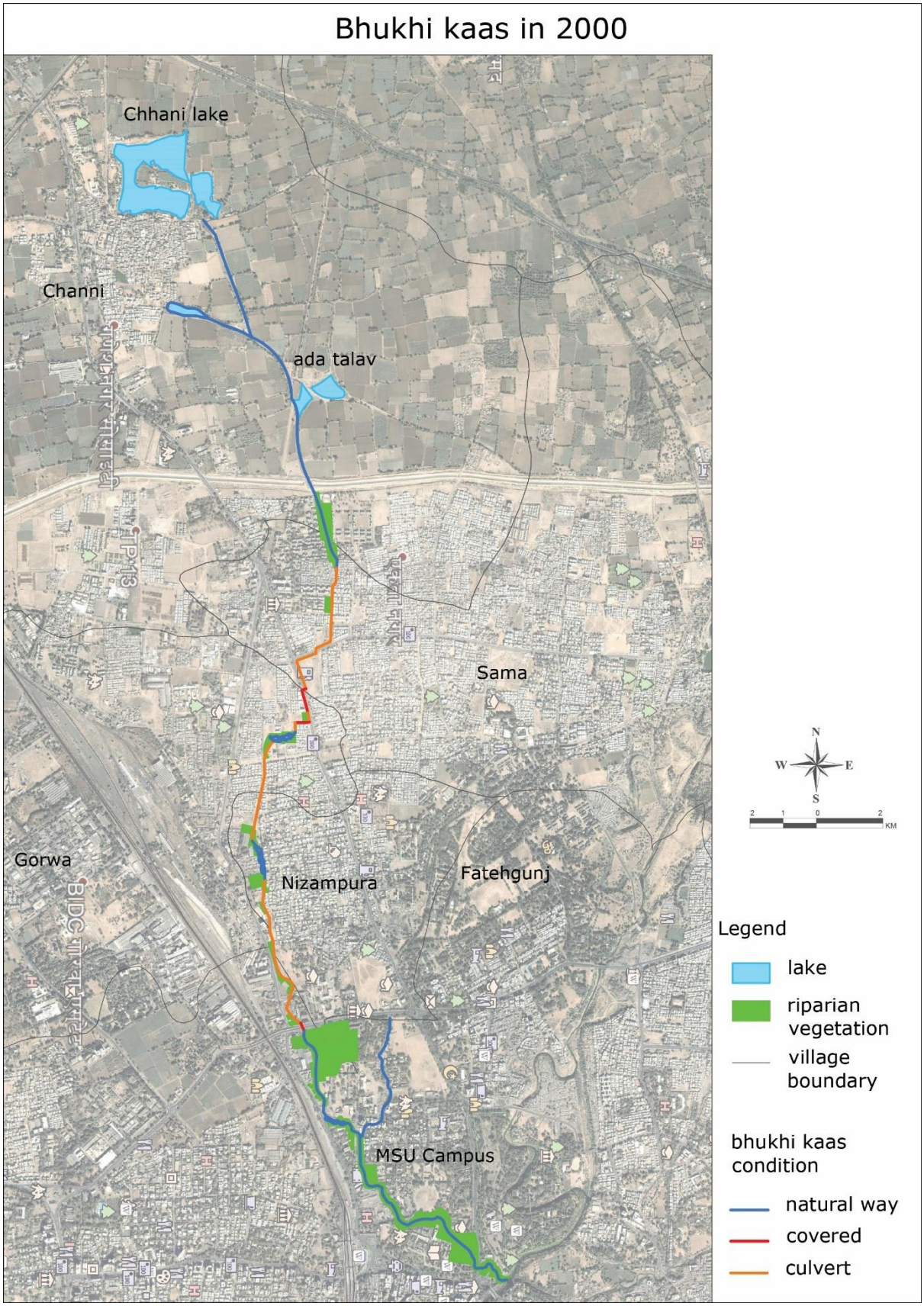


FIGURE 18: BHUKHI KAAS CONDITION IN 2000

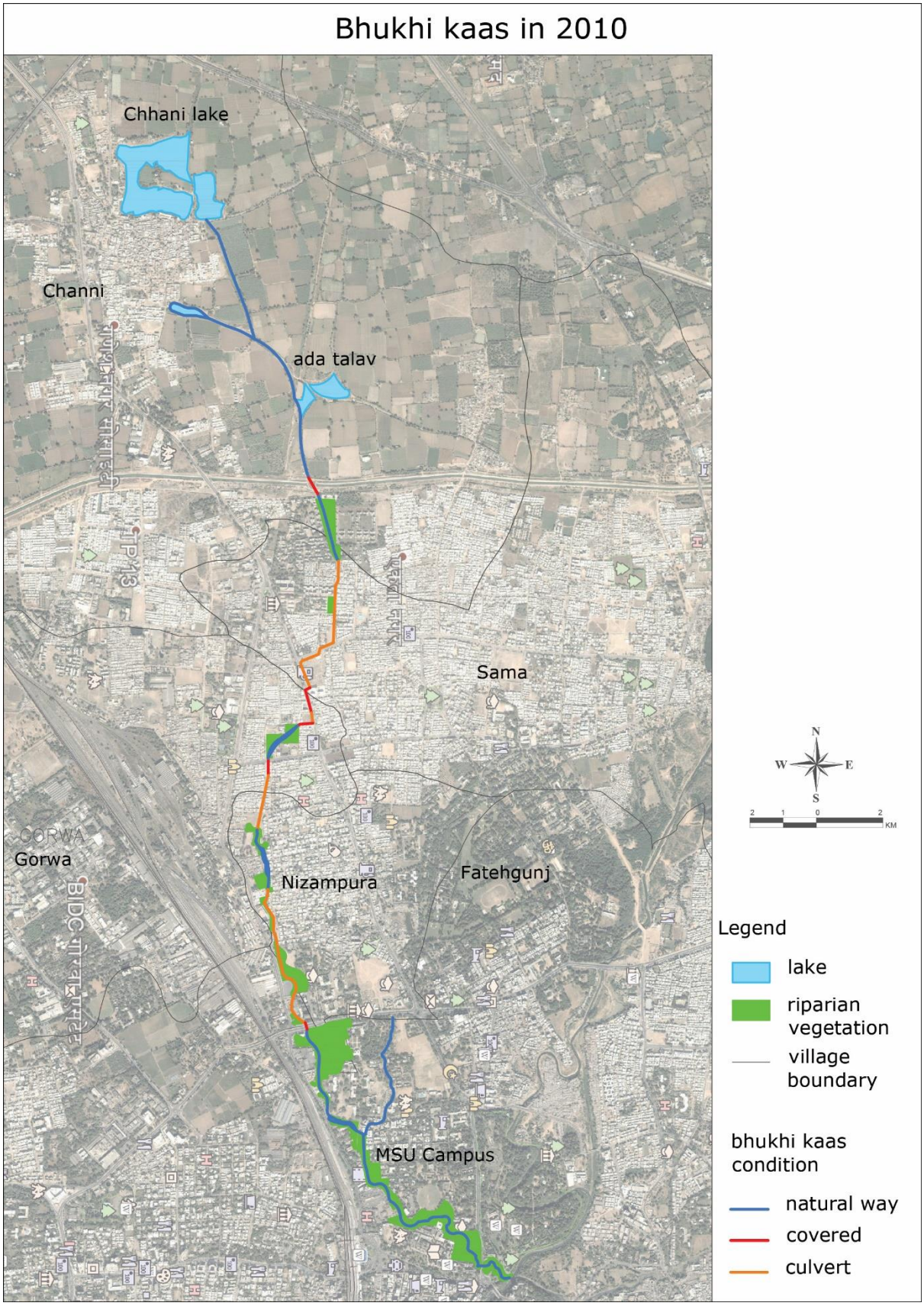


FIGURE 19: BHUKHI KAAS CONDITION IN 2010

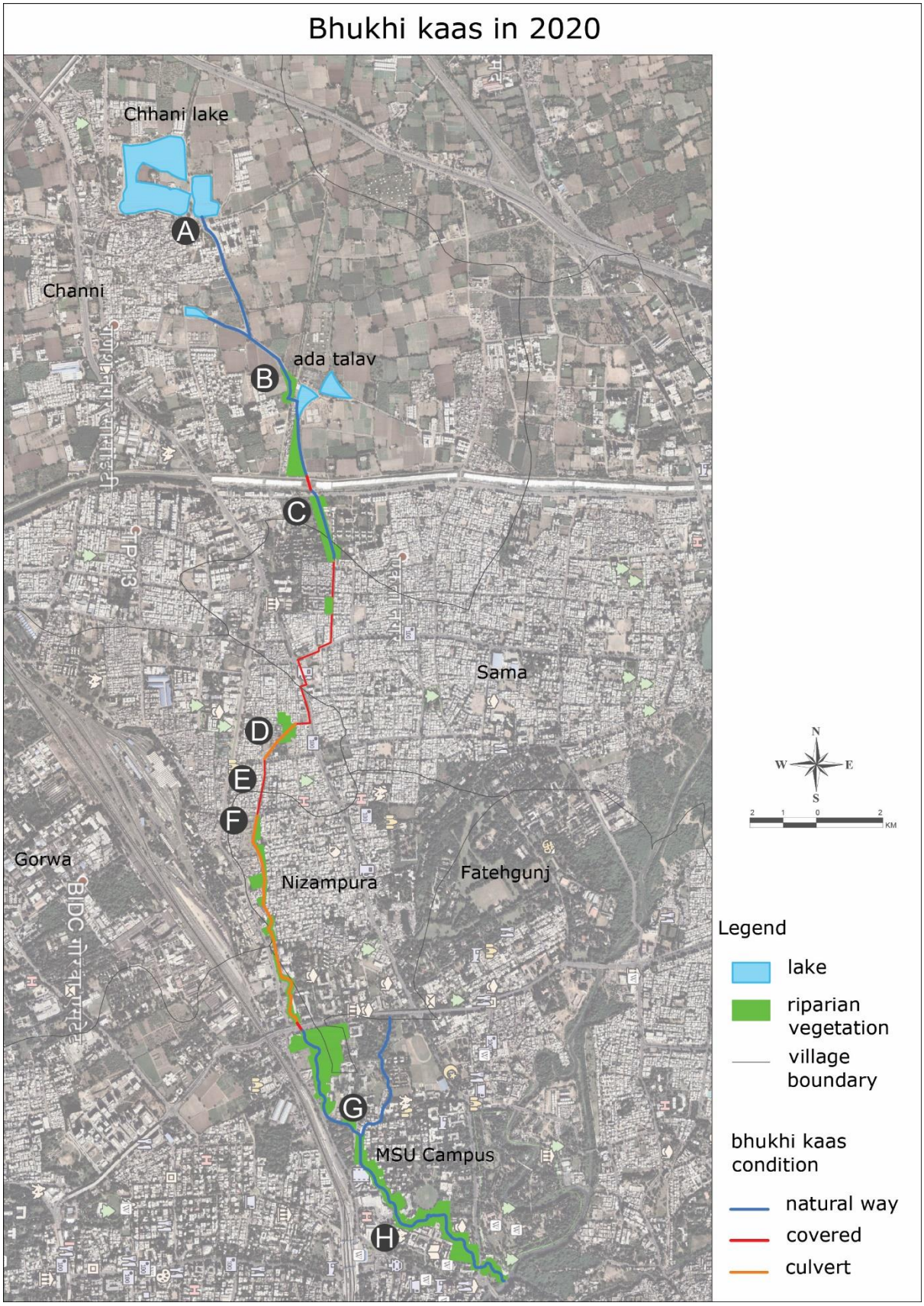


FIGURE 20: BHUKHI KAAS CONDITION IN 2020

4.3.2 Qualitative analysis through expert interviews.

I conducted expert interview for the evaluation of health of the Bhukhi kaas. The following table shows the experts panel who have been aware of this topic. And they have also worked on the concerned topic in their respective fields.

TABLE 5: INTERVIEWED EXPERT'S DETAILS

Sr. No.	**Name**	**Expertise**	**Qualification**	**No. of Respondent**	**Occupation**
1	Professional	Botany	Ph.D.	2	Professional, Researcher
2	Assistant professor	Botany	Ph.D.	3	Academician, Researcher
3	Professor	Ecologist	Ph.D.	1	Academician, Researcher
4	Assistant professor	Environmental Science	Ph.D.	3	Academician, Researcher
5	Assistant professor	Geography	Ph.D.	1	Academician, Researcher
6	Professional	Geography, Planning	Post Graduates	2	Academician, Professional
7	Assistant professor	Zoology	Ph.D.	2	Academician, Professional

Major factors leading to the natural ecology degradation of Bhukhi kaas is deforestation and soil erosion because of flood, otherwise there is no soil erosion in monsoon. Below fig.21 shows that, 64% respondents were no idea about it. And 22% and 14% respondents considered soil erosion and deforestation as factors which lead to degradation of kaas respectively.

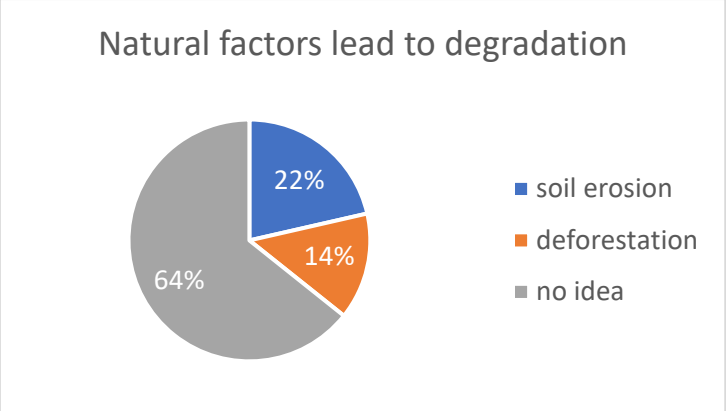


FIGURE 21: THE NATURAL FACTORS THAT LEAD TO DEGRADATION

Human actions are more responsible than the natural factor in degradation of kaas. Influence of Anthropogenic activities are major factor that leading to the degradation of Bhukhi kaas.

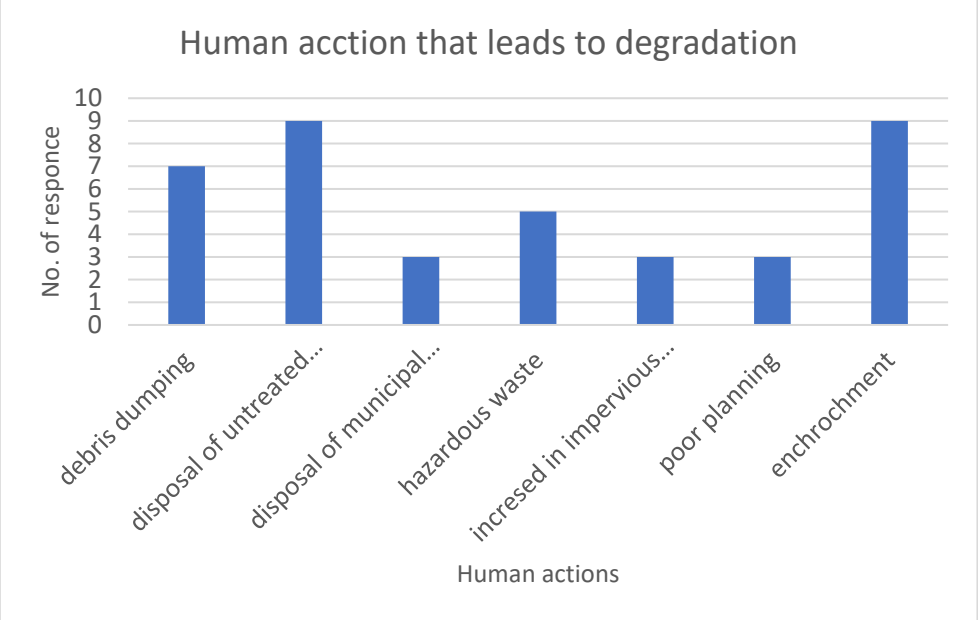


FIGURE 22: HUMAN ACTIONS THAT LEADS TO DEGRADATION

From the fig. 22, we can see that Firstly, all kinds waste dumping into the stream and on the banks including construction debris dumping shown in fig. 9-16, disposal of untreated sewage from the sewage treatment plant near Chhani and as shown in fig. 23, disposal of liquid and solid from the locals, disposal of toxic-hazardous waste from laboratory near lower bridge into MSU campus by the MSU and nearby small factories and

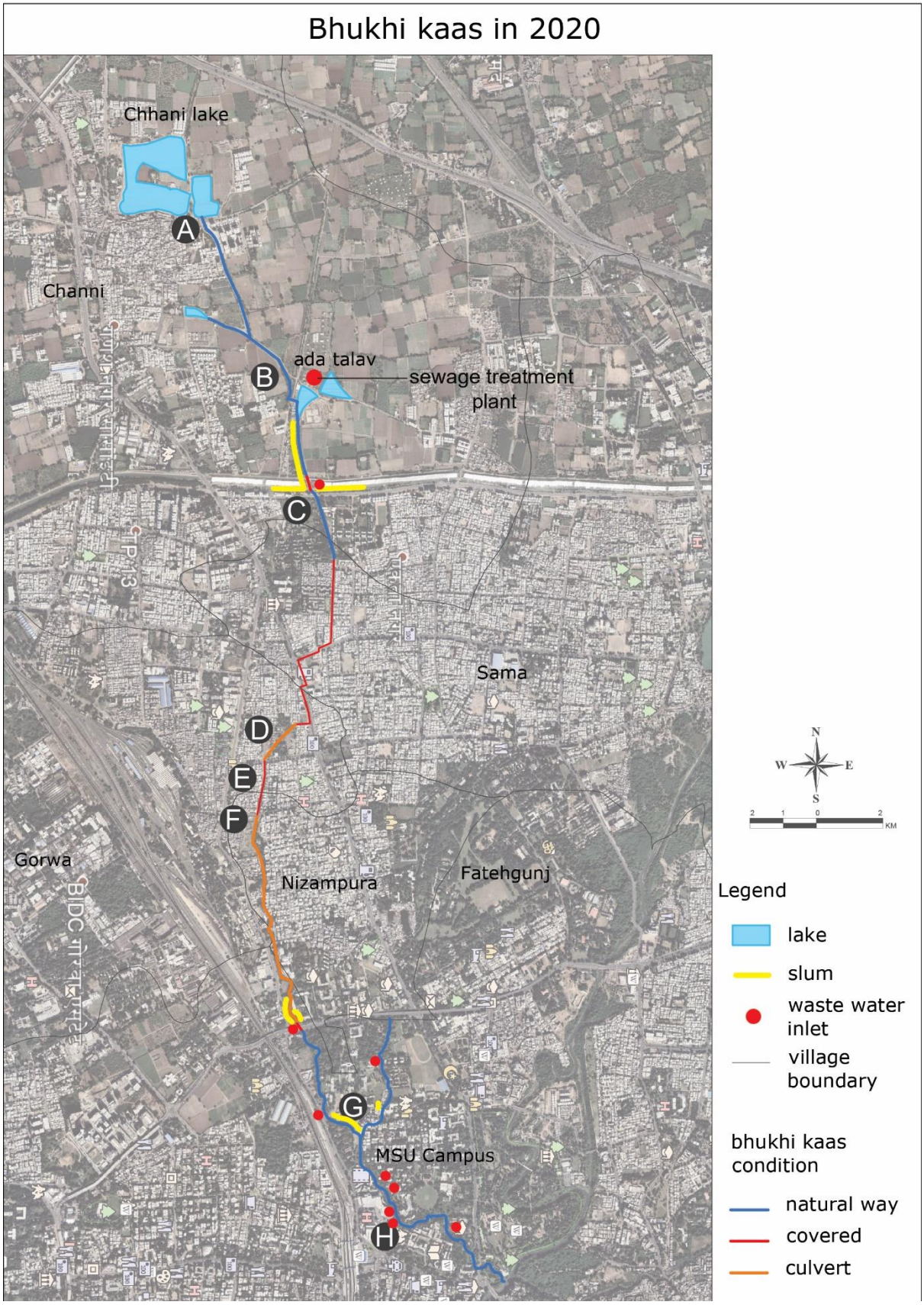


FIGURE 23: MAP SHOWS SLUM AND INLET LOCATION

commercial activities like poultry farm, vehicle service garages, sawmill at Pratapgunj area. When wastes disposal are dumped on the banks of kaas, the width of kaas is reduced and it became narrower. The Local Authority and politicians have contributed in allowing illegal liquid and solid waste into the Bhukhi kaas. The second factor is the filling in ravines to grab more land as population is increased in surrounding area to use more land for development of ecologically illegal encroachments on the banks of stream. At last, civic authority plays important role in planning of landuse along water bodies. In Vadodara, Vadodara Municipal Corporation (VMC) is established in 1950 to regulate the growth of the city. But it failed in planning Town Planning Schemes and Development plan when the Bhukhi kaas is concerned because roads were proposed on Bhukhi kaas (input from experts of botany). The fourth factor is increase in impervious surfaces as the stream passes from urban area.

Once it started deteriorating then whenever heavy rain occurred, it resulted into floods in surrounding area that lead to people constantly complain about Bhukhi kaas and finally it leads to its deteriorated stage that we can see now.

In last 40 years, Riparian vegetation have been changed drastically along the kaas. Before that, Pratapgunj area along the kaas was full of wilderness. The Bhukhi kaas was the richest part in the and Vegetation was much denser city (input from expert of Zoology). Now vegetation is decreased as compared to earlier. Vegetation pattern and species composition in 1993-94 was quite different than now. There was more variety of flora and fauna earlier. More soil and water interaction and soil exposure were there (input from expert of Zoology). As per fig. 24, 62% respondent experience that riparian vegetation was changed to great extent. 23% and 15% respondents said that riparian vegetation was changed to much extent and to less extent respectively.

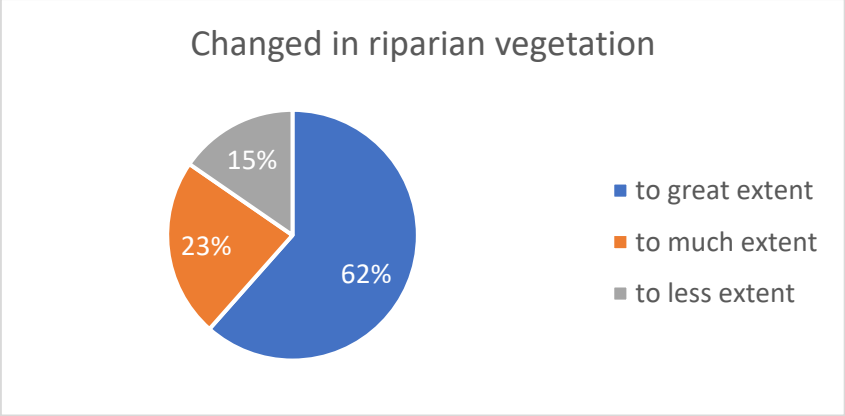


FIGURE 24: CHANGED IN RIPARIAN VEGETATION

From the below fig.25, we can see that there are 8 respondents are experience that riparian vegetation is affected by disposal of sewage discharge. 7 and 6 respondents experience that riparian vegetation is affected by debris dumping and encroachments respectively.

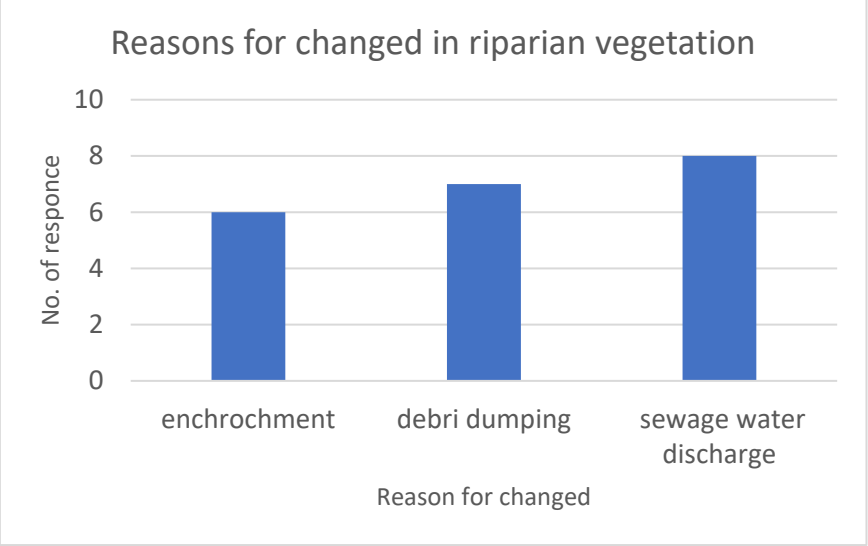


FIGURE 25: REASONS FOR CHANGED IN RIPARIAN VEGETATION

Riparian Vegetation is changed in Bhukhi stretch and MSU campus area over the years. As the water quality is changed, the plant species has also changed. Earlier water was low in nutrient. Nowadays, water carries high nutrient urban sewage. "*BOD (Biological Oxygen Demand), Nitrogen and Phosphorus are high in water at present"* input from Environment Science Department. The system is degraded with higher pollution levels. That is why the plants which grow aggressively are left. The species which got

acclimatised with degraded system remained in the stretch. So, the species which occurred previously are not seen now (input from the expert of Botany).

It is also changed because of encroachments on banks. Also, MSU started throwing construction debris around that resulted in alteration of riparian vegetation. Because of that the Bhukhi kaas became narrower and a lot of vegetation is cleared (input from the expert of Botany).

As a major influence of pre-monsoon activity to clean the kaas, native plants are removed. Only the herbaceous vegetation including grasses, rushes, ferns, forbs is left on the banks. So, the invasive plants which come to the kaas with monsoon water are grown easily. The native species have narrow ranges of ecological aptitude but the invasive species have broad range of ecological aptitude, so the native species are reduced and invasive species are increased due to increase of pollutants in the water (input from the expert of Botany).

From the below fig.26, we can see that 54% experts experienced change in diversity. And 23% and 23% experts experienced not much changed and no idea about diversity.

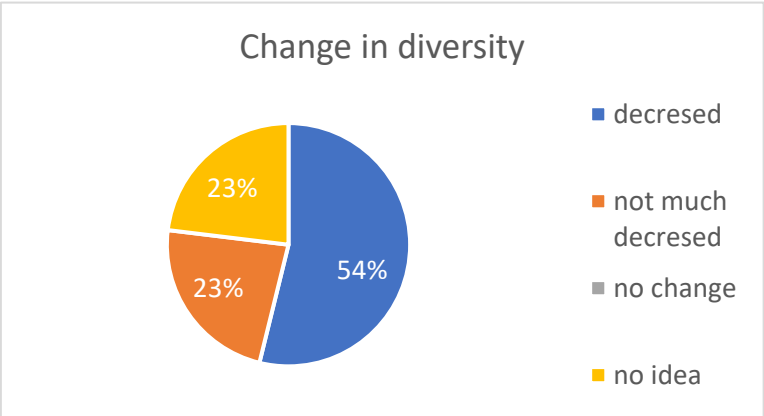


FIGURE 26: PIE CHART SHOWS THE CHANGE IN DIVERSITY

The flora is also changed. It's diversity in the area around the kaas is decreased. It is almost nil in one way (input from the expert of Botany). 50-60% species are completely lost (input from the expert of Botany).

Several herbs are homogeneous herds at present. 40 years ago, there were heterogeneous. Floral diversity is also affected by the dumping of waste. In another way, newer variety of flora may rejuvenate the kaas (input from the expert of Botany).

Whereas water quality is better near Adhyapak Kutir area which is behind the Rosary school. It is less disturbed area and lot of vegetation is there as sewage discharge is very less. Because of vegetation we can find some aquatic species like fishes and wilderness in that area.

As input from expert of Botany as mention below:

An example of floral diversity: *"A grass called Parthenium was introduced earlier, then it has been changed to Prosopis (Gando baval). Authorities have decided to introduce Conocarpus which will eventually replace Prosopis in next 10 years to make our city look greener. The diversity of fauna specially the birds and other animals is affected because the Conocarpus seed, flowers, fruits are not eatable by native fauna. currently, few plants are flowering but in future numbers of flowering plants are going increase. Consequently, Baroda is going to face another problem of respiratory disorders. Plant species like cassia tora, cassia orituleta, cassia arithserpolia were naturally changed to cassia alatha, hence new species was introduced (Head of the department, Botany)." And "change is law of nature."*

Below fig.27, 54% experts experience that native species are at higher risk. 23% and 15% people experience that they are in not much and very less risk. 15% experts have no idea about it.

Native species are at risk because pollutants water is high in kaas. Native species need more specific condition to grow. Native species grows in low nutrient water at earlier but nowadays Bhukhi kaas has carried high nutrient water in which invasive/exotic species grow easily so the invasive species are increased and invasive/exotive species are replaced many native species. Native species are always at risk like Presence of kanaj,

bushes, Ficus are declined now. Because they have to fight out with invasive species.

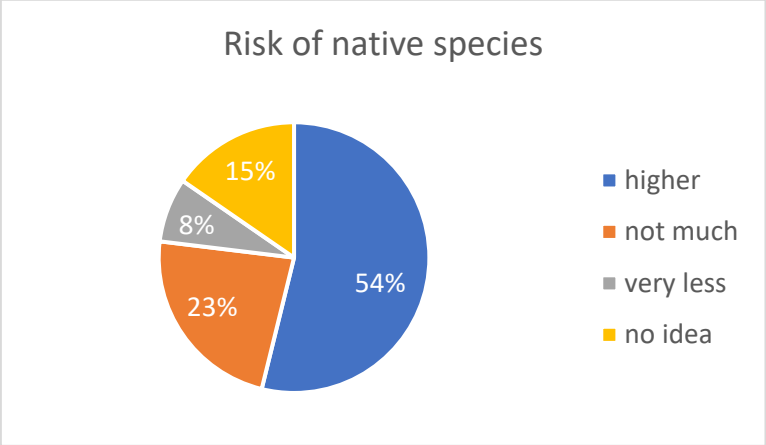


FIGURE 27: THE RISK OF NATIVE SPECIES

Once upon a time it has already dominated by the Pongamia, Ficus, other and now specially in university itself number of Ficus, Pongamia is reduced. Antigone is also gone down. Other are already gone down specially in the campus area. There is used to be lots of trees of Pithecellobium (Goras ambli), Salvadora persica (meswak), Millettia pinnata (Karanj), Which are native trees near the stream earlier. Now, the numbers of trees are reduced. Certain native grass species which can absorb water and prevent soil erosion and bank erosion. due to Prosopis the grass species are disappeared (input from the expert of Botany).

FIGURE 28: PONGAMIA PINNATA (KARANJ)

Source: Biofuel park, University of Agricultural Science, Bangalore.

FIGURE 29: PITHECELLOBIUM (GORAS AMBLI)

Source: Author

As in the fig.30, we can see that 46% respondents felt that invasive species are present over greater extent in riparian vegetation while 16% and 23% respondents felt that presence of invasive species are in too much extent and too less extent respectively. Whereas, 15% respondents had no information about it.

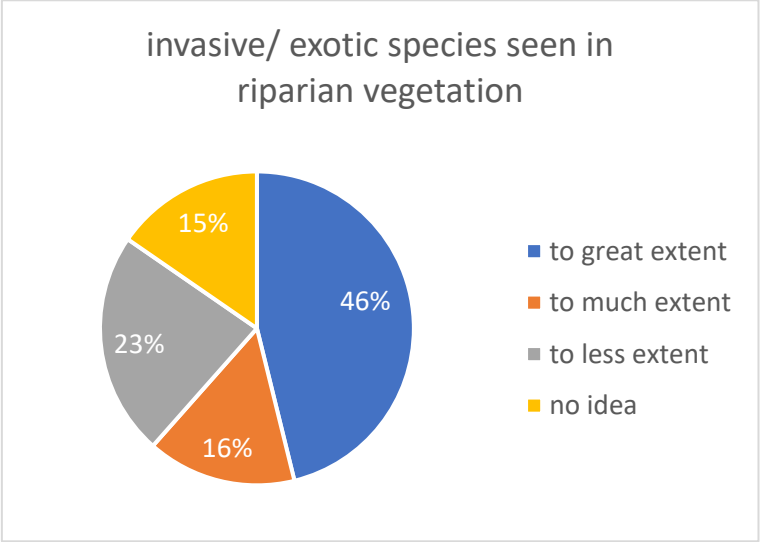


FIGURE 30 : INVASIVE/EXOTIC SPECIES SEEN IN RIPARIAN VEGETATION

Many invasive or Exotic species like Alangium Salvifolium (Ankol), Prosopis juliflora (Gando baval), Castor plant, Ice cream creeper, Parthenium (carrot grass) are on the banks of the stream. Castor plant along the Bhukhi kaas in MSU campus is extensive but its root doesn't have soil holding capacity.

Gando baval are not huge trees they form small thickets. They are responsible for blockage because they have low height and doesn't prevent the free flow of water. It can prevent soil erosion but at time of flood, high trees let the flood water flow freely but the small bushes tend to break the water, as a result flow of water slows down. Travel time of water coming from Bhukhi to the Vishwamitri river is reduced so that water starts flowing on the roads because of the kaas is blocked with Gando baval bushes (input from the expert of Botany). It also helps to clean stream flood water as plastic bags tend to hang in baval bushes. It is a highly aggressive tree. It thrives in difficult physical conditions, Due to its ability to strike root and flourish in highly degraded soil and water and affecting native green cover. This species is growing at the cost of other indigenous trees. For example, the researchers of 'The annual expansion rate of mesquite cover indicates a significant threat to indigenous biodiversity' study found that ''Gando baval'' has replaced neem trees". It is claimed to have destroyed the Banni grassland in Kutch.

Ice cream creeper is seasonal creeper growing between May to November. It is drastically affecting indigenous species. It has been growing in waterways and riparian area. It spreads rapidly in natural forest, climbing into the canopy of mature trees and forming dense monoculture stands. In addition, it has high capacity for natural dispersal. It is an aggressive invasive vine with the potential to collapse native plant communities by displacing native species, changing community structure and altering ecological functions.

Parthenium (carrot grass) is a weed. It is known to cause many health hazards which have now reached epidemic. Its invasive capacity and allelopathic properties have rendered it with the potential to disrupt the natural ecosystems. Very sparse or sometimes no other vegetation can be seen in carrot grass-dominated areas. For example, it has been reported to be causing a total habitat change in native Australian grasslands, open

woodlands, river banks and flood plains (Lakshmi and Srinivas 2007). These weeds rapidly invade new surroundings often replace the indigenous species and pose a serious threat to biodiversity in India. It affects the production of crops, human and animal health, and biodiversity.

Exotic species are cultivated species present in the whole stretch; they need less conditions to grow. Few species for example Mucuna and Ficus hispida species were not there earlier, they are not only increased in individuals but almost out grown others.

In 1963-65 for the first time Invasive/Exotic species like Parthenium (carrot grass) and Prosopis (Gando baval) entered in India at the sea shore of Kandla. In 35-45 years, they encroached everywhere. In old days, all the banks had native species but nowadays we only see Gando baval. both are exotic in the nature and have been introduced by the govt. of India and forest department. Below fig. shown the invasive or exotic species present in riparian vegetation.

FIGURE 31: CASTOR PLANT

Source: www.agrifarming.in/castor-cultivation-information-guide

FIGURE 32: ICE CREAM CREEPER

Source: www.indiaplants.com/plantdetails.php?x=iJXqi09Mlvw

FIGURE 33: PROSOPIS (GANDO BAVAL)

Source: https://en.wikipedia.org/wiki/Prosopis

FIGURE 34: PARTHENIUM (CARROT GRASS)

Source: https://en.wikipedia.org/wiki/Parthenium

Formerly, Bhukhi was also having fishes and other aquatic animals. Currently, aquatic ecosystem is there but it has extensively degraded. So, we don't find planktons, fish and vegetation because untreated sewage waste is disposed to the stream. We can only find species in terrestrial and riparian area now. Bhukhi is connected to Vishwamitri ecosystem. From the ravines of Vishwamitri animals like porcupines, crocodiles migrate to Bhukhi and they move back. Terrestrial ecosystem is already on the worse job of alteration because plants which used to be there in last 35-40 years are not there now. And some part of Bhukhi is already encroached by the societies, so the above concerned of ecosystem is forgotten.

From the below fig. 35, 46% experts observed that species has been changed to greater extent while 31% experts observed that species has

been changed too much extent. Whereas, 23% experts have no information about it.

The fauna species indicate that this is healthy ecosystem. A variety of birds like the common Black drongo, Flan tail, Fly catcher are nesting here. Iora, Tailorbird, Oriole, several varieties of passerine birds like house sparrow used to nest here historically but the later on the house sparrow disappeared from Sayajigunj area. Pithecellobium (Goras ambli) trees were near the Geology Department in the MSU campus. It is one of favourite food of rosy starling which are migratory birds. They used to come to campus in thousands and feed, but their numbers are reduced. Numbers of peacocks are reduced. There are species like Vultures which are not found now. But there are species like Gray hornbills which are breeding population in Baroda after 2010 (input from the expert of Zoology).

Slowly and gradually as vegetation cleared and dumping increased, a lot of animals decreased in numbers. Common Indian civets, Jackals, Hyenas were also found here earlier but have disappeared now. You can occasionally find Porcupine but numbers of species are decreased considerably. Some of the snake species like green keel back, Checkered keelback, vipers are not seen at all in last 20 years. Indian cobra and rat snack are reduced in numbers. Also, the decrease in number of species is result of increase in roads and population. Cobra breeds here. Any kaas or ravine is used by crocodiles as a temporary refuge. So main population of crocodiles are in Vishwamitri river. Bhukhi kaas is used by crocodile as temporary refuge, if there is fight among crocodiles for territory in the Vishwamitri river. They migrate in the Bhukhi and stay for some time till the breeding season (summer) is over (input from the expert of Zoology).

As shown in below fig.36, 69% experts were aware about catchment connectivity of Bhukhi kaas. 31% experts were not aware about it.

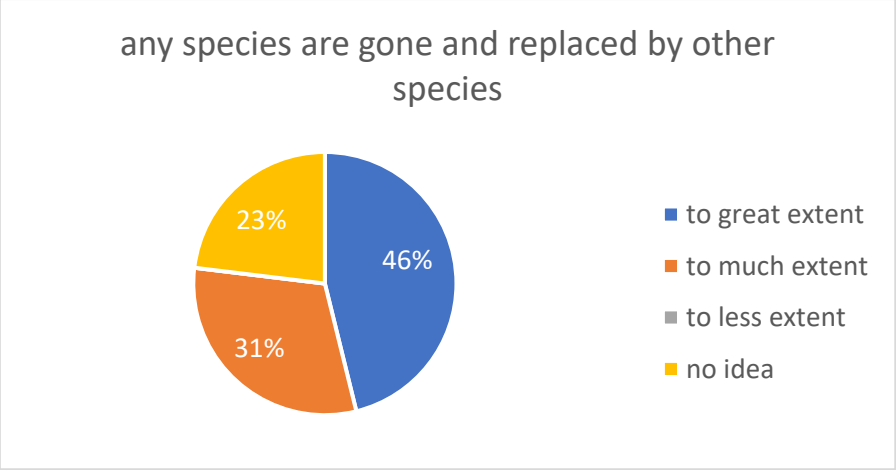


FIGURE 35: SPECIES GONE AND REPLACE BY NEW SPECIES

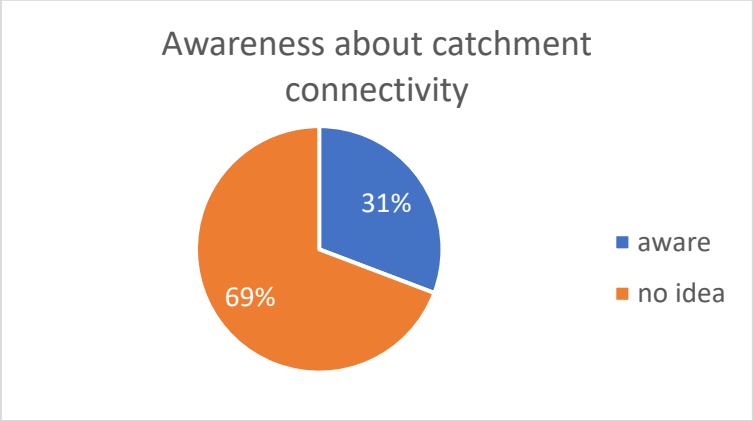


FIGURE 36: AWARENESS AMONG THE EXPERTS ABOUT CATCHMENT CONNECTIVITY

Bhukhi originates from the Chhani lake. And watershed of Chhani lake is very large in area as shown in fig.37. It covers Savli, Asoj, Sisva, Dumad villages. It is connected with Dumad and Sisva lake. But the connectivity is lost because no culvert provision is there in the Express Way, as a result inflow of the water in the lake reduces (input from the expert of Botany). In urban areas Bhukhi kaas is generally getting water from the concrete structures as change in landuse pattern and concretization of its banks in the Vadodara city. Watershed area is also reduced due to change in landuse pattern (input from the expert of Environment Science).

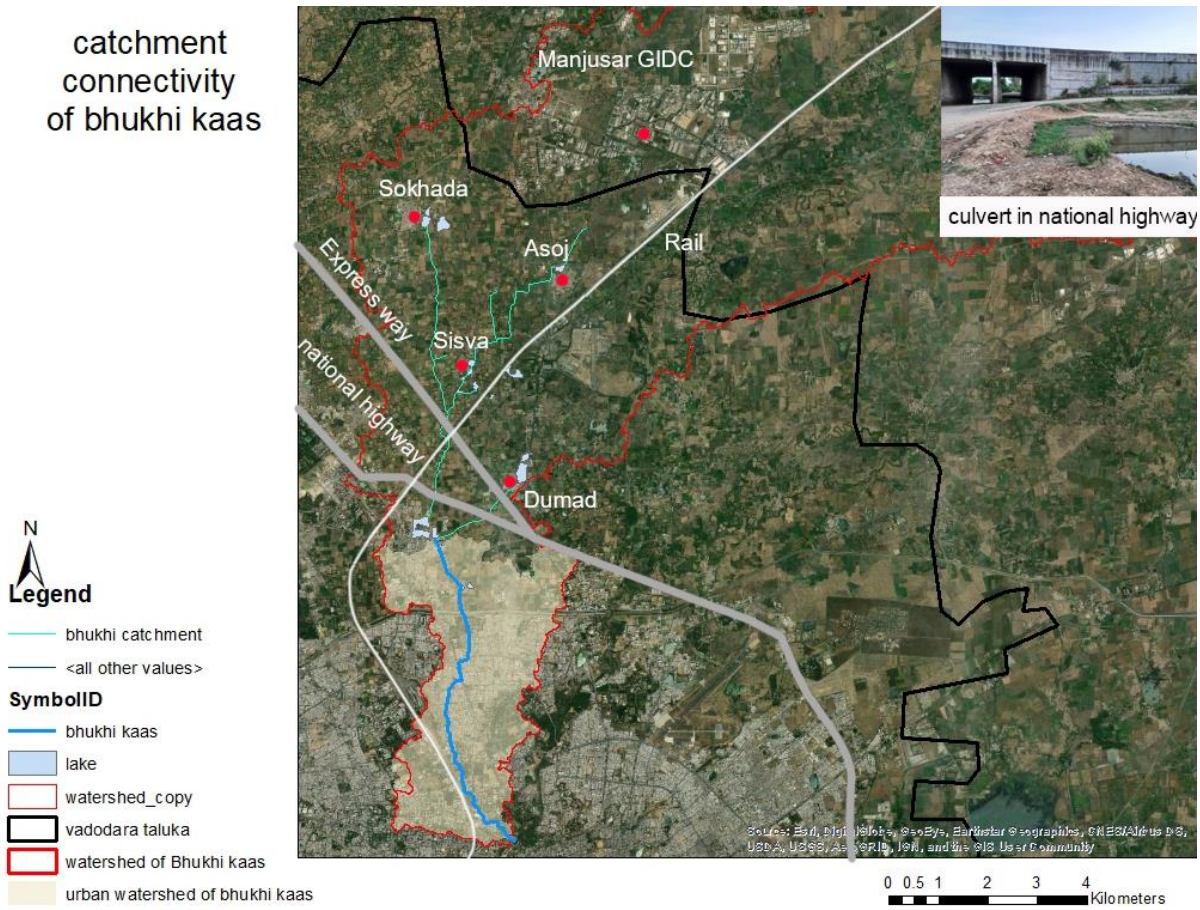


FIGURE 37: CATCHMENT CONNECTIVITY MAP OF BHUKHI KAAS

Among a group of surveyed experts, 62% have no awareness about impact of loss of connectivity in fig.38. Only 38% experts are aware about it. In which 23% and 15% experts stated that there is flood and waterlogging respectively in upper catchment area due to loss of catchment connectivity. No natural recharge systems are left in kaas. So that is adding pressure to Bhukhi kaas flood waters. Loss of catchment connectivity in upper watershed areas is there due to water logging during heavy monsoon.

As shown in below fig.39, 85% experts stated that MSU is concerned about Bhukhi kaas present in MSU campus from last one or two years. Earlier they dumped all the university waste on the banks of Bhukhi kaas. 15% experts stated that MSU is not concerned. Now, disposal of waste from the university is strictly restricted since last year on the banks of

kaas. In fact, they also started to remove all the existing waste from the banks. There is complete lack of policy for Bhukhi kaas but it will be developed in future.

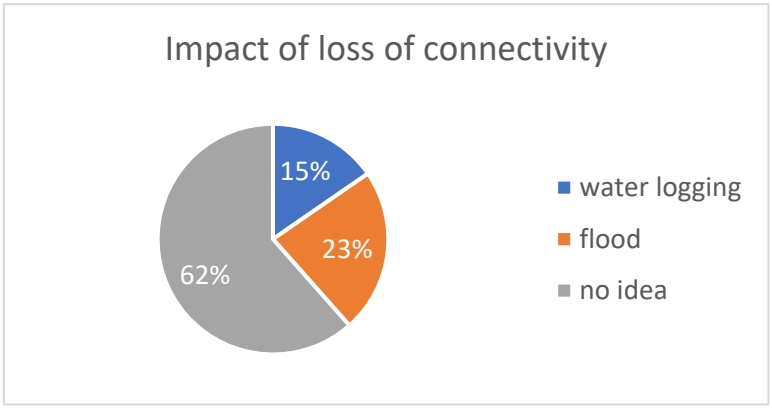


FIGURE 38: THE IMPACT OF LOSS OF CONNECTIVITY

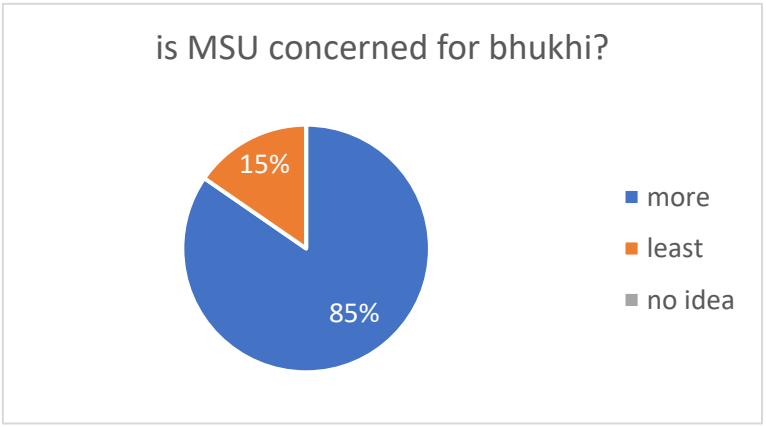


FIGURE 39: MSU CONCERNED FOR BHUKHI KAAS

In below fig.40, 79% experts felt that Local Authority is not concerned about the Bhukhi kaas and 7% experts felt Local Authority is least concerned about the natural drainage and its importance. Only 14% experts felt that Local Authority is concerned about kaas. Local Authority removes vegetation during pre-monsoon activities to reduce flood effect only. Local Authority has no policy for Bhukhi kaas. Experts said that Bhukhi kaas is being Channelized and became narrower to grab land for development in the city.

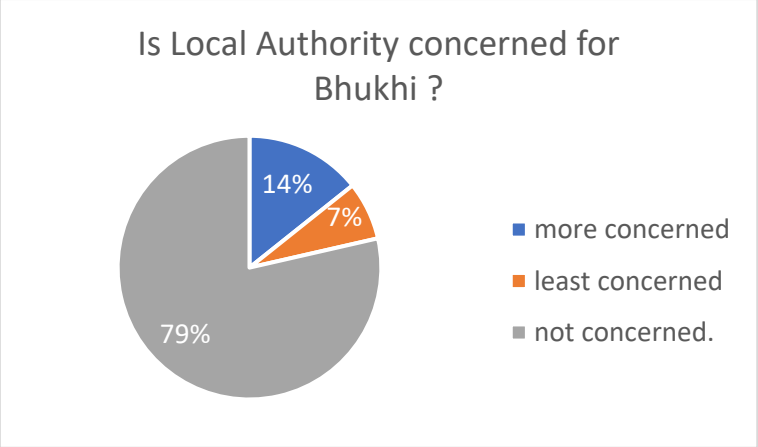


FIGURE 40: LOCAL AUTHORITY CONCERNED FOR BHUKHI KAAS

4.3.2 Survey of Residence in proximity of Bhukhi

Primary survey was conducted to study resident's knowledge awareness and perception about Bhukhi kaas. The form was circulated among the friends and relatives who resides with in 500m from Bhukhi. The questionnaire of the survey is attached in appendix iii at the end of the report.

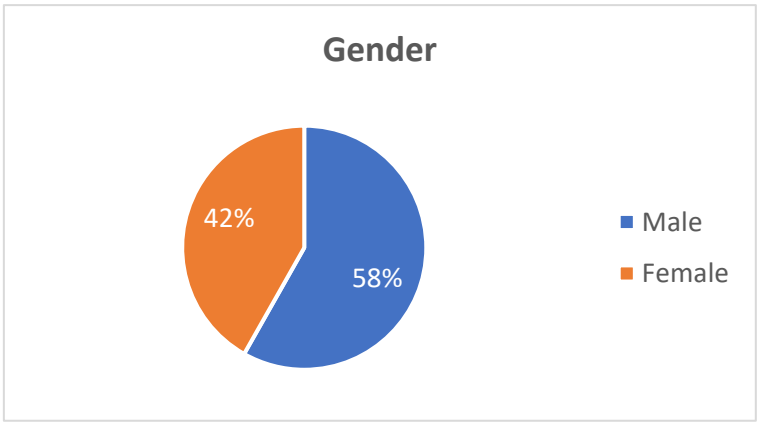


FIGURE 41: SURVEYED GENDER COMPOSITION

Out of total people surveyed, there were 58% male participants and 42% female participants as shown in fig.41.

In the survey, four different area are studied. The area composition was as shown in fig.42. Highest number of respondents were from Chhani, it has 38% of the total respondents. And rest of the participants were from

the other area - 20% from Sama, 24% from Nizampura and 18% from Pratapgunj.

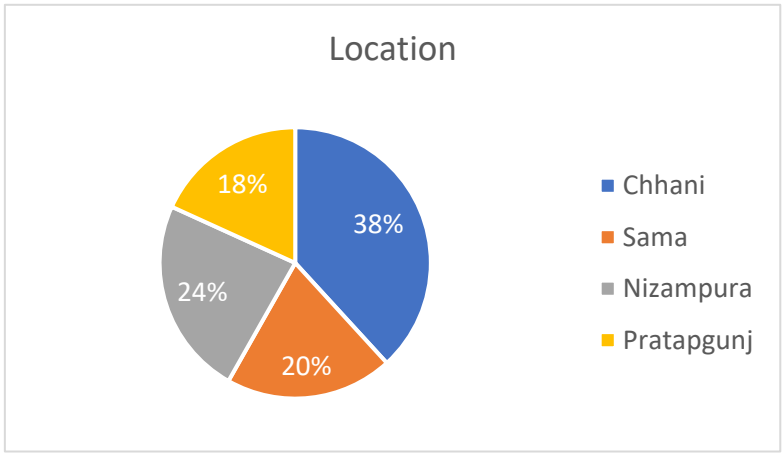


FIGURE 42: SURVEYED LOCATIONS

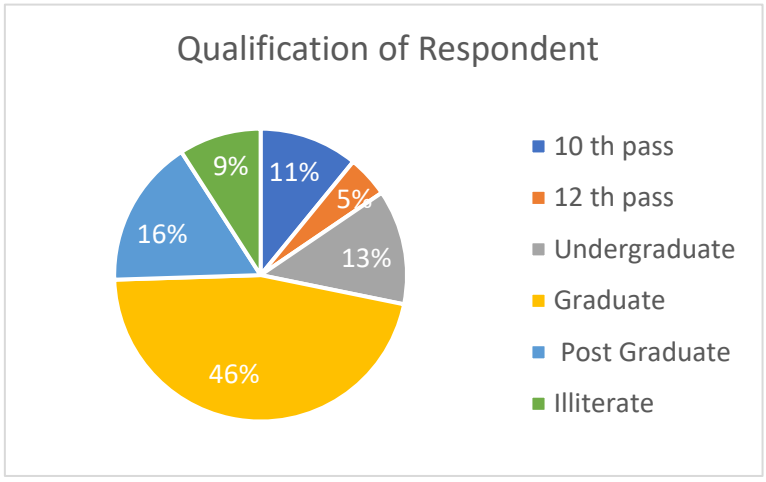


FIGURE 43: QUALIFICATION OF RESPONDENTS

As shown in fig.43, 11%, respondents were having secondary schooling as highest degree of education, 5% respondents were having higher secondary schooling as highest degree of education. 13% respondents were undergraduate, 46% respondents were graduate, 16% respondents were post graduate and 9% respondents were illiterate. Over all 62% respondents are graduates and post graduates still there is no awareness and education about importance of water resources and natural drainage (kaas). 91% people residing near Bhukhi kaas are literate and 9% are illiterate. So, it means that literate people become illiterate by polluting

kaas with disposal of untreated sewage waste water and throwing solid waste like construction debris, glass, plastic waste, thermocol into it.

Out of total, highest number of respondents which consist of 50% are employed in private and Government services, 9% people have their own business whereas homemakers, labor, students are 20%, 11%, 10% respectively as shown in fig. 44.

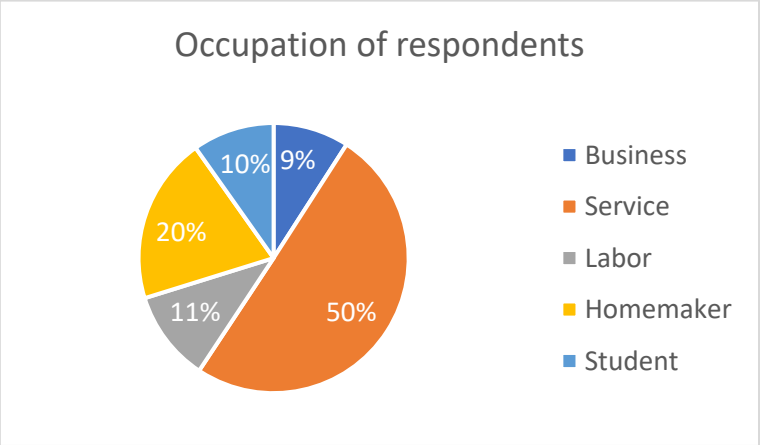


FIGURE 44: OCCUPATION OF RESPONDENTS

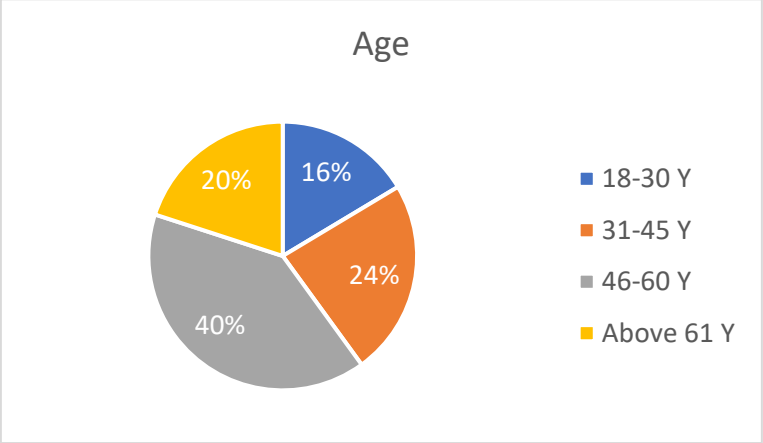


FIGURE 45: AGE COMPOSITION OF RESPONDENTS

The above fig. 45 shows the age composition of the people surveyed. Out of total, highest number of respondents which consist of 40% belong to 46-60 years age group, 24% belong to 31-45 years age group, 20% belong to above 60 years age group, 16% belong to 18-30 years age

group. Almost 60% people may have seen changes in Bhukhi kaas which led to degradation in last 40 years. They have shared their experiences with me about the earlier condition which may help to revive Bhukhi in its natural way.

As shown in fig.46, 50% respondents are residing in double-storey houses, 24%, 16% and 10% respondents are residing in single-storey, multi-storey and mud houses respectively. 10% of the participants have mud houses, there is fair chance that the land acquired by them is encroached from the kaas. This group of people are also utilising wood as fuel affecting riparian vegetation and disposing waste water into it which contributes to Bhukhi kaas degradation. As we observed from the chart that there is less percentage of multi-storey buildings, study area is not densely populated so it will be easier to revive the kaas.

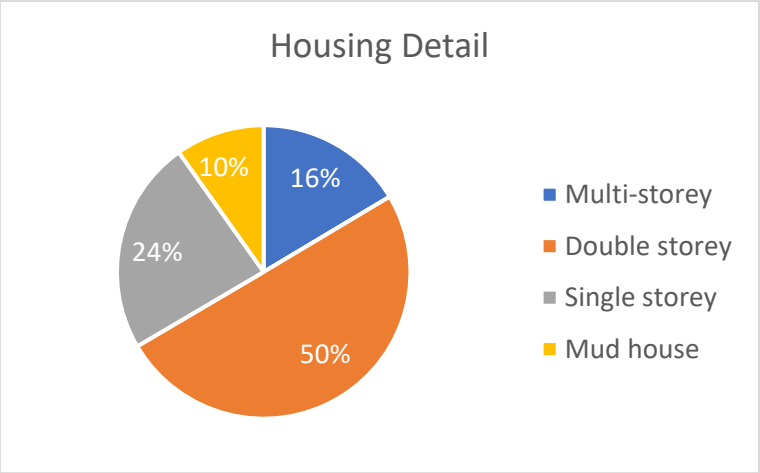


FIGURE 46: HOUSING COMPOSITION

Out of the total people surveyed (fig.47), 18% resides in proximity of 100 meters to Bhukhi kaas, 13%, 14%, 20% and 35% resides in proximity of 101-200, 201-300, 301-400 and 401-500 meters to Bhukhi kaas respectively. People living near to 0-100m of kaas are most affected by pollution and flooding. And also, they are contributing in pollution and affecting the flora and fauna.

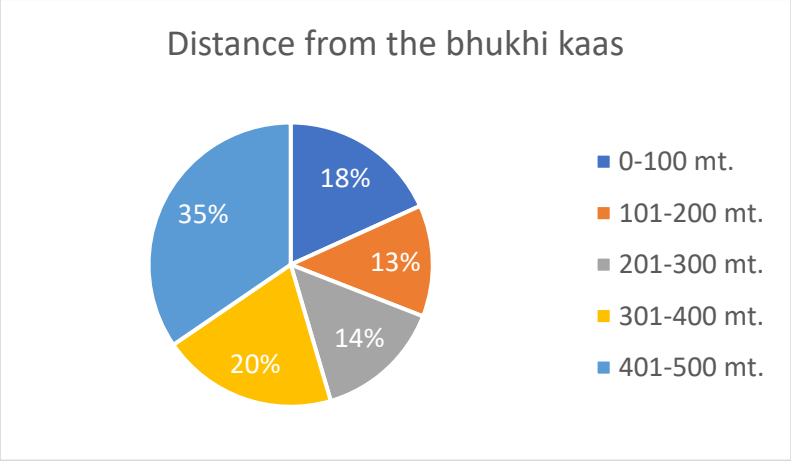


FIGURE 47: SURVEYED PEOPLE PROXIMITY TO KAAS

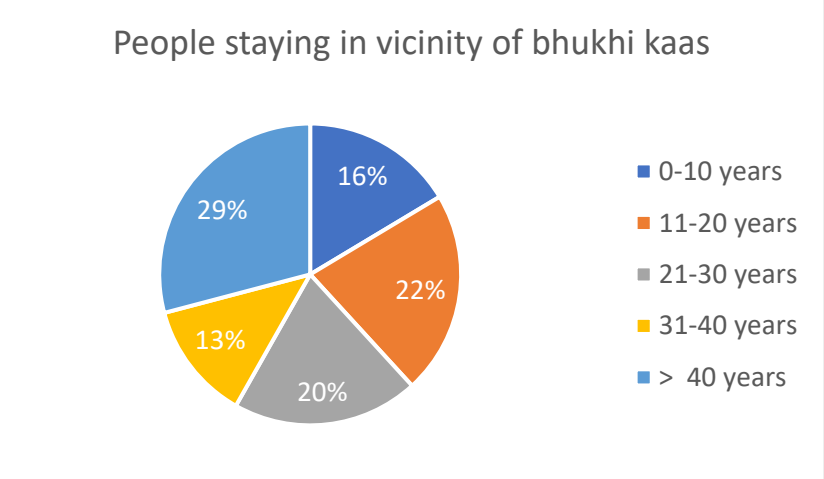


FIGURE 48: PEOPLE STAYING IN VICINITY OF KAAS

As shown in fig.48, 29% respondents are residing near Bhukhi for more than 40 years. 13%, 20%, 22% and 16% respondents are residing in vicinity of Bhukhi kaas for 30-40 years, 21-30 years, 11-20 years and less than 10 years respectively. Almost 60% people may have seen changes in Bhukhi kaas which led to degradation in last 40 years. They have shared their experiences with me about the earlier condition which may help to revive Bhukhi in its natural way.

As shown fig.49, Bhukhi kaas has been changed in last few years. Firstly, majority of people observed that width of kaas is reduced in its whole stretch. Secondly, kaas is covered with concrete slab in Sama, Nizampura

area. Thirdly, it is also channelized in Sama, Nizampura area and near MSU poly technique college in 3x4 meters concrete culverts. Lastly, its depth has also been also reduced.

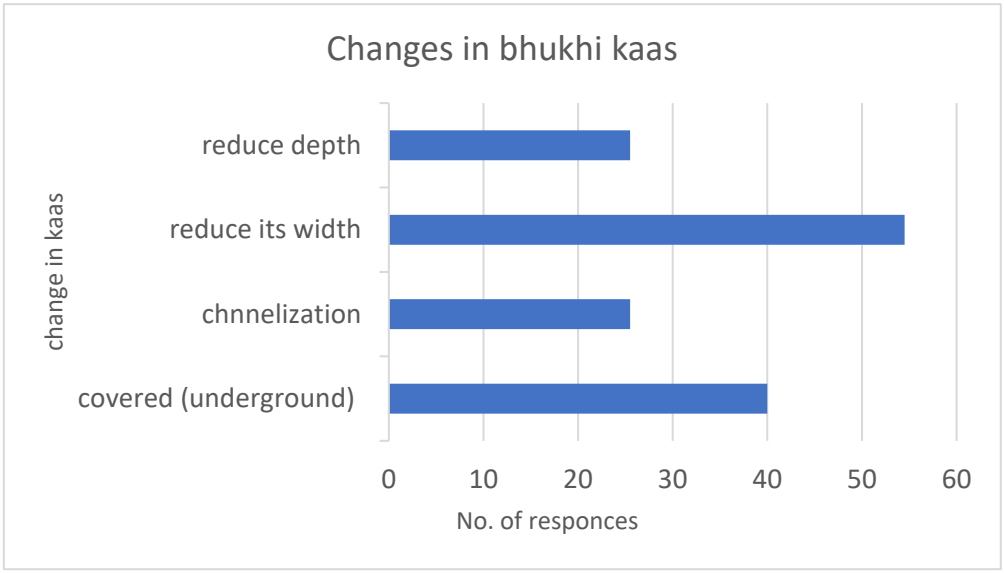


FIGURE 49: CHANGE IN BHUKHI KAAS

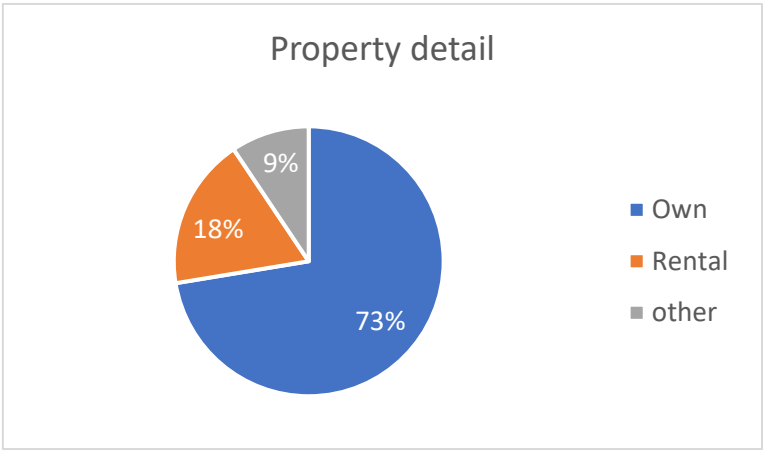


FIGURE 50: PROPERTY DETAIL

Out of total surveyed, 73% respondents are staying in their own houses, 18% are staying in rental houses and 9% are residing in the slum which is illegal as shown in fig.50. There is fair chance that the land acquired by slum is encroached from the kaas. This group of people are also disposing waste water into it because they don't have sewage connection. Highest

number of people residing near the kaas have their own house. So, they will be helpful in creating awareness and revival of it.

As shown in fig.51, Majority of people have been facing flood problem during monsoon. People experience foul smell from the kaas because of disposal of untreated sewage waste. They throw solid waste in the kaas. In nearby areas water logging has been experienced in monsoon due to low lying area. Very few experiences of animal risk during monsoon season have been reported by respondents.

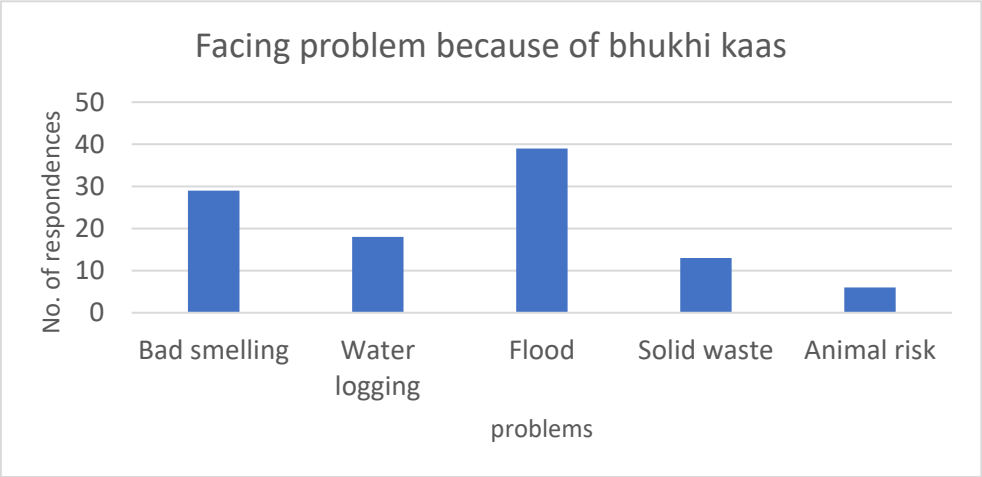


FIGURE 51: FACING PROBLEMS DUE TO KAAS

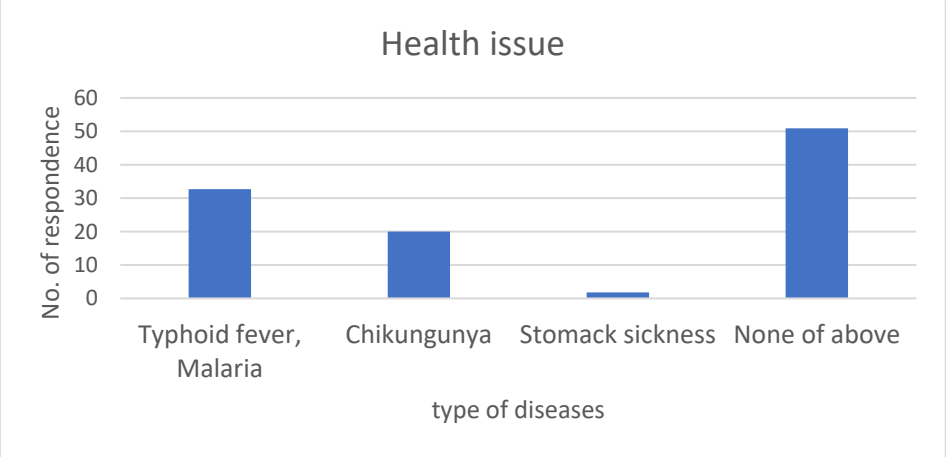


FIGURE 52: HEALTH ISSUES

51% respondents responded that they didn't face any health issues due to Bhukhi kaas. 30% respondents face health issues due to typhoid and malaria, 20% and 2% people face health issues due to chikungunya and stomach sickness respectively as shown in fig.52. Maximum health threat

is caused by mosquitoes. Stagnant water of Bhukhi serves as breeding ground for mosquitoes.

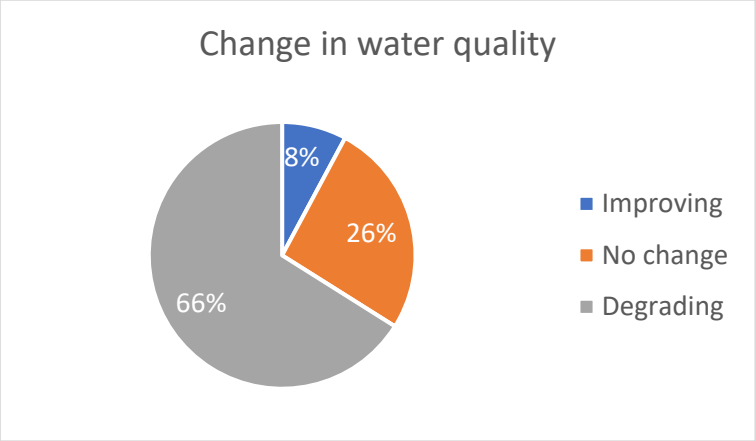


FIGURE 53: CHANGE IN WATER QUALITY

As shown in fig.53, 66% of respondents observed that water quality is degraded in last few years. 26% observed no change in water quality in last few years and 8% observed that water quality is improving. The main reason of degrading water quality is illegal disposal of untreated sewage and waste water in it.

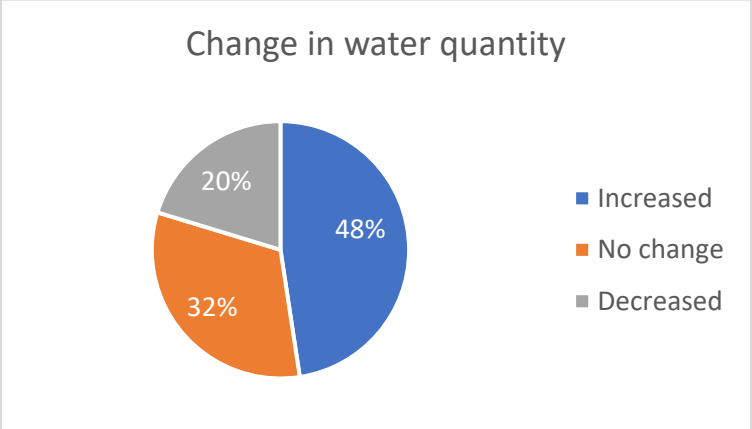


FIGURE 54: CHANGE IN WATER QUANTITY

As shown in fig.54, 48% of respondents observed that Water quantity is increased while 32% respondents observed that no change in that. 20% respondents observed that water quantity is decreased. Overall water

quantity is increased due to disposal of sewage and waste water and increase in impervious surfaces.

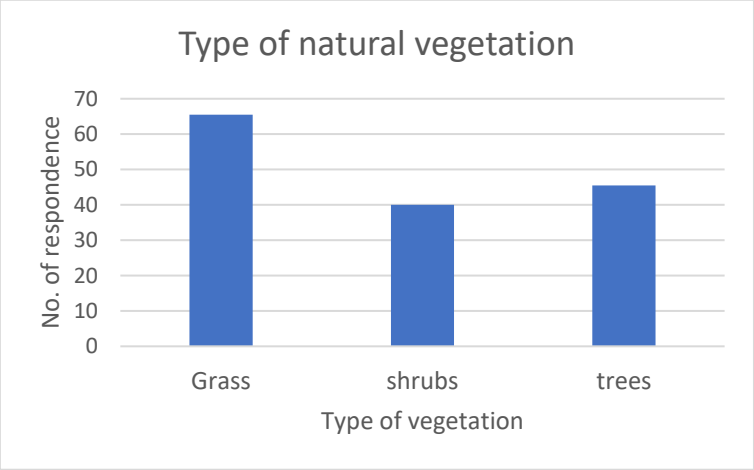


FIGURE 55: TYPES OF NATURAL VEGETATION

Fig.55 shows the types of natural vegetation along the kaas. There are three types of natural vegetation, grass, shrubs and trees. Based on respondents' input, there is 65% grass, 40% shrubs and 45% trees right now. There are lot of factors depending on vegetation like soil holding capacity, water quality and fauna. Trees helps to keep low water temperature by providing shading on the stream. Grass reduces the nutrient load from surface runoff from impervious surface in the stream. Natural vegetation maintains a micro-climatic zone along the riverbanks by providing fresh and clean air. Nowadays, growth of natural vegetation is affected by boundary walls, disposal of waste water and channelization of the stream.

As shown in fig.56, Majority of respondents noticed that 60% vegetation is evergreen and 40% vegetation is seasonal along the kaas. Therefore, green cover of the kaas is preserved for most of the time throughout the year. There is minor variation in it due to seasonal changes.

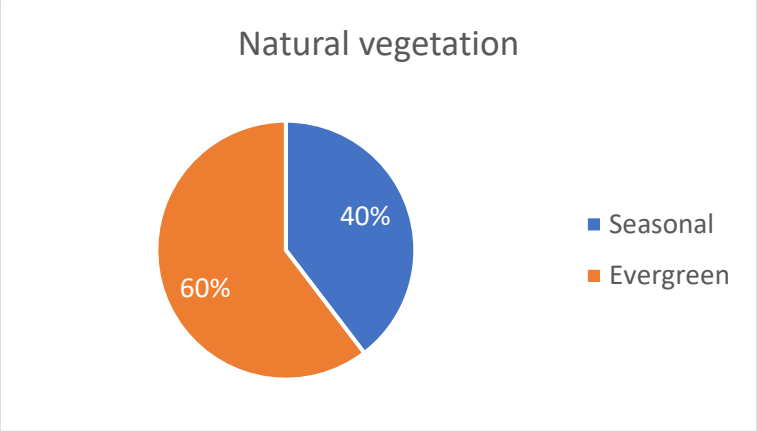


FIGURE 56: TYPES OF NATURAL VEGETATION

Fig. 57 shows the types of native trees which grow in this area naturally. Following are the tress which are most found in this area, they are: Neem, Pipal, Banyan, Babul, Karanj, Desi baval, Ber, Goras ambli. Majority of the trees are Desi baval and Neem. Banyan, Goras ambli, Pipal are decreasing due to urban development activities.

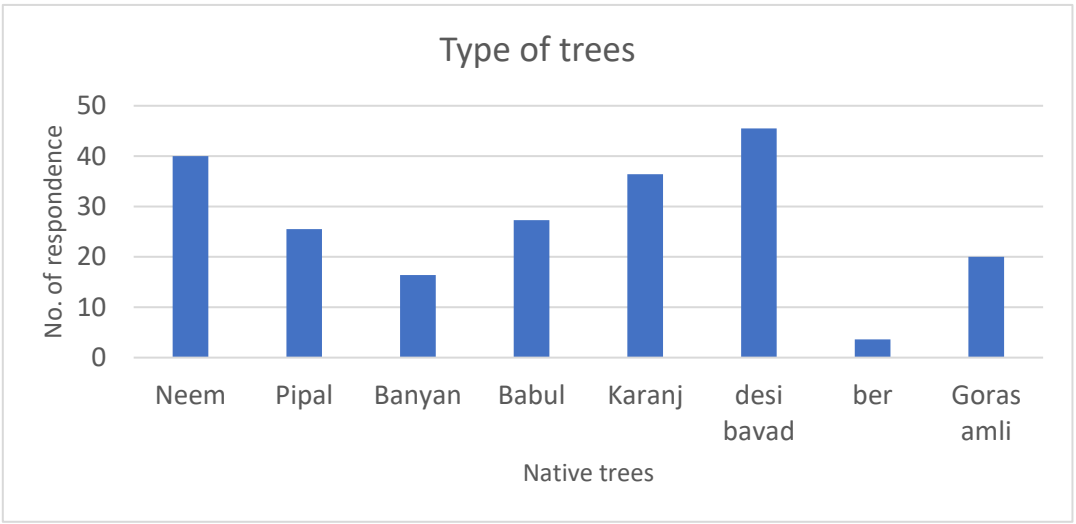


FIGURE 57: TYPES OF TREES

Bhukhi kaas has been changing rapidly in past few years. So, the impact of change in Bhukhi kaas can be seen in natural vegetation. Natural vegetation is affected by anthropogenic disturbance in kaas. As chart shows 42% respondents felt that change in natural vegetation because of cut down of the trees. 27% and 31% respondents felt change in natural

vegetation have been because of covering the kaas and channelization respectively as shown in fig.58.

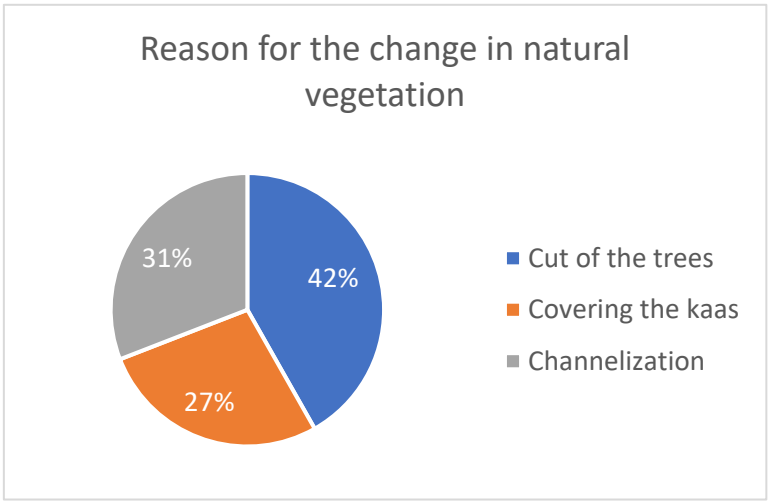


FIGURE 58: REASONS FOR CHANGE IN NATURAL VEGETATION

Fauna mainly depends on vegetation (flora). If natural vegetation decreases it affects fauna. Present condition of fauna represented in fig. 59. In majority of stretch birds are seen regularly. Fishes are seen very less since the availability of biochemical oxygen demand (BOD) is less which is caused due to high nutrient load in the water. Insects like mosquitoes occurring in vicinity of kaas round the year are root cause of health problems. Amphibians and reptiles are seen only in monsoon season. Reptiles like crocodiles are seen in monsoon because of flood, they move from Vishwamitri to the Bhukhi kaas.

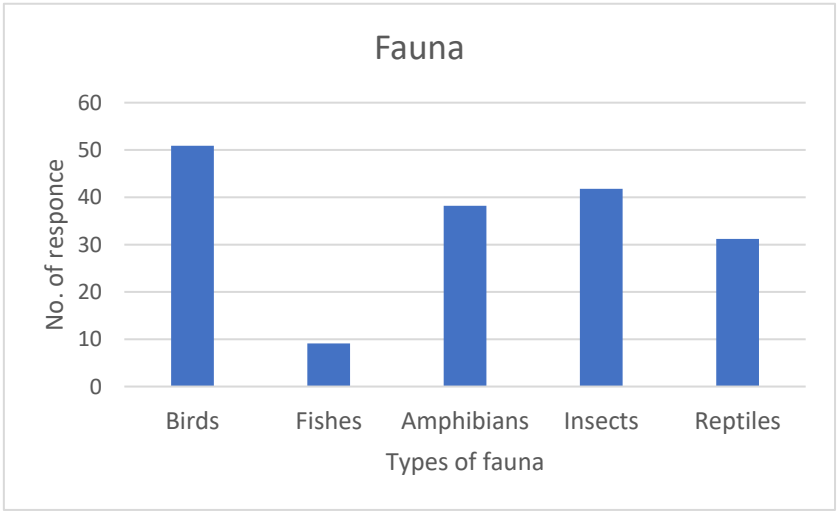


FIGURE 59: TYPES OF FAUNA

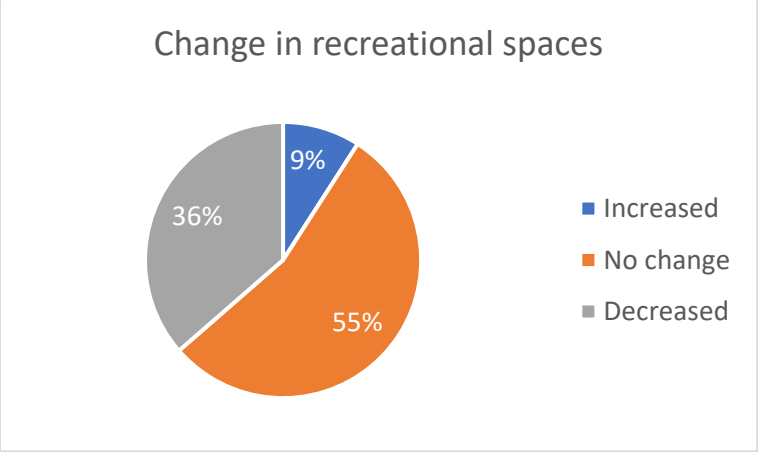


FIGURE 60: CHANGE IN RECREATIONAL SPACES

From the fig. 60, we can say that 55% respondents feel that there is no change in recreational spaces around the Bhukhi. While 36% and 9% locals stated that recreational spaces are decreased and increased respectively. Overall, we can say that there is decrease in recreational spaces.

Fig. 61 shows that the respondents observed that there are 45% informal spaces, 31% trails and 24% garden/parks. If authorities increase the number of recreational spaces, then it might create awareness among people to revive Bhukhi.

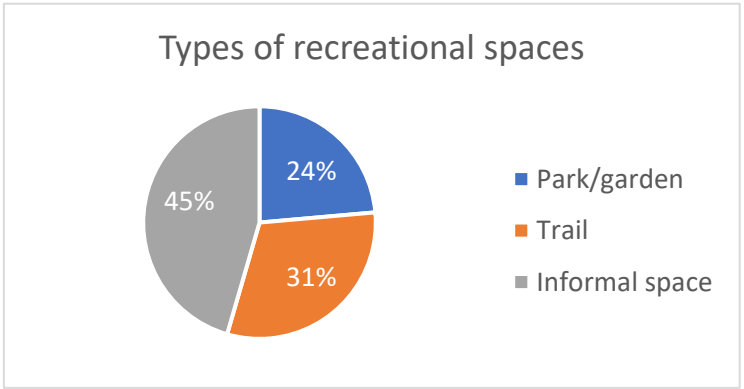


FIGURE 61: TYPES OF RECREATIONAL SPACES

As fig.62 shows that majority of respondents, which is 42% would like to have children's play area as recreation place. While 25%, 24% and 9%

would like to rest and relax, enjoy the landscape and meet up for picnic as recreation spaces.

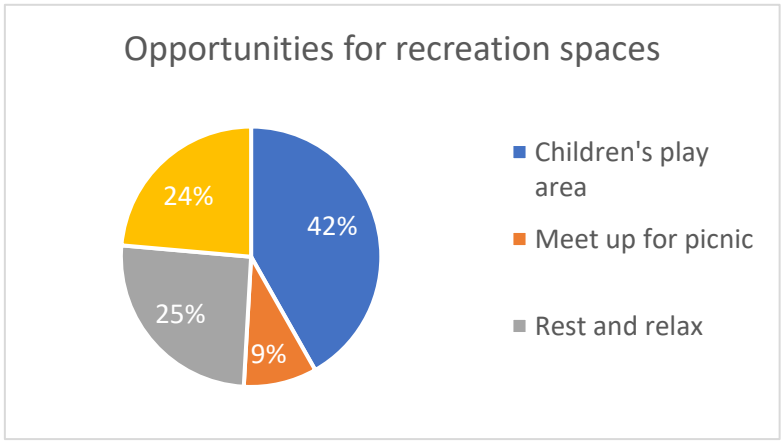


FIGURE 62: OPPORTUNITIES FOR RECREATIONAL SPACES

CHAPTER 5

CONCLUSION

In this study, we have used the Bhukhi basin as a subtropical case to assess the relationships between land use, riparian vegetation and catchment area. Based on the results obtained by employment of GIS and RS applications, it is concluded that the landuse landcover (LULC) practices in the study area have altered significantly in 40 years. The LULC shift in the watershed area was evident by the decline in the area of other class (21.6%) and augmentation of area covered by classes of built-up (16%). Additionally, all these alterations in the LULC patterns adversely affected water quality and quantity and it is responsible for further loss of riparian Vegetation cover in the watershed areas.

Earlier, Bhukhi kaas was seasonal kaas carrying storm water on rainy days but nowadays it carries sewage and waste water round the year and it became perennial nala. It is never looked as a kaas which can take flood water out from the upper catchment area. It just looks as nala with no ecological importance and it was never recognised or highlighted by the Local Authority (VMC) and that lead to illegal dumping of sewage and solid waste into it that way it started deteriorating. It shows that there is lack of awareness among the communities, decision makers like MSU, Local Authority and politicians.

Over the period of time Bhukhi kaas is being narrow down and transformed to channels (culverts) and covered with concrete slab. Actually, covering the kaas has increased problems like foul-smelling, cleaning of silting which comes with monsoon water and a major harm to aquatic life due to low oxygen contact. Channelization provides no ecological or aesthetic value and leads to narrowed stream which causes flooding in monsoon because it stops water infiltration into the soil. The

concrete structures are environmentally harmful, causing unnatural erosion of the banks and generate pollutant loading downstream. It also causes degradation of water quality because of no contact with soil and vegetation. It has severely reduced the ability of the stream to provide conveyance of water and sediment, purification of air and water, nutrient cycling, and habitat for native wildlife. Urban stream is connected through highly engineered drainage networks, resulting in excessive storm water runoff, lower groundwater levels and increased loads of urban pollutants.

Native species are at risk because of disposal of untreated sewage waste and solid waste into water and on the banks. Even if green cover is increased most of the species are invasive or exotic which is putting the ecosystem at risk now. This is caused due to change in soil and water conditions. Certain native grass species which can absorb water and prevent soil and bank erosion are depleted as they are removed in pre-monsoon cleaning activities. Due to Gando baval (Prosopis) also the grass species have disappeared. Once upon a time the area was dominated by native species but now invasive species are increasing. Invasive species are affecting ecosystem adversely, their effect will be seen in long-term. Changes in flora and fauna will affect ecosystem quality which in turn affects ecosystem services.

Apart from this, the way are roads are planned, it prevents the water from flowing freely. They became mini check-dams and lead to water logging in areas. Therefore, future river restoration or management should limit the discharge of nutrients through the removal of point-source waste discharges in urban areas.

In my research, there is communication and participation gap from builder lobby as they were not ready to reply any of my questions. Representative of forest dept. Vadodara don’t have much information about riparian vegetation of Bhukhi kaas because they get transferred in every 3 years. Representative of Solid waste management cell of VMC has not working on illegal solid waste dumping on banks of Bhukhi kaas.

CHAPTER 6

RECOMMENDATION

There are several recommendations based upon the conclusion of the study for the proper management and conservation of the water resources and riparian vegetation.

- Proper land use planning should be done for the watershed prior to any developmental project being conducted in the area and must be preceded by Environmental Impact Assessment (EIA).
- An effective water management practice could be breaking down major river basin into sub-watersheds and prioritizing the sub-watershed for conservation and management based on degradation level so as to conserve and minimize the human induced impacts faced by it.
- Bhukhi should be incorporated in urban development and town planning levels where riparian buffer zone should be provided up to 5m from waterbody. To achieve this, Comprehensive General Development Control Rules (CGDCR) (part III, pg.no. – 27, 35) should be strictly implemented by VMC.
- Urban planner should always seek advice from ecologist or botanist before approving town planning schemes and development plans. There should be proper ecological planning for urban area (input from expert of Botany). Specific policy must be there for riparian vegetation.
- Tree planting should be promoted in riparian buffer zone by VMC and they must collaborate with non-governmental organizations and educational institutes like – MSU for such activities. Plantation should be done with help of experts from discipline like Botanist, Ecologist, Geo-spatial sciences, Landscape architect and Planners.

- Another step forward in protecting and restoring the riparian vegetation would be providing incentives to the local people for guarding the new plantations.
- It can be suggested that riparian buffer zone can be developed as garden which can be used for green transport, children's play area, senior citizen park.
- Bhukhi kaas should be kept in its natural way and further stop channelization and covering it.
- Local Authority should stop disposal of untreated sewage, illegal dumping and encroachment and further take strict steps against it. Nature based solutions should be used to clean water and remove existing debris from the banks to increase the carrying capacity of the water. The traditional ecological and bioengineered structures can be established along the stream. The structures must be site specific and in consideration of the stream design i.e. straight, meandering, sinuous and irregular.
- Whenever new roads are planned, natural drainage should be taken care of and culverts should be provided wherever necessary according to catchment area and surface runoff. We have to maintain the inlet points in its upper catchment area linkages between Dumad, Sisva and Chhani pond and increase capacity of Chhani lake.
- Build recharge wells in the Bhukhi kaas itself, so that ground water recharges the aquifers.
- Take measures to increase sensitization and awareness among local communities and decision makers.

APPENDICES

Appendix 1: Questionnaire for local resident

Questionnaire used in the quantitative study (google form).

Local people awareness and Perception about the stream

Questionnaire: Closed Questions Duration: 4 to 5 minutes

This questionnaire is used to assess ***"the impact of land use/landcover change on health of urban stream - a case of Bhukhi kaas"*** as a thesis project.

This survey is being done by the student of masters in urban and regional planning from the M.S. University of Baroda.

<u>Personal detail:</u>

Gender: Male / Female / other

Location:

◯ Chhani ◯ Sama ◯ Nizampura ◯ Pratapgunj

Qualification of respondent:

◯ 10th Pass ◯ 12th pass ◯ Undergraduate ◯ Graduate

◯ Post Graduate ◯ Illiterate

Occupation of respondent:

◯ Business ◯ Service ◯ Labour ◯ Student

◯ Homemaker

Age:

◯ 18-30 Y ◯ 30-45 Y ◯ 45-60 Y ◯ ABOVE 60 Y

Housing Detail:

◯ Mud house ◯ single story ◯ double story ◯ multistory

---

1. How far you are from Bhukhi Kaas:

◯ 0-100 mt. ◯ 100-200 mt. ◯ 200-300 mt.

◯ 300-400 mt. ◯ 400-500 mt.

2. Type of land use:

◯ Residence ◯ Commercial ◯ Industrial ◯ Mix use

3. How long you have been staying near Bhukhi Kaas?

◯ 0-10 years ◯ 10-20 years ◯ 20-30 years ◯ 30-40 years

◯ 40-50 years

4. Have you seen any change in Bhukhi kaas in last few years?

◯ Covered (underground) it ◯ Channelization

◯ Reduce its width ◯ Reduce depth

5. Do you stay in _____ house?

◯ Own ◯ Rental ◯ Other

6. Are you facing any problems because of Bhukhi Kaas?

◯ Bad smelling ◯ Waterlogging ◯ Flood ◯ Solid waste

◯ Animal risk

7. Did you face any health issue due to Bhukhi Kaas last 10 years?

◯ Typhoid fever, Malaria ◯ Chikungunya

◯ Stomach sickness ◯ Skin diseases

8. Did you see any change in water quality in last 20 years?

◯ Improving ◯ No change ◯ Degrading

9. Water quantity is _____ in last 20 years?

◯ Increased ◯ Not changed ◯ Decreased

10. What is type of natural vegetation along Bhukhi Kaas?

◯ Grass ◯ Shrubs ◯ Trees

11. Is the natural vegetation along Bhukhi Kaas:

◯ Seasonal ◯ Ever green

12. Types of trees you find near Bhukhi Kaas?

◯ Neem ◯ Pipal ◯ Banyan ◯ Babul

◯ Karanj ◯ Desi baval

Any other: _____

13. Did you see any change in natural vegetation in last few years?

◯ cut down trees ◯ concreting on banks ◯ covered it

14. Which of the following fauna(animal/habitat) have you seen there?

◯ Birds ◯ Amphibians, e.g. frogs ◯ Crocodile

◯ Fishes ◯ Insects, e.g. dragonflies

15. Do you think that recreational spaces along Bhukhi Kaas are?

◯ Increased ◯ Not changed ◯ Decreased

16. What type of spaces are reduced along Bhukhi Kaas?

◯ Park/garden ◯ Trail e.g. cycle/walking along it

◯ Informal spaces e.g. setting spaces under the trees/on the banks

◯ Enjoy the landscape

17. What are opportunities for recreation spaces along Bhukhi Kaas?

◯ Children's play area ◯ Meet up for picnic ◯ Rest and Relax

18. Effect of Bhukhi Kaas on land prices in last few years?

◯ Increase ◯ Not changed ◯ Decrease

Any comments:

_____

Give thanks and end the interview

Appendix 2: Questionnaire for experts

This questionnaire is used to assess ***"the impact of land use/landcover change on health of urban stream - a case of Bhukhi kaas"*** as a thesis project.

This survey is being done by the student of masters in urban and regional planning from the M.S. University of Baroda.

Name of Respondent: _____ Date: _____

Field of expertise:

◯ Environment ◯ Botany ◯ Designer(architect/planner)
◯ Microbiology ◯ Geography ◯ Ecologist ◯ Zoology

Qualification of respondent:

◯ Graduate ◯ Post Graduate ◯ Ph.D. ◯ Post doc.

Occupation of respondent:

◯ Researcher ◯ Professional ◯ Academician

---

1. What are the major factors leading to natural degradation of Bhukhi Kaas?

◯ change in topography ◯ erosion ◯ deforestation
◯ removal of natural vegetation

2. What are the major human actions leading to degradation of Bhukhi Kaas?

◯ Debris dumping ◯ Disposal of untreated sewage
◯ Disposal of municipal waste ◯ Hazardous waste
◯ Increased in impervious surface ◯ Channelization

◯ Poor planning e.g. TP schemes, development plan

3. Is the riparian vegetation changed in last 40 years?

◯ Increase ◯ Not changed ◯ Decrease

4. Why is riparian vegetation changed?

◯ Encroachment ◯ Removal of vegetation

◯ River bank stabilization with concrete

Any other: _____

5. Is there any change in population of flora along the Kaas?

◯ Increase ◯ No change ◯ Decrease

In which part? _____

6. Are Native species at any risk?

◯ Yes ◯ No

And why? _____

7. Are Invasive or exotic species seen in riparian vegetation?

◯ Yes ◯ No

Where? _____

8. How Invasive or exotic species are affecting the Bhukhi Kaas in terms of its ecosystem?

_____

9. Are any species/insects gone and replaced by other species?

_____

10. How to protect riparian vegetation along Bhukhi Kaas?

_____

11. Are you aware that connectivity of Bhukhi Kaas is lost? Where and why?

_____

12. What is the impact of loss of connectivity on Bhukhi Kaas?

◯ Waterlogging ◯ Flood

13. Do you think that MSU is concerned about Bhukhi Kaas?

◯ Yes ◯ No

14. Are there any policies to protect Bhukhi Kaas? If any, what are the impacts of these policies?

◯ Yes ◯ No

_____

15. What are the steps taken to revive Bhukhi Kaas?

_____

16. Do you think that VMC is concerned about Bhukhi Kaas?

◯ Yes ◯ No

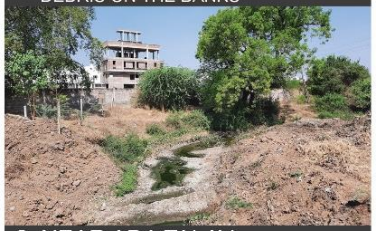
17. What are the steps taken by VMC to revive Bhukhi Kaas?

_____

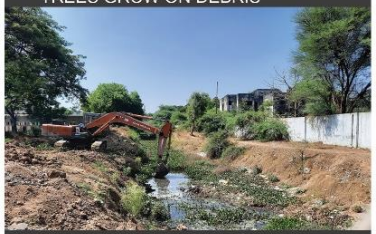
Give thanks and end the interview

Appendix 3: Bhukhi kaas existing condition in 2021

1. ORIGIN OF BHUKHI
SHRUBS GROW ON CONSTRUCTION DEBRIS ON THE BANKS



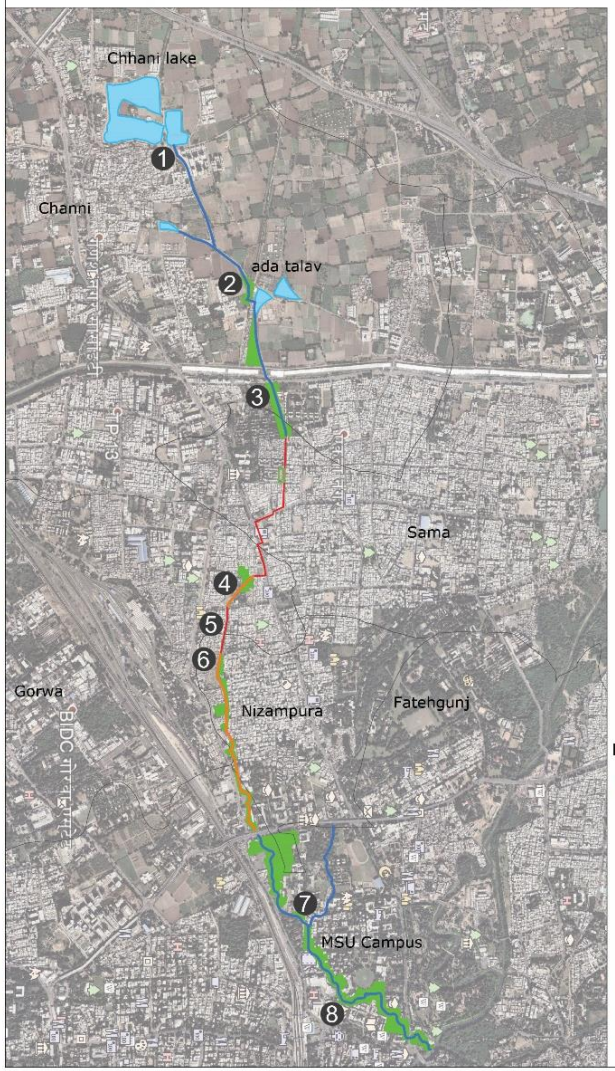
2. NEAR ADA TALAV
IN DRY STATE, NO MINOR SHRUBS & TREES GROW ON DEBRIS



3. NEAR NARMADA CANAL
MINOR SHRUBS (GANDI BAVAL) GROW ON DEBRIS, CARRIES WASTE WATER

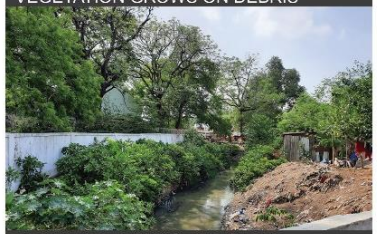
4. SAMA
NO VEGETATION, CHANALIZATION, CONSTRUCTION DEBRIS

Bhukhi kaas in 2020

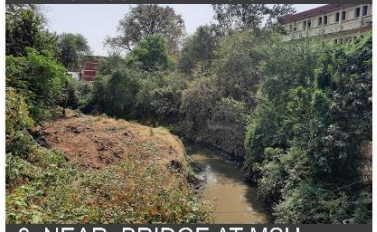


5. NIZAMPURA
COVERED WITH CONCRETE SLAB

6. NIZAMPURA
CHANELIZED, DUMPING OF WASTE, VEGETATION GROWS ON DEBRIS



7. NEAR BOY'S HOSTEL
SHRUBS GROWN ON DEBRIS AND ENCHROCHMENT BY SLUM



8. NEAR BRIDGE AT MSU
CONSTRUCTION WASTE DUMPING, MORE VEGETATION

Appendix 4: Fauna species

Bird species

Oriole

Marshall Iora

Black Drongo

Tailorbird

Gray hornbills

Rosy starling

Peacock

House sparrow

Vulture

Source: https://indianbirds.thedy namicnature.com

Source: https://birdsofgujarat.co.in

Source: https://ebird.org

Source: https://animals.howstuffworks.com

Source: https://www.britannica.com

Animal species

Fox

Jackals

Common Indian civet

Hyena

Porcupines

Green keel

Viper

Checkered keelback

Source: http://www.indiansnakes.org

Source: https://www.eurekalert.org

Source: https://bangkokherps.files.

Source: https://en.wikipedia.org

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