Conservation of an inland salt water lake: A case of Sambhar lake, Rajasthan

Thesis submitted in partial fulfilment of the requirements for the award of the degree of

MASTER OF PLANNING
(Environmental Planning)

By
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Declaration

I **Shraddha Dewangan**, Scholar No. **2018MEP006** hereby declare that the thesis titled **Conservation of an inland salt water lake: A case of Sambhar lake, Rajasthan**, submitted by me in partial fulfilment for the award of Master of Planning (Environmental Planning), at School of Planning and Architecture, Bhopal, India, is a record of bonafide work carried out by me. The matter/result embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.

Shraddha Dewangan
Signature of the Student
Date: 10-07-2020

Certificate

This is to certify that the declaration of **Shraddha Dewangan** is true to the best of my knowledge and that the student has worked under my guidance for one semester in preparing this thesis.

RECOMMENDED

Signature of the Guide

ACCEPTED

Signature of Head,
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Date: 10/07/2020
Place: Bhopal

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Abstract

Wetland is among the world's most vulnerable habitats and active ecosystems. They play an important role in conserving water, controlling flooding and recharging reservoirs, providing biota with protected habitat and much more. Wetland losses are three times faster than loss of forests. According to the concept of wetland, lakes are also considered as wetlands, and depending on the chemical composition, they fall under fresh water lake and salt water lake. Many salt water lakes around the world are diminishing at alarming levels, reducing habitat and benefits for water birds, while risking human health. In India, there are very few salt water lakes which exist and those which are present are getting degraded in terms of quantity and quality. Sambhar lake is one such wetland which is an inland salt water lake in Rajasthan with an area of 190 sq.km. to 240 sq.km. and has a catchment area of 5700 sq.km. It got its designation as Ramsar site on March 23, 1990 because thousands of pink flamingos and waterfowl birds migrate to this lake. This lake is a breeding area for flamingos during winters. Due to large scale salt production from water of Sambhar lake, Rajasthan becomes third largest producer of salt in the country. Degradation of Sambhar lake is continuously happening over the years, with respect to surface area and in quality. Sambhar lake was earlier fed by four rivers which are currently not feeding it because of the construction of dams and anicuts on the upstream ends of those rivers. These rivers have been dry for last 40 years and as per the experts they are beyond revival. Degradation is happening due to encroachment all around the lake, over exploitation of water for salt extraction and change in land use and land cover. Due to the decrease in the surface water flamingos that used to visit lake in several thousands have reduced to just a few. Due to the water quality degradation, from November 10 - 23, 2019 more than 18,000 birds died. The lake has an ecological importance and it is degrading gradually due to anthropogenic activities and it would get fully degraded in the coming years. The aim of this academic exercise is to study and assess the impacts of various activities which have led to the degradation of the lake and to formulate strategies for its conservation. For achieving the aim, objectives have been formulated. Under each of the objectives, various analyses have been done and then proposals for conserving the lake have been developed.

सार

वेटलैंड वर्डी के सबसे कमजोर आवासों और सक्रिय पारिस्थितिक तंत्रों में से एक है। वे पानी के संरक्षण, बाढ़ को नियंत्रित करने और जलाशयों को रिचार्ज करने, संरक्षित आवास के साथ बायोटा प्रदान करने और बहुत कुछ करने में महत्वपूर्ण भूमिका निभाते हैं। वेटलैंड के नुकसान जंगलों के नुकसान से तीन गुना तेज हैं। वेटलैंड की अवधारणा के अनुसार, झीलों को वेटलैंड्स भी माना जाता है, और रासायनिक संरचना के आधार पर, वे ताजे पानी की झील और खारे पानी की झील के नीचे आते हैं। दुनिया भर में कई खारे पानी की झीलें आईआईएमआई पर कम हो रही हैं, मानव पक्षियों को जोखिम में डालते हुए जल पक्षियों के आवास और लाभों को कम कर रही हैं। भारत में, बहुत कम खारे पानी की झीलें हैं जो मौजूद हैं और जो मौजूद हैं वे मात्रा और गुणवत्ता के मामले में खराब हो रही हैं। सांभर झील एक ऐसी आर्द्रभूमि है, जो राजस्थान में 190 वर्ग किलोमीटर के क्षेत्र में एक आईआईएडी साय पानी है। से 240 वर्ग कि.मी. और 5700 वर्ग किमी का जलग्रहण क्षेत्र है। 23 मार्च, 1990 को इसे रामसर साइट के रूप में नामित किया गया क्योंकि हजारों गुलाबी राजहंस और जलपक्षी पक्षी इस झील में प्रवास करते हैं। यह झील सर्दियों के दौरान राजहंस के लिए एक प्रजनन क्षेत्र है। सांभर झील के पानी से बड़े पैमाने पर नमक उत्पादन के कारण, राजस्थान देश में नमक का तीसरा सबसे बड़ा उत्पादक बन गया है। सतह क्षेत्र और गुणवत्ता के संबंध में, सांभर झील का ह्रास लगातार हो रहा है। सांभर झील को पहले चार नदियों द्वारा खिलाया गया था, जो वर्तमान में उन नदियों के बांधों के ऊपरी छोर पर बांधों और aicuts के निर्माण के कारण इसे नहीं खिला रही हैं। ये नदियाँ पिछले 40 वर्षों से सूखी हैं और विशेषज्ञों के अनुसार वे पुनरुद्धार से परे हैं। झील के चारों ओर अतिक्रमण, नमक निकासी के लिए पानी के दोहन और आईएंड के उपयोग और आईएंड कवर में परिवर्तन के कारण गिरावट आ रही है। सतही जल राजहंस में कमी के कारण जो कई हजारों में झील की यात्रा करते थे, वे घटकर कुछ ही रह गए हैं। पानी की गुणवत्ता में गिरावट के कारण, 10 से 23 नवंबर, 2019 तक 18,000 से अधिक पक्षियों की मौत हो गई। झील का एक पारिस्थितिक महत्व है और यह एंथ्रोपोजेनिक गतिविधियों के कारण धीरे-धीरे अपमानजनक है और यह आने वाले वर्षों में पूरी तरह से नीचा हो जाएगा। इस अकादमिक अभ्यास का उद्देश्य विभिन्न गतिविधियों के प्रभावों का अध्ययन करना और उनका मूल्यांकन करना है, जो कि ईक के क्षरण को रोकते हैं और इसके संरक्षण के लिए रणनीति बनाते हैं। उद्देश्य प्राप्त करने के लिए, उद्देश्यों को तैयार किया गया है। प्रत्येक उद्देश्य के तहत, विभिन्न विश्लेषण किए गए हैं और फिर झील के संरक्षण के प्रस्ताव विकसित किए गए हैं।

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Abbreviations

IVRI – Indian Veterinary Research Institute

MoEFCC – Ministry of Environment, Forest and CIimate Change

NWCP – National WetIand Conservation Programme

USGS – United States Geological Survey

lUCN – InternationaI Union for Conservation of Nature

WGBIS – Western Ghats Biodiversity Information System

NLCP – National Lake Conservation Program

DEM – Digital Elevation Model

CGWB – Central Ground Water Board

NGT – National Green Tribunal

LULC – Land Use and Land Cover

UTM – Universal Transverse Mercator

GIS – Geographic Information System

RSPCB – Rajasthan State Pollution Control Board

CHAPTER 1 INTRODUCTION

1.0. Background

1.0.1. Sambhar Lake

Sambhar lake is the country's largest inland salt water lake. It is located in Rajasthan state and is 64 km away from Jaipur city. On 23 March 1990, Sambhar lake was named as Ramsar site, an internationally important wetland. Surface area of lake varies from 190 sq.km. to 240 sq.km. and has a catchment area of about 5700 sq.km.

This large saline lake was once fed by four ephemeral rivers is a shallow wetland and subjected to seasonal variations. Aravalli hills, sandy plains and dry thorn scrubs surround the Sambhar lake. It is an important site for a range of wintering migratory birds which include great number of flamingos. Anthropogenic activities include production of salt and cattle grazing (Ramsar, Ramsar sites information service, 1990). Sambhar lake is a region where tens of thousands of migratory birds' winter. From Sambhar lake country's huge amount of salt is being produced and due to this Rajasthan becomes the third largest producer of salt in the country.

Issues at Sambhar lake are loss of biodiversity, degradation of lake in terms of quantity and quality, extinction of lake, over exploitation of resources, over extraction of ground water for salt extraction, encroachment all around the lake and construction of dams and anicuts.

Figure 1: Issues of lake

Source: (Study IQ Blog, 2019), (India Today, 2018), (Down to Earth, 2015), (Sangha, 2009)

Degradation of lake is happening in quantity of surface water and in quality of the water. As per geologist's degradation of lake is happening at the catchment level and at the peripheral level.

Degradation of lake is happening at catchment level because the ephemeral rivers which used to come to lake and fed lake with water does not come to the lake now because anicuts have been made on these rivers and they have also become dry due to less rainfall and as per the geologists these rivers have become beyond repair. Degradation of lake happening at the peripheral level is because of the sewage and waste water of the villages and towns around the lake is being discharged into the lake, very few amount but dumping of solid waste is also been done around the periphery of the lake, increase in the number of salt pans and change of land use and land cover around the lake.

The present scenario of the lake is worse as these migratory birds are coming to the lake in very less numbers due to reduction of surface water content in the lake. Recently, between November 10 - 23, 2019 more than 18,000 of local birds died because of the increase in the salinity content in the water.

As per the report prepared by Indian Veterinary Research Institute (IVRI), Bareilly Avian Botulinum toxin caused the death of the local birds. This disease is caused by neurotoxin protein produced by a bacterium named clostridium leotulinum. This infection spread over a vast area of 65 sq.km. in Sambhar lake.

According to the report by IVRI it stated that the most affected bird species were omnivore and insectivore species. According to the report by IVRI it is stated that the most affected bird species were omnivore and insectivore and as per the locals and bird experts a greater number of local birds had died. In July 2019, the lake became brim-full with water due to heavy rainfall which reduced its salinity. As water evaporated and flowed into dry land, however, it raised the salinity there, particularly around the edges of the lake bed. Increasing salinity thus caused the death of certain birds at shores, which ate crustaceans and plankton and preferred to be restricted to the edges of the lake.

1.0.2. Need for conservation of lake

Conservation of wetlands is needed as wetlands are being lost at a very fast rate. To increase wetland functions because they are highly valued by society, as people

living near the wetland mainly depend on the wetland resources for livelihood. It provides various ecosystem services like habitat to wildlife, improves water quality, reduces flood damage, offers recreational value and many more facilities. Without wetlands, floods would be devastating to communities residing nearby, hurricane storm surges will reach further inland, animals would get are displaced or even die, and supply of food would get disrupted, including livelihoods.

In India there are many numbers of lakes present. The lakes are categorized according to how they were built and the water quality (freshwater or saltwater). Lakes contain freshwater 4 times more than rivers, but if they are not supplied continuously with freshwater, they may get disappeared through desiccation or sediment accumulation. A lake helps to maintain an even circulation of the river during dry seasons. The lakes can also be used for hydel power generation.

Saline lakes are diminishing across the globe. Many of the saline lakes around the world are diminishing at alarming levels, reducing habitat and economic benefits for water birds, thus risking human health. In India there are very few saline water lakes which needs to revived, conserved and restored. Saline lakes existence is important as many migratory birds survive on these lakes.

Conservation of wetlands are important and for this in September, 2017 India has adopted the Wetlands (Conservation and Management) Rules, 2017 for protecting, conserving and managing these wetlands. Under the scheme of Ministry of Environment, Forest and Climate Change (MoEFCC) the National Wetland Conservation Programme (NWCP) the conservation rules are made for the conservation of lake and funds are also being allocated and have asked the states to identify wetlands of importance in their state for such management.

Conservation of Sambhar lake is needed because the lake is getting degraded at a very fast rate due to the anthropogenic activities which are happening around the lake and the recent tragedy of death of birds has increased great concern for the its conservation. The bulk of the peripheral zones are leading the lake towards degradation in respect to quality and quantity. So, a great concern for its conservation is to be drawn towards it, as this lake is a lake of international importance.

Figure 2: Location map of Sambhar lake, Rajasthan

Source: Bhuvan, Maps of India and USGS Earth explorer

1.1. Aim

To study and assess the impacts of various activities which led to the degradation of lake and to formulate strategies for its conservation.

1.2. Objective

The objectives framed for the study to proceed are as follows –

1. To get an understanding and analyse the causes of degradation of lake
2. To analyse the impacts of anthropogenic activities on the detailed study area
3. Proposal of strategies for conservation of lake

1.3. Scope and limitation

Scope and limitations of the study are –

- Conservation of lake is a necessity for the hour as migratory birds loss is happenings
- Detailed study on the vicinity would be done for the settlements that have maximum anthropogenic activities happening
- Intervention of strategies would for the vicinity only as most of the anthropogenic activities are in the vicinity around Sambhar lake
- Detailed proposal will be on one area due to manpower and time constraint and that can be incorporated for other areas for intervention

1.4. Methodology

The methodology for study has been formulated for each objective following a type as tools and techniques used, data required and its outcomes. Figure 3 shows methodology for the study.

In objective 1 for understanding about causes of degradation of salt water lakes first task was to do literature study of different salt water lakes in India and around the globe which had almost same characteristic as of Sambhar lake, so that a clear understanding on degradation of salt water lakes was known. Then the next task was to understand and analyse the causative factors responsible for Sambhar lake degradation in which the sub tasks was to study the baseline scenario of lake, find the causative factors through literature study and assess and analyse those causes. For literatures of Sambhar lake degradation factors responsible two categories were looked upon that was factors of catchment area and anthropogenic activities happening around the vicinity of lake. For analysing the causes Leopold's matrix was used.

In objective 2 for analysing on the impacts of anthropogenic activities on the detailed study area was done spatially. In this objective software used was ArcMap 10.2.2. First task was to do spatio - temporal change for analysis of surface area change of lake, which was done by using Landsat imageries for the years 1990, 2000, 2010 and 2019. Mapping was done to analyse the decadal change from the year 1990 as Sambhar lake got its designation as a site of international importance in the year 1990. Second task was to identify settlements surrounding the lake vicinity, which was done by using satellite imageries and census, 2011 atlas on districts and tehsils of the districts which came under vicinity of the lake. Third task was to identify the settlements those are most dependent on the lake for its resources and for doing this data required was the socio-economic profile of the area. This was captured through the census handbook of 2011 and primary surveys. Under the primary surveys, focus group discussions, stakeholder consultation and expert opinion surveys were undertaken. Fourth task was to delineate the detailed study area which due to anthropogenic activities is primarily affecting the lake. The anthropogenic activities include land use land cover change, dumping of solid waste, disposal of sewage and increase in the area under salt pans. In this also, through focus group discussions, stakeholder consultation and

expert opinion surveys existing scenario of the detailed study area was assessed. Secondary data was collected pertaining to the salt pans, borewells, salt producing industries, sewerage networks, waste dump sites, areas most frequented by flamingos and other birds, vegetation types, rainfall data, terrain and slope. Fifth task was to analyse the delineated detailed study area by analysing the anthropogenic activities happening, change in ground water level, land use land cover change, sewage and waste water disposal, water budgeting and reviewing the primary and secondary data was done. Amount of sewage disposal being done at the edge of lake is being calculated for knowing the scenario.

In objective 3 for proposing strategies for conservation of Sambhar lake first task was to do literature study. For literature study strategies used by different salt water lakes were studied that had similar characteristic as that of Sambhar lake. While doing the primary survey experts were asked about what strategies can be used for conserving the lake so that lake existence was there. Best practices of strategies for conservation of salt water lake was done by others for conservation were referred. Second task was to propose feasible strategies for conservation of Sambhar lake.

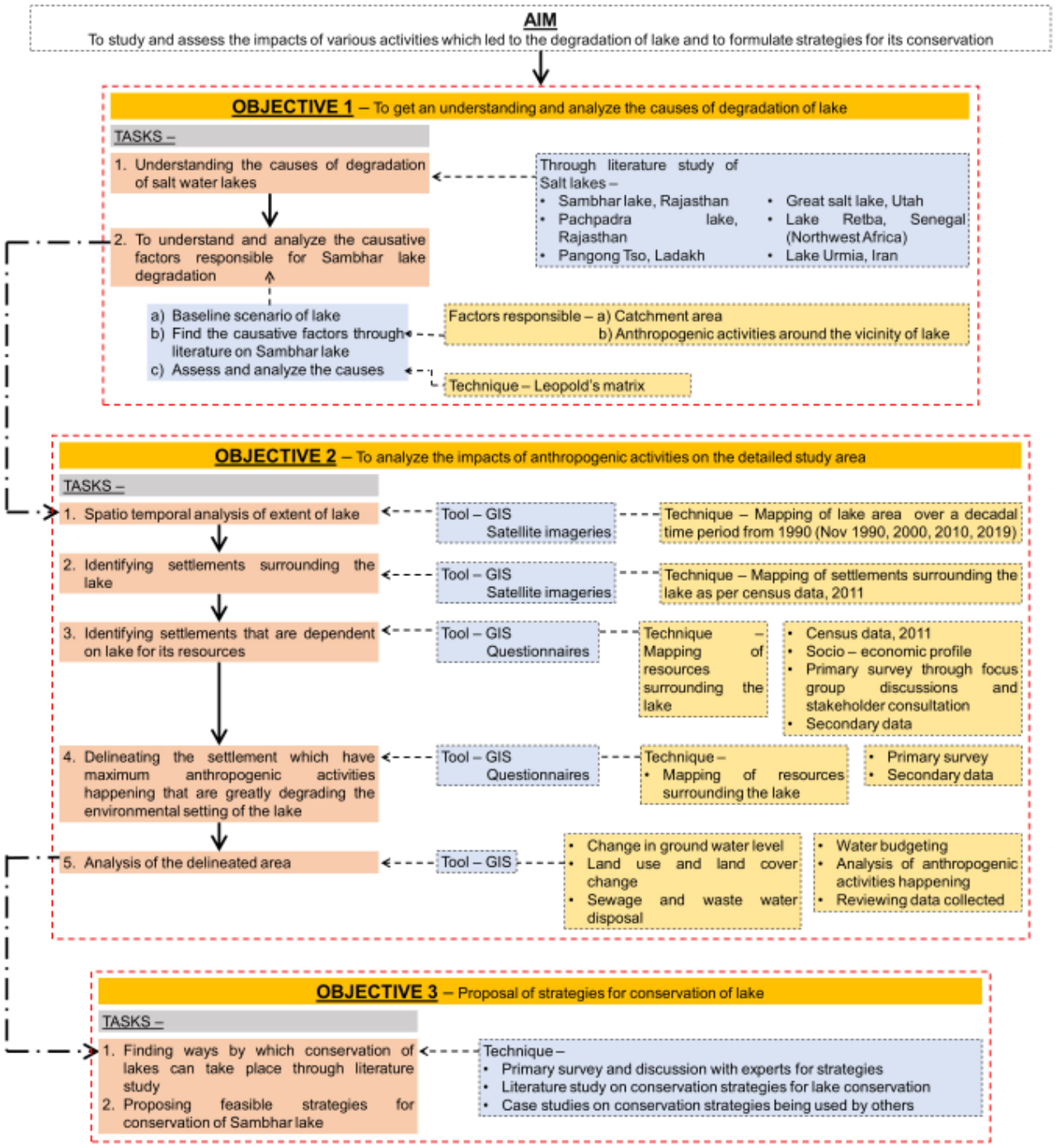


Figure 3: Methodology for the study

Source: Author

1.5. Expected outcome

The outcome of the study was to propose strategies for conservation of lake by addressing the causes of degradation of lake by assessing and analysing the causes. Analysis was through qualitative and quantitative methods.

CHAPTER 2 LITERATURE REVIEW

2.0. Terminologies

1. Ramsar convention – Wetlands convention is an intergovernmental agreement with a mission is “the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world” (Ramsar convention of wetlands, 2016).

2. Wetlands – According to Ramsar convention Wetlands definition is “areas of marsh, fen, peat-land or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 m” (National Wetland Alas: Wetlands of International importance under Ramsar Convention, March 2013).

3. Lakes – Lake is a large natural body of water collected in a depression. It differs from a pond/ tank due to its larger size, presence of biotic life and many other ecological factors. Though a reservoir is similar to a lake, it comprises less habitat and is mostly man-made (Balasubramanian, 2015).

4. Saline or salt water lakes – Salt lakes depth ranges from shallow to deep, vary from small to very huge, shape vary from circular to dendritic; these lakes are indefinite, intermittent or episodical; levels of water may fluctuate or constant widely seasonally or secularly, they have variations in salinity content of water (Saline lakes, 2006).

5. Conservation – Meaning of conservation is official monitoring of wetlands so as to conserve and protect them by careful management (Dictionary.com, n.d.). Conservation also be described as a wide-ranging approach to maintaining what already exists, and due care and consideration to preserve it for the future. This is also committed to return everything to a natural state and preserve balance (Sandbrook, 2015).

2.1. Literature for theoretical framework for the study domain

2.1.1. Ramsar convention

The Wetlands Convention is the oldest of the new, intergovernmental environmental agreements in the world. Countries and non-governmental organizations concerned with the growing loss and destruction of wetland habitat for migratory water birds negotiated the agreement in the 1960s. It was introduced in 1971 in Ramsar's Iranian area, and came into force in 1975.

Wetlands are the only habitats in the world to have the Ramsar Convention, a special convention and agreement for the protection of wetlands. The Ramsar Convention, which entered into force on 21 December 1975, is the intergovernmental agreement that provides the basis for wetland conservation and wise use of its resources. It is also known as the Wetlands Convention. It is named for the Iranian city of Ramsar. The purpose of the Convention is “the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world”.

Perhaps the most complex and productive habitats are the wetlands. They have critical infrastructure and all of our fresh water supplies.

Criteria for Identifying global Important Wetlands are –

Table 1: Criteria for Identifying globally Important Wetlands

Criteria for the designation of Wetlands of International Importance		
Group A of the criteria Sites containing representative, rare or unique wetland types		**Criterion 1**: A wetland should be considered internationally important if it contains a representative, rare or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Group B of the criteria Sites of international importance for conserving biodiversity	Criteria based on species and ecological communities	**Criterion 2**: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities
		Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region
		Criterion 4: A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions
	Specific criteria based on waterbirds	**Criterion 5**: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds
		Criterion 6: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird
	Specific criteria based on fish	**Criterion 7**: A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity
		Criterion 8: A wetland should be considered internationally important if it is important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend
	Specific criteria based on other taxa	**Criterion 9**: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland dependent non-avian animal species

Source: (Ramsar, The Criteria for Identifying Wetlands of International Importance, 1971)

2.1.2. Wetlands

Wetlands are fragile ecosystems; these are the areas where water acts as an element for holding the environment and its related flora and fauna. Wetlands are habitats that hold water and is covered with water all the year round or seasonally.

Wetlands have a special characteristic as it accommodates vegetation of aquatic plants and has faunal biodiversity. Wetlands are the most endangered species and are most fertile ecosystems in the world. They play an important role in conservation of water, regulating flood, recharges aquifers, supplies safe habitat to flora and fauna and many such other things are being facilitated by wetlands.

Wetlands also provide livelihood to human beings and are a great support since ages. Wetlands whether they are perennial rivers or bigger water bodies always they have been the origin of water and as a result evolution of settlements took place. Settlements in the early ages used to start besides these wetlands for shelter and growing food (National Wetland Alas: Wetlands of International importance under Ramsar Convention, March 2013). These ecosystems provide various resources for the human beings. Natural wetlands occupy just about 4% of the ice-free area of the Earth and 1% of rice paddies (Prigent, December 15, 2001).

Wetlands are of different types in which lakes also come under its classification. Lakes are also of different types according to its quality and existence. Lakes are made up of either filling up of depression areas through rainfall or are made up from the remains of sea or oceans. Fresh water lakes are in a large quantity in the world whereas saline lakes are only few in quantity.

Present scenario of wetlands is such that there is an increasing concern on the existence of wetlands, as wetlands are getting degraded at a very fast rate. Wetlands are also among the most endangered. These degradations are happening due to anthropogenic activities, blockage of rivers/streams for agriculture and many such other things which are affecting the wetlands and are causing changes in its surface area and quality of the water.

Wetlands are the only ecosystems in the world to have a special convention and agreement for the conservation of wetlands that is Ramsar convention. Ramsar Convention is the intergovernmental agreement that provides the basis for wetlands and their resources to be conserved and used wisely.

It is estimated that wetlands cover some 8.6 million sq.km. (6.4%) of the surface of the earth (IUCN). India has 67,429 wetlands covering some 4.1 million hectares. In which 1.5 million hectares are natural, and 2.6 million hectares are artificial that

is made by man. The mangroves occupy a further 6,740 sq.km. (WGBIS, research paper).

According to Ramsar convention wetlands are broadly classified into three main groups, namely inland wetlands, marine/coastal wetlands and human made wetlands. Other range of classes for defining wetlands are –

- Marine (coastal wetlands, including coastal lagoons, rocky shores and coral reefs)
- Estuarine (including deltas, tidal marshes, and mangrove swamps)
- Lacustrine (wetlands associated with lakes)
- Riverine (rivers and wetlands along rivers and streams)
- Palustrine (marshes, swamps and bogs)

Human-made wetlands protected by the Ramsar Convention contain aquaculture, agricultural ponds and permanently or temporarily inundated farmland-such as paddy fields, salt pans, dams, gravel pits, sewage farms and canals (The Economics of Ecosystems and Biodiversity for water and wetlands, 2013).

2.1.3. Lakes

Lakes cover about 1.8% of surface of earth. Almost 2,80,000 cu.km. of water present of surface of earth is in the formation of lakes (Balasubramanian, 2015). Lakes are amongst the most endangered and fragile ecosystems and are under huge threat in terms of its existence. Under classification of lakes there are (Classification of lakes , 2015) -

- Temporary lakes – These exist for a temporary period filling up small depressions of undulating earth surface after a heavy rainfall. In these lakes, evaporation is greater than precipitation such as small lakes of deserts.
- Permanent lakes – These are deep lakes and can contain large amount of water that cannot be easily evaporated. In these lakes' evaporation is less than precipitation.
- Fresh water lakes – These lakes are made up from rivers and streams which fed the lake. Almost all the lakes in the world are fresh water lakes.

- Saline lakes – These lakes are formed where there is no outlet of water naturally from the lake or where the evaporation of water is rapid in comparison to other lakes. These lakes have high salt content present on its surface. Due to high evaporation rate these lakes become saline. Such as Great Salt Lake, Utah.

2.1.4. Saline lakes

Saline lakes are lakes found in arid regions and semi-arid regions where rate of evaporation is greater than precipitation rate. They accounted for only marginally less water volume worldwide (0.008%) than their counterparts in freshwater (0.009%) (Figure 4). Typically, they are found in hydrologically closed (endorheic) basins and are thus the end of inland drainage basins (inflows with no outflows) (Robarts, 2009). Saline lakes are brackish in taste. They have a salinity content 10% more than seawater and has a fairly constant sodium chloride composition (Beltran, January, 2013).

Many saline lakes are like bathtubs without a drain, from which water can only get out one way, through evaporation. This usually occurs when the lake basin is the bottom of a large catchment, like Great Salt Lake (United States) or Lake Eyre (Australia). On the other hand, saline lakes may be fed with salts from either saline groundwater discharges (e.g., the Davsnii Lake in Mongolia), or the washing out other salt lakes, evaporite rocks like gypsum, or some volcanic rocks (e.g., Mono Lake in the United States).

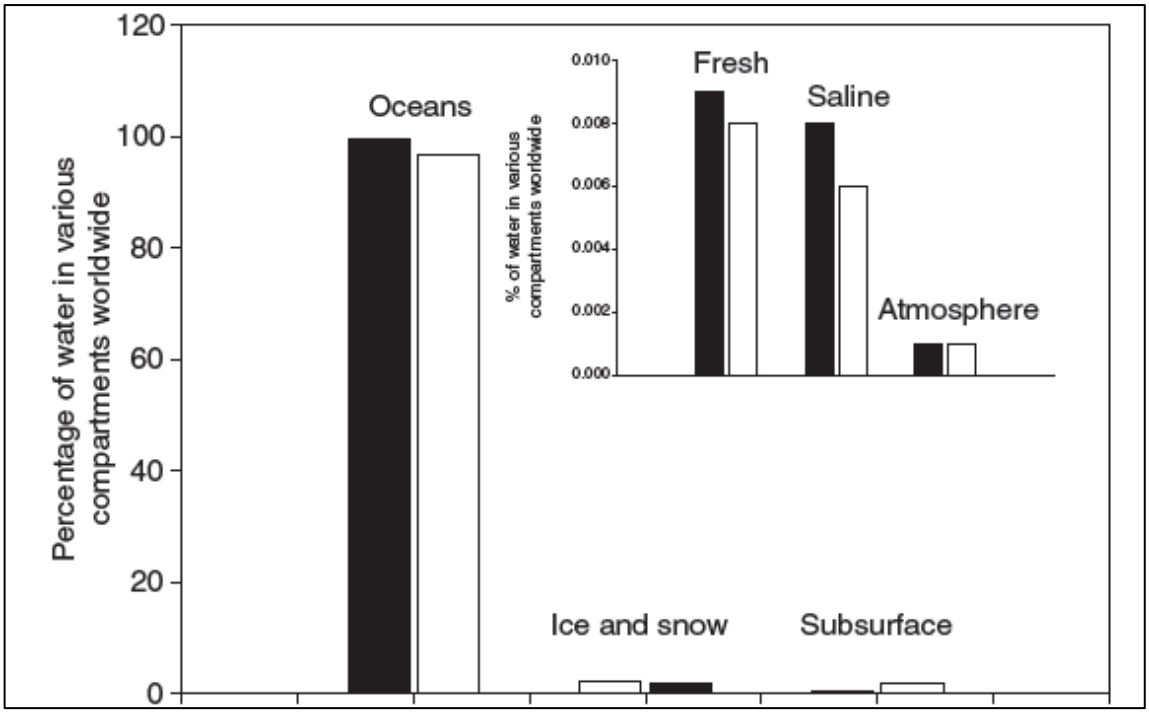


Figure 4: Worldwide, proportion of water in various compartments

Source: (Robarts, 2009)

Incoming water sources include rainfall, groundwater inlet, underground springs (mostly in karst situations), creeks, and rivers. Around 1/10 of the surface of Earth is composed of these closed or endorheic drainage basins (Figure 5).

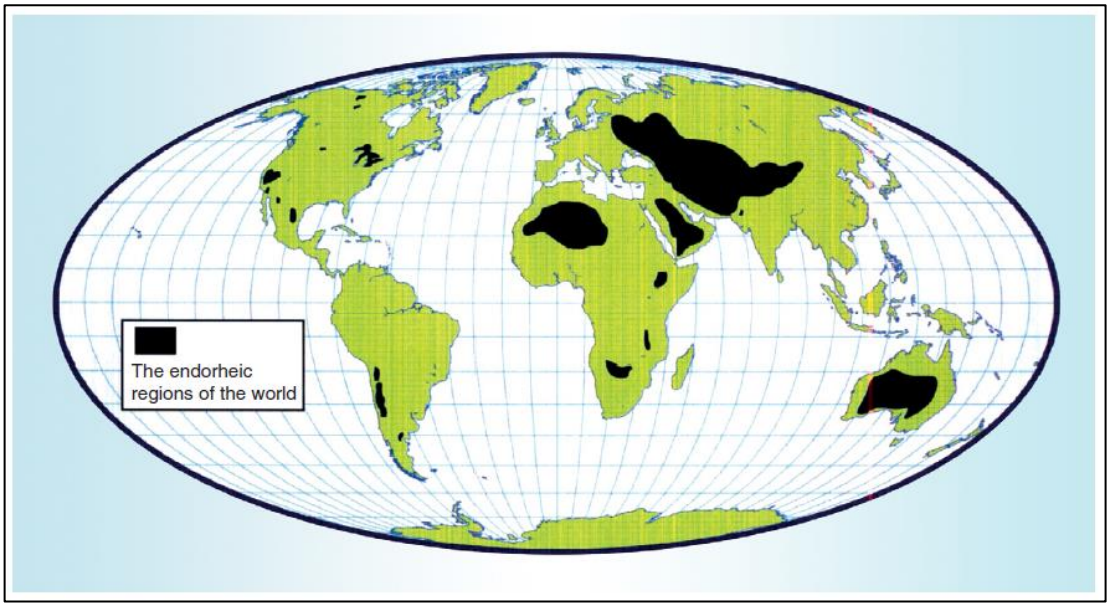


Figure 5: Endorheic drainage basins of the world

Source: (Robarts, 2009)

There are many saline lakes in the world (Figure 6) some of them are –

- Great Salt Lake, Utah
- Lake Retba, Senegal (Northwest Africa)
- Lake Ercek, Turkey
- Lake Urmia, Iran
- Mar Chiquita lake, Argentina
- Lake Baskunchak, Russia

Figure 6: Salt water lakes around the globe

Source: (Wayne A. Wurtsbaugh, 2017)

Saline lakes in India (Figure 7) (India, 2010) –

- Sambhar lake, Rajasthan
- Pachpadra lake, Rajasthan
- Lonar crater lake, Maharashtra
- Chilika lake, Odisha
- Pulicat lake, Andhra Pradesh and Tamil Nadu
- Pangong Tso, Ladakh

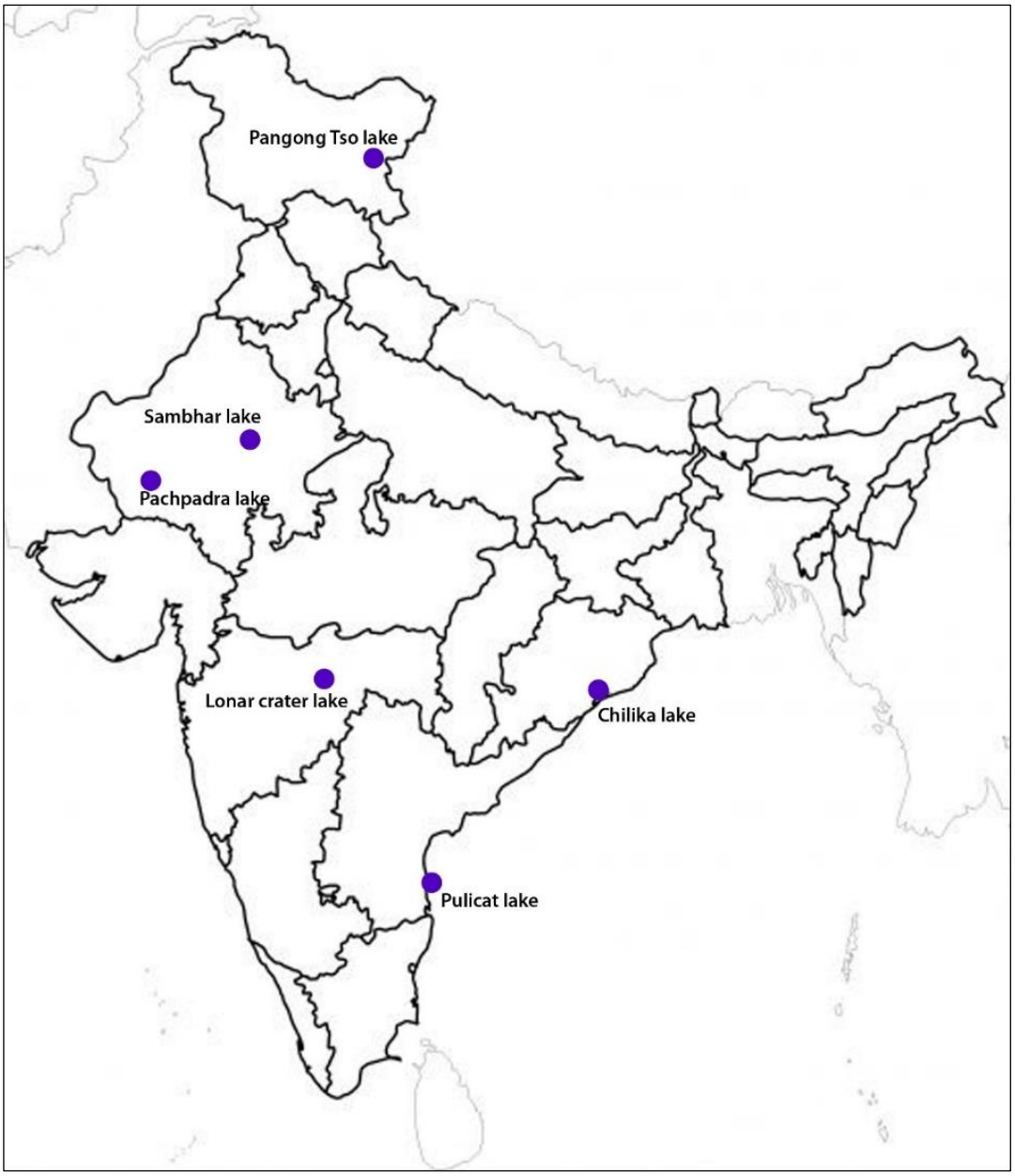


Figure 7: Salt water lakes in India

Source: Author

Saline lakes in Rajasthan (Figure 8) (Seema Kulshreshtha, 2013) –

Rajasthan's arid zone has five saline lakes, namely Sambhar lake, Phulera lake, Kuchaman lake, Pachpadra lake and Deedwana lake; the Deedwana lake has already disappeared out of them while Phulera lake lies on the verge of disappearance.

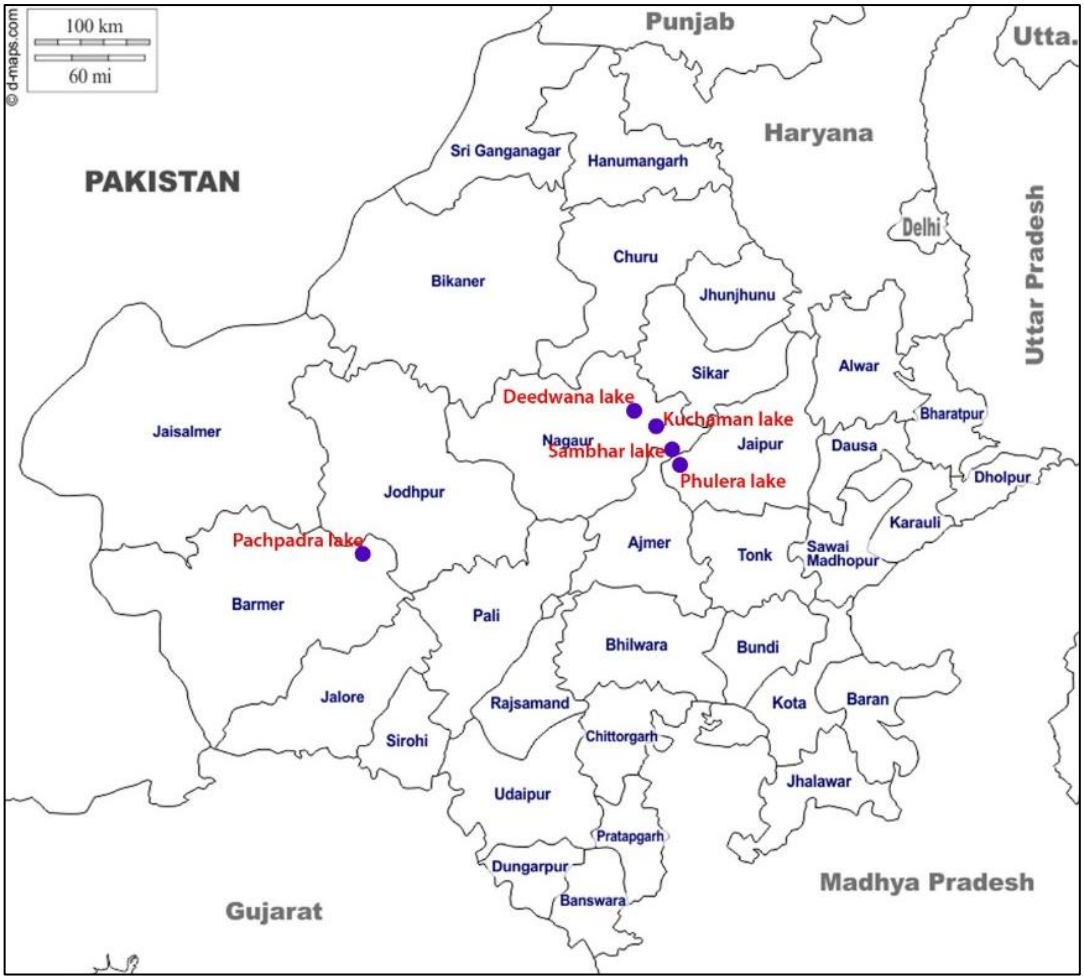


Figure 8: Salt water lakes in Rajasthan

Source: Author and d-maps.com

2.2. Concepts/theories

2.2.1. Leopold's matrix

In Honduras, environmental impact recognition is based upon Leopold Matrix. The rows in the matrix cover the main environmental and social aspects, while the columns list the activities of the project at all project phases. Each interaction box will decide if the behaviour at issue will affect the given environmental factor. If it has an impact, then it will be defined the impact qualitatively as: (A) High (B) Moderate or (C) Low, this can be numerical numbering also. The construction of the matrix requires three steps –

1. Place a diagonal line on all boxes where the environmental effects of the operation are deemed important (Figure 9).

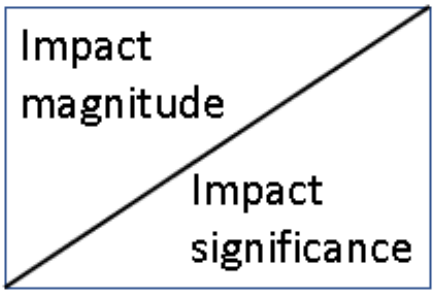


Figure 9: Leopold's matrix

Source: (Development, 2016)

2. Rating is done from 1 to 10, 1 being the lowest and 10 being the highest, with number put in each box listed in step 1 to indicate the magnitude of the effect of the particular action on that environmental dimension. Place the number in the upper left corner.

3. Using same rating system, rating is made in the lower right corner of the specified boxes, which represents the significance of impact to the project.

Once all of the impacts are defined and classified, a comprehensive narrative must be written to explain and justify the importance of the effect. Table 2 shows how the Leopold's matrix table would look after rating the things.

Table 2: Description of a Leopold Matrix for determining impacts

Developmental Activities/ Projects / Characteristics of existing environment	Site preparation	Construction/ usage	Transportation	Thermal power station	Water based industries	Chemical industries	Cement industry	Port activities	Allied industries (including salt production)	Commercial developments	Urban developments	Intensive agriculture	Land quarry mining	Intensive fishing	Coral mining	Hazardous waste disposal	Aqueous discharges	Employment	Immigration	Total
Climate	3/1				3/3	5/3	10/5		5/5		10/5		5/10		10/10	5/5	10/10			66/57
Land use/Land cover	10/5		5/3	3/3	3/5	3/3	5/5		5/3	3/1	10/10	10/5	10/5			5/5				72/53
Surface water				10/10	10/5			3/5	3/5		3/3			1/1	3/5		3/5			36/39
Groundwater		10/5		10/5	10/10	10/5			10/3	5/3	10/5	10/10	5/10			10/5				90/61
Air quality			10/5	5/5	5/3	10/10	10/10		10/10	10/3	10/10									70/56
Ecological characteristics	5/3	1/5	3/3	5/10			5/10	5/5		1/1	5/3	10/5	10/10	10/10	10/10	5/10	10/10			85/95
Soil quality												10/5	10/5			10/10				30/20
Noise level	3/1	3/1	5/3	5/1				5/3		5/5	10/10		10/5		5/3					51/32
Mangroves	10/10			5/10	1/1	1/3			10/10		3/5					10/5				40/44
Wetlands					3/5				10/10		3/5	3/5				10/10	1/3			30/43
Flora/Fauna	5/5			3/5	3/5	3/5	10/5	5/3	10/3		10/5		10/10	10/5	10/5	10/10	10/10			99/76
Aquatic life	1/3	1/1		10/10				5/3	5/5		5/5			5/3	10/5		10/10			52/53
Population density																		5/10	10/10	15/20
Employment structure										10/5	10/5							5/10		30/20
Local economy								10/10		10/10	10/5							5/5	10/5	45/35
Education			3/5								3/5							10/10		16/20
Health service facilities			3/5								10/10							10/10		23/25
Housing										10/10	10/10							10/10	1/3	31/33
Tourism								1/3		5/5	3/5									91/3
Total	37/28	15/12	29/24	56/59	38/37	32/29	40/35	34/32	68/52	59/43	25/106	43/25	60/55	29/19	48/38	65/60	44/48	50/55	23/18	

Source: (Govindaraju, 2002)

2.2.2. Water budgeting for doing the calculations for water losses and availability of water

A water budget is a list of all the water flowing into and out of area. This region could be wetland, lake, or some other landmark. Development may alter the natural water supply and severely impact an environment, especially if nearby ponds or wetlands are present. Water budgets are foundations for successful management of water supplies and the environment. Table 3 shows water budgeting of twin lakes of Mokokchung (Nagaland). This was done for the project of conservation and restoration of the lakes as degradation of the lakes were happening.

Table 3: Calculation for water budgeting

Water budget of twin lakes		
Components	**Lake A**	**Lake B**
Average rainfall	2000 mm	2000 mm
Total rain water received	3.2 mcum	4.8 mcum
Water storage capacity	40929.8 cu m	50232 cu m
Water demand	40929.8 cu m	50232 cu m
Innovative Assessment (Water losses)		
Percolation	15% = 0.48 m cu m	10% = 0.48 m cu m
Evaporation	10% = 0.32 m cu m	5% = 0.24
Absorption in soil strata	5% = 0.16 m cu m	10% = .48 m cu m
Water retention in pools & ditches	5% = 0.16 m cu m	8% = 0.38 m cu m
Water diversion	20% = 0.64	15% = 0.72 m cu m
Net water availability		
Rain water	3.2 m cu m	4.8 m cu m
Water losses	1.76 m cu m	2.3 m cu m
Water availability for recharging	1.44 m cu m	2.5 m cu m
Net water requirement	0.04 m cum	0.05m cu m

Source: (Tetra Tech India Ltd., 2009)

2.3. Best practices

2.3.1. Great Salt Lake, Utah (EPA)

Organizations interested in the management and protection of Great Salt lake wetlands are leading a wide range of wetland projects, from waterfowl habitat management and wetland preservation to wetland development and awareness

protection planning. Many of the most concrete attempts are being made by groups in relation to the protection and management of the Great Salt lake wetlands.

- Bear River Migratory Bird Refuge - The refuge's Wildlife Education Centre gives the public opportunities to learn about the importance and advantages of wetlands.
- Great Salt lake Shorelands Preserve - The Nature Conservancy operates the Great Salt lake Shorelands Preserve and maintains a visitor centre that allows the public to view wetlands directly.
- Great Salt lake Comprehensive Management Plan - Although the Great Salt lake Comprehensive Management Plan does not tend to play a significant role in the management of wetlands, the plan provides the Great Salt Lake with a valuable long-term, overall management perspective. The Great Salt Lake Technical Team grew out of the plan and has been able to provide an ongoing forum for the sharing of knowledge on control, analysis, ideas and programs affecting the natural systems of the Great Salt Lake.

2.3.2. Case study 2

Wetlands in Bangalore (waterbodies-lakes, tanks), Karnataka State, lndia, are threatened due to pressures from unplanned urbanization and land use activities. ln order to serve the burgeoning population, some of the wetlands in the city have made it to residential layouts, industrial complexes, and so forth. lt has contributed to the declining quality of water and significant change in local climate. The socioeconomic survey in the vicinity of lake ecosystem revealed that about 65% of the residents were willing to pay for its restoration, conservation, and efficient management.

Appropriate management and restoration mechanisms need to be implemented in order to regain and protect the physical, chemical, and biological integrity of wetland ecosystems. Management goals should not only involve buffering wetlands from any direct human activities that could affect their normal functions, but also in maintaining prime natural processes operating on them that may be altered by anthropogenic activities. Some of the strategies are – to regulate inputs on water quality standards for promoting their normal functioning, involve institutions, colleges, and regulating bodies in conducting regular water quality

monitoring of surface water, groundwater, and biological samples, correct non-point source pollution problems and administer the Pollution Prevention Program through environmental awareness programs, creating buffer zones for wetland protection, limiting anthropogenic activities around the demarcated corridor of the wetland, could revive their natural functioning and many such other strategies were given for the restoration of wetlands and for its proper functioning (Ramachandra, 2001).

2.4. Experiences

Studies done for conservation of Salt lakes and Sambhar lake –

2.4.1. Conservation of salt lakes

For proposing strategies for conservation of salt water lakes firstly the use of lake and value of salt lakes is to be studied. Value of salt water lakes in terms of economic use, cultural value, aesthetic value scientific value, recreational value and ecological value should be studied.

Other aspect which needs to be looked upon is the impact of human on salt lakes. Activities happening at the catchment/drainage basin, surrounding areas, its impacts on the flora and fauna of the area, physical impacts on lake basins and climatic and atmospheric changes.

Conservation measures that can be taken for conservation of salt water lakes (Williams, 1993) –

One of the important first steps in maintaining and preserving any habitat is the identification of its values and the provision of a clear description of these values and the position of the habitat, its main characteristics, the hazards it faces, and the available information about it.

2.4.2. Research paper on conservation of Sambhar lake

This paper is written by three people namely Seema Kulshreshtha, B. K. Sharma, and Shailja Sharma. In this report authors have talked about Sambhar lake in terms of its area, surrounding areas, faunal and floral biodiversity of the lake, historical background, geographical features, catchment area, settlements around the lake, land use pattern around, satellite wetlands of Sambhar lake, geographical profile of lake, climatic condition, rainfall, physical characteristics of lake water. The

authors have also talked about possible threats to the Sambhar lake that affect the lake's ecology –

- Shrinkage in the spread of water area
- Siltation and lake bed disturbances
- Excessive resource utilization
- Change in the pattern of land use
- Deforestation
- Activities by humans

Authors have also talked about government conservation initiatives - Sambhar lake was selected as one of the lakes for conservation along with 11 lakes within the “11th Five-Year Plan” of the Indian government under the National Lake Conservation Program (NLCP) for beautification and conservation of wetlands.

Authors have at last provided some conservation suggestions for Sambhar lake, such as –

- Conservation work is to be taken in a phased manner, priorities for phased manner should be in respect to most affected areas or zones which needs special attention and then the areas which are lesser threatened.
- The watershed to the lake which has some fresh water lakes that should also be conserved so that water can also seep from these water bodies to ground for recharging the groundwater.
- Tourism aspect of the lake should also be looked upon and its beautification should be done.
- All the resources should be managed by the locals and ownership of the locals towards lake should be encouraged.

CHAPTER 3 STUDY AREA

3.0. Introduction of Sambhar lake

Sambhar lake is the country's largest inland salt-water lake. It is located in Rajasthan state and is 64 km away from Jaipur city. It lies within the latitudes and longitudes of 26°52’ to 27°02’ North and 74°54’ to 75°14’ East. The catchment of Sambhar lake is 5700 sq.km. of area. Sambhar Lake is at an attitude of 360 m above mean sea level. The lake surface area varies from 190 sq.km. to 240 sq.km. The lake is elliptical in shape and has a major axis North-East and South-West direction. The catchment spreads over four districts in the state of Rajasthan that is, Jaipur, Ajmer, Nagaur and Sikar whereas lake spreads across three districts namely, Jaipur, Ajmer and Nagaur. Figure 10 shows the location of Sambhar lake.

This large saline lake was once fed by four ephemeral rivers namely Mendha river, Khandel river, Rupangarh river and Kharian river. Mendha river came from North, Khandel river came from East, Rupangarh river came from South and Kharian river came from North-west direction. These rivers were only seen during monsoon season and when there was good amount of rain, but as per the locals and the geologists these rivers have disappeared from the past 40 years and was not seen from a very long time. Aravalli hills, sandy plains and dry thorn scrubs surround the Sambhar lake.

On 23 March 1990, Sambhar lake was named as a Ramsar site, an internationally important wetland. This lake was declared a Ramsar site, since there were variety of water birds visit Sambhar lake during winters and came here for breeding. There are various types of water birds that rest and mainly comprises of a large number of flamingos. Sambhar Lake is a region where tens of thousands of migratory birds’ winter.

The lake's length is 35.5 km and the lake's width is 9.5 km and the average depth is 0.6 m and the maximum depth goes up to 3 m only when there is heavy rainfall. Sambhar lake is very shallow. The lake consists of two unequal sections (Figure 11) and is divided by a 5.16 km dam (Figure 12) made of sandstone between two settlements namely Gudha salt in North and Jhapok in South. These portions have two different uses that is the Eastern portion (Figure 13) which covers 80 sq.km.

and is used for extraction of salt whereas the Western portion (Figure 14) is a natural water portion where migratory and the local birds breed and, in this portion, it is an undisturbed surface of water.

From Sambhar lake country's huge amount of salt is being produced and due to this Rajasthan becomes the third largest producer of salt in the country.

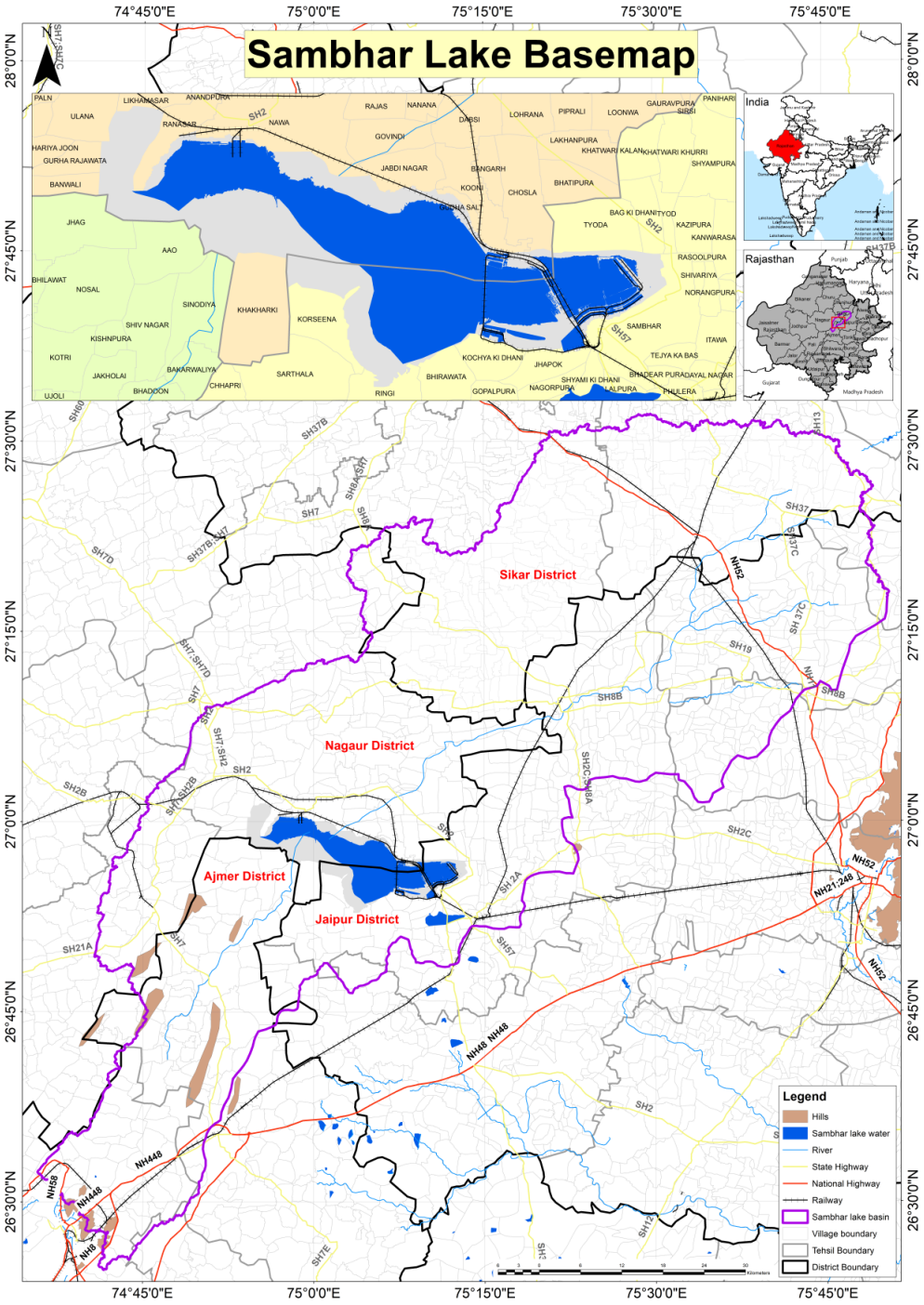


Figure 10: Location map of Sambhar lake, Rajasthan

Source: Author

Figure 11: Division of lake into two unequal portions by a dam

Source: Author and google earth

Figure 12: 5.16 km long sandstone dam dividing the lake into two unequal portions

Source: Primary survey

Figure 13: Salt extraction area (Eastern portion of dam)

Source: Primary survey

Figure 14: Natural water portion (Western portion of dam)

Source: Primary survey

3.1. Mythological context and history

As far as 5000 years back, Sambhar town is being mentioned as a capital of Brishparva who was king of demons, in the ninth volume of Adi Parva in Mahabharata and in the two chapters of ancient Bhagavat purana. Devyani daughter of royal priest Shukracharya married here to Yayati who is tenth descent from Lord Brahma and was the king of the then Bharatvarsh, which is now India. As per traditions it is attributed that Sambhar lake formed in 551 a.d. when Chouhan Rajput's goddess Shakambhari granted her blessings to a religious devotee in exchange for some offered milk and transformed the forest into a massive field of silver which later, on the appeal of residents of Sirthula converted to salt (Figure 15). From records it is shown that for the past 1,500 years, production of salt has been happening using Sambhar Lake. From archaeological excavations it is indicated clearly that Sambhar town is as old as the periods of Kushan and Gupta and from the historical records it is proven that this place was the Chauhan kings first capital. Near the temple of Shakambhari devi there's a small temple of Bherudeo which is situated on the periphery of lake. during the reign of Emperor Akbar, income generated by salt production from lake was estimated around about 2,50,000 Rs. per month and which by time rose to 15,00,000 Rs. during Emperor Aurangzeb reign. From 1844 onwards this lake was owned by a joint government of Jodhpur and Jaipur. During that time, Gudha and Nawa were small hamlets but they slowly grew into salt markets. By 1970, British government took over the works of salt from the kings of Jodhpur and Jaipur. After

independence of India in 1947, Sambhar salt plant was relabelled to Hindustan salts limited and this was administered by Indian central government. At present the production of salt is managed by a joint venture of Hindustan salts limited and Rajasthan state government that is Sambhar salts limited. Figure 16, Figure 17 shows the iodization plants. (Seema Kulshreshtha, 2013).

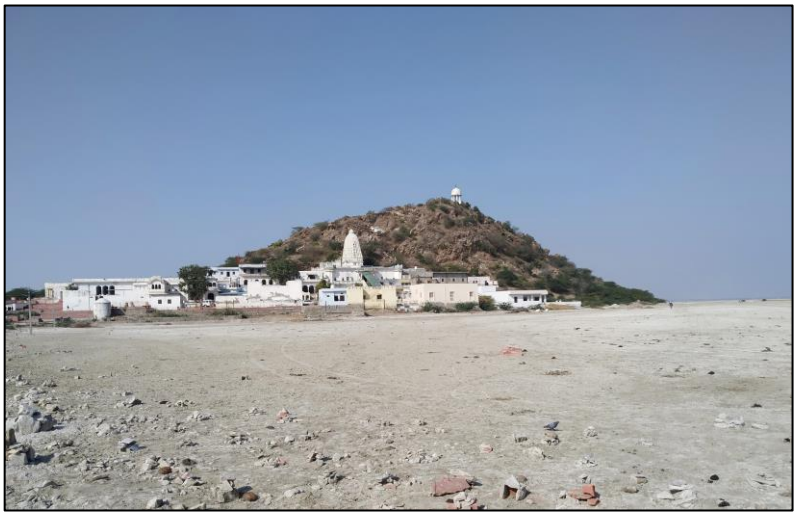


Figure 15: Shakambhari devi ancient temple located at the fringe of Sambhar lake

Source: Primary survey

Figure 16: Plant set up for extraction of salt at Sambhar town

Source: (Seema Kulshreshtha, 2013)

Figure 17: Other salt extraction plants setup by private salt producers

Source: Primary survey

3.2. Settlements

There are a total of 936 settlements (Table 4) comprising of villages, towns, census towns and out growths in the Sambhar lake catchment area. Figure 18 shows the settlements in the Sambhar lake catchment area. Town which is in the East of lake is Sambhar town and town which is in the North of lake is Nawa town.

Table 4: Number of settlements

Number of settlements					
Districts	Tehsil	In the catchment area			
		Villages	Census town	Town	Outgrowths
Jaipur	Shahpura	25	-	-	-
	Chomu	99	1	1	-
	Phulera	173	-	3	2
	Amber	68	-	-	-
Ajmer	Kishangarh	72	-	1	-
	Ajmer	41	1	-	-
Nagaur	Parbatsar	29	-	1	1
	Nawa	147	-	2	-
Sikar	Danta Ramgarh	153	3	-	-
	Sri Madhopur	110	1	2	-

Source: Census 2011 atlas of districts and tehsils

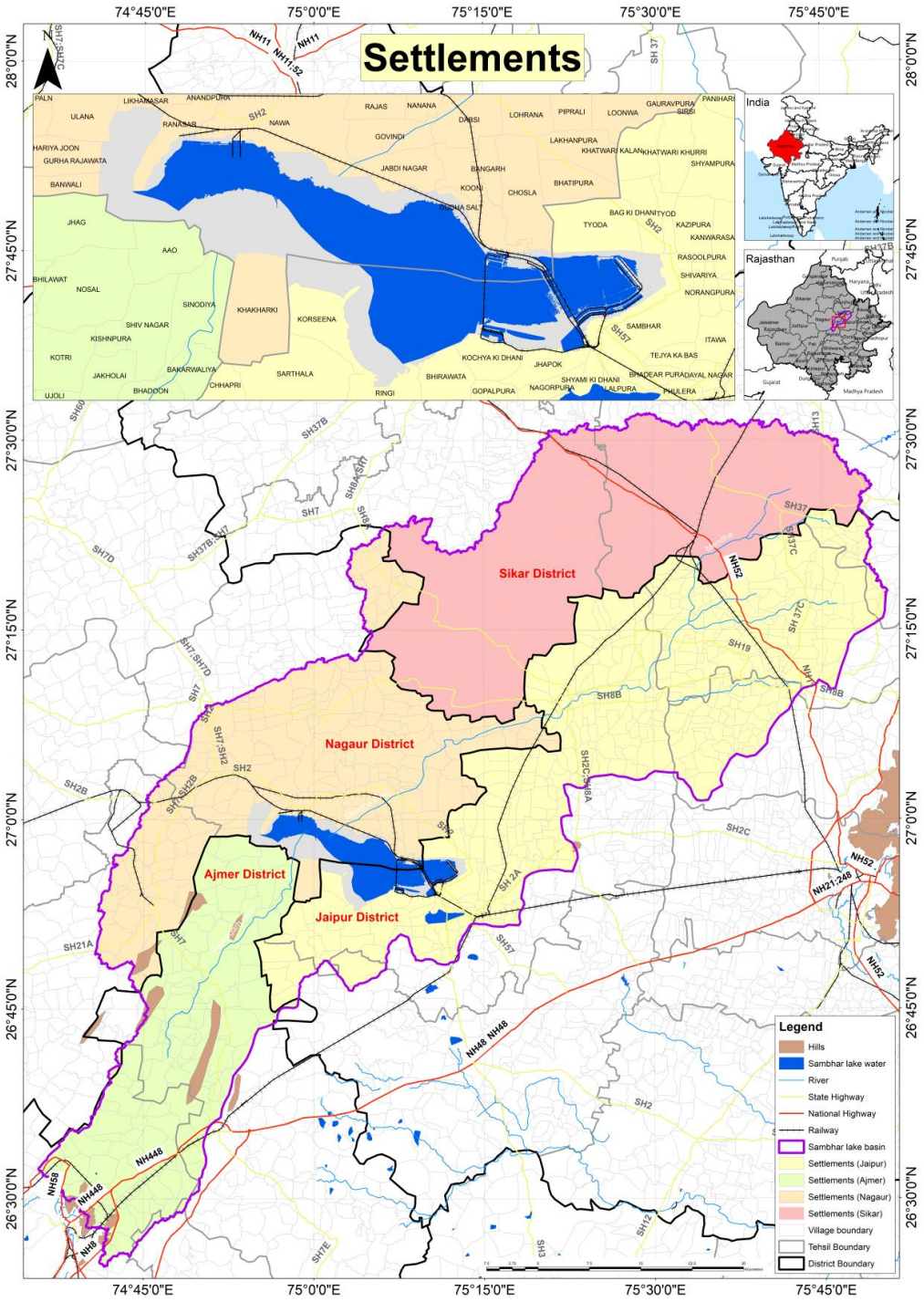


Figure 18: Settlements present in the Sambhar lake catchment area

Source: Author

3.3. Climate

Sambhar lake comes under semiarid zone in the west of India. Lake lies in the typical subtropical climate with annual changes in season. In the summer, hot winds blow and the atmosphere remains very dry and warm and storms of dust blow at a speed of 30 km/h to 36 km/h whereas the temperature range from 32.4°C

to 41°C and maximum temperature rises to 45°C to 47°C which causes the shallow lake water to evaporate fast. In winter, the temperature drops to 5°C to 19.7°C, falling as Iow as 1.8°C in January during extreme winters. Average annual rainfall (Figure 19) of the area is scanty and that is 474.14mm. Majorly the rainfall period ranges from July to September.

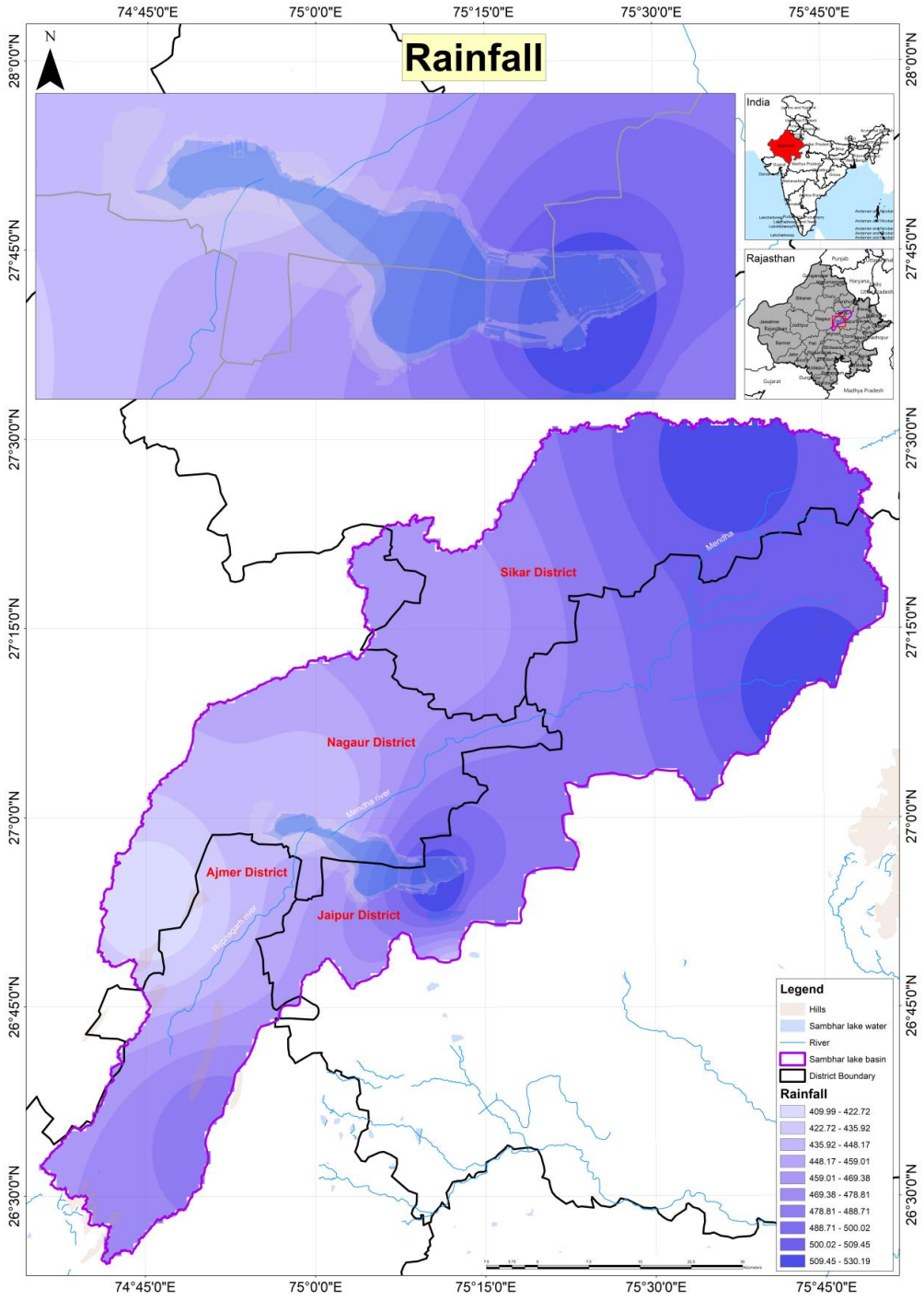


Figure 19: Rainfall map (data obtained from 9 rain gauge stations from years January 1980 to December 2019)
Source: Author

3.4. Geology

The Aravalli series underline the basin of Sambhar lake and surrounds the lake on almost all sides. The hill range itself is not continuous here, but is composed of residual hills with several gaps. Micaceous schists overlain with limestone nodules buried in clay form the basin bottom. Above these spreads a thick layer of sand that, in turn, is covered by a 20 m thick layer of saliferous silt. High terrace and clay deposits are also found in Aravalli outcrops around the lake basin. The origin of salt in the lake has been a topic of considerable discussion among chemists and geologists. Chemical weathering of Aravalli hills, resulting in the production of soluble sodium salts and their drainage into the Sambhar basin, is the most widely accepted explanation. (Ashok Kumar Jain, 2005)

3.5. Slope

The slope of catchment of the lake varies from 0% to 56.8% (Figure 20). This slope is obtained from the Digital Elevation Model (DEM) (Figure 21) from NASA Earth data. The lake bed is almost flat with a slope of less than 10 cm per km.

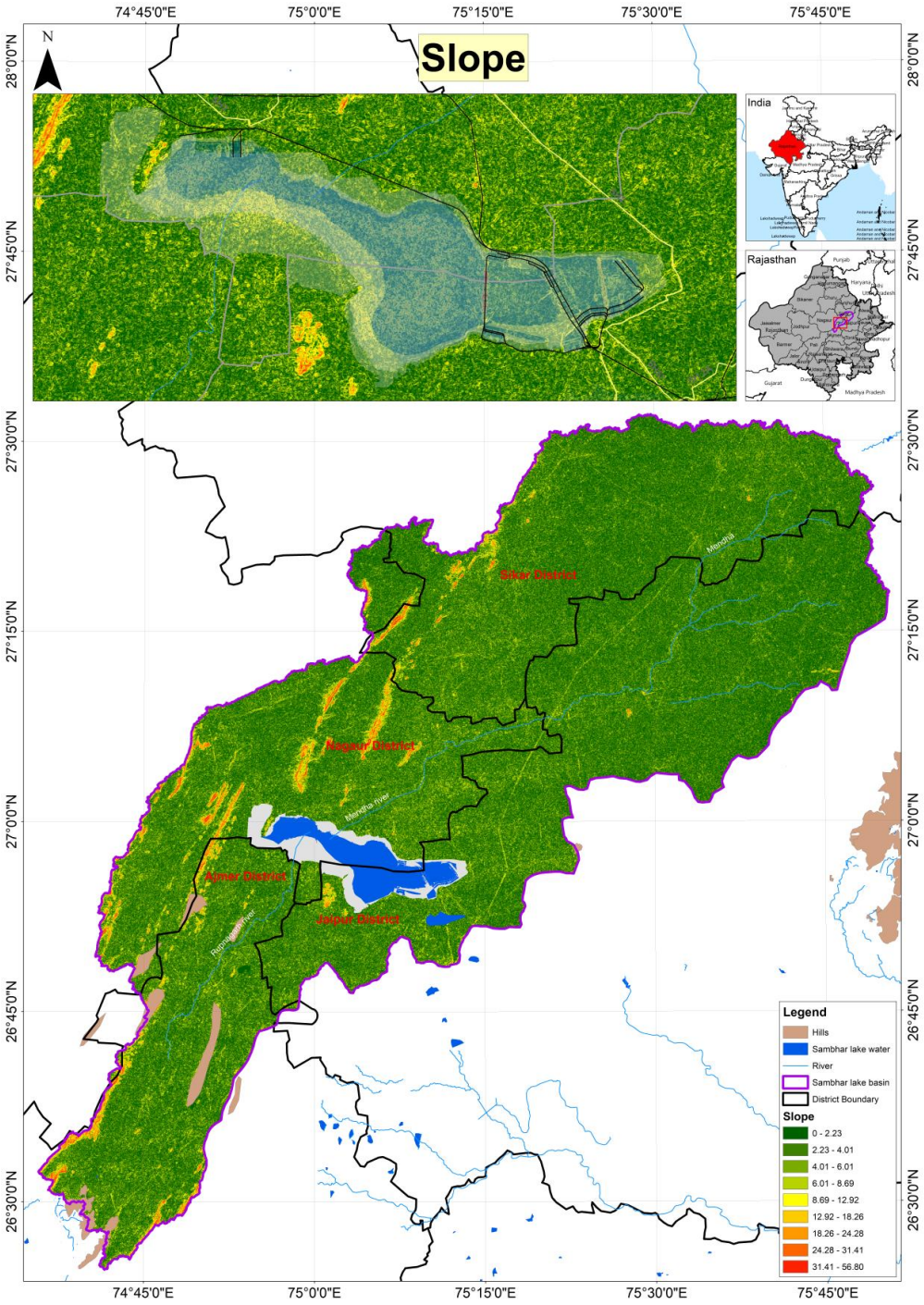


Figure 20: Slope of catchment of Sambhar lake

Source: Author

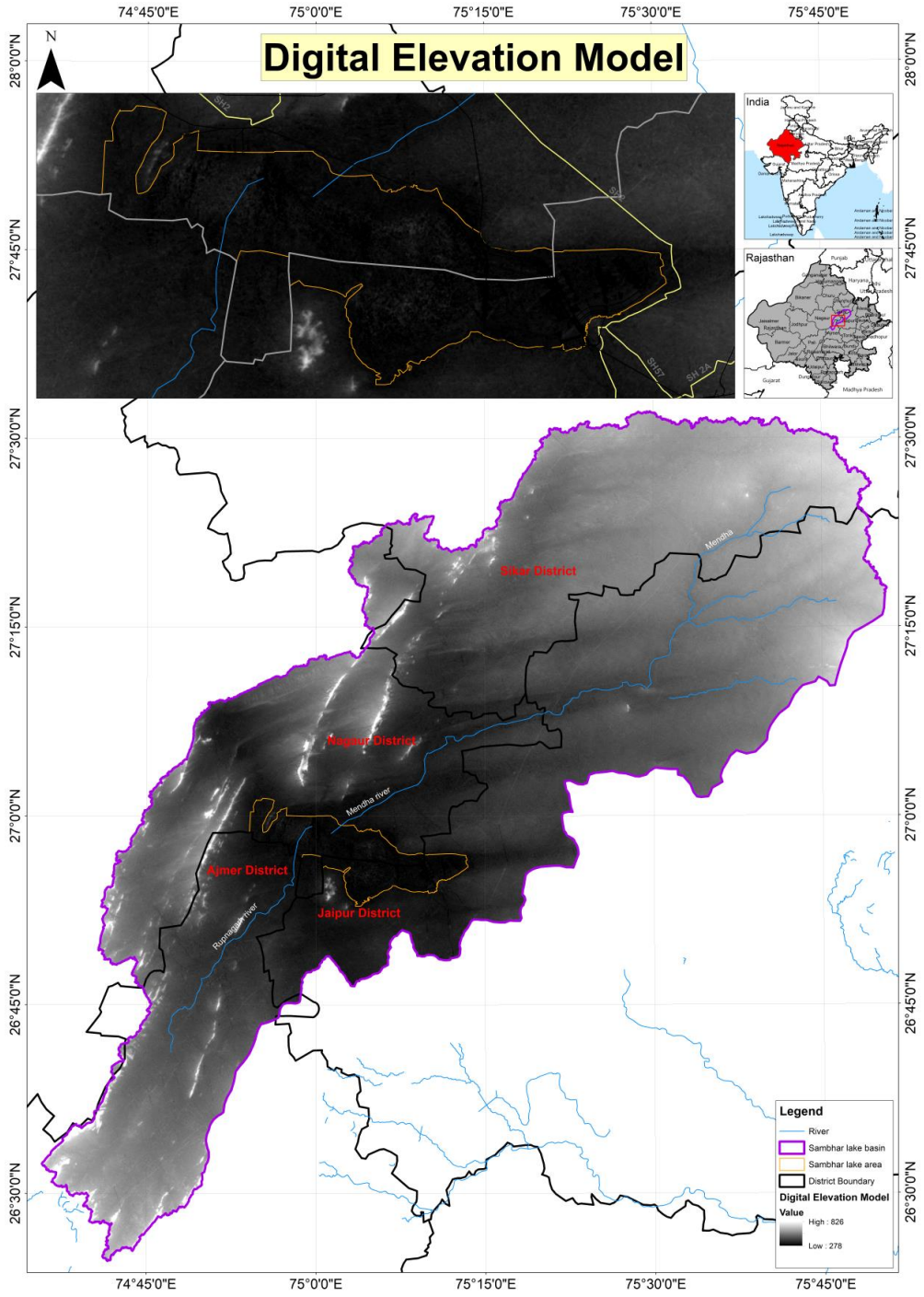


Figure 21: Digital Elevation Model (DEM) of catchment area of Sambhar lake

Source: Author

3.6. Catchment

The lake catchment is spread across four districts of Rajasthan namely Jaipur, Nagaur, Ajmer and Sikar close to the desert fringe line. The lake is spread across three districts namely Jaipur, Ajmer and Nagaur. To the northwest and west of the catchment, the Aravalli Ranges rises abruptly to a height exceeding 700 m in the

form of hillocks, scattered along northern and southern periphery of the lake. This largest playa is situated in the gaps of Aravalli hill range and occupies a depression in the Aravalli schist's, which is a gateway to the Thar Desert. Though most part of the lake lie in Jaipur and Nagaur districts and small part in Ajmer district, the lake shares the Thar characteristic of the desert (Fauna of Sambhar lake (Rajasthan) Wetland ecosystem series 6, 2005).

The Lake has a wide catchment area of about 5700 sq.km., and covers Jaipur, Nagaur, Ajmer district extending up to Sikar district. It was once fed by four ephemeral streams, Mendha, Rupangarh, Kharian and Khandel, besides the other rivulets and surface runoff.

River Mendha was the largest stream which fed the lake with water, originated in the Sikar district and ran southwest and west before entering the lake from the north. The river flowed over an area of about 3600 sq.km., and most of it was a sandy, undulating area, surrounded by residual Aravalli outcrops to the north, east and west. The catchment area is subjected to sand encroachment and to land transformation by agriculture activity. Various paleochannels lie submerged underneath the sand. For instance, in the last two decades some segments of the two major Mendha river tributaries, namely Anokhi and Ranoli have disappeared under the sand. The movement of sand thus plays significant role in the catchment, influencing runoff and flow of river entering the lake (Ashok Kumar Jain, 2005).

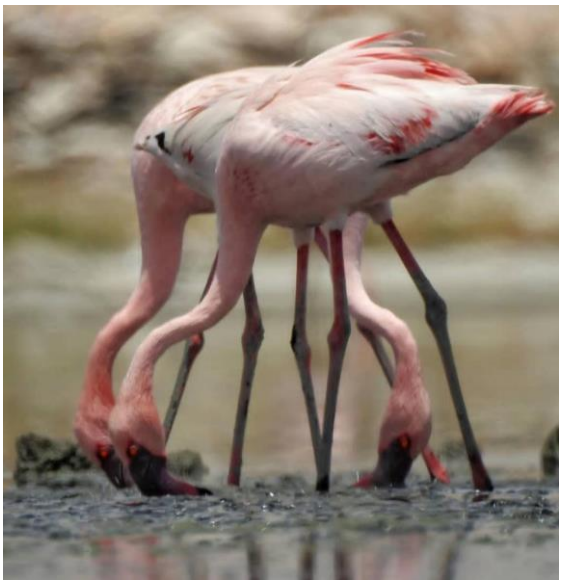
River Rupangarh also drained into the lake originated in the Aravalli near Ajmer city in the south and ran north to northwest to enter lake from south. This river spread over an area about 625 sq.km., which was mainly rocky. The other two i.e. the Kharian and the Khandel rivers were smaller streams and entered into lake from the northwest and east side of the lake basin respectively (Ashok Kumar Jain, 2005).

There were large numbers of wetlands in the whole catchment both brackish and freshwater. These were all scattered around the Sambhar Lake. due to less rainfall in the area small wetlands disappeared. Other than Sambhar Lake, Devyani tank, large pond near to Jhapok village and lake Phulera are the important wetlands. The sizes of these lakes range from few hectares to less than one hectare (Ashok Kumar Jain, 2005).

3.7. Biodiversity

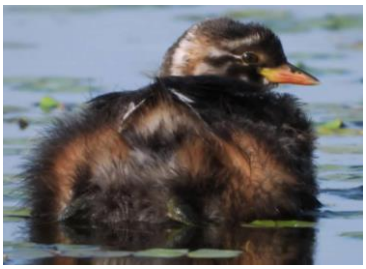
The catchment of Sambhar Lake has a variety of ecosystems, out of which the most important is the wetland ecosystem. Since the water is salty, at first instance it appears that a little number of organisms is there but the reality is that the lake includes a remarkable amount of bio diversities in nature. It comprises of a broad variety of benthic invertebrates, phytoplankton, zooplankton, waterfowl and fish (Ashok Kumar Jain, 2005).

There are different types of flora and fauna found around Sambhar lake. There are different types of reptiles, terrestrial birds, aquatic birds, mammals and livestock found (Dr. Seema Kulshreshtha and Devendra Kumar Bhardwaj, 2019). Figure 22 shows some of the migratory birds found during December 2019 primary survey.



Lesser Flamingo

Siberian chiffchaff



Little grebe

Eurasian collared dove

Long tailed shrike

Common coot with chicks

Bluethroat

Red wattled lapwing

Common pochard

Long tailed shrike

Bluethroat

Figure 22: Some of the migratory birds found during December 2019 site visit

Source: Bird expert Kishan Meena (Jaipur)

3.8. Vegetation

The naturaI vegetation present in the catchment area are northern tropicaI dry mixed deciduous forests and thorn forest. Most of the areas have typical nature of vegetation of arid and semi-arid nature. The hilly areas consist of mainly degraded Dhok (Anogeissus pendula) Salar (Boswellia serrata), Capparis sp. with some bushy vegetation. The plain area is dominated by Acacia nilotica, Acacia senegal, Salvadora persica etc. The nearby by area of rivers and streams having the sandy nature with good amount of moisture, the Dalbergia sissoo is the common tree (Ashok Kumar Jain, 2005). Other important species is the Azadirachta indica, Prosopis cineraria and Prosopis juliflora.

The degraded areas in the catchment and lake surrounding have major vegetation as the Prosopis juliflora. Yet in the saline condition the other species do not survive easily but the growth of Prosopis juliflora is in abundance. Even people use this as the fuel-wood. There are various kinds of grass, herb and shrub species found in the vicinity of Sambhar lake which have great medicinal advantages and these are also used as food for animals. There are various types of trees and agricultural species found in the vicinity of Sambhar lake (Dr. Seema Kulshreshtha and Devendra Kumar Bhardwaj, 2019).

3.9. Socio economic profile

The rural economy of the people in the whole catchment is based on agriculture production. Whereas in the vicinity of Sambhar lake most of the people are into the work of salt extraction from salts pans or in salt production industries. However, the scanty sweet water availability is the constraint for good agriculture. The Kharif crop is the main source of agriculture production. Eastern part of the catchment is comparatively better in agriculture production. Other source of economy is cattle resources and population of cattle is very high. Camel, goat, buffalo and sheep comprise major cattle population. This indicates grazing pressure in the catchment of lake. Surrounding area of the lake has pressure of salt extraction.

3.10. Tourism and film shooting

In terms of tourism in Sambhar lake people do visit the lake for bird watching and for staying there are no such better facilities so there are few visitors to the lake.

Bird watching happens during November to February as migratory birds arrive Sambhar lake during these months.

Due to the large scenic beauty this place has been noticed by some of the film makers for shooting some scenes and almost about 12 movie scenes have been shoot here like Jodha Akbar, Delhi-6, Veer, Gulaal, Highway, Drona, Zila Gaziabad, PK, Tevar, Goliyon ki Raasleela Ram-Leela, Super 30 and Bard of Blood. Some songs have also been shot here such as DJ wale babu, Car me music baja and Lahore.

3.11. Issues of Sambhar lake

There are various issues of Sambhar lake, which are loss of biodiversity due to less amount of surface water present in the lake; degradation of lake in term of quantity of surface water and quality of surface water; extinction of lake is happening as water is not present in the lake because of construction of anicuts and dams on the rivers which used to fed the lake with water and now the lake is now only fed by rainwater; workers who work in salt pans for their living face health related issues like joint pains, skin diseases, blood pressure rise, eye problems, bone deformities, rashes and waterborne diseases; over exploitation of resources; over extraction of ground water by the salt producers to extract more amount of salt for which they have dug borewells and tube wells and have been installed in a very large number almost more than 265 in number (as per Vinod Kapoor committee investigation report on illegal salt pans, presented on 20th April, 2010); encroachment of lake area all around the lake for making salt pans and construction of houses.

3.12. Degradation of Sambhar lake

Factors responsible for degradation of lake are of two scales: catchment and vicinity. At the catchment level the lake is getting degraded because of construction of anicuts and dams which is shown in Figure 23 which were built across ephemeral feeder streams through government initiatives for providing irrigation water to the agricultural fields. Thus, no water flow reaches the lake through these streams. The rivers on which these anicuts and dams have been made have dried up from past 40 years. As per locals, geologists, geographers and stakeholders these rivers have come to a situation that it is beyond repair and it cannot be

revived or done anything so that it can be brought back. This cannot also be brought back to the time when water was available in the river is also because of the land use and land cover change on banks of the rivers. Trees have been cut, land has become barren and also due to less amount of rainfall in the area. Over exploitation of surface water of rivers and ground water have led to drying up of rivers.

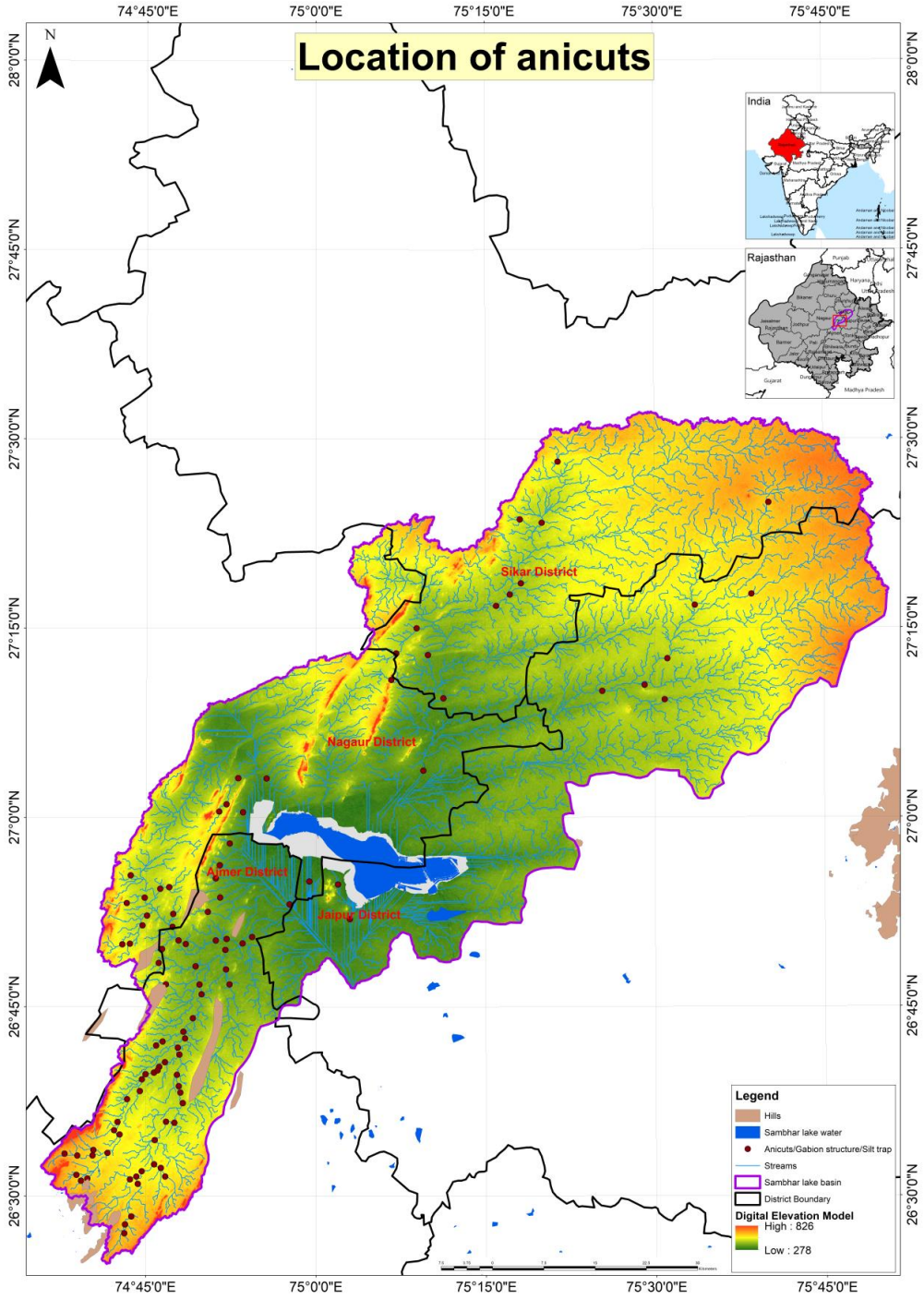


Figure 23: Location of anicuts in the catchment area of Sambhar lake
Source: Author and (Ritesh Vijay, 2016)

At the vicinity level the lake is getting degraded because of the anthropogenic activities which are happening. Anthropogenic activities which are happening at this level are over exploitation of whatever water which is left in the surface for extraction of salt, over exploitation of ground water by pumping out huge amounts of water for extraction of salt, digging of borewells and tube wells for extraction of salt, movement of vehicles on the lake bed where the bed has become dry, very few amount but dumping of solid waste at the edges of the lake, disposal of sewage and waste water of villages and towns into the edges of lake area, due to movement of vehicles as people use the dry part of the lake as a shortcut to commute between the villages and less amount of surface water present in the lake the number of migratory birds and other local birds have reduced to just few thousands which used to be tens of thousands in number in the past times and conversion of some parts of land around the lake for making salt pans.

These have led to degradation of Sambhar lake to an extent where the experts say that this lake would be no more within few years if these activities continue to increase. According to Central Ground Water Board (CGWB) report ground water extraction is largest threat on Sambhar. Road made between Nawa and Khakharki divided the natural portion of the lake into 2 parts which affected congregation of flamingos in winter.

Several articles have been published saying the “Lake will be no more” (news article of Times of India published on 18th January, 2018) or “Choked on salt” (article on Down of Earth magazine published on 4th July, 2015) or article saying “Is it worth the salt” (article on India water portal published on 12th December, 2012) or “Sambhar ka namak mang rha apna haq” (article on Patrika newspaper published on 29th November, 2018). Several PIL’s have also been filed against illegal borewell mafia and illegal encroachments around Sambhar lake. These PIL’s have been filed in the Supreme court and NGT by people.

Vinod Kapoor committee was also formed by the state government for looking into the matter of illegal borewells which was presented on 24th April, 2010. This committee had presented the locations where illegal borewells have been dug up, Table 5 shows the location and number of illegal borewells been dug, as per the committee this number is just approximate number and as per them this number

may be beyond 265 also. The committee also presented that many borewells were shut down, but people here are so unconcerned about lake's survival that they continued salt production by digging borewells in other locations. During site visit, few points were raised by different stakeholders such as, digging of borewells usually occur during night and wee hours, borewell digging has got political patronage and more number of illegal wells are present in Nagaur district.

Table 5: Location and number of illegal borewells dug

S.No.	Area	Number of borewells
1	Jabdi nagar lake area	13
2	From behind of Nawa police station to hills near Mohanpura	40
3	From Khardiya to phooti paal talab	10
4	In the way of bavli Gudha to hills of Jhak	15
5	In front of Aau turning point	10
6	Near and in front of chinai pillar of Aau	18
7	Near pits and canla of tibu of Aau	12
8	Near hut of Aau bavariya in lake	15
9	On the way of Aau	10
10	On the tibe inside the chinai pillar towards Sinodiya	22
11	In the lake area on the way to Sinodia	8
12	In front of hills of Mohanpura	10
13	In the lake area in front of Modi Salt near Mohanpura hills	17
14	Back to the old Khardiya railway station behind the hills of Mohanpura	15
15	In the main lake between Mohanpura and Aau	13
16	In the jungle of Khejadi	4
17	Khakhardi roadside lake area	8
	TOTAL	240

Source: Investigation report by Vinod Kapoor committee

3.13. Mass bird deaths at Sambhar lake

Sambhar lake is a wintering area for migratory birds and they used to come to lake in tens of thousands which have reduced to just a few thousands. Recently, between November 10 - 23, 2019 more than 18,000 of local birds died (Figure 25) because of the increase in the salinity content in the water. There has been no precedent for such an extent of mass bird deaths.

As per the report prepared by IVRI, Bareilly Avian Botulinum toxin caused the death of the local birds. This disease was caused by neurotoxin protein produced by a bacterium named clostridium leotulinum. This infection spread over a vast area of 65 sq.km. in Sambhar lake. Due to the intake on this toxin birds got paralysed within few seconds as they ate them and died within few minutes.

According to the report by IVRI it is stated that the most affected bird species were omnivore and insectivore and as per the locals and bird experts a greater number of local birds had died. In July 2019, the lake became brim-full with water due to heavy rainfall which reduced its salinity. As water evaporated and flowed into dry land, however, it raised the salinity there, particularly around the edges of the lake bed. Increasing salinity thus caused the death of certain birds at shores, which ate crustaceans and plankton and preferred to be restricted to the edges of the lake. Flamingos and several other migratory birds, which resided at the centre of the lake, however survived. The surface area of the lake degraded and this resulted in the increase in salinity content in water.

It was early in the month of November, 2019 that villagers and birdwatchers began to notice decomposed carcasses on the shores. The news soon hit the headlines. Until the middle of last week of November, 2019, more than 18,000 birds had been found dead in and around the lake.

As per bird experts, hundreds of carcasses of birds including plovers, common coot, black winged stilt, northern shovelers, ruddy shelduck, and pied avocet were found scattering at the edges of about 12-13 km of the lake's area. Figure 24 shows that during primary survey in December 2019, dead birds feathers was found floating on the edges of the lake.

Figure 24: Bird’s feathers floating on the lake in December 2019
Source: Primary survey

Figure 25: Mass bird deaths at Sambhar lake during November 10 - 23, 2019

Source: (India Today, 2018)

CHAPTER 4 DATA ANALYSIS

4.0. Causative factors leading to the degradation of lake

For assessing and analysing the causes of degradation of Sambhar lake a Leopold's matrix has been plotted (Table 6). It has been plotted taking developmental factors versus environmental characteristics of lake.

The developmental factors have been found from literature studies and from interviewing the locals, stakeholders and experts. These developmental factors are leading to the lake degradation and these are happening mainly in the vicinities of the lake.

From Leopold's matrix, it can be inferred that, among the detrimental developmental factors, sewage and waste water disposal stands at first position followed with salt pan expansion and the encroachment of buildings.

From Leopold's matrix, it can be inferred that, top three environmental characteristics of the lake which are affected adversely by the developmental factors are surface water quantity, surface water quality and biodiversity. The deterioration of water quality and reduction in quantity have led to the mass bird deaths in November 2019.

Table 6: Leopold's matrix for assessing and analysing the causes of degradation of Sambhar lake

Developmental factors ---------> / Env. Characteristics of lake	Encroachments	Construction of anicuts and dams	Salt pan expansion	Industries	Population growth	LULC change	Sewage and Waste water disposal	Movement of vehicles	Borewells in the lake bed	Total	
Surface water quantity	7/10	7/10	10/7	7/5	7/3	7/10	10/10	5/3	5/3	65/61	1st
Water quality	3/1	3/5	10/10	7/7	3/1	7/5	10/10	1/1	7/10	51/50	2nd
Biodiversity	5/7	1/7	7/5	1/1	5/7	5/7	7/7	7/7	7/1	45/49	3rd
Siltation	5/3	5/7	7/10	1/1	1/1	1/1	7/5	1/3	3/3	31/34	
Flora/Fauna	5/7	5/7	3/7	1/3	3/1	3/5	7/10	3/3	1/1	27/35	
Inlet/outlet	7/10	10/10	1/3	3/7	1/1	5/7	5/3	1/1	1/1	34/43	
Ground water level	5/1	1/3	7/7	3/3	1/1	1/1	3/7	1/1	10/10	31/37	
Total	37/39	32/49	45/49	23/27	21/15	29/36	49/52	19/19	34/29		
	3rd		2nd				1st				

Ranks	Very low	1
	Low	3
	Moderate	5
	High	7
	Very high	10

Impact magnitude / impact significance

Source: Author

4.1. Spatio temporal analysis of extent of lake

Land Use and Land Cover (LULC) changes over the last four decades (1990 - 2019) have been analysed to understand the spatio-temporal changes happened to the lake catchment. Starting year of analysis has been considered as 1990, because that was year in which Sambhar lake got the recognition as a Ramsar site, an internationally important wetland. All the images used for analysis across the decades were of the month of November (post-monsoon season).

The analysis has been done taking the Landsat imagery from USGS earth explorer. The Landsat imagery for November, 1990 is Landsat 4-5; Landsat imagery for November, 2000 is Landsat 7; Landsat imagery for November, 2010 is Landsat 4-5 and Landsat imagery for November, 2019 is Landsat 8. Sambhar lake comes under UTM zone 43N in the projected coordinate system.

The LULC change detection has been done by using supervised classification using software GIS that is ArcMap 10.2.2. Supervised classification is the most commonly used method for quantitative analysis of data by remote sensing of imageries. In this classification specifying of various spectral signatures or pixels values having same class is associated with each other is done. This process is done by selecting samples which represent type of land use and land cover and is done for classifying various land covers.

The LULC change detection has been done for the vicinity villages and towns and water body area so that the change in surface water quantity and extent of change of lake is analysed and the changes in vicinity LULC is analysed. Figure 26, Figure 27, Figure 28 and Figure 29 shows LULC change of years 1990, 2000, 2010 and 2019 respectively.

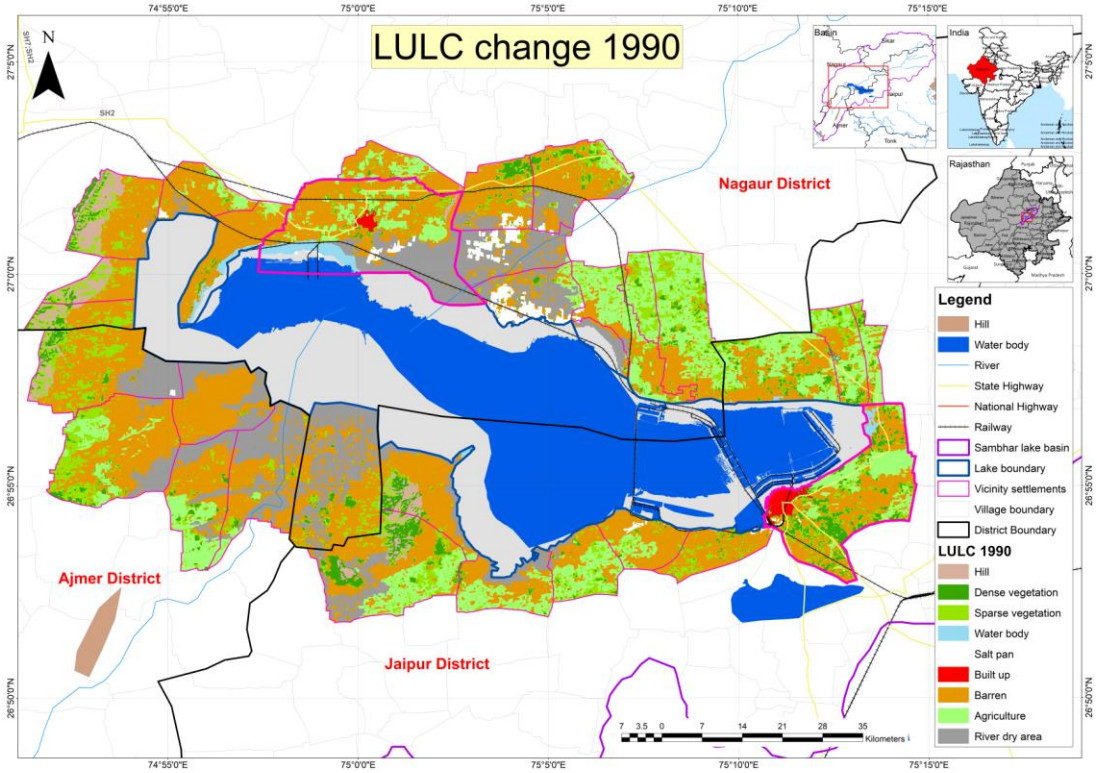


Figure 26: LULC change of year 1990

Source: Author

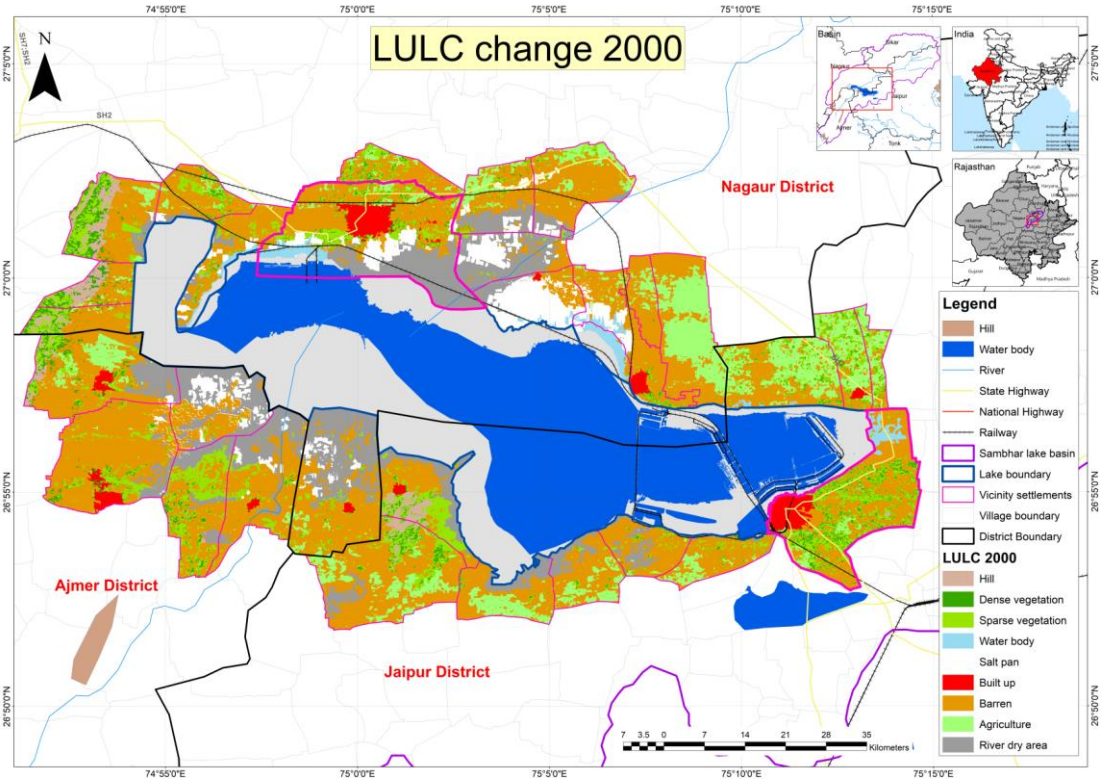


Figure 27: LULC change of year 2000

Source: Author

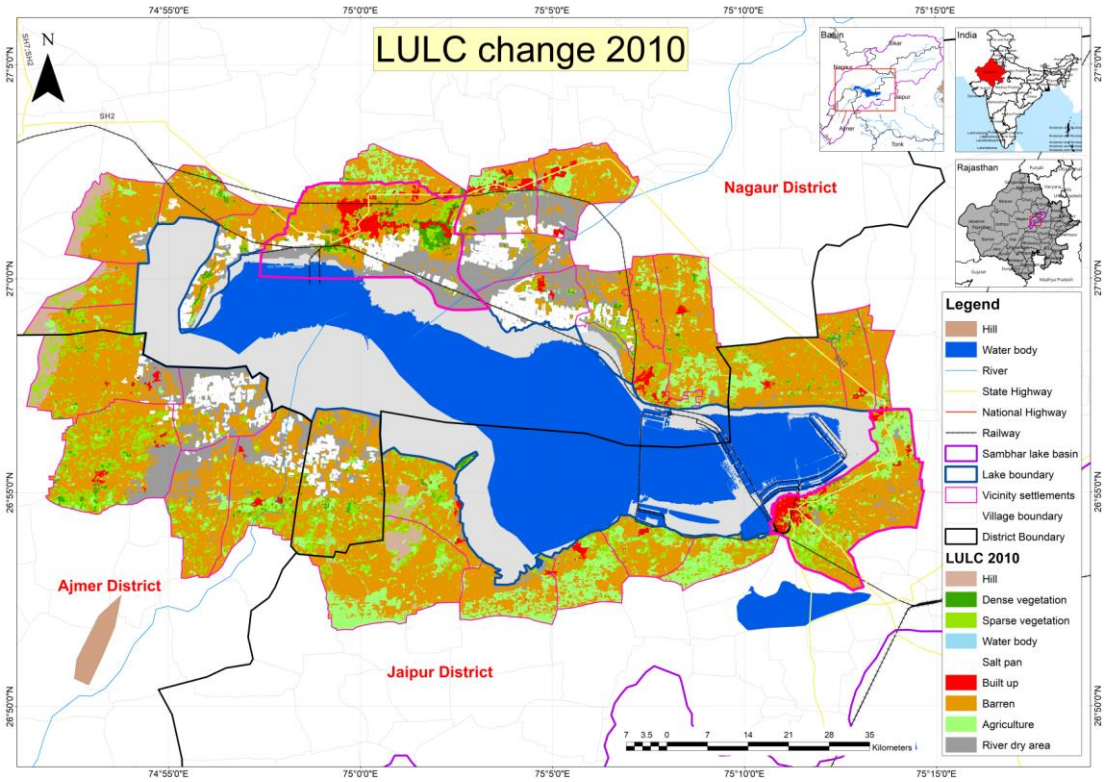


Figure 28: LULC change of year 2010

Source: Author

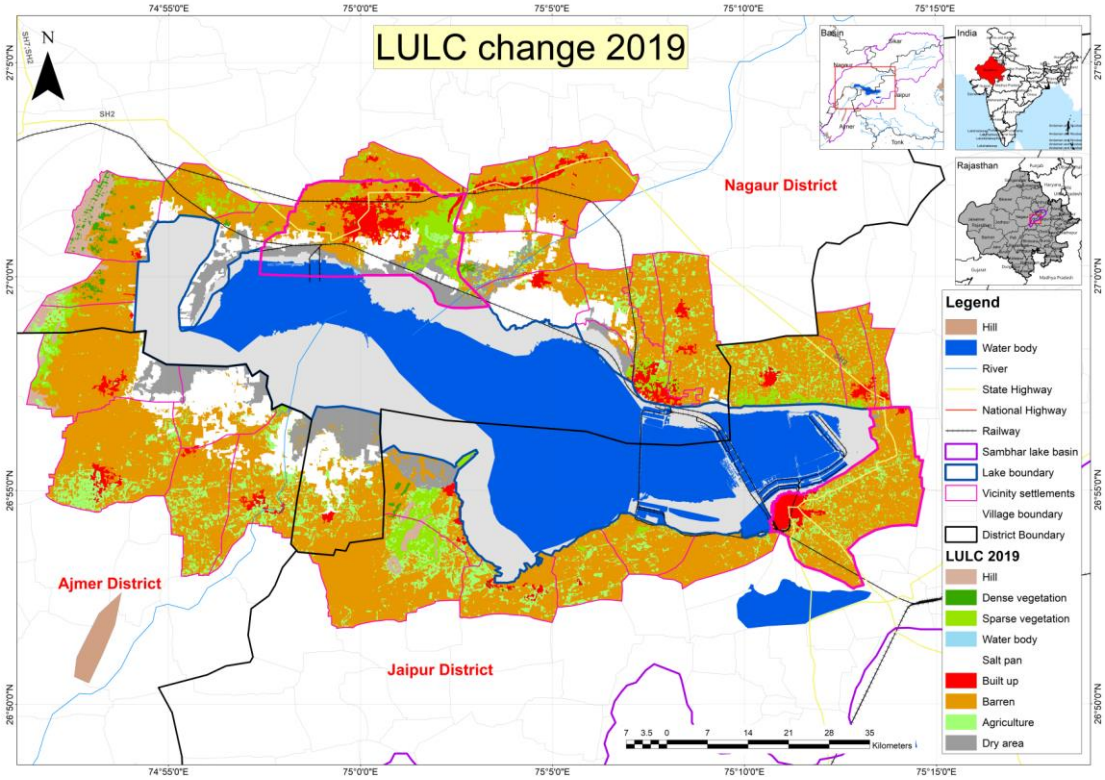


Figure 29: LULC change of year 2019

Source: Author

4.1.1. Analysis

From the Figure 30, Figure 31, Figure 32, and Figure 33 it can be seen that the percentage increase and decrease happened in the nine classes of LULC change and the classes are hill, dense vegetation, sparse vegetation, water body, salt pan, built up, barren land, agricultural land and dry area of Sambhar lake. From 1990 to 2019 area of hill decreased from 2% to 1%; area of dense vegetation decreased from 2% to almost 0%; area of sparse vegetation decrease from 8% to 3%; area of surface water of Sambhar lake decreased from 1990 (25%) to 2010 (15%) but it increased in 2019 (21%) due to heavy rainfall in July, 2019; area of salt pans increased from 5% to 11%; area of built-up increased from almost 0% to 3%; area of barren land increased from 30% to 40%; area of agricultural land decreased from 10% to 7% and the dry area of the lake bed increased from 1990 (18%) to 2010 (21%) but decreased in 2019 (14%) due to heavy rainfall in July, 2019.

Table 7 and Table 8 shows the amount of change in areas of LULC from year 1990 to 2019 and percentage of change in areas of LULC classes from year 1990 to 2019 respectively. In these tables minus sign indicates that there is decrease in areas and positive sign indicates that there is increase in areas.

From LULC change analysis it can be inferred that some of areas which were in dense vegetation got converted to sparse vegetation thus decreased the area of dense vegetation. Some of the areas which were previously in sparse vegetation got converted to barren land thus increased area of barren land. Some of areas which were in sparse vegetation and agricultural land got converted to built-up area thus decreased sparse vegetation and agricultural land. Surface water of Sambhar lake decreased because the ephemeral rivers which used to fed the lake has been stopped by constructing anicuts and dams and more usage of water by people for extracting salt also decreased the quantity of water. Decrease in surface water increased the dry area of lake bed to a great extent. Some of the agricultural land and dry area of lake bed got converted to salt pans area further causing change in these areas.

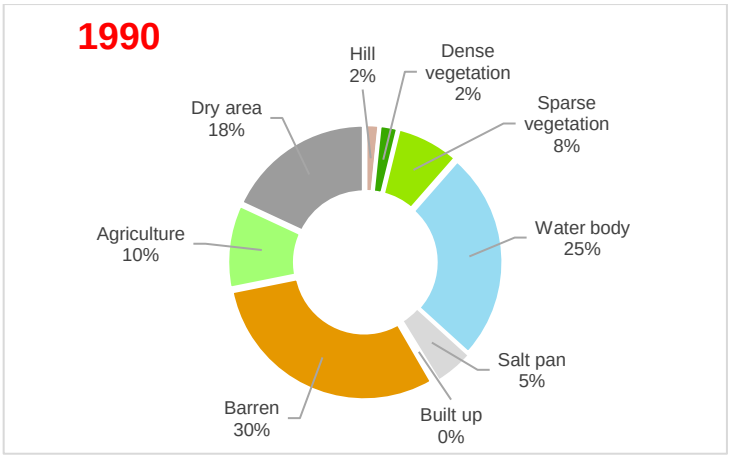


Figure 30: Pie of LULC change 1990

Source: Author

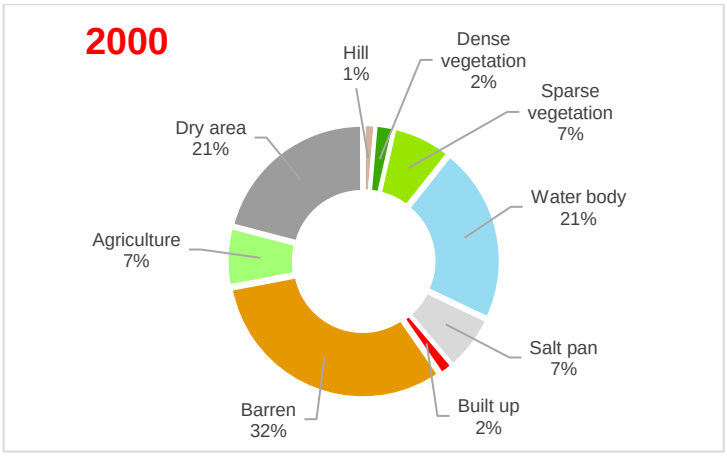


Figure 31: Pie of LULC change 2000

Source: Author

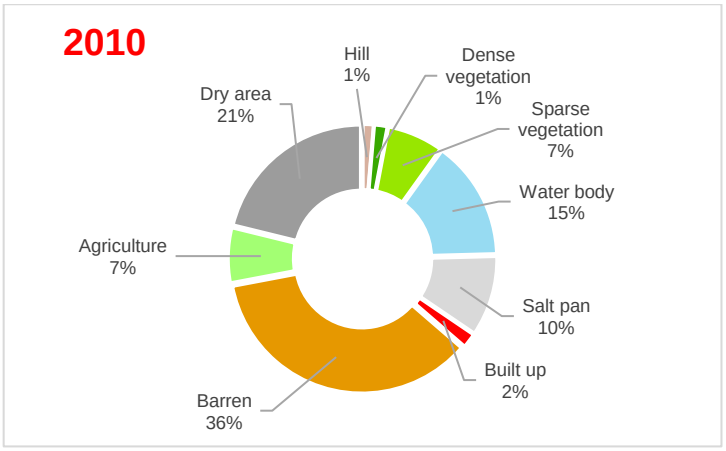


Figure 32: Pie of LULC change 2010

Source: Author

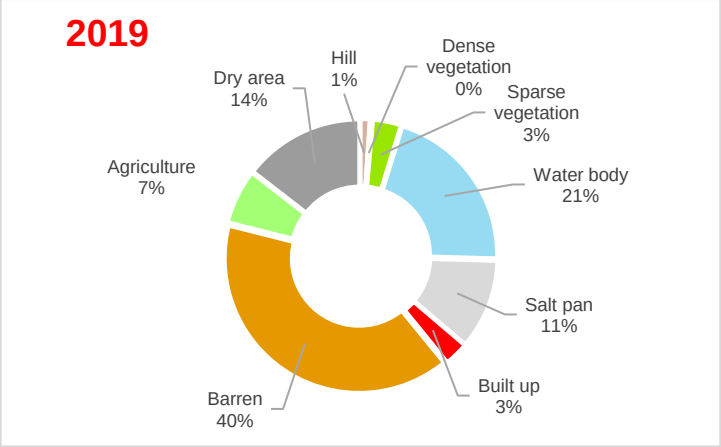


Figure 33: Pie of LULC change 2019

Source: Author

Table 7: Areas change of LULC from year 1990 to 2019

	1990	2000	2010	2019	Deacadal change in area (1990 to 2000)	Decadal change in area (2000 to 2010)	Decadal change in area (2010 to 2019)
Hill	9.17	7.65	7.50	6.06	-1.53	-0.14	-1.44
Dense vegetatio	12.17	12.13	9.15	1.94	-0.04	-2.98	-7.22
Sparse vegetatio	42.19	39.49	38.33	18.60	-2.70	-1.16	-19.73
Water body	140.39	118.66	81.41	114.59	-21.73	-37.24	33.18
Salt pan	24.84	37.36	55.02	59.89	12.51	17.66	4.87
Built up	2.31	8.92	10.30	16.06	6.60	1.39	5.76
Barren	167.74	175.53	198.04	220.97	7.79	22.52	22.93
Agriculture	55.94	39.19	37.82	36.40	-16.75	-1.37	-1.42
Dry area	100.31	116.17	117.49	80.57	15.86	1.32	-36.92

Source: Author

Table 8: Individual areas change of LULC classes from year 1990 to 2019

Hill		
Year	Shape_Area (Sq.km.)	% increase
1990	1.65	-
2000	1.38	-16.67
2010	1.35	-1.89
2019	1.09	-19.26

Dense vegetation		
Year	Shape_Area (Sq.km.)	% increase
1990	2.19	-
2000	2.19	-0.34
2010	1.65	-24.54
2019	0.35	-78.85

Sparse vegetation		
Year	Shape_Area (Sq.km.)	% increase
1990	7.60	-
2000	7.11	-6.41
2010	6.91	-2.93
2019	3.35	-51.47

Water body		
Year	Shape_Area (Sq.km.)	% increase
1990	25.29	-
2000	21.38	-15.48
2010	14.67	-31.39
2019	20.64	40.75

Salt pan		
Year	Shape_Area (Sq.km.)	% increase
1990	4.48	-
2000	6.73	50.35
2010	9.91	47.28
2019	10.79	8.85

Built up		
Year	Shape_Area (Sq.km.)	% increase
1990	0.42	-
2000	1.61	285.23
2010	1.86	15.55
2019	2.89	55.91

Barren		
Year	Shape_Area (Sq.km.)	% increase
1990	30.22	-
2000	31.62	4.64
2010	35.68	12.83
2019	39.81	11.58

Agriculture		
Year	Shape_Area (Sq.km.)	% increase
1990	10.08	-
2000	7.06	-29.94
2010	6.81	-3.49
2019	6.56	-3.75

Dry area		
Year	Shape_Area (Sq.km.)	% increase
1990	18.07	-
2000	20.93	15.81
2010	21.17	1.14
2019	14.52	-31.43

Source: Author

4.2. Settlements identification and their dependency on lake for its resources

There are a total of 32 settlements (Table 9) comprising of 30 villages and 2 towns in the vicinity of Sambhar lake. Figure 34 shows the villages and towns which are in the vicinity of Sambhar lake. In all the settlements they have direct dependency on the lake for its resources. The resources used by the settlements was grazing of animals on the banks of lake, cutting of dry trees and plantation for burning and using for fuel, drawing of water from lake for extraction of salt, very few amount but dumping of solid waste in the dry lake bed area, sewage and waste water of the towns and villages are being discharged into the lake bed, movement of vehicles over the dry lake bed also helps to commute from one place to another as it acts as a shortcut because the lake bed has become dry in most of the parts.

From year 1990 to 2019 built up area has increased and this also has put immense pressure on the lake resources as the situation has come where over exploitation of resources is happening and anthropogenic activities are increasing day by day.

There are 2 towns which are just adjacent to the lake and are putting pressure on the lake. Sewage and waste water of these towns are being discharged in the lake bed area which is creating pollution and the quality of water is deteriorating. For detailed study, one of the towns has been selected.

Table 10 shows the towns and their number of households, total population and areas that are in the vicinity of Sambhar lake.

Table 9: Number of settlements in the vicinity of lake

Number of settlements									
		In the catchment area				In the vicinity			
Districts	Tehsil	Villages	Census town	Town	Outgrowths	Villages	Census town	Town	Outgrowths
Jaipur	Shahpura	25	-	-	-	-	-	-	-
	Chomu	99	1	1	-	-	-	-	-
	Phulera	173	-	3	2	11	-	1	-
	Amber	68	-	-	-	-	-	-	-
Ajmer	Kishangarh	72	-	1	-	5	-	-	-
	Ajmer	41	1	-	-	-	-	-	-
Nagaur	Parbatsar	29	-	1	1	-	-	-	-
	Nawa	147	-	2	-	14	-	1	-
Sikar	Danta Ramgarh	153	3	-	-	-	-	-	-
	Sri Madhopur	110	1	2	-	-	-	-	-

Source: Census 2011 atlas of districts and tehsils

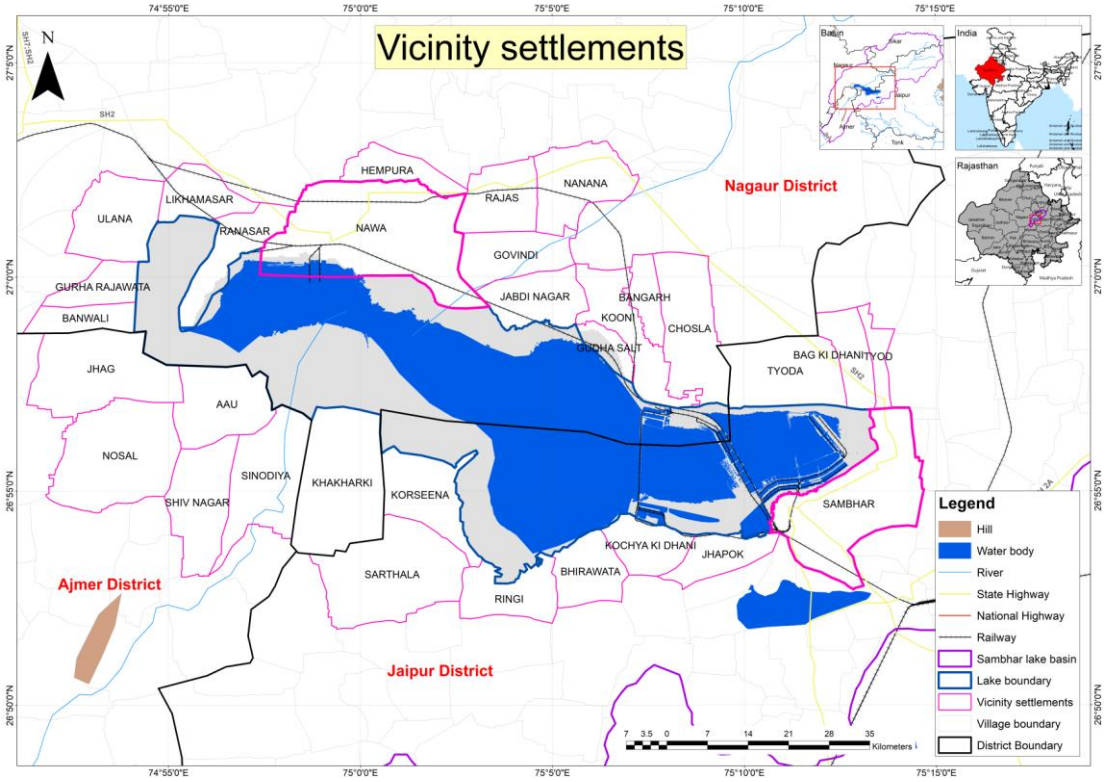


Figure 34: Settlements in the vicinity of Sambhar lake

Source: Author

Table 10: Settlements in the vicinity of Sambhar lake

District	Tehsil	Type	Name	Number of households	Total population	Area (Sq.km.)

Jaipur	Phulera (Hq. Sambhar)	Village	Ringi	133	841	8.72254
		Village	Sarthala	137	758	21.0988
		Town	Sambhar (M)	4003	22327	24.5205
		Village	Korsina	335	1930	10.8417
		Village	Bhirawata	125	789	7.85684
		Village	Kochya ki dhani	92	559	6.88084
		Village	Tyoda	539	3232	14.0906
		Village	Jhapok	74	484	6.36297
		Village	Bag ki dhani	88	631	6.51338
		Village	Tyod	321	1848	3.056
Ajmer	Kishangarh	Village	Sinodiya	310	1566	15.1877
		Village	Nosal	397	2240	20.9526
		Village	Aau	137	827	12.1638
		Village	Jhak	194	1067	18.3133
		Village	Shiv nagar	188	1084	12.6038
Nagaur	Nawa	Village	Rajas	262	1614	9.19698
		Village	Ulana	182	1185	12.0574
		Village	Ranasar	367	2320	9.13611
		Village	Hempura	205	1275	5.82458
		Village	Chosla	434	2290	14.967
		Village	Khakharki	355	2067	20.9721
		Village	Nanana	111	563	11.8599
		Town	Nawa (M)	3754	22088	33.3154
		Village	Govindi	377	2108	9.32351
		Village	Kooni	249	1448	10.7675
		Village	Banwali	148	911	5.05752
		Village	Gurha rajawata	126	623	5.16892
		Village	Likhamasar	130	772	6.81104
		Village	Jabdi nagar	284	1696	9.01479
		Village	Gudha salt	777	4370	3.1765
		Village	Bangarh	135	788	4.16202
Sambhar lake						195.113
Total area of vicinity						555.08964

Source: Census 2011 atlas of districts and tehsils and Author

4.3. Selection of detailed study area

For detailed study selection criteria are (Figure 35) –

- Area of town
- Sewage and waste water disposal

- Dumping of solid waste
- Location of mass bird deaths
- Water quality testing areas after bird deaths

By considering the above points for selection of detailed study area, the town selected was Nawa town which is situated at the North of Sambhar lake.

Nawa was selected for the detailed study area because it fulfilled all the points taken up for selection criteria for detailed study area. The area of Nawa town was found to be more than Sambhar town. From primary survey it was found that disposal of sewage and waste water was happening at the edge of the lake and very few amount of dumping of solid waste was also being done at the edge of the lake. The number of salt pans were more in number as compared to Sambar town, as, in Nawa town private salt producers have made more salt pans for salt extraction whereas in Sambhar town there were salt pans only owned by Sambhar salts limited (Sambhar salts limited is subsidiary company of Hindustan salts limited which is an enterprise of Government of India). The salt producers here have dug borewells illegally in this area for drawing ground water for extraction of salt as surface water of Sambhar lake was not available in that much quantity for which was required for extraction of salt. Birds which died in November, 2019 were more in number in this area and reason which was found for the bird deaths says that they died because of the dumping of sewage and wastewater from this area, so when heavy rainfall happened in July, 2019 the water got contaminated (water quality testing done after death of birds by Rajasthan State Pollution Control Board (RSPCB) Figure 36) as the slope is towards the lake and in that water Botulism toxin grew and mass birds died (Figure 37).

Figure 35: Showing areas of salt pans, sewage and waste water disposal, solid waste dumping and borewell
Source: Author

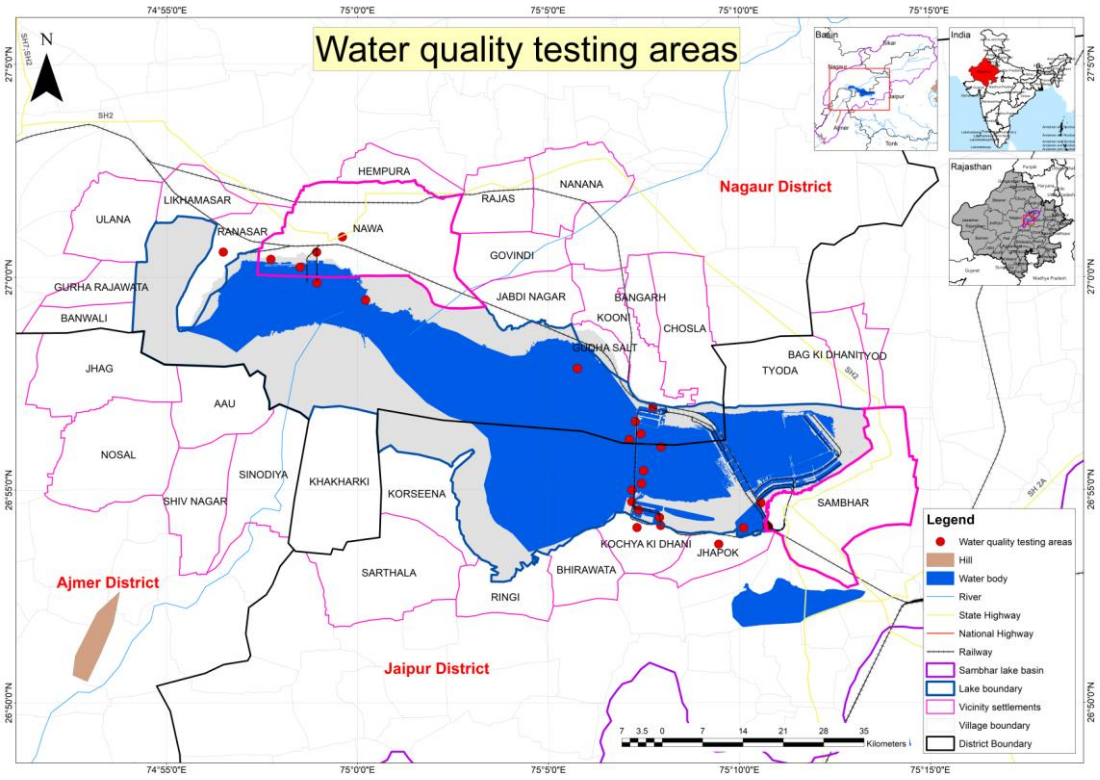


Figure 36: Water quality testing areas after death of birds

Source: Author

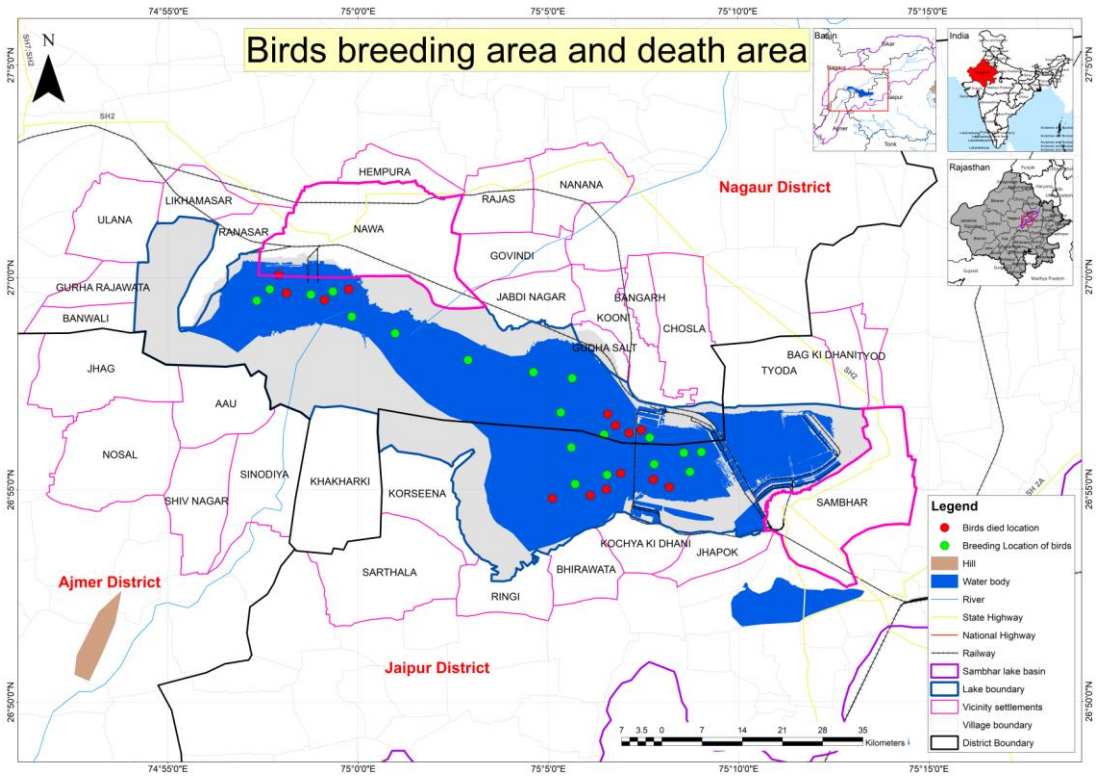


Figure 37: Location of migratory birds and other birds and location of were mass bird deaths happened

Source: Author

4.4. Analysis of detailed study area

Nawa town is located at the north of Sambhar lake. Population of Nawa town as per census 2011 is 22088 and the number of households are 3754. Though population and households are less in number but due to the presence of industries sewage and waste water of the area is more in quantity. The people here were majorly involved in extraction of salt. Many salt processing industries had come up in Nawa from the past 30 years.

4.4.1. Change in annual average rainfall

The annual average rainfall of the area is 474.14 mm. Rainfall data was taken from year 1980 to know the previous year's rainfall amount happened in the area. Figure 38 shows the average annual rainfall of the area from year 1980 to 2019, from the figure it was inferred that there is high fluctuation in the rainfall amount from year 1980 to 1996 and from the year 1996 the amount rainfall happened has decreased but in the year 2019 rainfall happened at a very good amount in comparison to previous years.

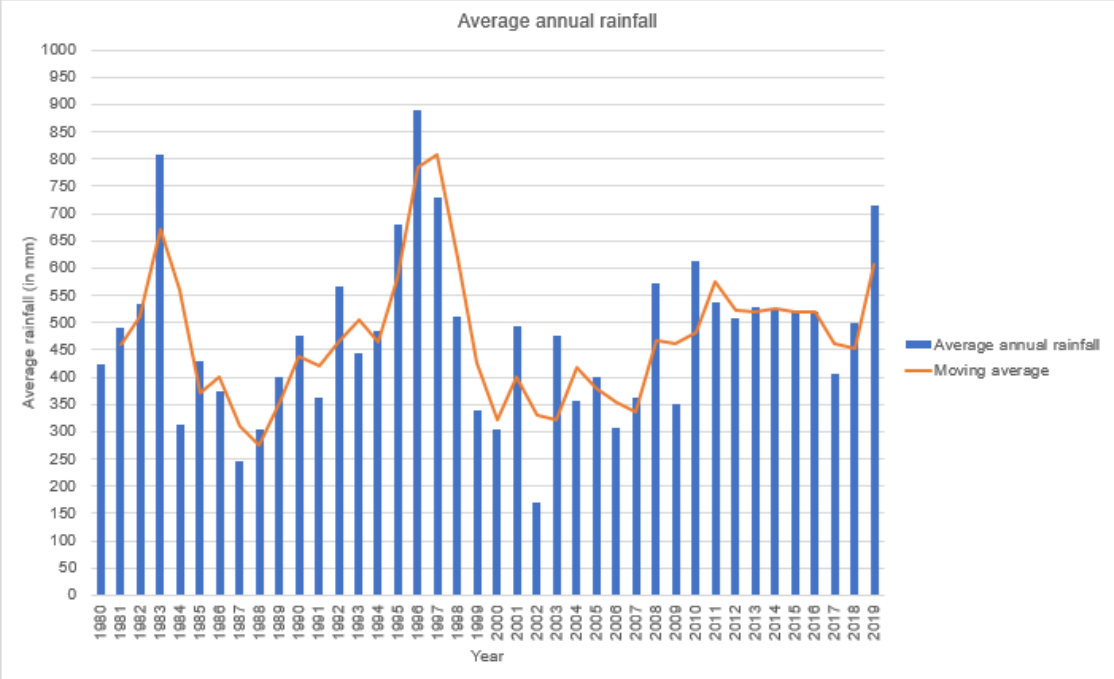


Figure 38: Annual average rainfall

Source: Indian Meteorological Department, Jaipur

4.4.2. Digging of borewells in the area

For the extraction of salt and producing more quantity, salt producers are digging borewells and tube wells in the area. The large amount of illegal borewells and

tube wells have been noted in this area as per Vinod Kapoor committee which was setup for investigation of illegal borewells. Table 11 shows the location and number of illegal borewells dug and it shows that maximum number are in Nawa town. From this it can be inferred that the level of decline in ground water is happening because of the over exploitation of ground water for the extraction of salt, as the private salt producers are extracting water from ground for salt extraction.

Table 11: Location and number of illegal borewells dug highlighting Nawa area

S.No.	Area	Number of borewells
1	Jabdi nagar lake area	13
2	From behind of Nawa police station to hills near Mohanpura	40
3	From Khardiya to phooti paal talab	10
4	In the way of bavli Gudha to hills of Jhak	15
5	In front of Aau turning point	10
6	Near and in front of chinai pillar of Aau	18
7	Near pits and canla of tibu of Aau	12
8	Near hut of Aau bavariya in lake	15
9	On the way of Aau	10
10	On the tibe inside the chinai pillar towards Sinodiya	22
11	In the lake area on the way to Sinodia	8
12	In front of hills of Mohanpura	10
13	In the lake area in front of Modi Salt near Mohanpura hills	17
14	Back to the old Khardiya railway station behind the hills of Mohanpura	15
15	In the main lake between Mohanpura and Aau	13
16	In the jungle of Khejadi	4
17	Khakhardi roadside lake area	8
	TOTAL	240

Source: Investigation report by Vinod Kapoor committee

4.4.3. Change in level of ground water

The ground water level of different areas in the catchment area is being monitored by CGWB for the months January, May, August and November on a regular basis. From CGWB the ground water levels available were from 1995 to 2019. Figure 39 shows that there has been decrease in the level of ground water from the year 1995 to 2000 to 2010 but has increased in 2019 in comparison to 2010 due to good

amount of rainfall. From the graph and Table 12 it was inferred that the level of ground water for the month of January from 1995 to 2019 decreased from 27.4 to 37.8 meter below ground level, level of ground water for the month of May from 1995 to 2019 decreased from 31.9 to 38.5 meter below ground level, level of ground water for the month of August from 1995 to 2019 decreased from 26.6 to 36.1 meter below ground level and level of ground water for the month of November from 1995 to 2019 decreased from 24.9 to 35.9 meter below ground level. The decrease in level of ground water shows that there is over withdrawal of ground water in the area and there are less of recharge of water in the ground.

Table 12: Level of ground water (meter below ground level)

Year	January	May	August	November
1995	27.4	31.9	26.6	24.9
2000	20.4	31.1	30.1	30.8
2010	44.4	42.9	44.9	44.3
2019	37.8	38.5	36.1	35.9

Source: CGWB, Jaipur

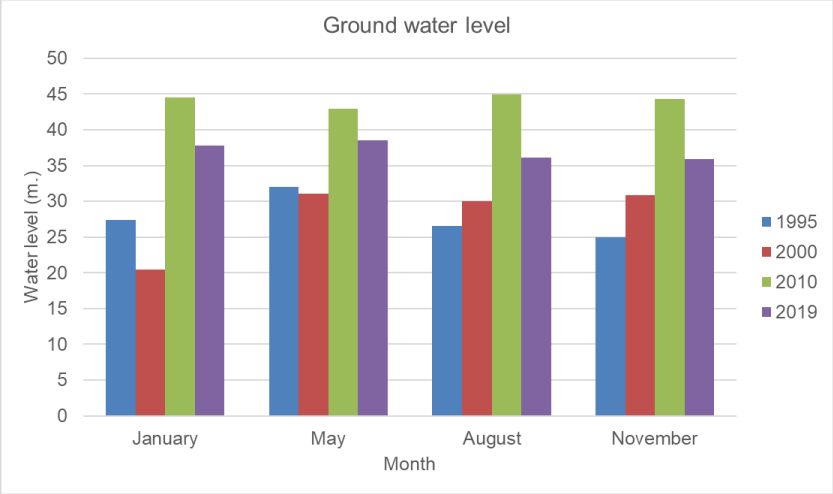


Figure 39: Ground water level of the area

Source: CGWB, Jaipur

4.4.4. Spatio temporal analysis of LULC change of Nawa town

LULC changes for Nawa town has been done for the same years as was done for the analysis of extent of lake LULC and all the steps was also same. Change in LULC of the area is also the main cause of degradation of lake. Figure 40, Figure 41, Figure 42 and Figure 43 shows LULC change of the town for years 1990, 2000, 2010 and 2019 respectively.

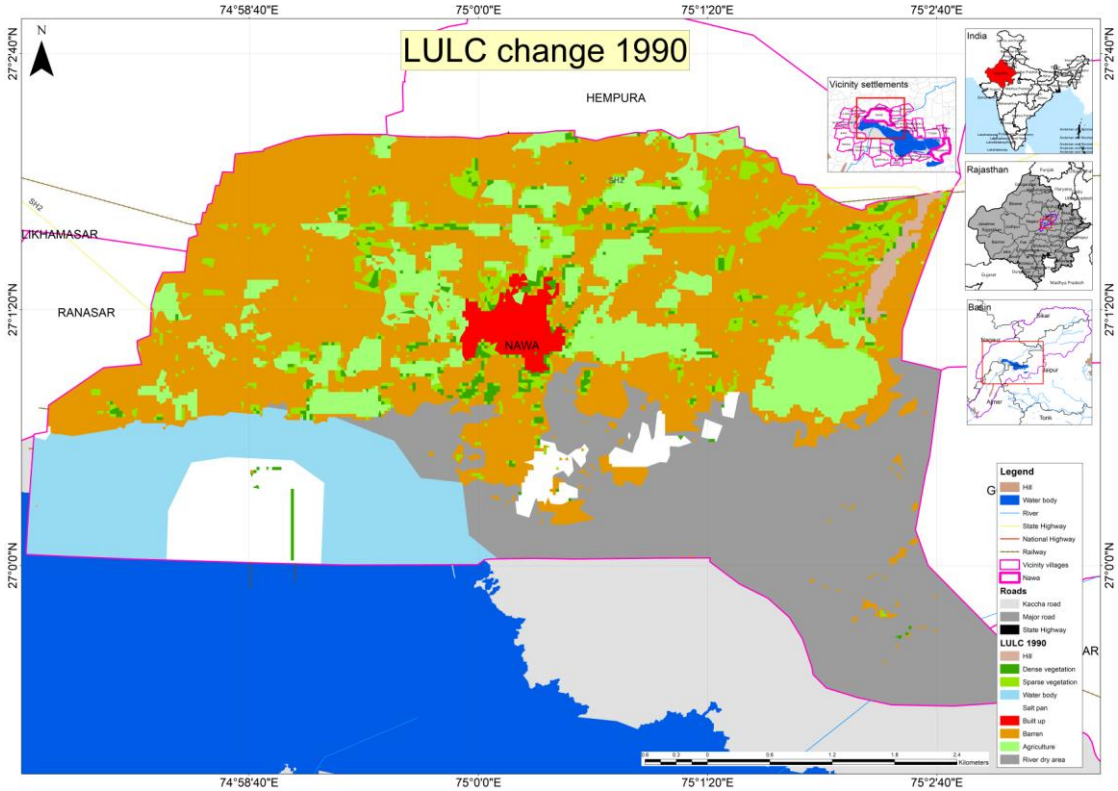


Figure 40: LULC change of Nawa (1990)

Source: Author

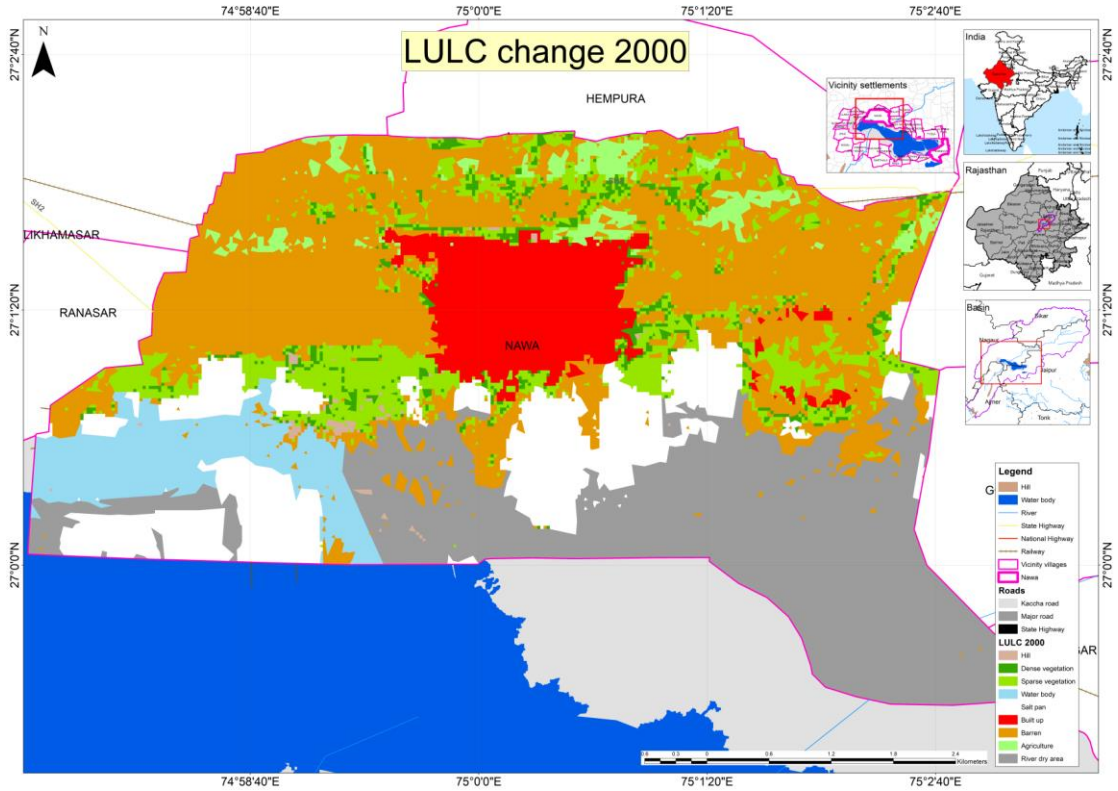


Figure 41: LULC change of Nawa (2000)

Source: Author

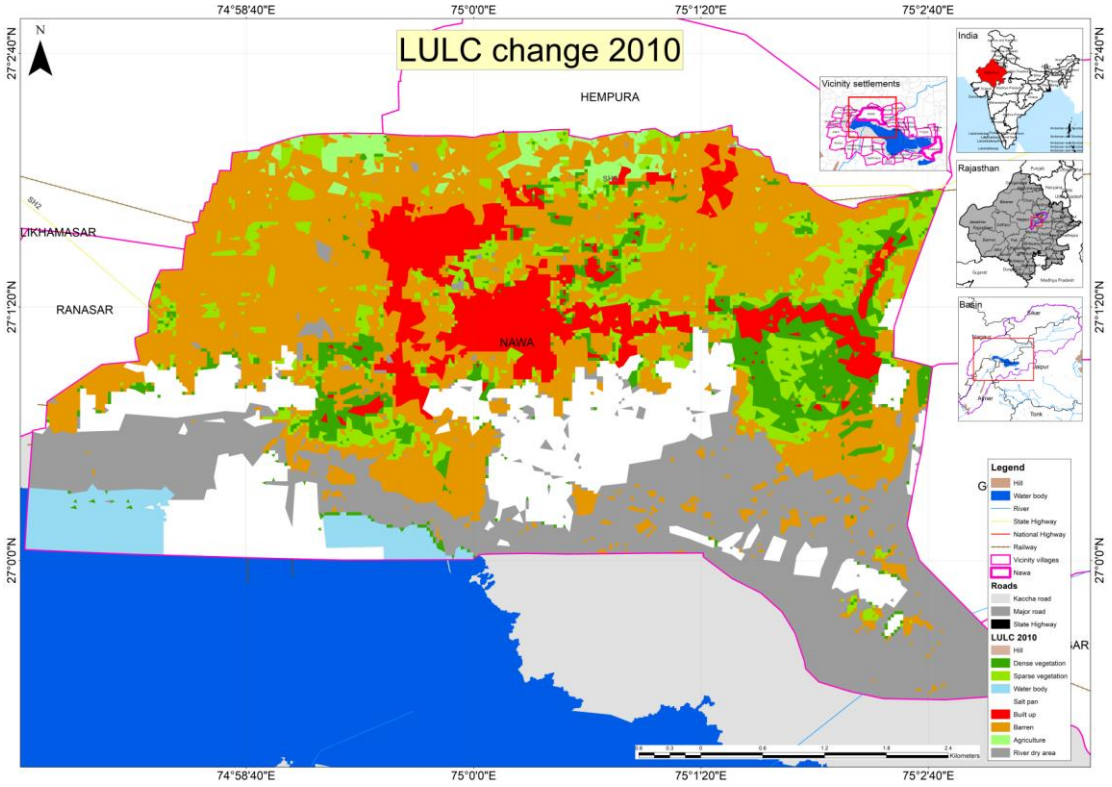


Figure 42: LULC change of Nawa (2010)

Source: Author

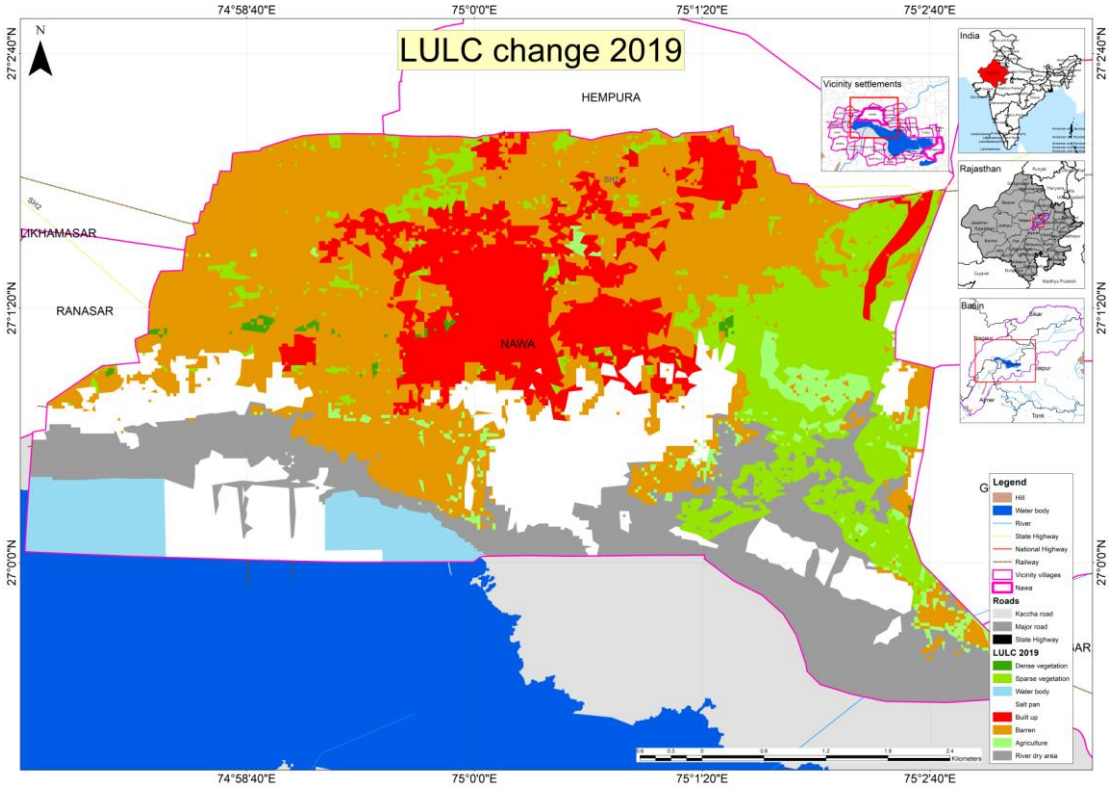


Figure 43: LULC change of Nawa (2019)

Source: Author

From the Figure 44, Figure 45, Figure 46 and Figure 47 it can be seen that the percentage increase and decrease happened in the nine classes of LULC change and the classes are hill, dense vegetation, sparse vegetation, water body, salt pan, built up, barren land, agricultural land and dry area of Sambhar lake. From 1990 to 2019 area of hill decreased from 1% to almost 0%; area of dense vegetation increased from 1990 (1%) to 2010 (6%) and then decreased majorly in 2019 (almost 0%); sparse vegetation area increased from 1990 (4%) to 2000 (9%) then decreased from 2000 (9%) to 2010 (8%) and again increased from 2010 (8%) to 2019 (13%); in the area of town area of surface water of Sambhar lake decreased from 12% to 5%; area of salt pans increased from 6% to 17%; area of built-up increased from 2% to 14%; area of barren land decreased from 1990 (38%) to 2000 (32%) then increased from 2000 (32%) to 2010 (34%) and then again decreased from 2010 (34%) to 2019 (33%); area of agricultural land decreased from 11% to 2% and the dry area of the lake bed decreased from 25% to 16%.

Table 13 and Table 14 shows the amount of change in areas of LULC from year 1990 to 2019 and percentage of change in areas of LULC classes from year 1990 to 2019 respectively. In these tables minus sign indicates that there was decrease in areas and positive sign indicates that there was increase in areas.

From LULC change analysis it can be inferred that some of areas which were in dense vegetation got converted to sparse vegetation thus decreased the area of dense vegetation. Some of areas which were in agricultural land and barren land got converted to built-up area thus decreased agricultural land and barren land. Surface water of Sambhar lake decreased because the ephemeral rivers which used to fed the lake has been stopped by constructing anicuts and dams and more usage of water by people for extracting salt also decreased the quantity of water. Decrease in surface water increased the dry area of lake bed to a great extent. But then these dry areas were converted to salt pans and thus increased the salt pans area. Some of the agricultural land also got converted to salt pans area further causing change in these areas.

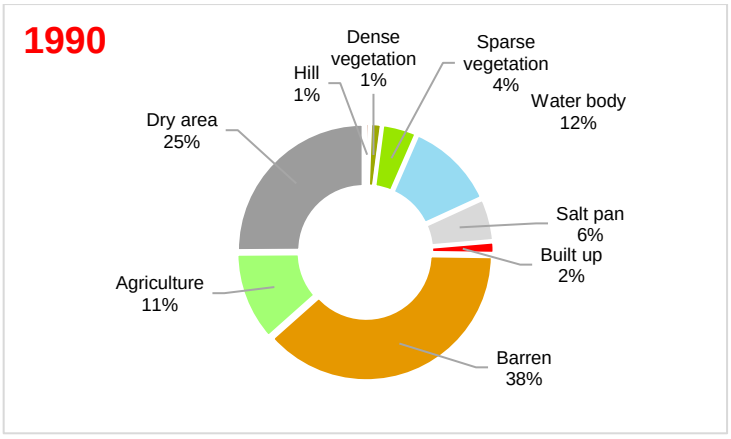


Figure 44: Pie of LULC change 1990

Source: Author

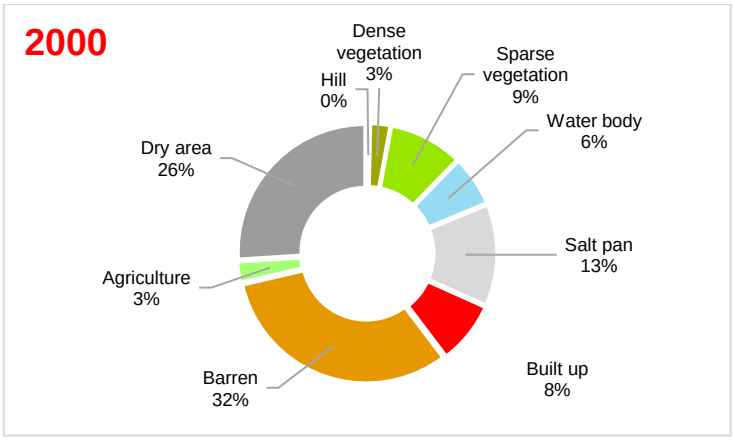


Figure 45: Pie of LULC change 2000

Source: Author

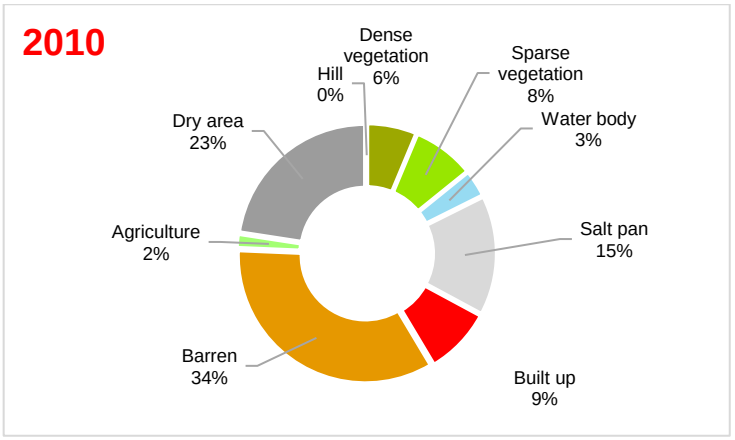


Figure 46: Pie of LULC change 2010

Source: Author

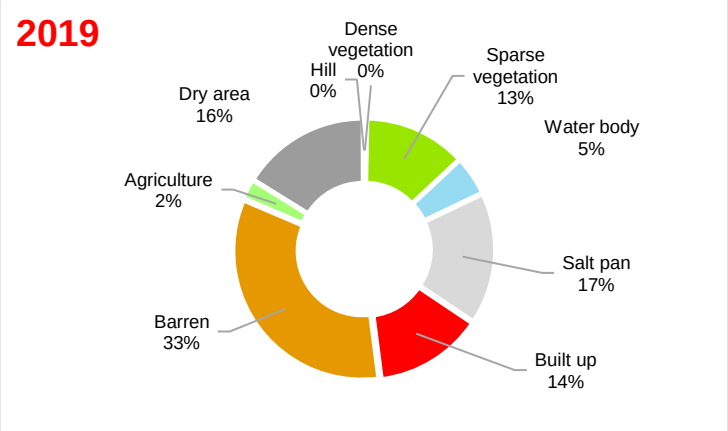


Figure 47: Pie of LULC change 2019

Source: Author

Table 13: Areas change of LULC from year 1990 to 2019

	1990	2000	2010	2019	Deacadal change in area (1990 to 2000) (Sq.km.)	Decadal change in area (2000 to 2010) (Sq.km.)	Decadal change in area (2010 to 2019) (Sq.km.)
Hill	0.193955	0.1188	0.00065	0	-0.07516	-0.11815	-0.000645
Dense vegetation	0.494864	0.8464	2.09997	0.09732	0.351556	1.253551	-2.002647
Sparse vegetation	1.492276	3.1309	2.6258	4.24366	1.638656	-0.505128	1.617852
Water body	3.866036	2.1445	1.1499	1.62814	-1.721582	-0.994553	0.478243
Salt pan	1.834468	4.3195	5.07214	5.49495	2.485058	0.752615	0.422806
Built up	0.519665	2.6616	2.85454	4.51309	2.141895	0.19298	1.658546
Barren	12.732914	10.55	11.4071	11.1456	-2.183074	0.857266	-0.261552
Agriculture	3.823426	0.8874	0.58392	0.80942	-2.936016	-0.303493	0.225505
Dry area	8.357726	8.6562	7.52129	5.38312	0.298432	-1.134873	-2.138164

Source: Author

Table 14: Individual areas change of LULC classes from year 1990 to 2019

Hill		
Year	Shape Area (Sq.km.)	% increase
1990	0.193955	-
2000	0.118795	-38.75126
2010	0.000645	-99.45705
2019	0	-100

Dense vegetation		
Year	Shape Area (Sq.km.)	% increase
1990	0.494864	-
2000	0.84642	71.04093
2010	2.099971	148.1004
2019	0.097324	-95.36546

Sparse vegetation		
Year	Shape Area (Sq.km.)	% increase
1990	1.492276	-
2000	3.130932	109.8092
2010	2.625804	-16.13347
2019	4.243656	61.61359

Water body		
Year	Shape Area (Sq.km.)	% increase
1990	3.866036	-
2000	2.144454	-44.53094
2010	1.149901	-46.37791
2019	1.628144	41.58993

Salt pan		
Year	Shape Area (Sq.km.)	% increase
1990	1.834468	-
2000	4.319526	135.4648
2010	5.072141	17.42356
2019	5.494947	8.335849

Built up		
Year	Shape Area (Sq.km.)	% increase
1990	0.519665	-
2000	2.66156	412.1684
2010	2.85454	7.250635
2019	4.513086	58.10204

Barren		
Year	Shape Area (Sq.km.)	% increase
1990	12.732914	-
2000	10.54984	-17.14512
2010	11.407106	8.125867
2019	11.145554	-2.292887

Agriculture		
Year	Shape Area (Sq.km.)	% increase
1990	3.823426	-
2000	0.88741	-76.79019
2010	0.583917	-34.19986
2019	0.809422	38.61936

Dry area		
Year	Shape Area (Sq.km.)	% increase
1990	8.357726	-
2000	8.656158	3.570732
2010	7.521285	-13.11059
2019	5.383121	-28.42817

Source: Author

4.4.5. Sewage and waste water disposal in the area

For the detailed analysis of Nawa town land use map (Figure 48) has been made for knowing the flow of sewage and waste water into the edge of lake bed. In the town salt producing industries were found in huge numbers that is 50 salt producing industries. Disposal of sewage and waste water are majorly from households and salt producing industries. The quality of water as per RSPCB was very contaminated. The water quality tests were done after the death of birds in the area near Nawa town. Previously in Figure 36 and Figure 37 it has also been shown. These figures show the areas were testing of water quality was done and the areas were mass bird deaths happened. As per locals, govt. officials and the experts, number of salt pans in Nawa town has increased from 1990 till date (can also be seen from spatio temporal change done previously) and sewage and waste water disposal from there has led to rapid deterioration of lake water quality.

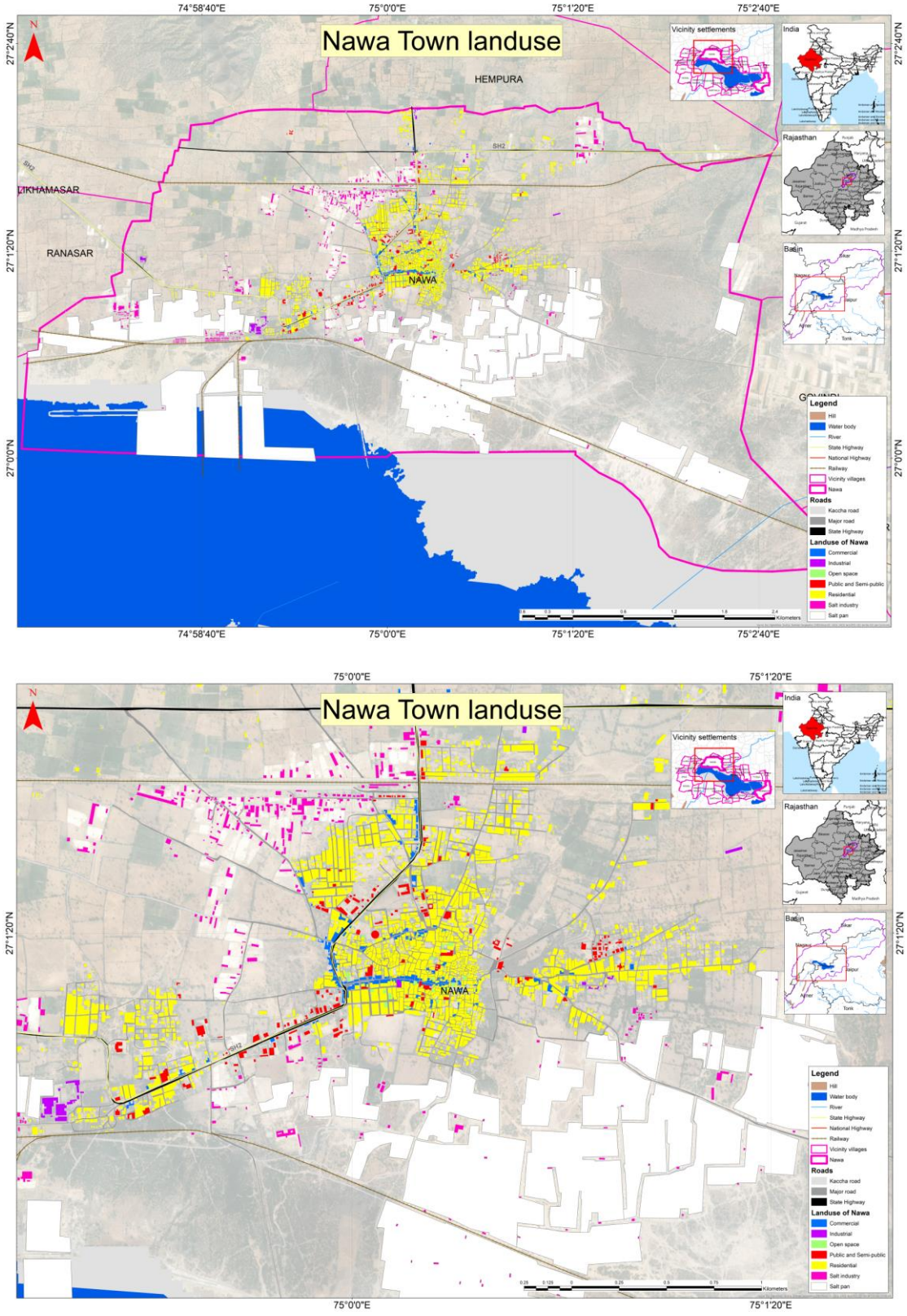
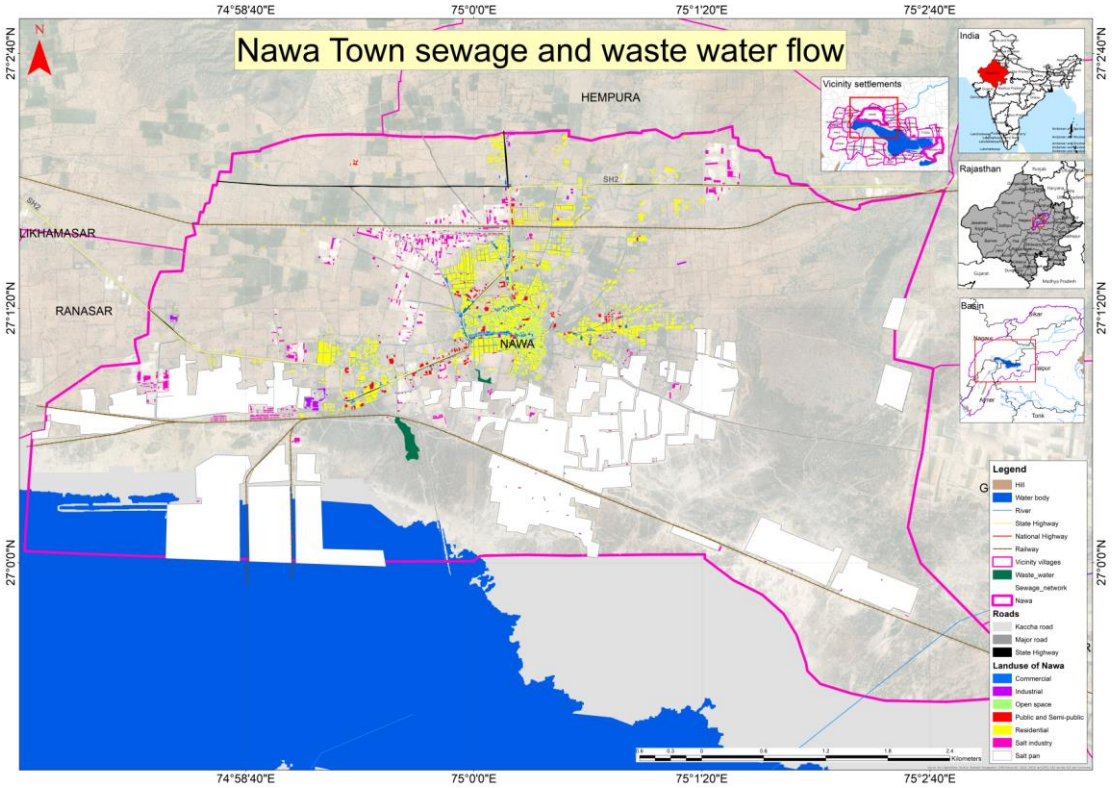


Figure 48: Nawa town land use map

Source: Author

The sewage and waste water disposal from Nawa town has been shown in Figure 49. From which, it was found clear that it was happening in the dried-up part of the

lake that is at the edge of the lake bed. Thus, when rainfall happens, as the slope is towards the portion of lake having water, this sewage and waste water flows into it resulting in its contamination. Very few amount but dumping of solid waste at the edge of the lake bed also happens creating contamination in the quality of water of lake.



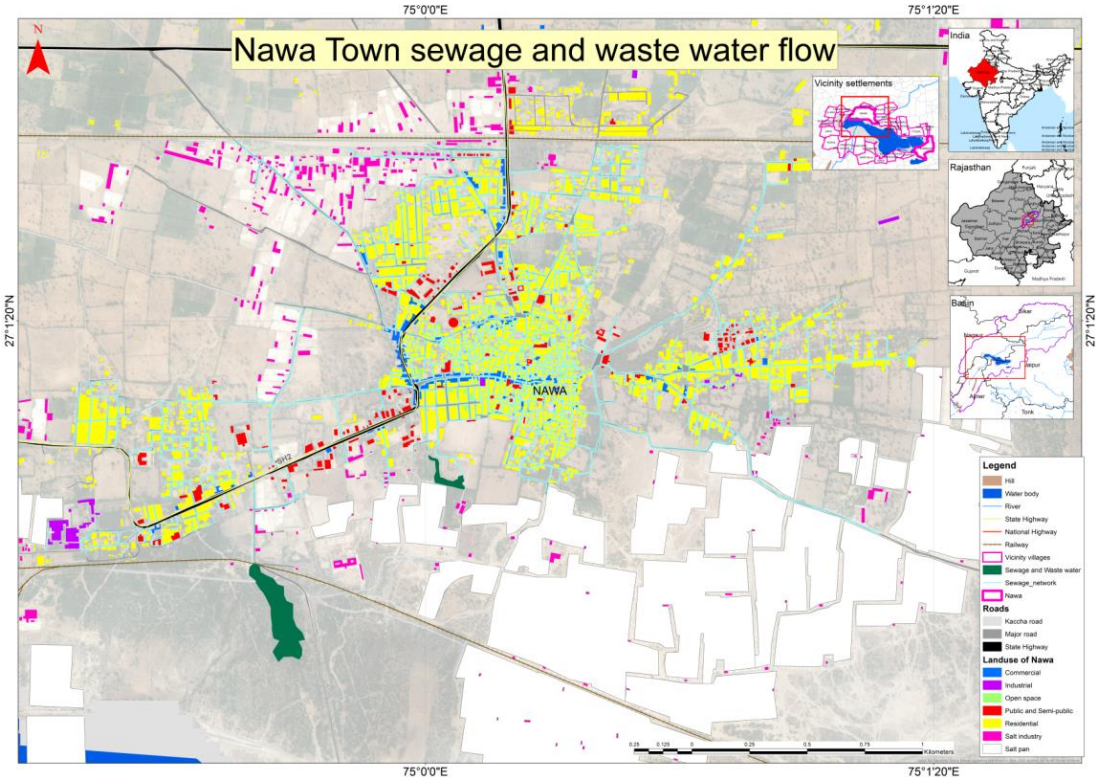


Figure 49: Sewage and waste water flow of Nawa town

Source: Author

Amount of sewage and waste water being disposed into the edge of lake bed –

For calculating the amount of sewage and waste water of area, type of land use is to be known as different type of land use dispose different amount of sewage and waste water at a time. Type of land use in Nawa town are residential, indurtrial (salt producing industry), salt pans, commercial and public & semi-public.

For calculating domestic sewage and waste water disposal amount population of the area is to be known. So, as per census, 2011 population of Nawa town is 22088 and as per the master plan made for the town from 2010-2031, population proposed is to be 47690 which have been calculated considering census, 2001 as the base year. So, domestic sewage flow –

Average sewage flow = 80% of water consumption

= 80/100 * 135 litres per person per day

Average sewage flow = 108 litres per person per day

Maximum daily flow = 2.5 * 108 * 47690

(where, 2.5 is peak factor as per CPHEEO, 2012)

= 1,28,76,300 litres per day

Maximum daily flow = 12.88 MLD

Industrial waste water flow –

There are almost 50 salt producing industry and approximately each produce 26898 litres per day. So, 50 * 26898 litres per day

= 1344900 litres per day

= 1.34 MLD

Waste water discharged from other public spaces = 0.12 MLD

Total sewage disposal (per day) = Domestic sewage flow + Industrial waste water flow + water discharged from public spaces

= 12.88 + 1.34 + 0.12

Total sewage disposal (per day) = 14.34 MLD

4.4.6. Water budgeting

Water budgeting was done to know the requirement of water required for filling up of lake to its fullest. Table 15 and Table 16 shows salient features of Sambhar lake and water budgeting for Sambhar lake respectively.

Table 15: Salient features of Sambhar lake

Salient features of Sambhar lake	
Features	Sambhar lake
Water spread area	190000000 sq.m.
Maximum depth	3 m
Average depth	0.6 m
Water storage capacity	114000000 cu.m.
Catchment area of lake	5700 sq.km.
Source of water	Rainfed and earlier it used to also happen by ephemeral rivers
Pollution sources	Salt pans, Sewage inflow some parts, Solid waste dumping at some parts, Vehicle movement

Environmental pressures	Anthropogenic activities

Source: Author

Table 16: Water budgeting

Water budgeting	
Components	Sambhar lake
Average rainfall	474.14 mm
Total rain water received	2702.589 million cu.m.
Water storage capacity	114000000 cu.m.
Water demand	114000000 cu.m.
Innovative Assessment (Water losses)	
Percolation	15% = 405.38835 million cu.m.
Evaporation	10% = 270.2589 million cu.m.
Absorption in soil strata	5% = 135.12945 million cu.m.
Net water availability	
Rain water	2702.589 million cu.m.
Water losses	810.7767 million cu.m.
Water availability for recharging	1891.8123 million cu.m.
Net water requirement	114 million cu.m.

Source: Author

CHAPTER 5 PROPOSAL OF STRATEGIES FOR CONSERVATION

Sambhar lake is one of its kind in the country and it is degrading very fast. The lake needs to be conserved and should be paid much more attention as it is the country's largest inland salt water lake. Some conservation strategies that has been taken up here are strategy for detailed study area and some policy level interventions for the conservation of lake.

5.0. Proposal of strategy for detailed study area

Proposal of strategy for detailed study area Nawa town is, providing a sewage treatment plant for the town so that sewage and waste water disposal is not done directly to the lake edge and needs to be treated before it goes to the lake. Due to the disposal of sewage and waste water the lake water quality has degraded to a limit that it has caused death to thousands of birds. As per the calculations done in the analysis part for sewage and waste water disposal amount it has come out to be such that the sewage treatment plant should be big enough so that it can treat 14.34 MLD of sewage and waste water on a daily basis which would run till year 2031 as master plan made for Nawa town is for 2010-2031.

Physical, chemical, and biological processes are used for removing pollutants and producing treated wastewater (or treated effluent) that is safe enough for release into the environment. A sewage treatment by-product is a semi-solid waste or slurry, called sewage sludge. Before being suitable for disposal or transfer to land, the sludge must undergo further treatment (CPHEEO, 2013).

As per CPHEEO, 2013 manual on sewerage and sewage treatment systems there are two types of treatment processes –

a) Primary treatment process

b) Secondary treatment process

The physical activities used to implement the processes are called unit operations. For example, the physical processes of screening, grit (sand) and suspended solids being settled out are together referred to as primary treatment. The

metabolic process is called secondary treatment. CPHEEO, 2013 manual has described biological treatment technologies for treatment of sewage –

a) Activated Sludge Process
b) Attached Growth Systems
c) Treatment Methods using lmmobilization Carrier
d) Treatment through stabilization Ponds
e) Anaerobic Treatment of Sewage

The manual also has described various recent technologies which have come up in treatment of sewage –

a) Recycled Nitrification / Denitrification Process
b) Wuhrmann Process
c) Step-feed Multistage Biological Nitrogen Removal Process
d) Anaerobic-oxic Activated Sludge Process
e) Bardenpho Process
f) Anaerobic-anoxic-oxic (A2O) Process (BioIogicaI Nitrogen and Phosphorus RemovaI Process)
g) Membrane Filtration
h) Membrane Bioreactor (MBR)
i) Sequencing Batch Reactors (SBR)
j) Moving Bed BiofiIm Reactors (MBBR)
k) Fixed Bed BiofiIm Activated SIudge Process
l) Submerged Immobilized Biofilm Technology
m) BlOFOR TechnoIogy (BioIogicaI FiItration and Oxygenated Reactor)
n) High Rate Activated SIudge BlOFOR-F TechnoIogy
o) Submerged Aeration Fixed FiIm (SAFF) TechnoIogy

p) Rim Flow Sludge Suction Clarifiers

q) Improved Circular Secondary Clarifier (HYDROPLUME®) CSIR-NEERI

Figure 50 shows the area where treatment plant would be proposed for Nawa town. Proposed location for treatment plant is southwest part of the town where there are salt pans and very less of residential and other land uses situated. Area required for the treatment plant range from 0.2 hectare to 1.0 hectare per MLD, as per CPHEEO, 2013 manual on sewerage and sewage treatment systems. The area available here for sewage treatment plant is 4.15 hectare. So, 0.2 * 14.34 = 3.87 hectare (0.0387sq.km.) is required for treatment plant. Power required for treatment of sewage and waste water vary from 12 kWh/person/year to 15 kWh/person/year or 2 HP to 2.5 HP per 1,000 population equivalent.

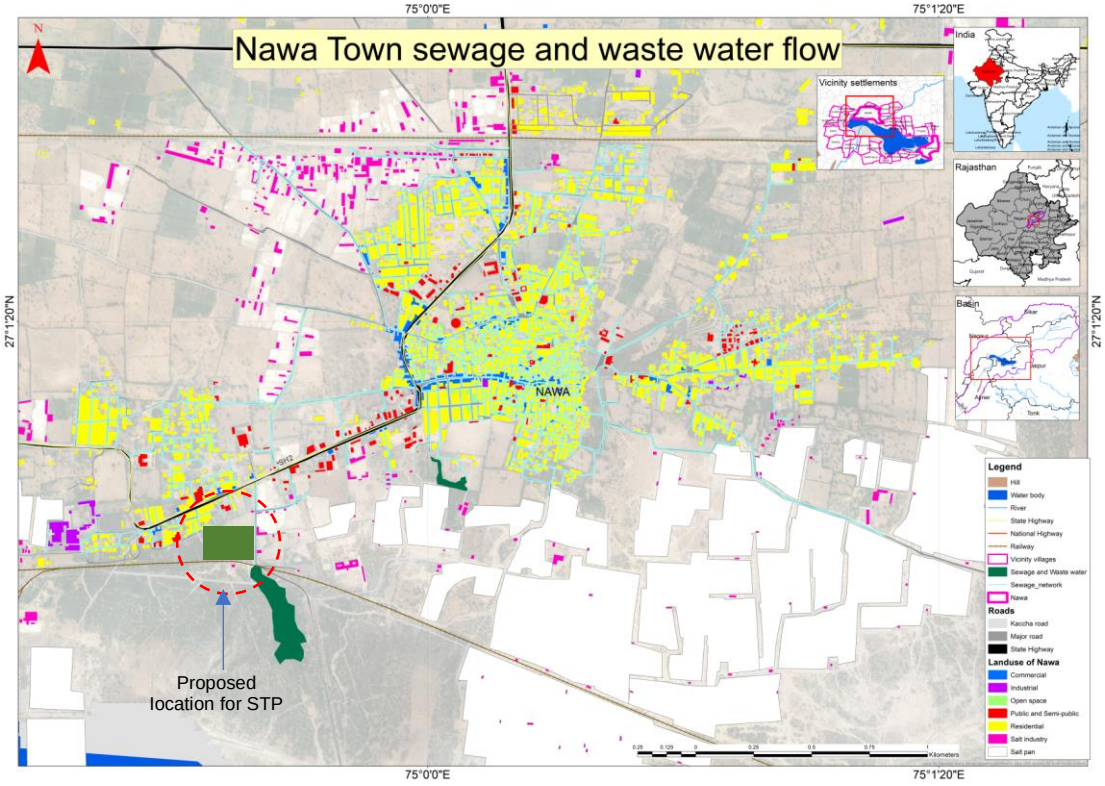


Figure 50: Spatial location for proposal of Sewage treatment plant

Source: Author

5.1. Proposal of strategy through policy

Proposal of strategy through policy for the conservation of lake are –

1. As per Rajasthan lakes (Protection and Development) Authority Act, 2015 in chapter 2 the geographical area surrounding of the lake should be marked

as a protected area and no construction activities should be undertaken in this area without prior permission from the authority. After applying this act for Sambhar lake, the surrounding area which is developing as a salt pan area would be limited and over exploitation of ground water would be limited. This act would also result in the restriction of change in land use and land cover of the area. A buffer area should be marked surrounding the lake for its protection. Buffer zone is a strip of land with a purpose, feature or zoning specifically designed to protect one region of land from impacts from another. Area around the lake should be protected from activities that lead to the degradation of lake. 5 km buffer distance taken from the lake boundary for defining protected area. Figure 51 shows map for spatially defining buffer area round the lake boundary as protected area.

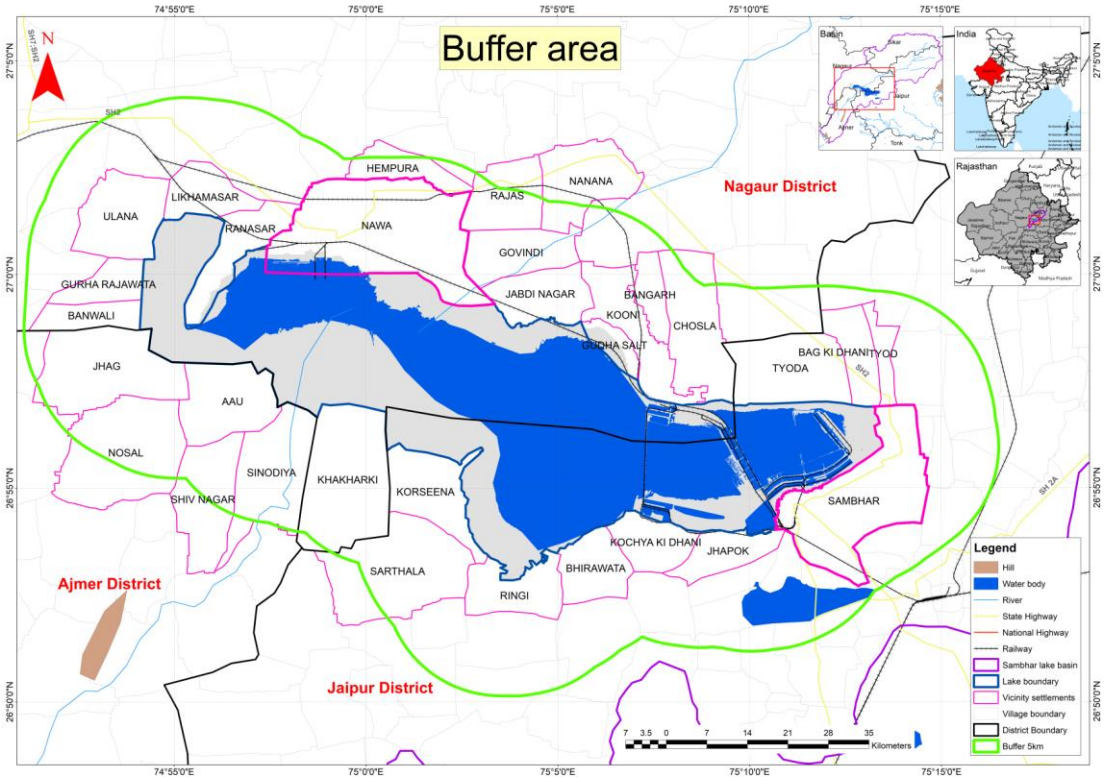


Figure 51: Spatially showing buffer area around the lake as protected area

Source: Author

2. To preserve the lake and its surrounding from the extraction of salt from salt making units, special efforts are required. It is possible by taking people into confidence, educating them towards conservation of the site, changing the attitude of the people towards ecological balance of the lake and other

aspects of conservation. In this making people know about the degradation in the level of ground water can also be told.

3. The role of law enforcement can be another tool for the conservation. The zone may be declared as a sanctuary due to the ecological importance and strong provisions can be made as a preventive measure to suppress the growth of new salt pans.

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