NATIONAL WETLAND ATLAS:

WETLANDS OF INTERNATIONAL IMPORTANCE UNDER RAMSAR CONVENTION

Sponsored by Ministry of Environment and Forests, Government of India



Space Applications Centre, ISRO
Ahmedabad

This publication deals with the updated database and status of wetlands, compiled in Atlas format. Increasing concern about how our wetlands are being influenced has led to formulation of a project entitled “National Wetland Inventory and Assessment (NWIA)” to create a database of the wetlands of India. The wetlands are categorised under 19 classes and mapped using satellite remote sensing data from Indian Remote Sensing Satellite: IRS P6- LISS III sensor. The results are organised at 1: 50, 000 scales at district, state and topographic map sheet (Survey of India reference) level using Geographic Information System (GIS). This publication is a part of this national work and deals with the wetlands of India that are Internationally Important under Ramsar Convention, through text, statistical tables, satellite images, maps and ground photographs.

Ramsar Convention laid down nine criteria for identifying wetlands of International Importance. These criteria are divided into two groups namely; A and B. Group ‘A’ comprises sites containing representative, rare or unique wetland types. Group ‘B’ comprises sites of International Importance for conserving biological diversity.

The atlas comprises wetland information arranged into five sections. How the NWIA project work has been executed highlighted in the third section. Digital remote sensing data has been used to map and decipher the status of the wetlands at national level on 1: 50,000 scale.

The methodology highlights how the four spectral bands of LISS III data (green, red, near infra red and short wave infra red) have been used to derive various indices and decipher information regarding water spread, turbidity and aquatic vegetation. As the aim was to generate a spatial database; details of the standards of database are also highlighted in the methodology.

The results and finding are organised in the fourth section; viz: Results pertaining to Ramsar sites of India. The Maps and Statistics are shown for each site and gives details area estimates. Since, the hydrology of wetlands are influenced by monsoon performance, extent of water spread and their turbidity (qualitative) in wet and dry season (post- monsoon and pre-monsoon period) are also given. Similarly the status of aquatic vegetation (mainly floating and emergent types) in two seasons is also accounted for. False Colour Composite (FCC) of the satellite images used (both the seasons) is shown along with the derived wetland map to give a feeling of manifestation of wetlands in remote sensing data and synoptic view of the area.

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Cover page: *Chilika Lagoon (Odisha) and its environs as observed on the IRS P6 LISS-III False Colour Composite of April 16, 2008. It is one of the first two wetlands designated as Ramsar site in India on 1981. It also has the distinction of the best managed site in Asia and received the Ramsar wetland conservation award - 2002.*

Back cover: *Photograph showing the unique floating vegetation masses called Phumdi found in Loktak Lake, Manipur, India*

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MESSAGE

Wetlands are of great ecological and economic significance. They are critical for human development and well being, especially in India where a large number of people are dependent on them for drinking water, food, and livelihood. They are highly productive eco-systems that provide a wide range of eco-systems services, in addition to supporting significant recreational, social and cultural activities. Despite their immense importance, wetlands today are under severe threat.

Realizing the importance of wetlands, Ministry of Environment and Forests has sponsored a National Inventory and Assessment of Wetlands on 1:50,000 scale based on resourcesat-1 LISS-III data of 2006 – 2007 to the Space Applications Centre, Ahmedabad. Under this programme a National Wetland Atlas and State Wetland Atlases have been prepared. This is the first time such atlases have been prepared on the basis of satellite imagery in a systematic manner. These atlases are of immense use to designate critical wetland to be protected under the Wetland (Conservation and Management) Rules, 2010.

Wetland conservation has been accorded a high priority in India. Since 1987 under the National Wetlands Conservation Programme of India, the Wetland Conservation Activities for about 115 wetlands are being supported. India is also a party to the Ramsar Convention under which 26 wetlands from India are included in the list of wetlands of International Importance.

The present atlas deals specifically with the internationally important wetlands under Ramsar Convention in India and is a part of the National Wetland Inventory and Assessment (NWIA) Project. The information is organized in the form of remotely sensed images, maps based on these images, salient characteristic from public literature and also field photographs. Indian satellite data from Resourcesat-1 LISS-III of 2006 (post-monsoon) and 2007 (pre-monsoon) was used to bring out the hydrological variability due to seasonal change. The mapping scale was 1:50,000. Through this atlas, an attempt is made to provide basic information pertaining to details on water spread and aquatic vegetation of existing Ramsar sites in India.

I congratulate the team of scientists led by Dr. J.S. Parihar, Deputy Director, Space Applications Centre, Ahmedabad and Dr. G.V. Subrahmanyam, Advisor, MoEF and his team for such an important study of the internationally important wetlands under Ramsar Convention in India.

I hope the spatial data base of Wetlands of International importance under Ramsar Convention provided in this atlas will be useful to researchers, decision makers, conservationists, administrators and students.

(Dr. V. Rajagopalan)

जहाँ है हरियाली।
वहाँ है खुशहाली॥

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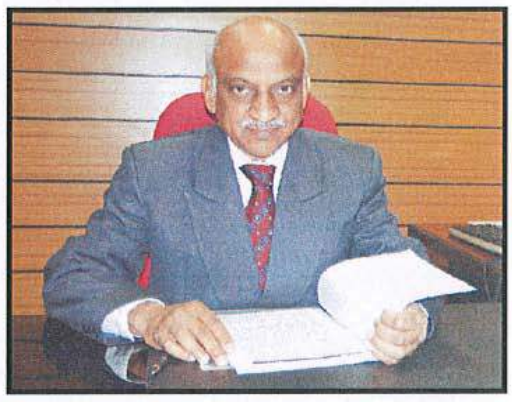

FOREWORD

One of the foremost goals of the Earth Observation Programme in India is focused on to the natural resources management and inherent planning requirement. Boastfully, today India has a number of state-of-art remote sensing satellites in orbit to meet the mapping and monitoring requirements of the natural resources at various scales. Under the initiative of Indian Space Research Organisation, spatial database of various natural resources themes are being prepared and updated from time to time under National Resource Census (NR-Census) programme. Wetlands are one of the most important resources which are important both ecologically as well as socio-economically. The first mapping of wetlands based on remotely sensed data at national level had been carried out by Space Applications Centre (SAC) on 250, 000 scale using IRS LISS-I/II data of 1992-93. At the behest of the ministry of Environment & Forests, Government of India, wetland mapping on 1: 50, 000 scale, was considered under the “National Wetland Inventory and Assessment (NWIA)” project. The wetland atlases of all the states and Union Territories have been released for public use since June 2011.

This atlas is part of the NWIA project towards the wetlands of International Importance under Ramsar Convention. These comprise sites constituting representative, rare or unique types and or sites of international importance for conserving biological diversity. Using the unique spectral characteristics of each site in the form of water-spread, study of aquatic vegetation and qualitative turbidity has been mapped. The seasonal variation of the above are also mapped using the post-monsoon and pre-monsoon data.

I applaud the scientific team at Space Applications Centre for taking this initiative to bring out this exclusive atlas on Ramsar Sites of India. I am sure that this atlas will be of enormous utility for researchers, planners as well as general public.

(A. S. Kiran Kumar)

Ahmedabad
March 03, 2013

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Wetlands are defined as 'lands transitional between terrestrial and aquatic ecosystems where the water table is usually at or near the surface or the land is covered by shallow water. Conservation of wetlands has gained momentum in recent years due to their significant role in ecological and hydrological processes. India with its large geographic spread, diverse climate and terrain harbours diverse types of wetlands. Inventory of wetlands at 1:50,000 scale has been considered as the minimum requirement, as numerous small size wetlands abound in India which have significant value to local environment. To fulfill this objective, the project "National Wetland Inventory and Assessment (NWIA)" has been taken up by Space Applications Centre, ISRO, Ahmedabad. We acknowledge the financial grant from the Ministry of Environment & Forests (MoEF), Government of India for the execution of the project. The project has been successfully completed and results have been brought out as Atlases for each state and Union Territory of India. We are grateful to H''ble Minister Shri Jairam Ramesh for gracing the function at SAC to release the publications for public use in June 2011. We are thankful to MoEF for facilitating public access to all the atlases and information brought out of this project through the MoEF website.

This atlas is part of the NWIA project addressing the wetlands designated under the Ramsar Convention. It is well recognised that Ramsar Convention is a land mark on wetland conservation, as it not only provided a frame work for conservation, but also a comprehensive definition of wetlands. India after becoming the contracting party to this Convention has identified twenty six wetlands as Ramsar sites. Monitoring of these wetlands to assess the ecological status is an important requirement under this convention. With objective, attempts have been made to bring out this Atlas on Ramsar sites.

We are thankful to Shri A.S. Kirankumar, Director, Space Applications Centre, for his overall support to carry out the work and printing of this exclusive atlas. Earnest thanks are also due to Dr. Jai Singh Parihar, Deputy Director, Space Applications Centre, who inspired us to carry out further churning of the NWIA results pertaining to Ramsar sites in India and and his guidance all along to publish this atlas. We are thankful to Dr. Ajit Pattnaik, Chief Executive, Chilika Development Authority, Bhubaneswar for sharing his experience on management issues faced in case of Ramsar sites and the information requirement, which provided a broad framework for the content of this atlas.

We acknowledge the positive role played by 16th SC-B (Standing Committee on Bioresources and Environment) of NNRMS (National Natural Resources Management System) meeting in formulating this project. We are extremely thankful to the members of the "Steering Committee" of the project, under the chairmanship of Dr. E. J. James, Director – Water Institute, Karunya University, for their periodical review, critical comments and appreciation of the efforts by the project team. We are thankful to SC-B under the chairmanship of Secretary, MoEF, for periodic review of the progress of the project and guidance towards timely completion of the work.

We are thankful to the Institutes/organizations who have participated as collaborating agencies to create thematic database of respective states, field data collection and accuracy assessment. We are grateful to Dr. G. V. Subramanyam, Adviser, MoEF, for his very active and positive role for implementation of the project. We are thankful to Dr. Harendra Kharwal, MoEF for his support in budget and project management related issues.

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(Sushma Panigrahy)

Project Director, NWIA

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1. Introduction

Wise use of the rapidly depleting natural resources is a global concern today. With the advancement in technology, holistic planning for the conservation and preservation of natural resources is gaining momentum. Wetlands are one of the most important resources. Wetlands have played a major role in human history. It is only wetlands, whether perennial rivers or large water-bodies, have been the sources of water and consequently the development of civilisations. These are transitional areas between aquatic and terrestrial ecosystems where the water table is at or near the surface, or the land is covered by shallow water. They are among the most productive ecosystems of the world, although they account only about 4 per cent of the earth's ice-free land surface (Prigent, 2001). But ironically, preservation of wetland ecosystem has received very little attention till recently. The ever increasing demand for economic growth during the last half century with utter disregard for the long term ecological consequences has lead to over exploitation of wetlands. Realising their importance, steps have been initiated world over during the past few decades, for preservation and conservation of this vital resource.

1.1 Importance of Wetlands

Wetlands provide many valuable services at population, ecosystem and global levels. These signify the importance of wetlands and the need for their conservation. The value of the wetlands in terms of the economic systems perceived by the human being and the need to consider the value of a wetland as a part of an integrated landscape differ with each other and most of the times conflicting. It is needless to mention that wetlands are highly productive ecosystems and are essential for preserving the biodiversity and ecological security. The interactions of physical, chemical and biological components of wetlands enable it to perform the vital functions. A detailed account of this is presented by Mitsch and Gosselink (2000). Following are the significant functions, values and attributes of wetlands which owe their importance to wetlands as depicted in Figure 1.

a) Functions

- Water storage
- Storm protection and flood mitigation
- Shoreline stabilisation
- Ground water recharge and discharge
- Water purification
- Retention of sediments, nutrients and pollutants
- Stabilisation of local climate particularly temperature and rainfall.

b) Values

- Water supply – maintenance of quantity and quality
- Fisheries
- Agriculture – through maintenance of water table
- Grazing
- Timber production
- Energy sources such as peat and plant matter
- Wildlife resources
- Recreation and tourism opportunities

c) Attributes

- Biological diversity: wetlands support avifauna, especially waterfowl; fish, reptiles, mammals, and invertebrate species as well as several plant species, besides a variety of microorganisms like plankton of both phyto and zoo origin.
- Cultural heritage: open landscapes, wildlife and local traditions.

1.2 Environmental Threats to Wetlands

Wetlands have been under constant threat of environmental degradation due to natural as well as anthropogenic activities. Some of the major environmental threats to the wetlands and their biodiversity are:

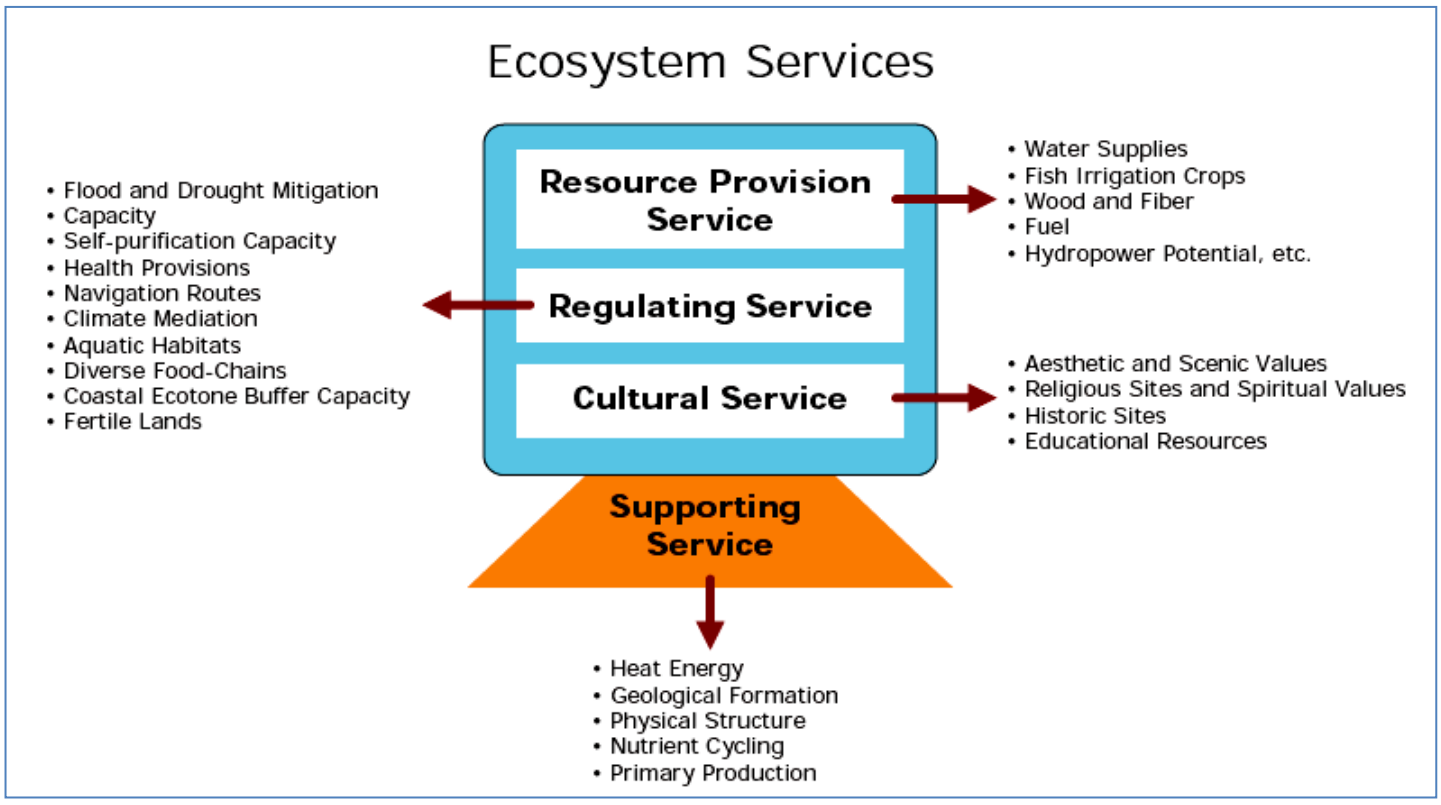


Figure 1: Ecosystem services provided by lakes and reservoirs (adopted from ILEC. 2007)

1.2.1 Encroachment

People consider wetlands as low value lands or wastelands and in order to 'develop' such lands they have been encroached for agriculture, urban expansion and other such purposes. This problem seems to plague the wetlands in spite of Legislation/Acts.

1.2.2 Pollution

A large number of wetlands are subjected to inflows of domestic sewage, solid waste and industrial effluents. Fertiliser and pesticide run-off from agricultural lands aggravate the pollution load. Pollution results in eutrophication, reduces dissolved oxygen, increases the biological oxygen demand etc. which, many a times causes large-scale mortality of fish and other aquatic life. Eutrophication creates ecological conditions that are deleterious to most aquatic life forms.

1.2.3 Aquaculture development

Indiscriminate use of wetlands for aquaculture is a major threat to the ecological character of wetlands. Intensive input of feed for the fish and prawn culture, subsequent draining of the nutrient rich water into adjacent sea/river system results in eutrophication and degradation of wetlands.

1.2.4 Siltation

Siltation is a natural ecological process in filling up of the wetlands. However, the anthropogenic activities in the catchment of a wetland would accelerate the process. This natural process coupled with anthropogenic activities would lead to shrinkage and loss of many wetland habitats as well as alteration in biological composition.

1.2.5 Weed infestation

The eutrophication process creates conducive conditions for the weeds to proliferate the wetlands and poses a threat. Aquatic species like *Eichornia crassipes* and *Ipomea aquatica* infestation is a common problem in India. It alters and impairs the ecological functions of wetlands. In addition to the above, natural succession, changes in hydrological cycle and sea level etc. are some of the other factors responsible for changing the character and quality of wetlands. Cumulative strain on wetlands brought out by the above factors is evident in the form of:

- Decrease in biological diversity
- Deterioration of water quality
- Sedimentation and shrinkage in areas under wetlands
- Decrease in migratory bird population
- Decrease in fish productivity
- Prolific growth of unwanted aquatic biota

2.0 Conservation of Wetlands

During the past few decades many efforts have been made world over to prevent exploitation of wetlands. Wetlands being diverse in nature, the conservation measures vary accordingly. Ramsar Convention and Convention on Biological Diversity (CBD) are the two landmark initiatives towards conservation of wetlands.

2.1 Ramsar Convention

The Convention on Wetlands of International Importance especially as Waterfowl Habitat is generally known as the Ramsar Convention. It owes its name after the town in Iran where it was adopted in 1971. It is the oldest and first inter-governmental conservation convention. It came into being due to serious decline in population of waterfowl and need for conservation of habitats of migratory waterfowl. The convention provides the framework for national action and international cooperation for the conservation and wise use of wetlands and its resources including biodiversity. Ramsar convention entered into force in 1975 and contracting parties joined from all over the world.

Under the text of the convention (Article 1.1) wetlands are defined as:

> ***"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".***

In addition, the Convention (Article 2.1) provides that wetlands:

> **"may incorporate riparian and coastal zones adjacent to wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands".**

Resultantly, a wide variety of habitats including rivers, shallow coastal waters and even coral reefs are included under wetlands. However, deep seas are not treated as wetlands.

2.2 Convention on Biological Diversity (CBD)

Convention on Biological Diversity (CBD) was enunciated during Rio earth Summit in 1992. India became a party to CBD in May 1994. The three objectives of the convention are:

- Conservation of biological diversity.
- Sustainable use of components of biological diversity.
- Fair and equitable sharing of benefits arising out of the utilisation of genetic resources.

As described by the Conference of the Parties (Countries) the ecosystem approach is the primary framework for action under the Convention. The Conference of the Parties in its Fifth Meeting endorsed the ecosystem approach and also gave operational guidance. The goal of ecosystem management is to maintain and enhance ecosystem health. CBD aims to encourage and enable all countries to conserve biological diversity, to ensure its use in support of national development is sustainable, and to reconcile national interests with the maintenance of highest possible levels of

global biodiversity. Each country has its own unique combination of living species, habitats and ecosystems that together make up its biodiversity. CBD also stipulates that each country may exploit sustainably its own biodiversity in any way, which it sees fit. Because each country also contributes to overall global biodiversity, it has a corresponding responsibility to play a part in its maintenance.

2.3 Common Concerns of Ramsar, CBD and other Conventions

With the increasing number of environmental conventions now in existence, the watchwords must be partnership and coordination. Links of course already exist between Ramsar and other international environmental conventions e.g. famed wetland like Keoladeo, Bharatpur in India figure on the lists of both Ramsar and the 1972 World Heritage Convention. The 1975 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) deals with trade in a number of wetland species and so has strong link with Ramsar convention. There is obvious potential for cooperation between Ramsar and the 1979 Bonn Convention on Migratory species. The adoption under Bonn, of the 'Agreement on Convention of African-Eurasian Migratory Water birds' opens the door for even broader cooperation, and there are prospects of similar agreements in other regions; thus the Ramsar Conference in Brisbane in March 1996, adopted the 'Brisbane Initiative' on the establishment of a network of listed sites along the East Asian-Australian flyway.

Ramsar convention has made a considerable contribution to the conservation and wise use of biological diversity in wetlands. Newer conventions such as the Montreal Protocol on substances that deplete ozone layer, Conventions on biological diversity, Climate change and Combating desertification adopt holistic approach to conservation of biological diversity. Global Environmental Facility (GEF) has recently adopted an operational strategy covering four focal issues (biodiversity, climate change, ozone layer depletion and international waters), all of which have relevance to wetlands. UN Framework on climate change also has major implications for wetlands, as for example, changes in weather patterns could mean that existing wetlands decline, to be replaced by new ones in other sites. Sea level rise is another phenomenon with a potential to bring severe changes in coastal wetlands. Similarly, international waters – wetlands such as the courses of major rivers or coastal zones require coordination and consultation between the states concerned, as provided by GEF's focal issue on international water, and in Ramsar's article on shared water systems. Of particular relevance to the Ramsar Convention is the CBD which defines biological diversity as:

'The variability among living organisms from all sources, including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems'.

2.4 Indian Scenario

A number of acts and legal provisions have been promulgated for the protection of environment and conservation of natural resources in India. Some of these acts which have relevance for wetland conservation include Forest Act, 1972; the Forest (Conservation) Act, 1980; the Wildlife (Protection) Act, 1972; the Water (Prevention and Control of Pollution) Act, 1974; the Water (Prevention and Control of Pollution) Cess Act, 1977 and the Umbrella provisions of the Environment (Protection) Act, 1986. The coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are influenced by tidal action in the landward side up to 500 m from the high tide line and the land between low tide line and high tide line are covered under the Coastal Regulation Zone Notification, 1991 under the provisions of Environment (Protection) Act, 1986. The Environment (protection) Act also specifies protection of ecologically fragile areas under which a number of wetland ecosystems in the country are being notified. Considerable efforts have been put in by the Government of India to evolve institutional mechanism for conservation of wetlands. Some of these are National Committee on Wetlands, National Committee on Mangrove and Coral reefs. These committees advise the Government on policy guidelines, identification of priority wetlands for intensive conservation and monitoring, implementation of management action plans, research and preparation of an inventory of wetlands. As a consequence of this the Ministry of Environment and Forests, Government of India

has declared 27 sites as notified wetlands, of which 26 are already declared Ramsar wetlands of International Importance. Some of the wetlands have been declared as Wildlife Sanctuaries for the protection of wildlife. In addition, various states have constituted authorities on wetland and lake development e.g. Chilika Development Authority (CDA), Loktak Development Authority (LDA), Jammu and Kashmir Lakes and Waterways Development Authority (J&K-LWDA), besides declaring a number of wetlands as notified under their own territory in the purview of respective Ministries/Department of Environment and Forests. Besides the initiatives taken up by the Government, the Non-Governmental Organisations (NGOs) have also been contributing their might in the conservation of wetland ecosystems along with their faunal and floral diversity.

2.4.1 Ramsar Sites in India

India became a contracting party to the Ramsar Convention in 1981. The Chilika lagoon in Orissa and the Keoladeo National Park in Rajasthan are the first two wetlands designated as Ramsar sites in 1981. Since then total 26 wetlands in the country have been designated as Ramsar sites by 2012. Maximum number of sites was designated during 2002. The latest one in the series is the Nal Sarovar bird Sanctuary in Gujarat designated during 2012 (Figure 2).

Though India has numerous wetlands of various types, there are certain criteria of selection of sites for Ramsar designation. As per the Article 2.2 of the Ramsar Convention, broadly the wetlands are categorised under two Groups under nine criteria. Group A sites are selected under the Criterion 1 as “Sites containing representative, rare or unique wetland types”. Group B sites are sites of international importance for conserving biological diversity. There are total eight criteria based on species and ecological communities under Group B. Also, there are certain commitments by the country to ensure preservation of the ecosystem.

A brief of these criteria is given below:

Group A of the criteria: Sites containing representative, rare or unique wetland types. Comprises only one criterion.

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 bio-geographic region.

Group B of the criteria: Sites of international importance for conserving biological diversity. This group comprises the rest of nine criteria which are 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 bio-geographic region.

Criterion 4: A wetland should be considered internationally important if it supports plant and/or animal species at critical stage in their life cycles or provides refuge during adverse conditions.

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 sub-species of waterbirds.

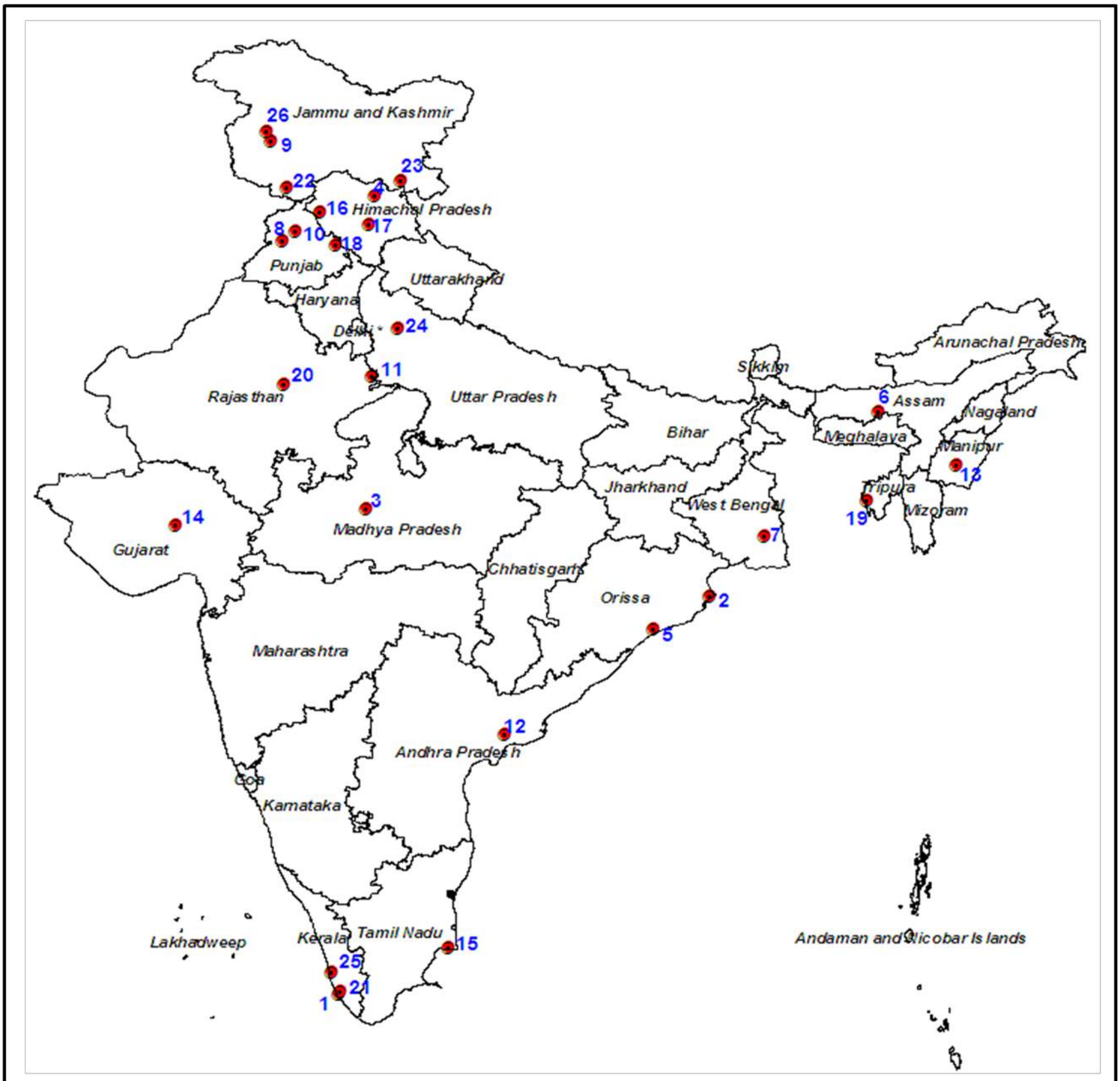
Criterion 7: A wetland should be considered internationally important if it regularly supports a significant proportion of indigenous fish subspecies or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.

Criterion 8: A wetland should be considered internationally important if it is an 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 species.

A detail of the sites in terms of location, area and criteria is given in Table-1.



Sr. No.	Wetland name	Sr. No.	Wetland name
1	Ashtamudi Wetland, Kerala	14	Nalsarovar Bird Sanctuary, Gujarat
2	Bhitarkanika Mangroves, Odisha	15	Point Calimere Wildlife and Bird Sanctuary, Tamil Nadu
3	Bhoj Wetland, Madhya Pradesh	16	Pong Dam Lake, Himachal Pradesh
4	Chandertal Wetland, Himachal Pradesh	17	Renuka Wetland, Himachal Pradesh
5	Chilika Lagoon, Odisha	18	Ropar, Punjab
6	Deepor Beel, Assam	19	Rudrasagar Lake, Tripura
7	East Calcutta Wetlands, West Bengal	20	Sambhar Lake, Rajasthan
8	Harike Lake, Punjab	21	Sasthamkotta Lake, Kerala
9	Hokera Wetland, Jammu & Kashmir	22	Surinsar-Mansar Lakes, Jammu & Kashmir
10	Kanjli, Punjab	23	Tsomoriri, Jammu & Kashmir
11	Keoladeo National Park,Rajasthan	24	Upper Ganga River (Brijghat to Narora Stretch), Uttar Pradesh
12	Kolleru Lake, Andhra Pradesh	25	Vembanad-Kol Wetland, Kerala
13	Loktak Lake, Manipur	26	Wular Lake, Jammu & Kashmir

Figure 2: Location map of Indian Ramsar sites

Table 1: List of Wetlands designated as Ramsar sites in India arranged alphabetically and their criteria
(*Ministry of Environment and Forests, Government of India)*

Sr. No.	Wetland name	State	Ramsar Criteria	Date of Declaration	Area (ha)
1	Ashtamudi Wetland	Kerala	1,2,3,8	19/08/2002	61400
2	Bhitarkanika Mangroves	Orissa	2,4,6,8,9	19/08/2002	65000
3	Bhoj Wetland	Madhya Pradesh	2,4,5,6	19/08/2002	3201
4	Chandertal Wetland	Himachal Pradesh	2,3	08/11/2005	49
5	Chilika Lake	Orissa	2,4,5,6,8,9	01/10/1981	116500
6	Deepor Beel	Assam	2,5	19/08/2002	4000
7	East Calcutta Wetlands	West Bengal	1	19/08/2002	12500
8	Harike Lake	Punjab	2,5,6	23/03/1990	4100
9	Hokera Wetland	Jammu & Kashmir	2,5,6	08/11/2005	1375
10	Kanjli	Punjab	3	22/01/2002	183
11	Keoladeo National Park	Rajasthan	2,5,6	01/10/1981	2873
12	Kolleru Lake	Andhra Pradesh	2,4,5,6	19/08/2002	90100
13	Loktak Lake	Manipur	2,5,6	23/03/1990	26600
14	Nalsarovar Bird Sanctuary	Gujarat	2,5,6	24/09/2012	12000
15	Point Calimere Wildlife and Bird Sanctuary	Tamil Nadu	2,4,5	19/08/2002	38500
16	Pong Dam Lake	Himachal Pradesh	2,5,6	19/08/2002	15662
17	Renuka Wetland	Himachal Pradesh	3,4	08/11/2005	20
18	Ropar	Punjab	5,6	22/01/2002	1365
19	Rudrasagar Lake	Tripura	2,3,8	08/11/2005	240
20	Sambhar Lake	Rajasthan	2,5,6	23/03/1990	24000
21	Sasthamkotta Lake	Kerala	1,2,7,8	19/08/2002	373
22	Surinsar-Mansar Lakes	Jammu & Kashmir	2,3,4	08/11/2005	350
23	Tsomoriri	Jammu & Kashmir	2,6	19/08/2002	12000
24	Upper Ganga River (Brijghat to Narora Stretch)	Uttar Pradesh	2,5	08/11/2005	26590
25	Vembanad-Kol Wetland	Kerala	4,5,6	19/08/2002	151250
26	Wular Lake	Jammu & Kashmir	2,5,6	23/03/1990	18900

3. National Wetland Inventory and Assessment (NWIA) Project

Inventory of wetlands is the first step towards evolving scientific management plan for wise use of wetlands. Realising the importance of many small wetlands that dot the Indian landscape, it was felt that inventory of the wetlands at 1:50,000 scale is essential. The task seemed challenging in view of the vast geographic area of the country with diverse wetland classes. Space Applications Centre with its experience in use of Remote Sensing and Geographic Information System in the field of wetland studies took up the task. This is further strengthened by the fact that guidelines to create geospatial framework, codification scheme, data base structure etc., for natural resources survey has already been well established by the initiative of National Resource Census programme of Indian Space Research Organisation. With this strength, the National Wetland Inventory and Assessment (NWIA) project was implemented by SAC during 2007-10, at the behest of the Ministry of Environment and Forests (MoEF), Govt. of India.

The main objectives of the project are:

- To map the wetlands on 1:50000 scale using two-date (pre- and post-monsoon) IRS LISS III digital data following a standard wetland classification system.

- Integration of ancillary theme layers (road, rail, settlements, drainage, administrative boundaries)
- Creation of a seamless database of the states and country in GIS environment, and
- Preparation of State-wise wetland atlases

3.1 Wetland Classification System

The broad frame work for inclusion of wetland classes follows the definition devised under the Ramsar Convention. The first task was to devise a classification system to account for all types of wetlands occurring in India that is amenable from remote sensing data and compatible with database. This was carried out with the help of an thematic and database expert/peer groups. Accordingly, 19 wetland classes organized under a Level III hierarchical system were considered (Table 2). Level one has two wetland classes: inland and coastal, these are further bifurcated into two categories as: natural and man-made under which all the wetlands occurring in India are suitably placed. It was for the first time that, high altitude wetlands, defined as those occurring above 3000 m amsl were also accounted and mapped. Wetlands put to agricultural use in any time of the year were not considered for mapping in this project.

Table 2: Wetland Classification System and coding

Wettcode*	Level I	Level II	Level III
1000	Inland Wetlands		
1100		Natural	
1101			Lakes
1102			Ox-Bow Lakes/ Cut-Off Meanders
1103			High altitude Wetlands
1104			Riverine Wetlands
1105			Waterlogged
1106			River/stream
1200		Man-made	
1201			Reservoirs/ Barrages
1202			Tanks/Ponds
1203			Waterlogged
1204			Salt pans
2000	Coastal Wetlands		
2100		Natural	
2101			Lagoons
2102			Creeks
2103			Sand/Beach
2104			Intertidal mud flats
2105			Salt Marsh
2106			Mangroves
2107			Coral Reefs
2200		Man-made	
2201			Salt pans
2202			Aquaculture ponds

*: Wetland type code

3.2 Spatial Framework and GIS Database

NNRMS (National Natural Resources Management System) standards were followed to create the NWIA data base. The geographic area of India is about 329 million ha covered in 5112 Survey of India topographical maps of 1:50,000 scale. Based on the extent and map sheet graticules, the

spatial framework for the GIS database was worked out. The four corners of the 1:50,000 (15' x 15') grids were taken as the tics or registration points to create each map taking master grid as the reference. The individual map information was then converted to district /state information following the recommended datum and projection to create seamless data base of each state/UT.

Feature codification scheme for every input element was worked out keeping in view the nation-wide administrative as well as natural hierarchy (State-district- within the feature class for each of the wetland category). All data elements are given a unique identity, which is self explanatory with short form.

Following wetland layers were generated:

- Wetland extent: As wetlands encompass open water, aquatic vegetation (submerged, floating and emergent) and surrounding hydric soils, the wetland boundary should ideally include all these. Satellite image gives a clear signature of the wetland extents from the imprint of water spread over the years.

- Water spread: Each Two water spread layers representing post-monsoon and pre-monsoon during the year of data acquisition.

- Aquatic vegetation spread: Two layers pertaining to presence of vegetation (mainly floating and emergent aquatic vegetation and shore vegetation) representing post-monsoon and pre-monsoon during the year of data acquisition.

- Turbidity of open water: Two spatial layers pertaining to a qualitative turbidity levels (low, medium and high) representing pre- and post-monsoon waters during the year of data acquisition (For large wetlands like lakes, reservoirs, rivers etc.)

- Small wetlands (smaller than minimum mapping unit i.e. 2.25 ha on 1: 50, 000 scale) mapped as point features.

- Base layers like major road network, railway, settlements, and surface drainage (either from the current image or taken from other project data base).

  The outputs of the project contained the image, maps, and field observation data known as ground truth)

3.3 Mapping using Remote Sensing Data

Maps relate the feature to any given geographical location have a strong visual impact. Maps are thus essential for monitoring and quantifying changes with time, and assist in decision-making. Initially the preparation of maps started with field survey technique. The Survey of India (SOI) topographic maps are the earliest true maps of India showing various land use/cover classes including water resources such as *lotic* and *lentic* wetlands of the country. Recent years have seen advances in mapping technique to prepare maps with much more information. Of particular importance is the remote sensing and geographic information system (GIS) technique. Remote sensing is now recognised as an essential tool for viewing, analysing, characterising, and making decisions about land, water and atmospheric components.

From a general perspective, remote sensing is the science of acquiring and analyzing information about objects or phenomena from a distance (Jensen, 1986; Lillesand and Keifer, 1987). In the current context satellite remote sensing is defined as the use of satellite borne sensors to observe, measure, and record the electromagnetic radiation (EMR) reflected or emitted by the earth and its environment for subsequent analysis and extraction of information. EMR sensors include visible light, near-, mid- and far-infrared (thermal), microwave, and long-wave radio energy. The capability of

multiple sources of information is unique to remote sensing. Of specific advantage is the spectral, temporal, and spatial resolution. Spectral resolution refers to the width or range of each spectral band being recorded. Since each target affects different wavelengths of incident energy differently, they are absorbed, reflected or transmitted in different proportions. Presently, there are many remote sensing satellites to monitor natural resource of the earth with sensors operating in the green, red, near infrared and short wave infra red regions of the electromagnetic spectrum, giving a definite spectral signature of targets due to difference in radiation absorption and reflectance from targets. Of particular interest to India is the indigenous series of satellites called Indian Remote Sensing satellites (IRS-Series). Since the launch of the first satellite IRS 1A in 1988, India now has a number of satellites providing data in multi-spectral bands with different spatial resolution. Resourcesat-1 and 2 are the current generation satellite that provides multi-spectral images of various spatial resolutions like: LISS IV of 5.8 m, LISS III of 23.5 m, and AWiFS of 58 m spatial resolutions. These sensors are of common use for land cover studies, including wetlands. The multi-band false colour composite (FCC) images are created using NIR, red and green bands assigned as red, green and blue colour. In FCC, the vegetation appears invariably red and water appears blue due to their spectral characteristics in visible and near IR wavelengths. A typical FCC image of a wetland is shown in Figure 3.

Geographic Information System (GIS) facilitates handling spatial as well as non-spatial data and aids indecision making. During the past few decades, technological advances in the field of satellite remote sensing sensors, and GIS have enhanced the ability to capture more detailed and timely information about the natural resources at various scales catering to local, regional, national and global level studies.

3.4 Data Used

Satellite Remote Sensing Data

Resourcesat-1 LISS III data was used to map the wetlands. Resourcesat-1 LISS III provides data in 4 spectral bands; green, red, Near Infra Red (NIR) and Short Wave Infra Red (SWIR) with 23.5 m spatial resolution and 24 day repeat cycle. The spatial resolution is suitable for 1:50,000 scale mapping. Ramsar sites are covered in 25 IRS LISS III scenes (Figure 4). Two-date data, one set acquired during March to May and another during October to November (acquired during 2006-7/8) were used to capture the pre-monsoon and post-monsoon hydrological variability of the wetlands respectively. Geocoded and orthorectified LISS III images of same path row of 2004-5 (procured from NRC programme on Land use/cover mapping) were used as master image to georeference the 2006-7 data.

Ancillary data

Remotely sensed data require certain amount of field observation called “ground truth” in order to convert it into meaningful information. Such work involves visiting a number of sites, usually taking the satellite data. The location of the features is recorded using the GPS. The standard proforma as per the NWIA manual was used to record the field data.

Satellite derived Digital Elevation Model was used to generate the elevation layer, this layer was used to identify the High Altitude Wetlands, mainly found in the Himalayas.

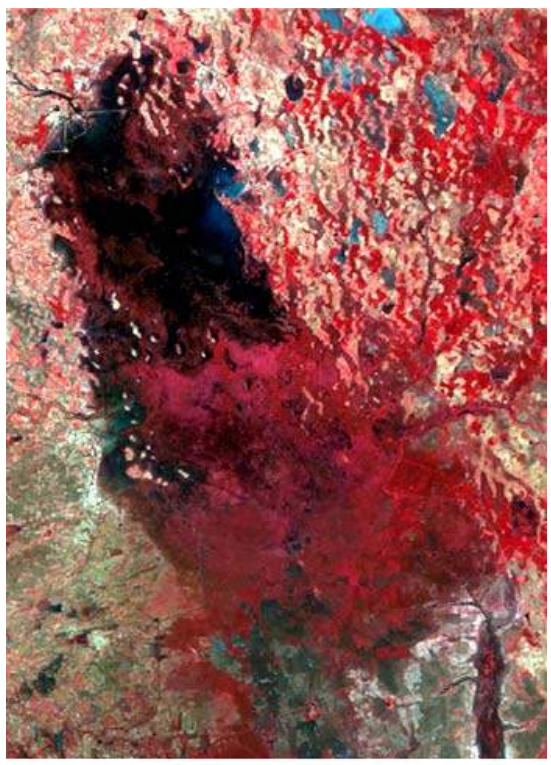
Ancillary layers of bio-geographic zones, agro-climatic zones were also used to generate zone-wise wetland maps and statistics.



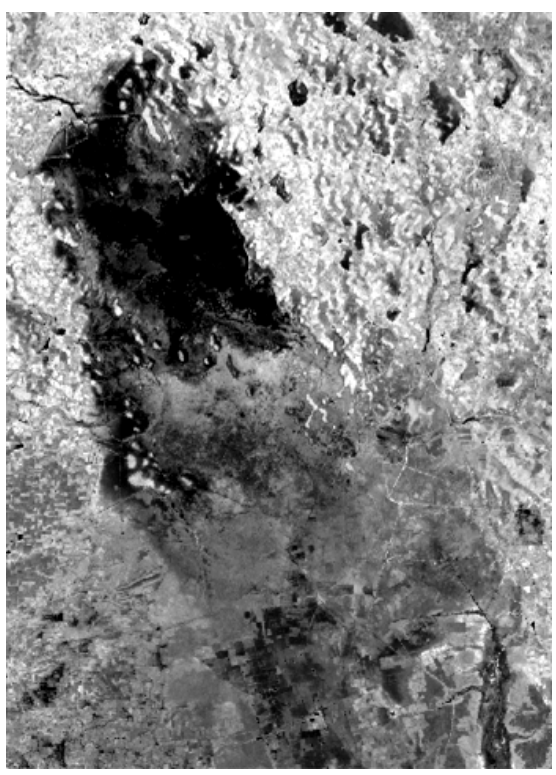
Band-1 (Green)



Band-2 (Red)



LISS-III FCC (G R NIR),
October 14, 2004

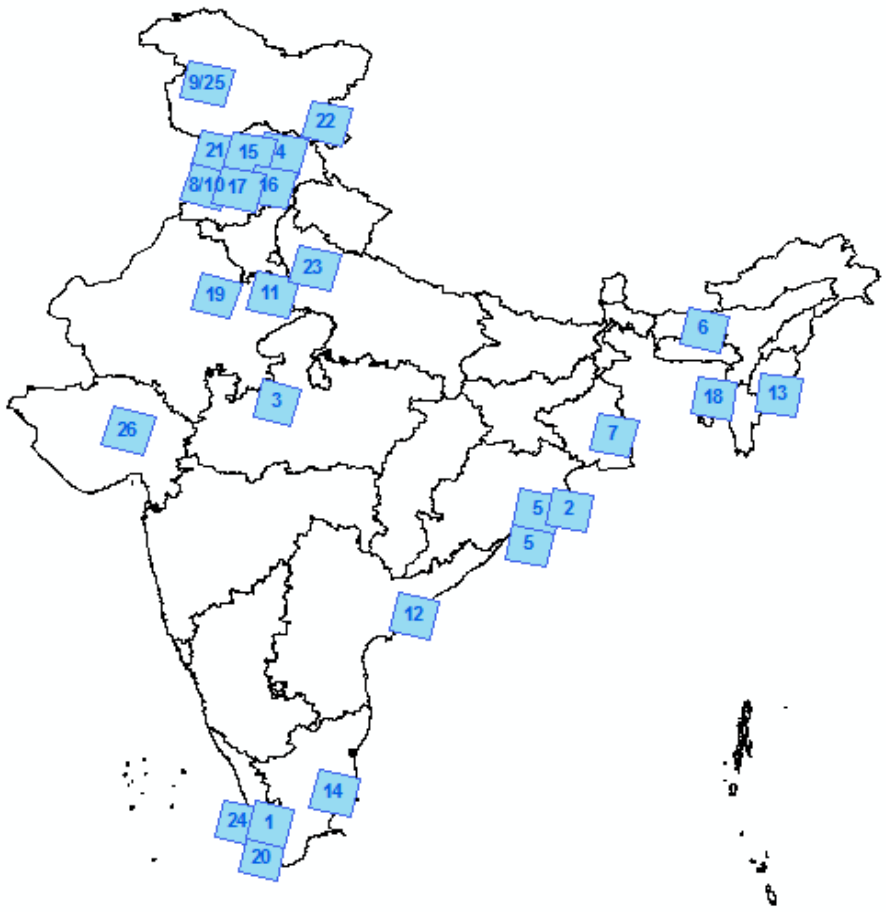


Band-3 (NIR)



Band-4 (SWIR)

Figure 3: Various wetland (Nalsarovar, Gujarat) features as they appear in four spectral bands and in a typical three-band False Colour Composite



Sr. No.	Name of the Ramsar site	Path-Row
1	Ashtamudi Wetland	100/67, 100/66
2	Bhitarkanika Mangroves	107/58
3	Bhoj Wetland	97/55
4	Chandertal Wetland	95/48
5	Chilika Lake	106/59, 106/58
6	Deepor Beel	110/53
7	East Calcutta Wetlands	108/56
8	Harike Lake	93/49
9	Hokera Wetland	92/46
10	Kanjli	93/49
11	Keoladeo National Park	96/52
12	Kolleru Lake	103/61
13	Loktak Lake	113/55, 113/54
14	Point Calimere Wildlife and Bird Sanctuary	102/66
15	Pong Dam Lake	94/48
16	Renuka Wetland	95/48
17	Ropar	94/49
18	Rudrasagar Lake	111/55
19	Sambhar Lake	94/52
20	Sasthamkotta Lake	100/67
21	Surinsar-Mansar Lakes	93/48
22	Tsomoriri	96/47
23	Upper Ganga River (Brijghat to Narora Stretch)	97/51
24	Vembanad-Kol Wetland	99/67
25	Wular Lake	92/46
26	Nalsarovar Bird Sanctuary	93/56

Figure 4: IRS P6 LISS-III coverage of Ramsar sites in India

3.5 Methodology

Salient features of methodology are:

- Generation of spatial framework in GIS environment for database creation and organisation.
- Geo-referencing of satellite data
- Identification of wetland classes as per the classification system and mapping of the classes using digital or on-screen interpretation
- Generation of elevation layer using DEM to identify high altitude wetlands
- Generation of base layers (rail, road network, settlements, drainage, administrative boundaries) from satellite image and ancillary data.
- Mosaicing/edge-matching to create district and state level database.
- Coding of the wetlands following the standard classification system and codification.
- Preparation of map compositions and generation of statistics
- Outputs on A3 size prints and charts for atlas.

Wetlands in satellite image were identified based on vegetation, visible hydrology and geography. Various indices derived using different spectral band combination is generally used to enhance different structural components of wetlands (Fig. 5). Normalised Difference Water Index - NDWI (McFeetres, 1986), Modified Normalised Difference Water Index – MNDWI (Xu Hanqiu, 2006), Normalised Difference Vegetation Index – NDVI (Townshend and Justice, 1986; Tucker and Sellers, 1986), Normalised Difference Pond Index – NDPI (Lacaux *et al*, 2007) and Normalised Difference Turbidity Index - NDTI (Lacaux *et al*, 2007) were used. The combination of indices used for extraction of various features is as below:

- Extraction of wetland extent:
  Combination of NDWI, NDPI and NDTI images were used to extract the wetland boundary through suitable hierarchical thresholds.

- Extraction of open water:
  MNDWI was used within the wetland mask to delineate the water and no-water areas.

- Extraction of wetland vegetation:
  NDPI and NDVI image were used to generate the vegetation and no-vegetation areas within a wetland using a suitable threshold.

- Turbidity information extraction:
  MNDWI image was used to generate qualitative turbidity level (high, moderate and low) based on signature statistics and standard deviation (Table-3). In the FCC images these generally appear in different hues from cyan (high) to blue/dark blue (low).

Table 3: Qualitative turbidity ratings

Sr. No.	Qualitative Turbidity	Conditional criteria	Hue on FCC
1.	Low	> $\mu+1\sigma$	Dark blue/blackish
2.	Moderate	> μ-1σ to <= $+1\sigma$	Medium blue
3.	High/Bottom reflectance	<= μ - 1σ	Light blue/whitish blue

The details of the methodology are given in the National Wetland Atlas: India (SAC, 2011, http:/www.moef.nic.in).

Since, this atlas specifically addresses the Ramsar wetlands, some additional work has been carried out as below:

Distribution pattern

The Ramsar designated wetlands are distributed over many states in the country. Many sites cut across districts and states. Thus, site specific data base preparation was taken up for the Ramsar wetlands to generate exclusive maps of each site at 1:50,000 scale. To facilitate understanding of distribution pattern of the Ramsar sites in relation to Bio-geographic and Agro-climatic regions of India, GIS data base was organised accordingly. The bio-geographic zone map prepared by Wild Life Institute of India having ten zones and the Agro-climatic region map of Indian Council of Agriculture Research were used.

Surrounding environment status

Since, the wetland hydrology is greatly influenced by the catchment area; each wetland map shows the catchment boundary to understand the general land use and land cover observed in satellite image. Also, a 12 km buffer line was shown. The wetlands (type, number and size) occurring in the catchment and 12 km buffer area of each Ramsar site was mapped and statistics generated.

3.6.1 The Outputs

Wetland statistics of each site:

- Wetland extent (area, perimeter)
- Open water spread (pre and post monsoon season)
- Aquatic vegetation (pre and post monsoon)
- Qualitative turbidity of open water (pre and post monsoon)
- Wetlands in the catchment (type, number, seasonal status)

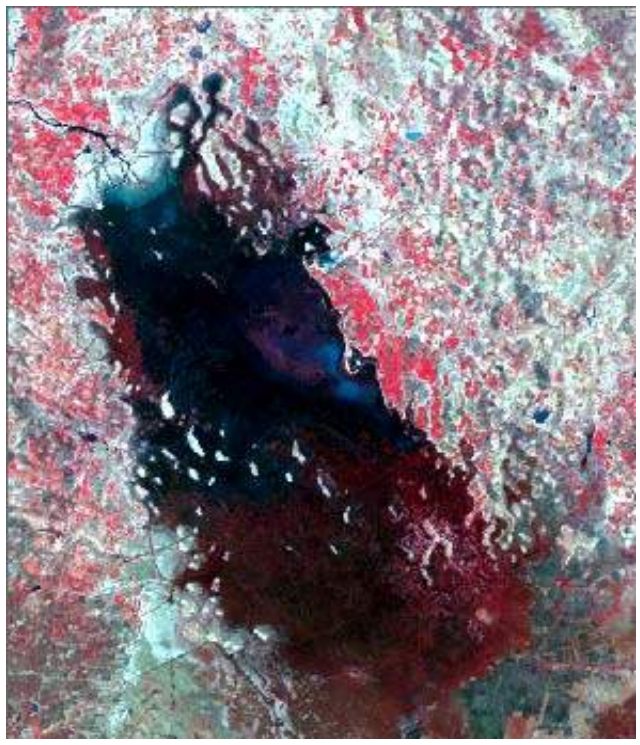
Maps:

- Wetland map (pre and post monsoon) with catchment boundary and 12 km buffer zone boundary
- False Color Composite of satellite image of the study site with catchment and buffer zone boundary
- Map showing distribution of sites in relation to bio-geographic zones
- Map showing distribution of sites in relation to agro-climatic zones

Other outputs

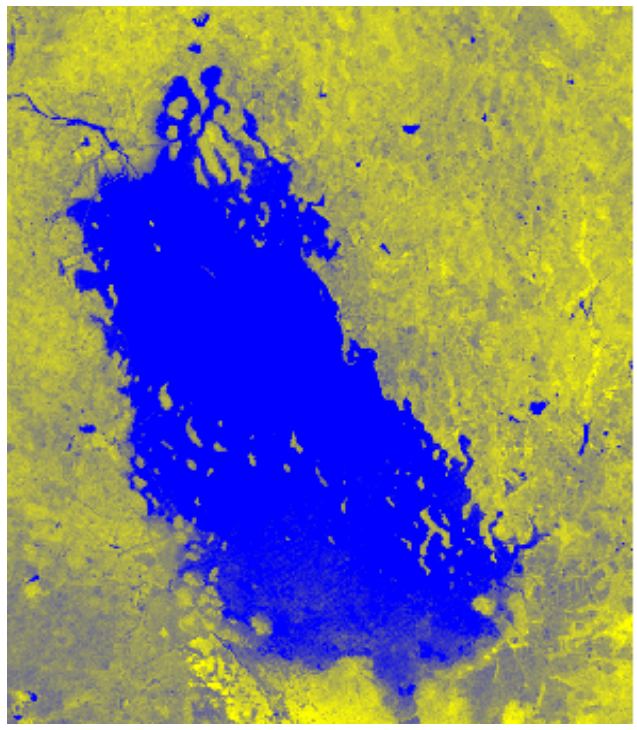
- Statistics of Ramsar site area/number in relation to total wetland area.

A



LISS-III FCC (G R NIR)

C

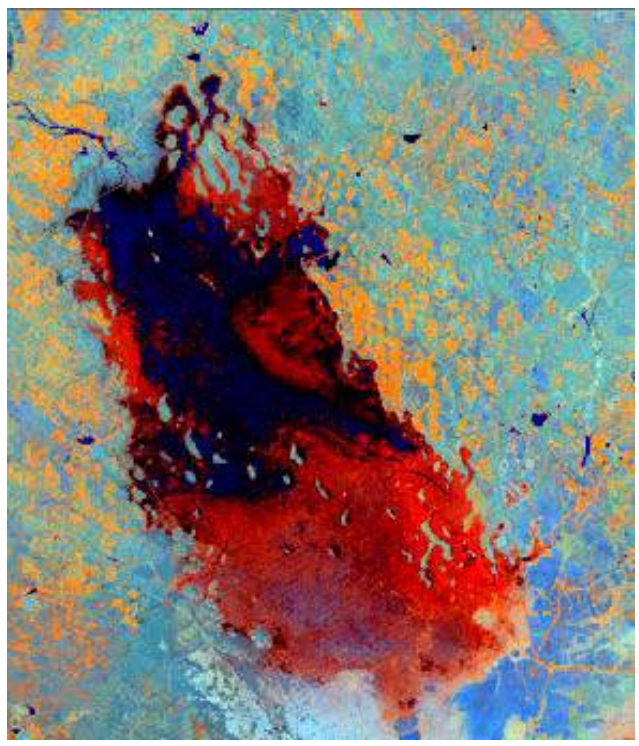


FCC of Indices (NDWI NDPI NDTI)

Nalsarovar, Gujarat
(Resourcesat-1 LISS-III data of 11/12/2004)

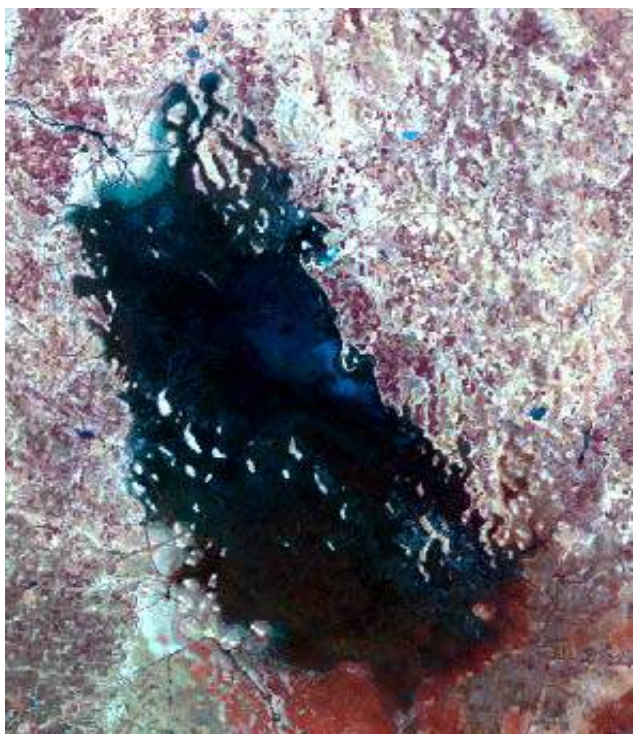
A. LISS-III FCC of G R NIR combination
B. LISS-III FCC of G R SWIR combination
C. FCC of Indices of NDWI NDPI NDTI combination enhances the wetland from it's surrounding land cover thereby enables easier for delineation
D. FCC of Indices of MNDWI NDPI NDVI combination enhances the open-water and vegetation specific to wetland thereby enables easier delineation
E. σ - based classified MNDWI image provides qualitative turbidity within open-water of a wetland

D



FCC OF Indices (MNDWI NDPI NDVI)

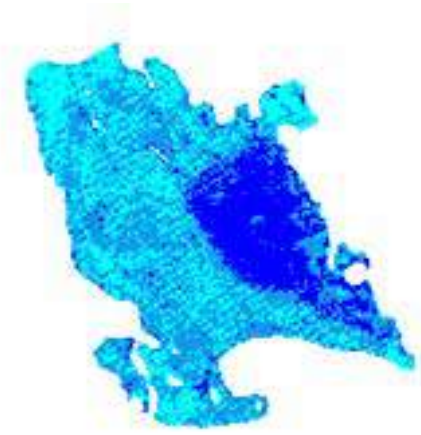
B



LISS-III FCC (G R SWIR)

E

σ - based classified MNDWI image
(for open-water polygon as an AOI)



Colour	MNDWI Pixel value	Qualitative
	>μ+1σ	Low
	>μ-1σ to <μ+1σ	Moderate
	< μ-1σ	High

Figure 5: Various combinations of the spectral/indices bands used to delineate components of wetland

4.0. Results

The total estimated wetland area in India is 15260572 ha (SAC, 2011, Panigrahy et al., 2012) which turns out to be 4.63 per cent of the geographic area. The summary area statistics shows that Inland: Natural wetlands dominate with about 43 % followed by Inland: Man-made wetlands (30 %) and Coastal: natural wetlands ((Figure 6A). The size-wise distribution of wetlands (Figure 6 B) reveals that large size wetlands (> 10000 ha) constitutes 49 % followed by the wetland between 100 and 10000 ha (37 %).

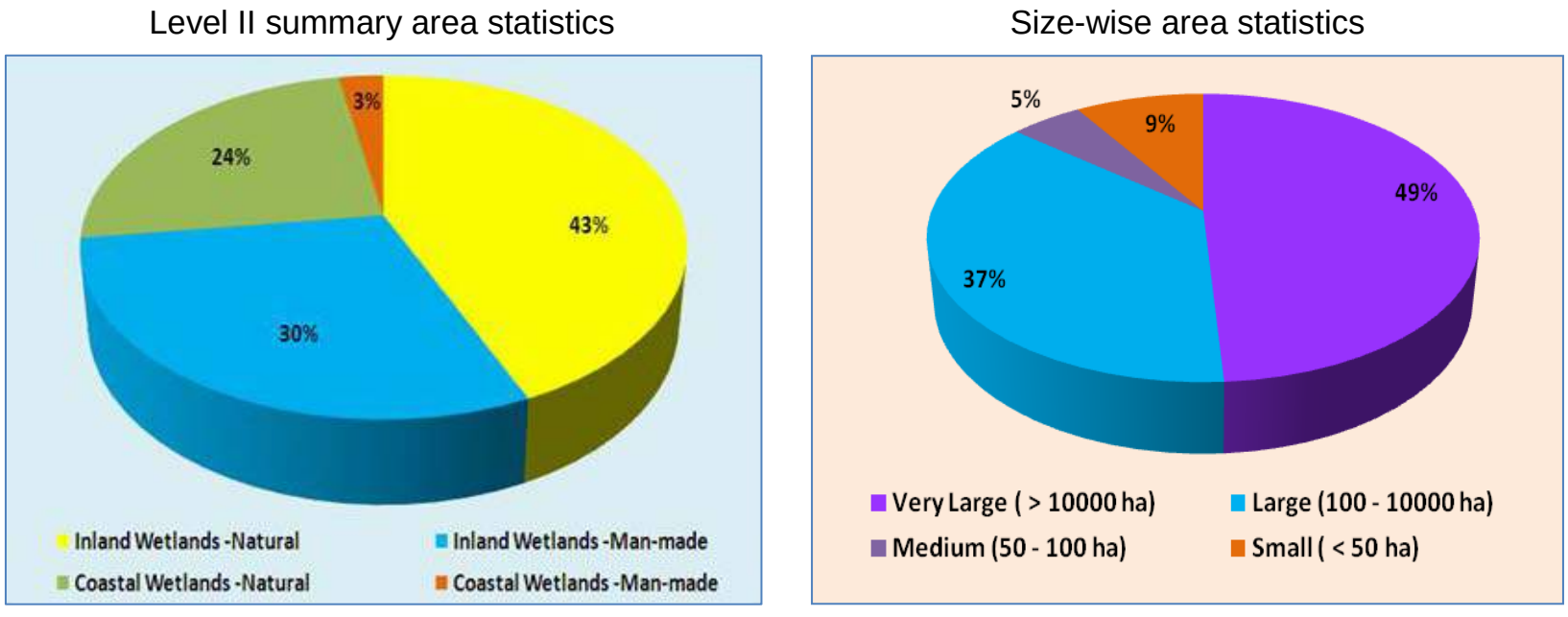


Figure 6: Aerial estimates of national wetland inventory and assessment based on Resourcesat-1 LISS-III data of 2006-07 on 1:50,000 scale

Type-wise statistics (Figure 7) reveals that River/Stream is the dominate type with 34.5 % of the wetland area followed by Reservoir/Barrage (16.3 %), Intertidal Mudflat (15.8 %) and Lagoon (8.6 %). Rest of the each wetland type comprised less than 5 % of wetland area.

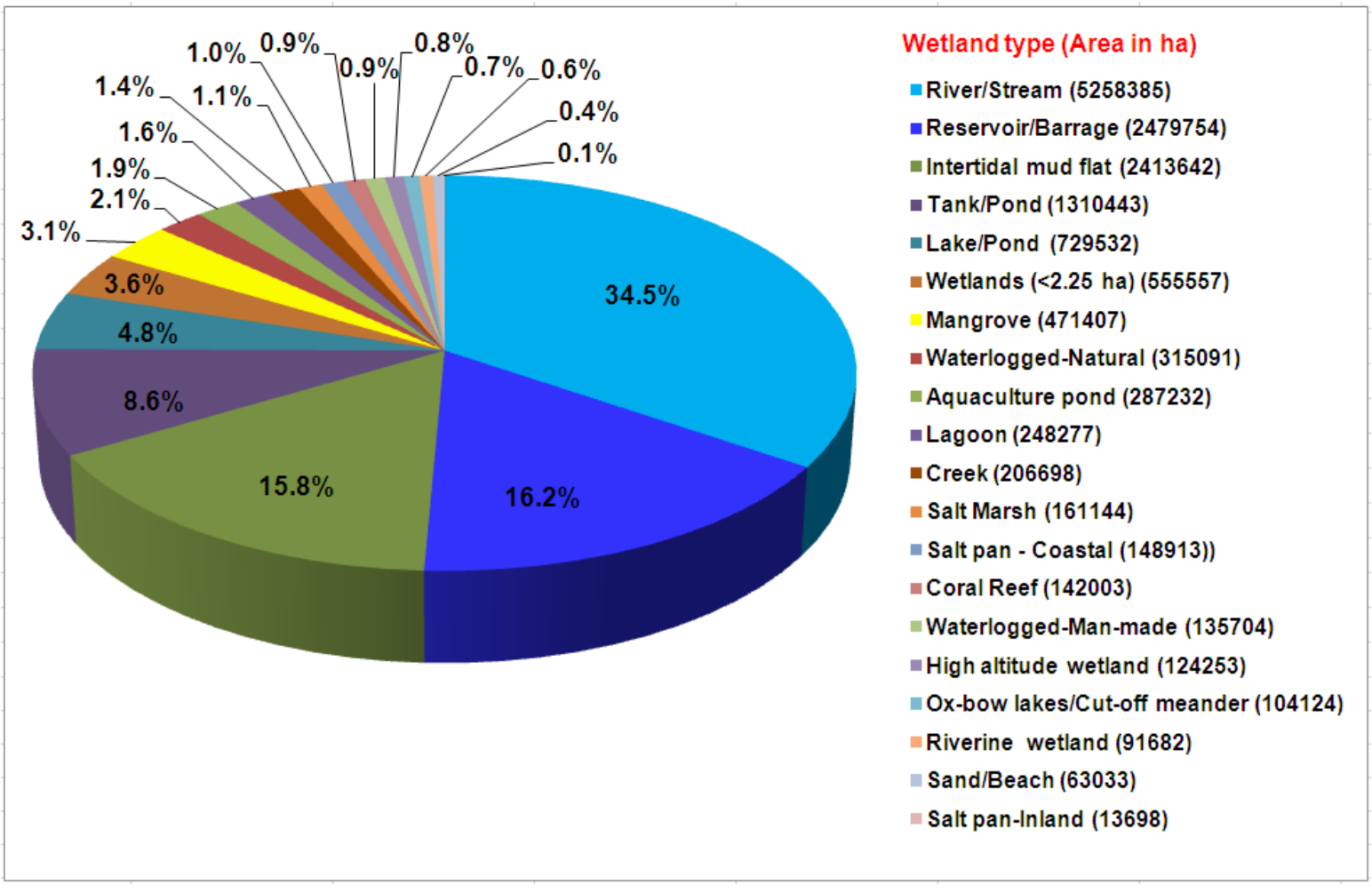


Figure 7: Aerial estimates of type-wise national wetland inventory and assessment based on Resourcesat-1 LISS-III data of 2006-07 on 1: 50, 000 scale

4.1 National Wetland Inventory vis-à-vis Ramsar Sites in India

India presently has 26 wetlands designated as Ramsar sites. The official figure of the extent of protected surface area of these 26 sites is 689131 ha (http://www.ramsar.org). This turns out to be 4.5 per cent of the total wetland area of the country. The geographic extent of these wetlands as observed on satellite image along with the wetland type, its code as per the NWIA classification system is given in the Table 4.

Table 4: Location of Indian Ramsar sites

Sr. No.	Wetland name and state	Coordinates		NWIA-based	
		Latitude	Longitude	Wetland type	Wetland code
1	Ashtamudi Wetland, Kerala	08° 56' 58"	76° 34' 53"	Coastal-Natural- Lagoon	2101
2	Bhitarkanika Mangroves, Orissa	20° 40' 36"	86° 55' 52"	Coastal-Natural-Mangrove	2106
3	Bhoj Wetland, Madhya Pradesh	23° 14' 46"	77° 20' 31"	Inland-Manmade- Reservoir/ Barrage	1201
4	Chandertal Wetland, Himachal Pradesh	32° 29' 12"	77° 36' 47"	Inland-Natural-High Altitude Wetland	1101
5	Chilika Lake, Orissa	19° 42' 24"	85° 20' 53"	Coastal-Natural-Lagoon	2101
6	Deepor Beel, Assam	26° 07' 24"	91° 38' 20"	Inland-Natural-Lake	1101
7	East Calcutta Wetlands, West Bengal	22° 27' 00"	88° 26' 52"	Inland-Manmade-Waterlogged	1203
8	Harike Lake, Punjab	31° 09' 33"	75° 00' 14"	Inland-Manmade-Reservoir/ Barrage	1201
9	Hokera Wetland, Jammu & Kashmir	34° 05' 35"	74° 42' 11"	Inland-Natural-Lake/Pond	1101
10	Kanjli, Punjab	31° 25' 03"	75° 21' 53"	Inland-Manmade-Reservoir/Barrage	1201
11	Keoladeo National Park, Rajasthan	27° 10' 30"	77° 30' 50"	Inland-Manmade-Waterlogged	1203
12	Kolleru Lake, Andhra Pradesh	16° 37' 04"	81° 11' 47"	Coastal-Natural-Lake/Pond	1101
13	Loktak Lake, Manipur	24° 33' 03"	93° 48' 47"	Inland-Natural-Lake/Pond	1101
14	Nalsarovar Bird Sanctuary, Gujarat	22 ° 46' 33"	72 ° 02' 21"	Inland-Natural-Lake/Pond	1101
15	Point Calimere Wildlife and Bird Sanctuary, Tamil Nadu	10° 19' 16"	79° 37' 53"	Coastal wetland complex	2102, 2104, 2106, 2201
16	Pong Dam Lake, Himachal Pradesh	32° 00' 14"	76° 02' 18"	Inland-Manmade-Reservoir/ Barrage	1201
17	Renuka Wetland, Himachal Pradesh	31° 36' 57"	77° 26' 59"	Inland-Natural-Lake/Pond	1101
18	Ropar, Punjab	31° 00' 56"	76° 29' 55"	Inland-Manmade-Reservoir/ Barrage	1201
19	Rudrasagar Lake, Tripura	23° 30' 07"	91° 18' 49"	Inland-Natural-Waterlogged	1105
20	Sambhar Lake, Rajasthan	26° 56' 08"	75° 04' 32"	Inland-Natural-Lake/Pond	1101
21	Sasthamkotta Lake, Kerala	09° 02' 15"	76° 38' 06"	Inland-Natural-Lake/Pond	1101
22	Surinsar-Mansar Lakes, Jammu & Kashmir	32° 41' 43"	75° 08' 36"	Inland-Natural-Lake/Pond	1101
23	Tsomoriri, Jammu & Kashmir	32° 54' 00"	78° 19'0 3"	Inland-Natural-High Altitude Wetland	1101
24	Upper Ganga River (Brijghat to Narora Stretch), Uttar Pradesh	28 ° 33' 08"	78° 13' 00''	Inland-Natural-River/Stream	1106
25	Vembanad-Kol Wetland, Kerala	9 ° 37' 21"	76 ° 24' 00"	Coastal-Natural-Lagoon	2101
26	Wular Lake, Jammu & Kashmir	34 ° 21' 9"	74 ° 33' 20"	Inland-Natural- Lake/Pond	1101

Source: NWIA GIS database

The distribution of Ramsar sites in terms of Bio-geographical zones shows that the highest number of sites (9) falls in the Semi Arid zone, followed by the Coasts (7). No sites are observed in the zones of the Indian desert, the Western Ghats and the Islands. However, if one considers the per cent of wetlands in each zone, highest share is observed in case of the Coasts (37.25%), followed by the North East India (5.38%) and the Indo-Gangetic plains (5. 31%) as given in Table 5. The distribution of Ramsar sites across various zones of Bio-geographic regions is given in Figures 8.

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Table 5: Bio-geographical zone-wise distribution of Ramsar sites in India

Sr. No.	Bio-geographic Zones	Geographic area (sq. km)	Number of wetlands#	Wetland area (ha) #	% wetland area#	Number of Ramsar sites	Area (ha) under Ramsar sites*	% Ramsar sites' area
1	Trans-Himalayas	189960	2470	275194	1.45	2	14579	5.30
2	The Himalaya	210636	4632	285539	1.36	3	12677	4.44
3	The Indian Desert	196549	17064	329880	1.68	-	-	-
4	The Semi-Arid Zone	526297	95666	1769715	3.36	9	77487	4.38
5	The Western Ghats	134672	12637	372538	2.77	-	-	-
6	The Deccan	1387445	325637	4864872	3.51	1	83501	1.72
7	The Gangetic Plain	353607	233676	1878224	5.31	1	11364	0.61
8	The Coasts	120794	59423	4502096	37.27	7	176948	3.93
9	North-East India	170363	16937	916524	5.38	3	25949	2.83
10	The Islands	7145	94	65990	9.24	-	-	-
	Total	**3297467**	**768236**	**15260572**	**4.63**	**26**	**402505**	**2.64**

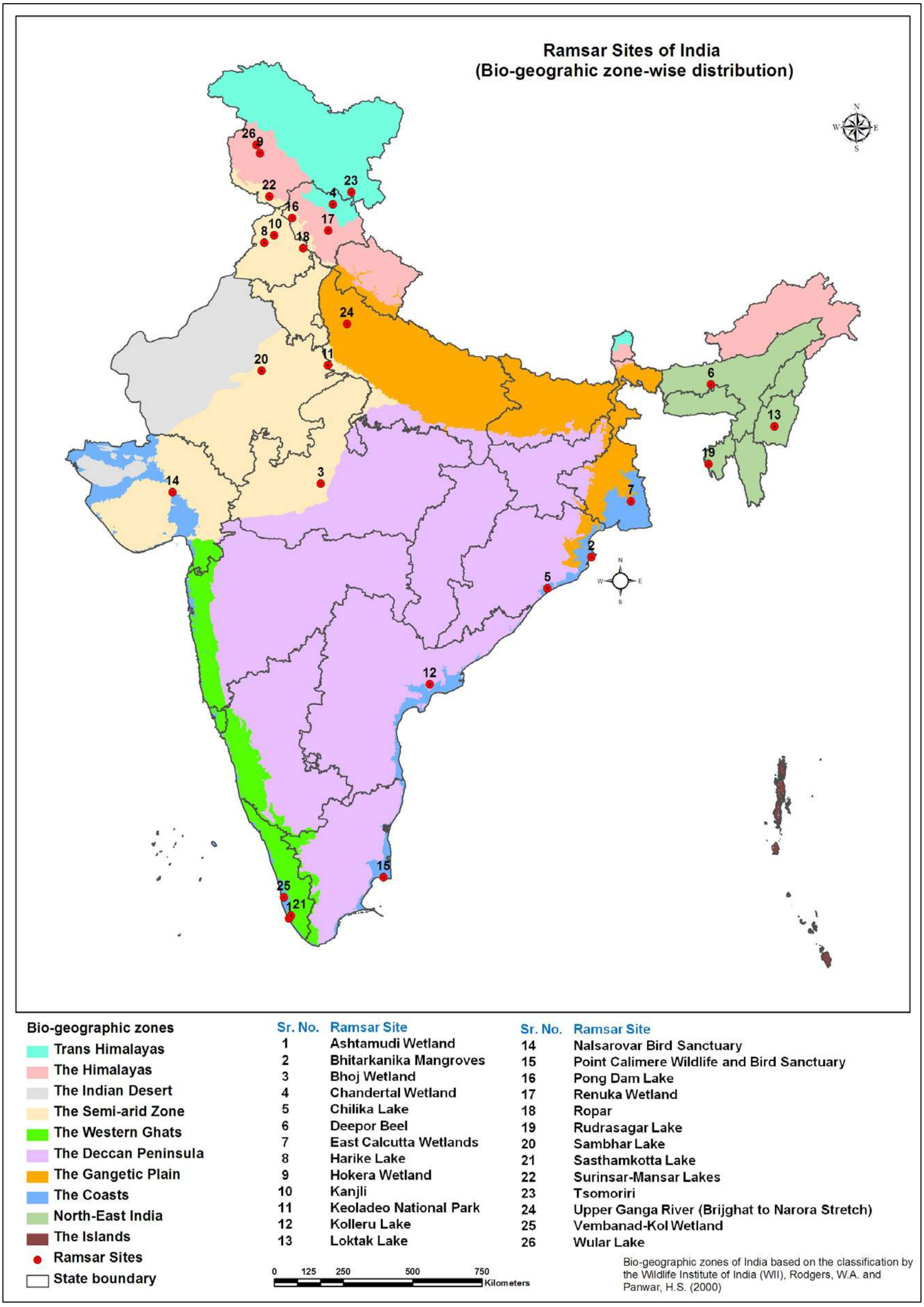
* The area estimates are based on satellite data of 2006 (post-monsoon) and 2007 (pre-monsoon), #: National level

The distribution pattern of the Ramsar sites in relation to the agro-climatic regions showed highest number of 8 sites in the Western Himalayan Region. On the other hand, no sites are present in the Middle Gangetic Plain Region, Eastern Plateau and Hills, Western Plateau and Hills, Southern Plateau and Hills and Island (Figure 9). Wetland statistics of Ramsar sites in relation to total wetland area in each zone is given in Table- 6.

Table-6: Agro-climatic Region-wise distribution of Ramsar sites in India

Sr. No.	Agro-climatic Regions	Geographic area (sq. km)	Number of wetlands	Total wetland area (ha)	% wetland area	Number of Ramsar sites	Area (ha) under Ramsar sites*	% Ramsar site area
1	Western Himalayan Region	347396	6225	648206	1.87	8	52021	8.03
2	Eastern Himalayan Region	272367	21115	1152427	4.23	3	25949	2.25
3	Lower Gangetic Plain Region	68071	137164	995607	14.63	1	12512	1.26
4	Middle Gangetic Plain Region	160589	67986	862069	5.37	-	-	-
5	Upper Gangetic Plain Region	146373	62634	661226	4.52	2	14276	2.16
6	Trans Gangetic Plain Region	124965	22335	122574	0.98	2	7423	6.06
7	Eastern Plateau and Hills	369879	143819	1097538	2.97	-	-	-
8	Central Plateau and Hills	330844	75792	1094127	3.31	1	3420	0.31
9	Western Plateau and Hills	333989	42215	1026572	3.07	-	-	-
10	Southern Plateau and Hills	406604	47649	1433081	3.52	-	-	-
11	East Coast Plains and Hills	200636	77549	1800459	8.97	4	224396	12.46
12	West Coast Plains and Hills	151133	21153	578611	3.83	3	23541	4.07
13	Gujarat Plains and Hills Region	195581	24687	3413084	17.45	1	14673	0.43
14	Western Dry Region	181418	14842	282396	1.56	1	24294	8.60
15	Island Region	7622	3071	92595	12.15	-	-	-
	Total	**3297467**	**768236**	**15260572**	**4.63#**	**26**	**402505**	**2.64**

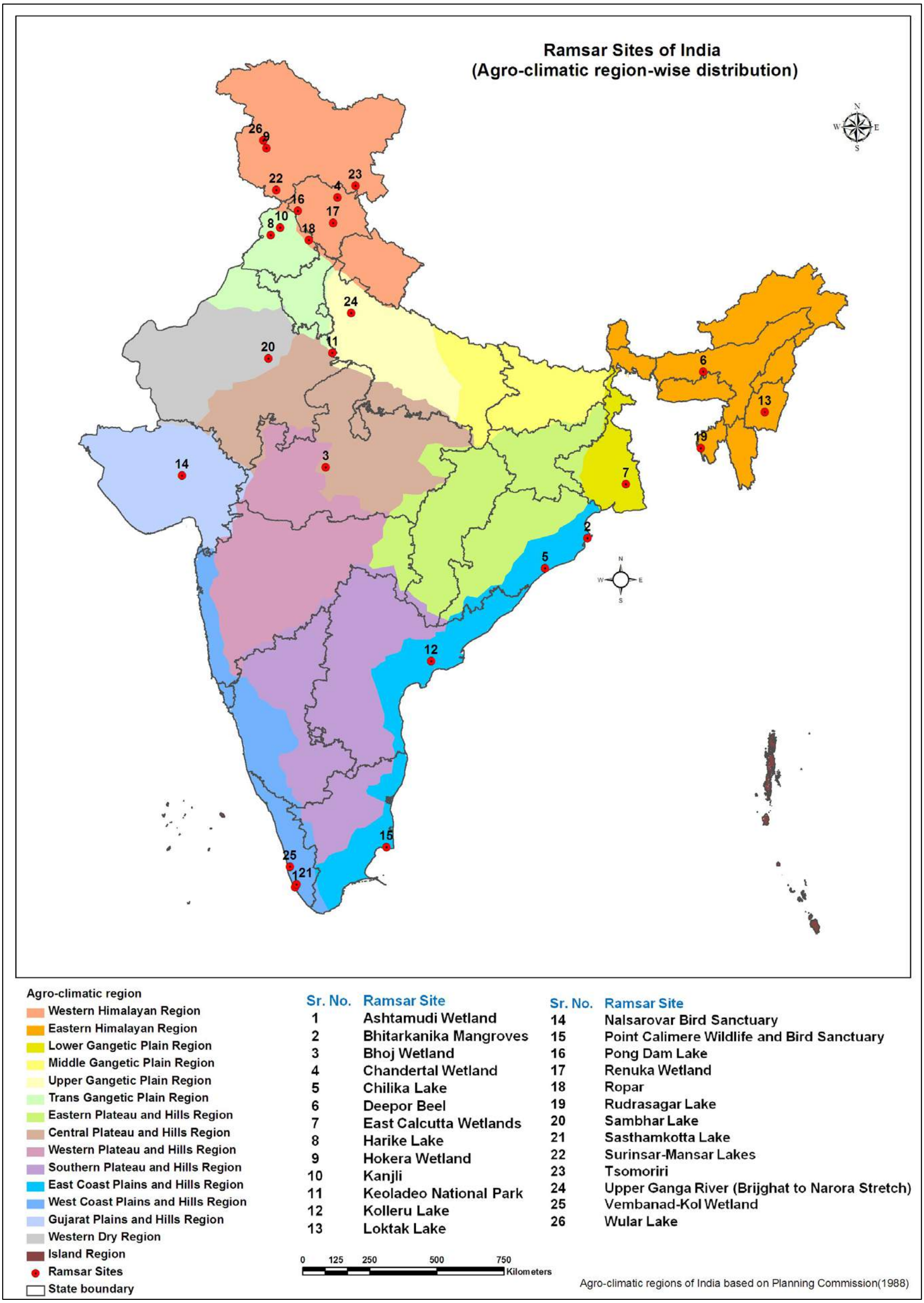
* The area estimates are based on satellite data of 2006 (post-monsoon) and 2007 (pre-monsoon), #: National level



Sr. No.	Ramsar Site
1	Ashtamudi Wetland
2	Bhitarkanika Mangroves
3	Bhoj Wetland
4	Chandertal Wetland
5	Chilika Lake
6	Deepor Beel
7	East Calcutta Wetlands
8	Harike Lake
9	Hokera Wetland
10	Kanjli
11	Keoladeo National Park
12	Kolleru Lake
13	Loktak Lake

Sr. No.	Ramsar Site
14	Nalsarovar Bird Sanctuary
15	Point Calimere Wildlife and Bird Sanctuary
16	Pong Dam Lake
17	Renuka Wetland
18	Ropar
19	Rudrasagar Lake
20	Sambhar Lake
21	Sasthamkotta Lake
22	Surinsar-Mansar Lakes
23	Tsomoriri
24	Upper Ganga River (Brijghat to Narora Stretch)
25	Vembanad-Kol Wetland
26	Wular Lake

Figure 8: Distribution of Ramsar sites of India under various Bio-geographical Zones



Sr. No.	Ramsar Site
1	Ashtamudi Wetland
2	Bhitarkanika Mangroves
3	Bhoj Wetland
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7	East Calcutta Wetlands
8	Harike Lake
9	Hokera Wetland
10	Kanjli
11	Keoladeo National Park
12	Kolleru Lake
13	Loktak Lake
14	Nalsarovar Bird Sanctuary
15	Point Calimere Wildlife and Bird Sanctuary
16	Pong Dam Lake
17	Renuka Wetland
18	Ropar
19	Rudrasagar Lake
20	Sambhar Lake
21	Sasthamkotta Lake
22	Surinsar-Mansar Lakes
23	Tsomoriri
24	Upper Ganga River (Brijghat to Narora Stretch)
25	Vembanad-Kol Wetland
26	Wular Lake

Figure 9: Distribution of Ramsar sites of India under various Agro-climatic Regions of India

4.2 Site-wise Description

The information derived for each wetland using the pre- and post- monsoon satellite images are compiled in the form of maps at 1:50,000 scale. The total extent estimated for the catchment including the 12 km buffer for each site includes the extent of the respective site also. The information regarding the Ramsar criterion, the flora and fauna have been used from the published literature.

4.2.1 Ashtamudi Wetland (Ramsar site no. 1204)



Ashtamudi is the second largest backwater system of the Kerala state. It was declared as Ramsar site on 19/08/2002 owing to the compliance of criteria 1, 2, 3 and 8. It is a good example of wetland that plays a crucial role in hydrological, biological and ecological roles in the region.

It supports endangered plant species like *zyzigium travencoricum* which is listed in Red data book of Indian plants for endangered species and *Calmus rotang* an endemic endangered species. The wetland also supports 43 species of plants. The dominant mangrove species are *Avicennia officinalis*, *Bruguiera gymnorrhiza* and *Sonneratia caseolaris*. Avifauna includes 57 species of birds out of which 6 are of migratory and 51 resident species. Near-threatened species namely; darter (*Anhinga melanogaster*) and oriental white ibis (*Threskiornis melanocephalus*) are recorded here. Wetland supports 97 species of fishes which include marine (42), estuarine-riverine (3) and (15) marine-estuarine. This wetland supports 21 recorded species of copepods. A number of bivalves are recorded here of which the dominant ones are *Villorita cyprinoides*, *Katelysia opima*, *Paphia malabaricas*, *Meretrix meretrix* and *M. casta*. These molluscs form an estimated 1200.78 ha of clam bed in the estuary of this wetland.

It is the deepest among all the estuaries of Kerala with a maximum depth of 6.4 m at the confluence zone. The major river discharging into the Ashtamudi is the Kallada, formed by the confluence of three rivers, viz., the Kulathupuzha, the Chendurni and the Kalthuruthy. The lagoon is palm shaped with eight prominent arms. The lagoon meets the sea near the Kollam town. Ashtamudi wetland and its environs as seen in LISS-III FCC are given in the Figure 10.

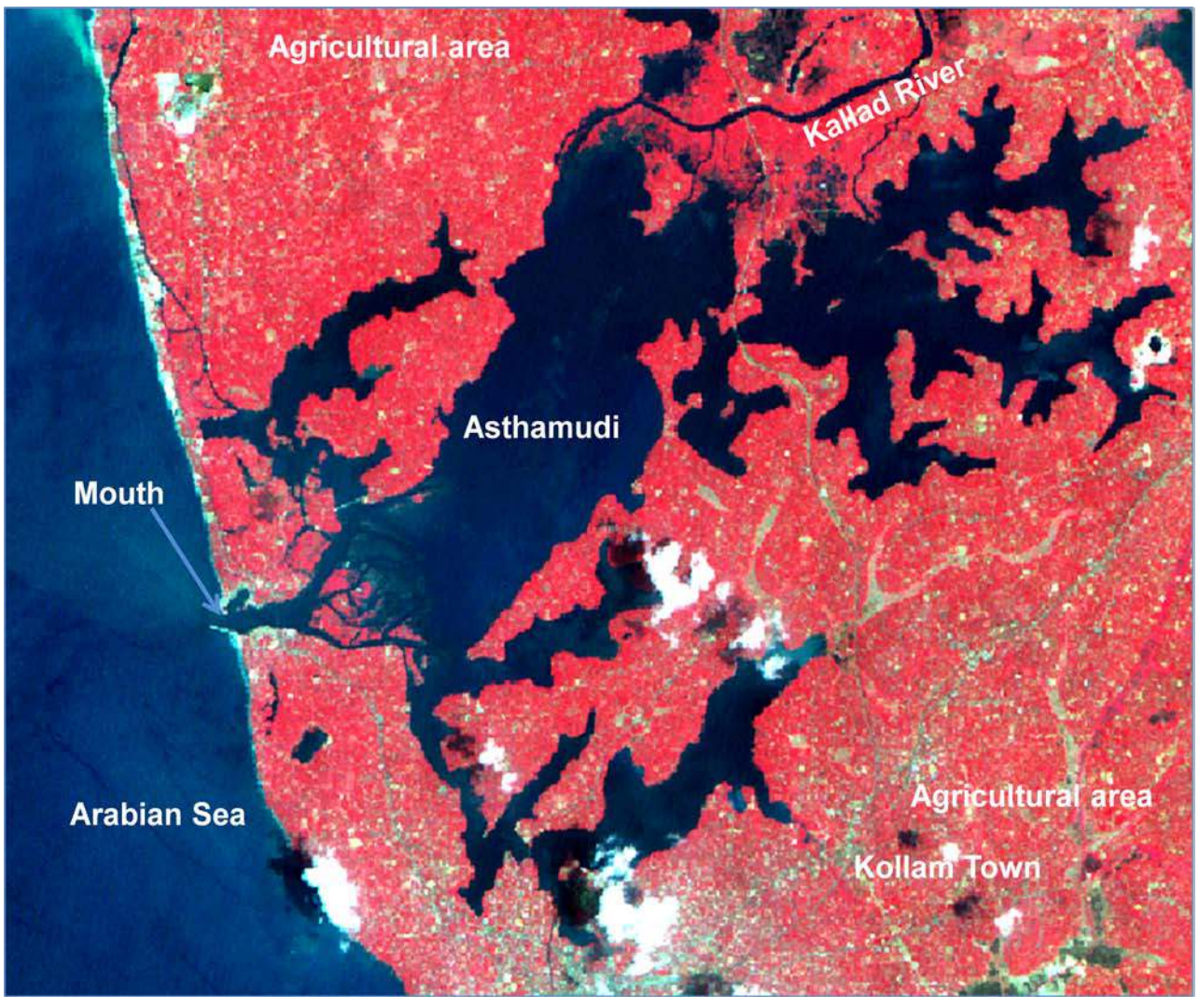

Figure 10: Ashtamudi wetland and its environ as seen in LISS III FCC (23-March-2007)

Based on the satellite images of 2006-07, the area extent of Ashtamudi wetland is estimated to be 5598 ha with a perimeter of 233 km. Wetland is almost free from aquatic vegetation. The vegetation is mainly mangrove and shore vegetation. Negligible seasonal changes in the wetland in terms of open-water spread and vegetation observed. The open-water spread is 5458 ha and the extent of vegetation is 140 ha. (Table 7). Over all turbidity of water is low in both the seasons.

Table 7: Salient observations of Ashtamudi wetland from satellite data

Name:	Ashtamudi Wetland
Location:	08° 52'53" to 09°01'17" N Latitude 76° 31'49" to 76° 40'40" E Longitude
Wetland Type:	Coastal-Natural-Lagoon
Wetland Area: Perimeter :	5598 ha 233 km
<u>Open-water</u> Post-monsoon: Pre-monsoon:	 5458 ha 5458 ha
<u>Vegetation</u> Post-monsoon: Pre-monsoon:	 140 ha 140 ha
Overall Turbidity:	Low

Agriculture is the dominant land use of the catchment of this wetland. The catchment of the Ashtamudi wetland including 12 km buffer area (76110 ha) harbour 165 wetlands with an area of 9841 ha. Natural waterlogged class dominates, followed by Rivers. Total 9 lagoons are there, Asthamudi being the largest one with 57 per cent of the wetland area in the catchment including buffer area. These wetlands show seasonal change in terms of vegetation spread.

Table 8: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Ashtamudi wetland

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-	Pre-	Post-	Pre-
1101	Lake/Pond	1	354	354	354	-	-
1105	Waterlogged (natural)	120	1178	499	414	685	651
1106	River/Stream	14	853	849	834	-	-
1202	Tank/Pond	12	286	245	117	45	168
2101	Lagoon	9	7092	6893	6898	177	171
2103	Sand/Beach	9	78	-	-	-	-
	Total	165	9841	8840	8617	907	990

Wetland map of the Ashtamudi catchment including the 12 km buffer area is given in the Plate 1. The seasonal status of open-water spread and vegetation are given in the Plates 2-5 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

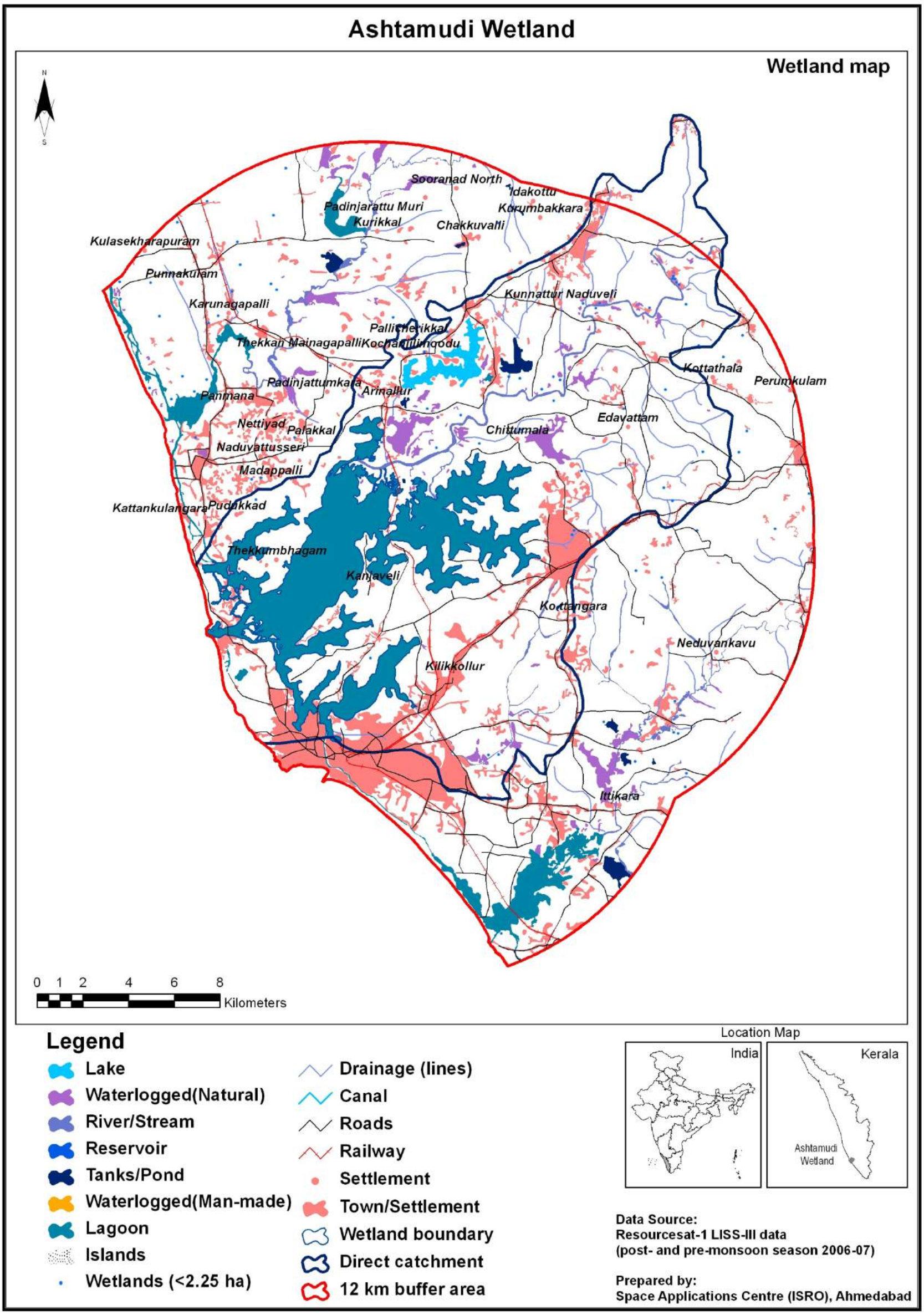

Plate 1:Distribution pattern of wetland types in the catchment including 12 km buffer area of Asthamudi lagoon based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

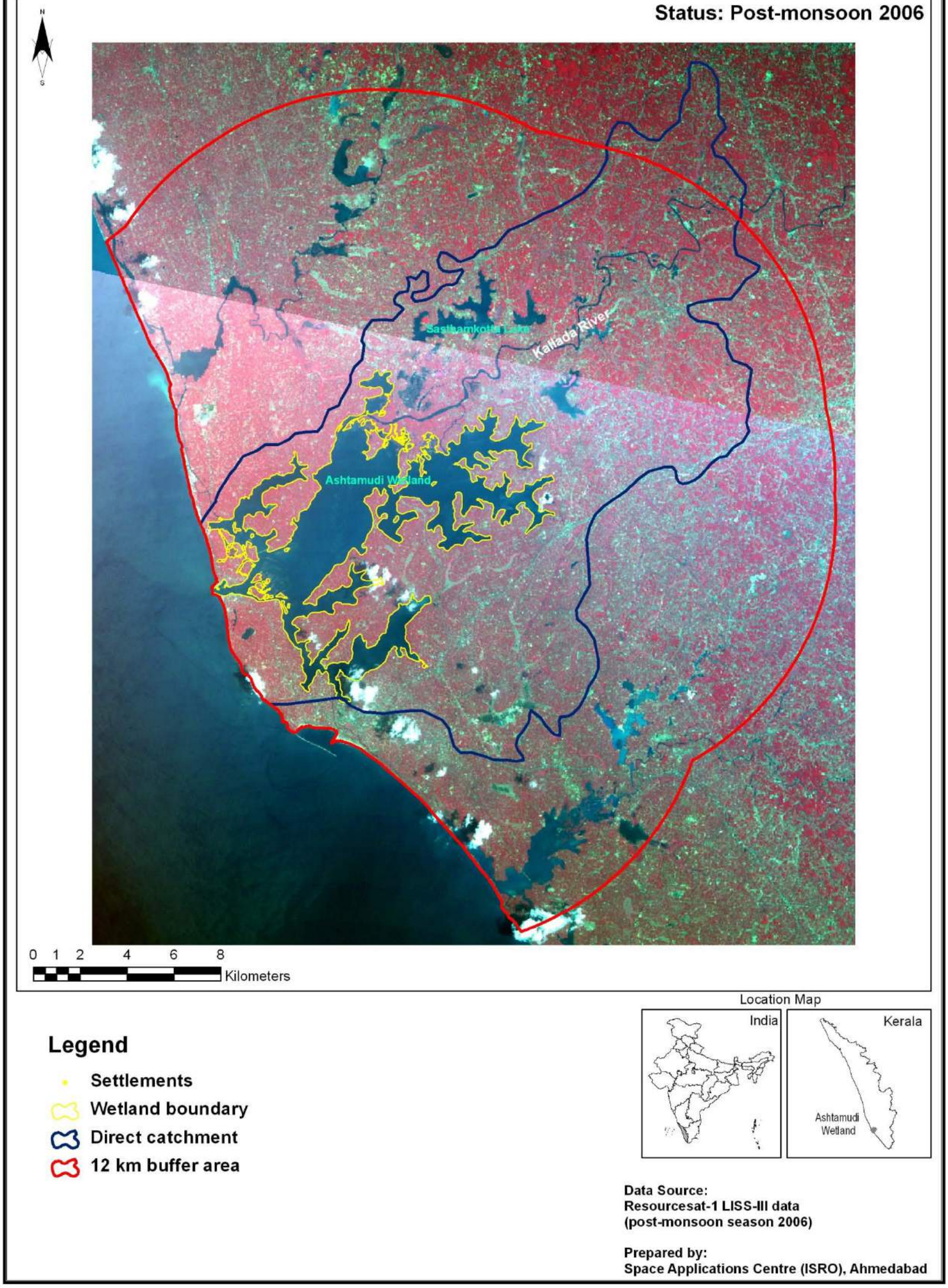

Plate 2: Ashtamudi Wetland and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon (28-November-2006)

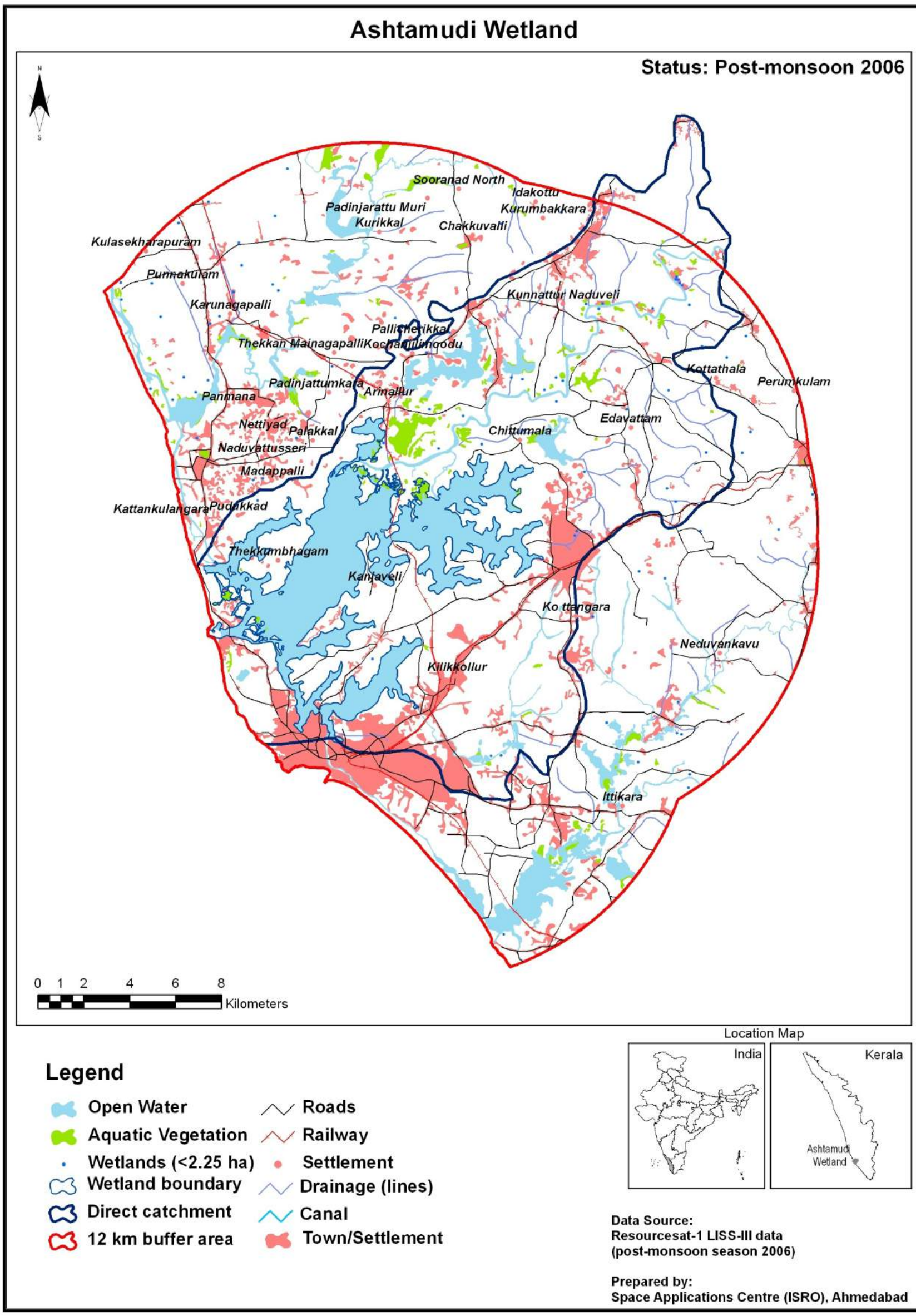

Plate 3: Open-water and vegetation status of Ashtamudi Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

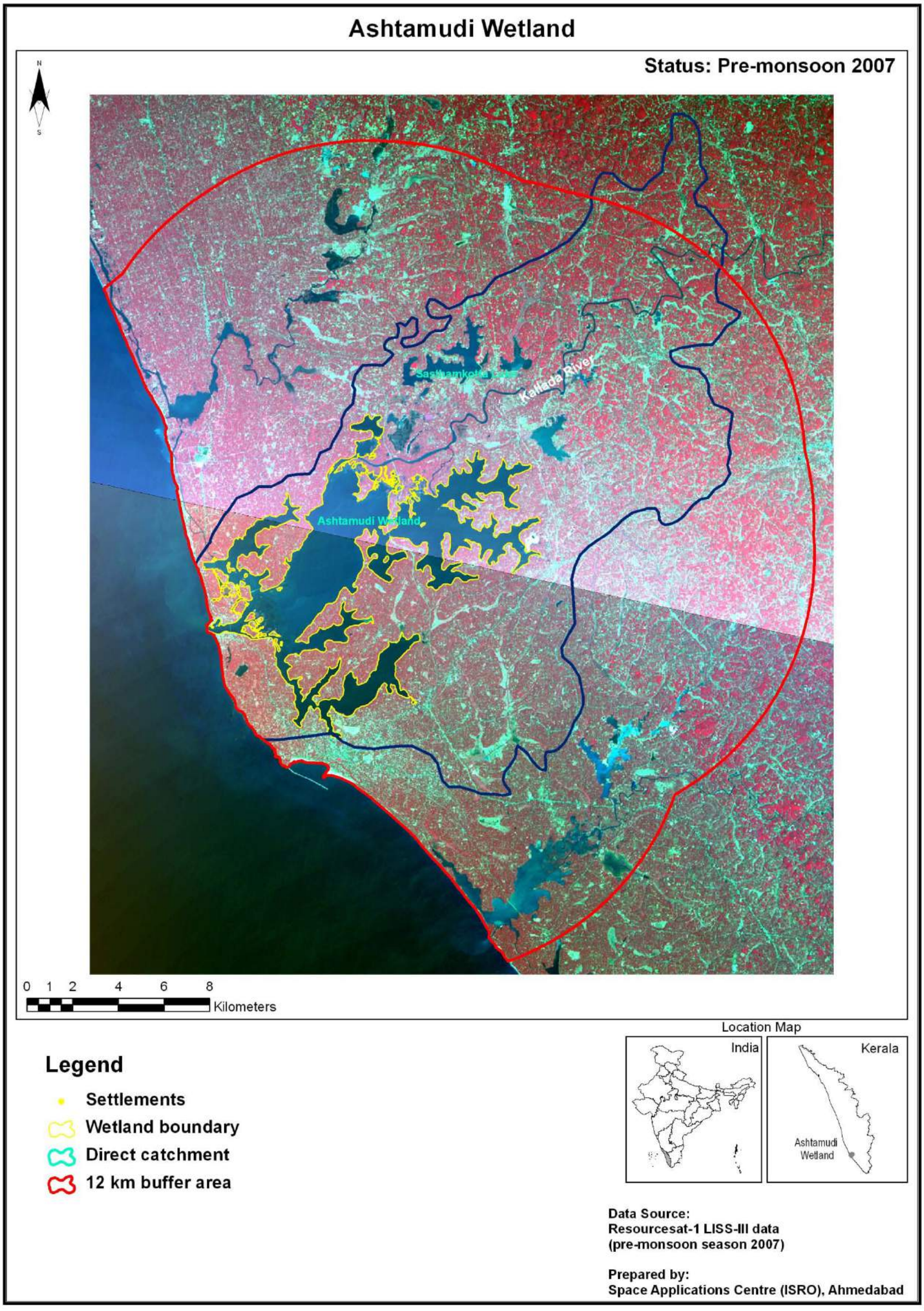

Plate 4: Ashtamudi Wetland and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (23-March-2007)

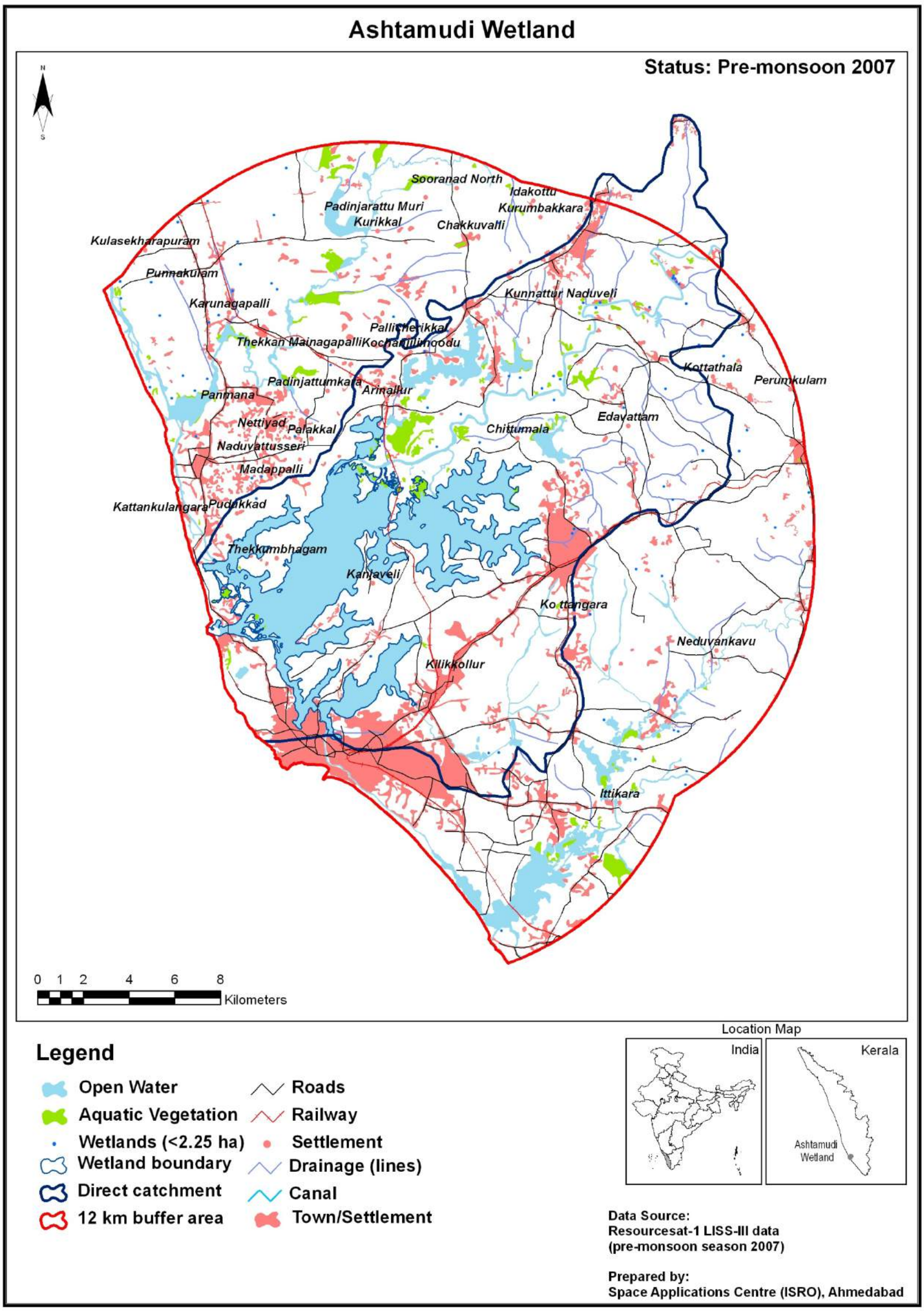

Plate 5: Open-water and vegetation status of Ashtamudi Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.2 Bhitarkanika Mangroves (Ramsar site no. 1205)



Bhitarkanika is one of the large contiguous patches of mangrove forest in the country, representing the Indo-Malayan community with 55 species. It is situated in the delta formed by Brahmani and Baitarani rivers in the Kendrapara district of Orissa. It was declared as Ramdsar site on 19/08/2002 owing to compliance of criteria 2, 4, 6, 8 & 9 as described below:

- Wetland supports threatened ecological communities.
- Wetland provides refuge during adverse conditions to threatened species.
- Wetland regularly supports 1 % of the individuals in a population of one species or subspecies.
- Wetland supports an important source of food for fishes, spawning ground, nursery and/or migration path.
- Wetland supports 1 % of the population of a wetland dependent non-avian species.

The area has many patches of mangrove. The major one is the Bhitarakanika National Park nestled between the Dhamra River and . Bhitarkanika mangroves are unique due to the presence of association of *Rhizophora stylosa*, *Sonneratia griffithii* and *Heritiera littoralis*. Another mangrove patch which forms the eastern boundary of Bhitarkanika Wildlife Sanctuary, known as Gahirmatha, supports the largest known nesting beach of olive ridley sea turtle in the world. Bhitarkanika is known for harbouring around 700 saltwater crocodiles (*Crocodylus porosus*) distributed in the creeks and rivers. Water monitor lizard is common here which is otherwise rare in most parts of India. One of the largest heronries in the country is located here. More than 20,000 birds consisting of 11 species nest in this heronry. Five species of marine dolphins have been recorded here. The most common species encountered is Indo-pacific humpbacked dolphin. Bhitarkanika mangrove and its environs as observed on Resourcesat-1 LISS-III images is given in the Figure 11.

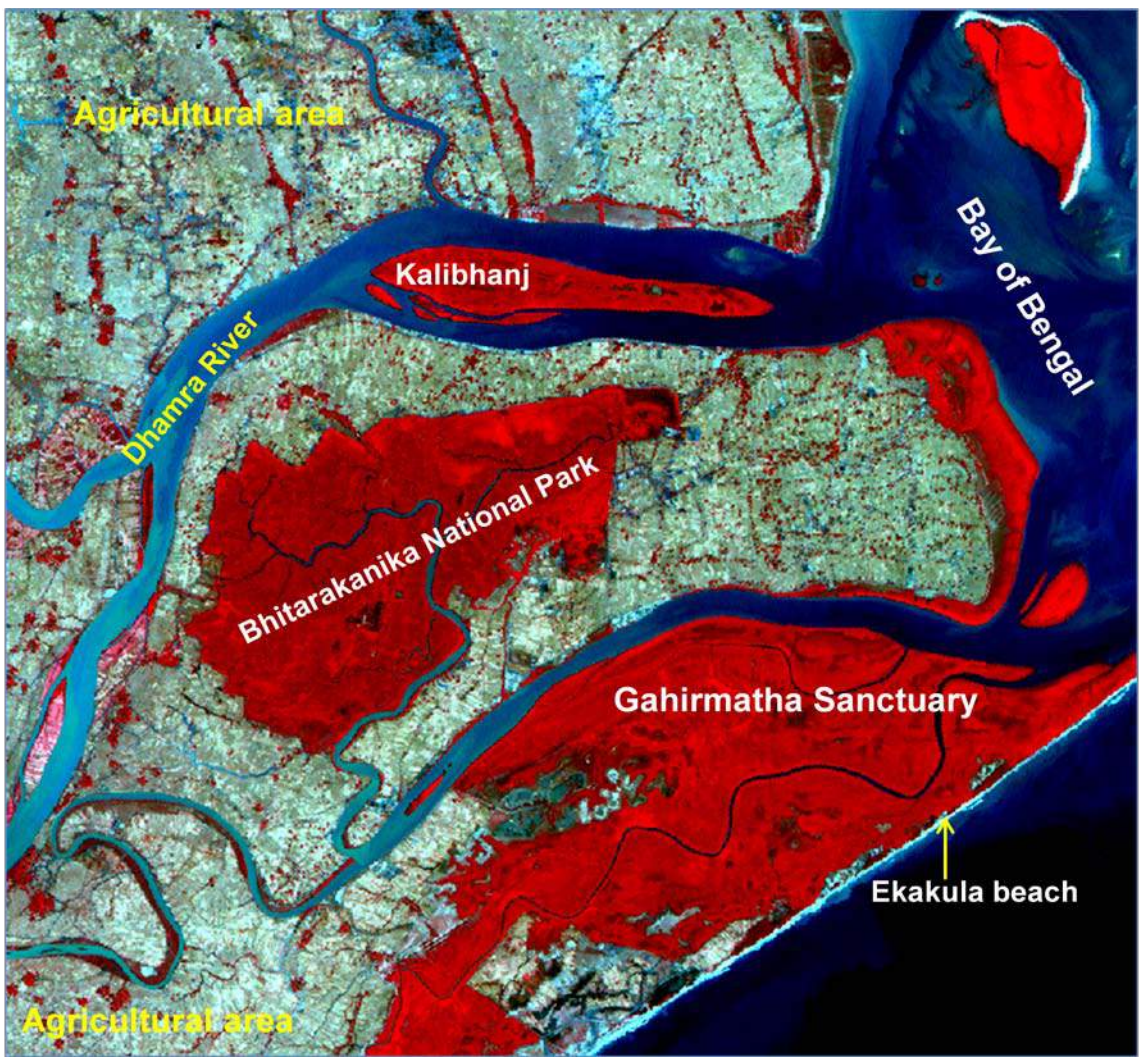

Figure 11: Bhitarakanika mangrove and its environ as seen in LISS-III FCC (04-December-2006)

Bhitarkanika Mangroves are divisible into 3 segments due to the presence of river-system. Based on the satellite images of 2006-07, the area of the Mangrove patch (along with the rivers/creeks) under the National Park is estimated to be 5199 ha with a perimeter of 55 km. (Table 9).

Table 9: Salient observations of Bhitarkanika Mangroves from satellite data

Name:	Bhitarkanika Mangroves
Location:	$20^0$30’04" - $20^0$48’07” N Latitude $86^0$46’21" - $87^0$00’47” E Longitude
Wetland Type:	Coastal-Natural-Mangrove
Wetland Area: Perimeter :	5119 ha 55 km
<u>Open-water:</u> Post-monsoon: Pre-monsoon:	 920 ha 920 ha
<u>Vegetation</u> Post-monsoon: Pre-monsoon:	 4199 ha 4199 ha
Overall Turbidity:	Moderate

The catchment including 12 km buffer area (82167 ha) comprises 325 wetlands accounting for 29904 ha. The dominant wetland type is Mangrove spread over 52 patches with an extent of 15265 ha. River/Stream (8116 ha) and Intertidal Mud-flat (3445 ha) are other major wetland types in catchment. The details for each of wetland types present in the catchment and buffer area are given in the Table 10.

Table 10: Type-wise area estimates of wetlands in the catchment and 12 km buffer area of the Bhitarkanika mangroves

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1105	Waterlogged	10	110	31	31	79	79
1106	River/Stream	30	8116	8116	8116	-	-
1202	Tank/pond	1	3	3	3	-	-
2103	Sand/Beach	4	440	-	-	-	-
2104	Intertidal Mud-flat	62	3445	-	-	-	-
2106	Mangrove	52	15265	-	-	15265	15265
2202	Aquaculture pond	166	2525	2525	2525	-	-
	Total	325	29904	10675	10675	15344	15344

Wetland map of the Bhitarkanika Mangrove catchment including the 12 km buffer area is given in the Plate 6.The seasonal status of open-water spread and vegetation are given in the Plates 7-10 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

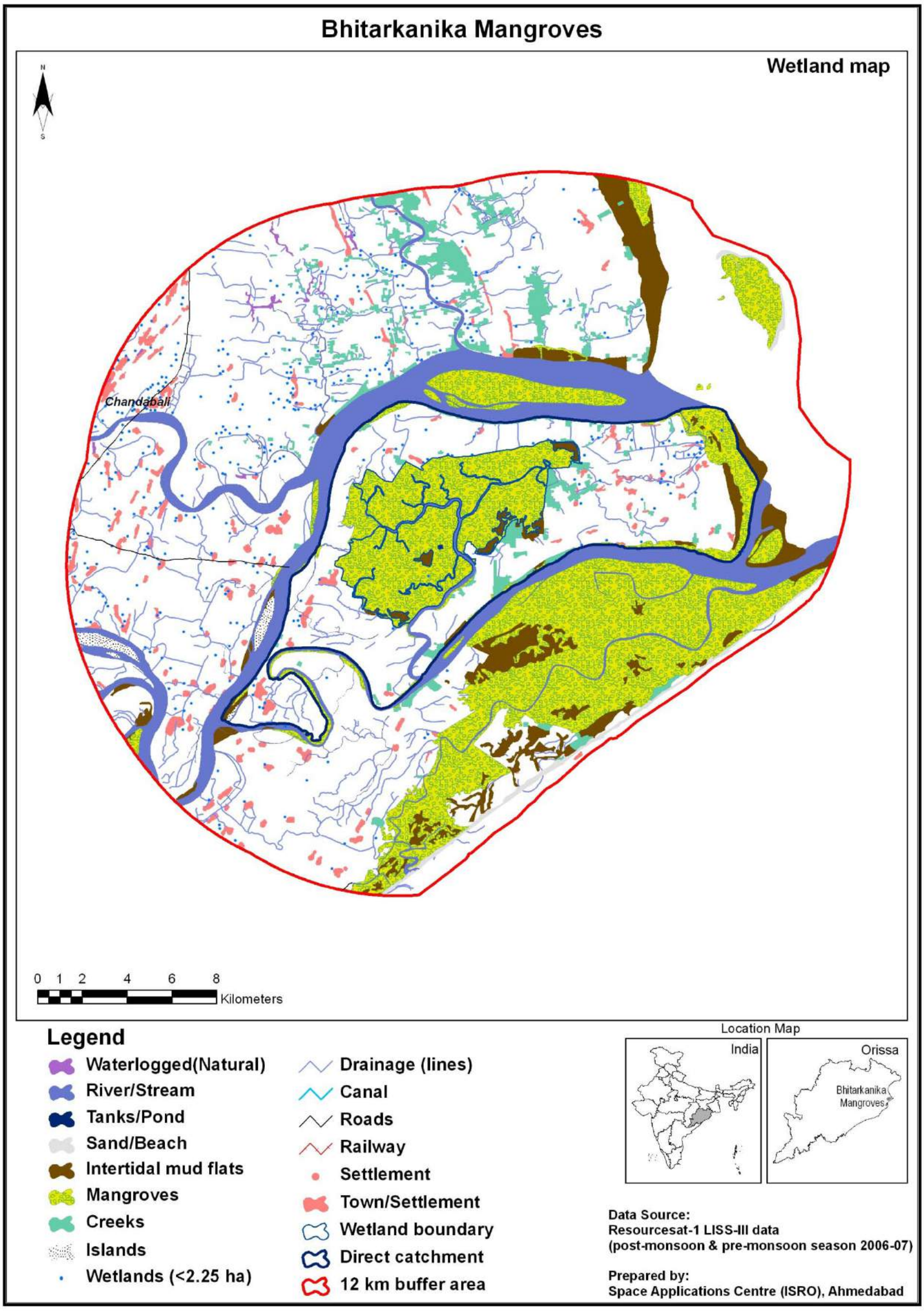

Plate 6: Wetland map of Bhitarkanika Mangroves (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

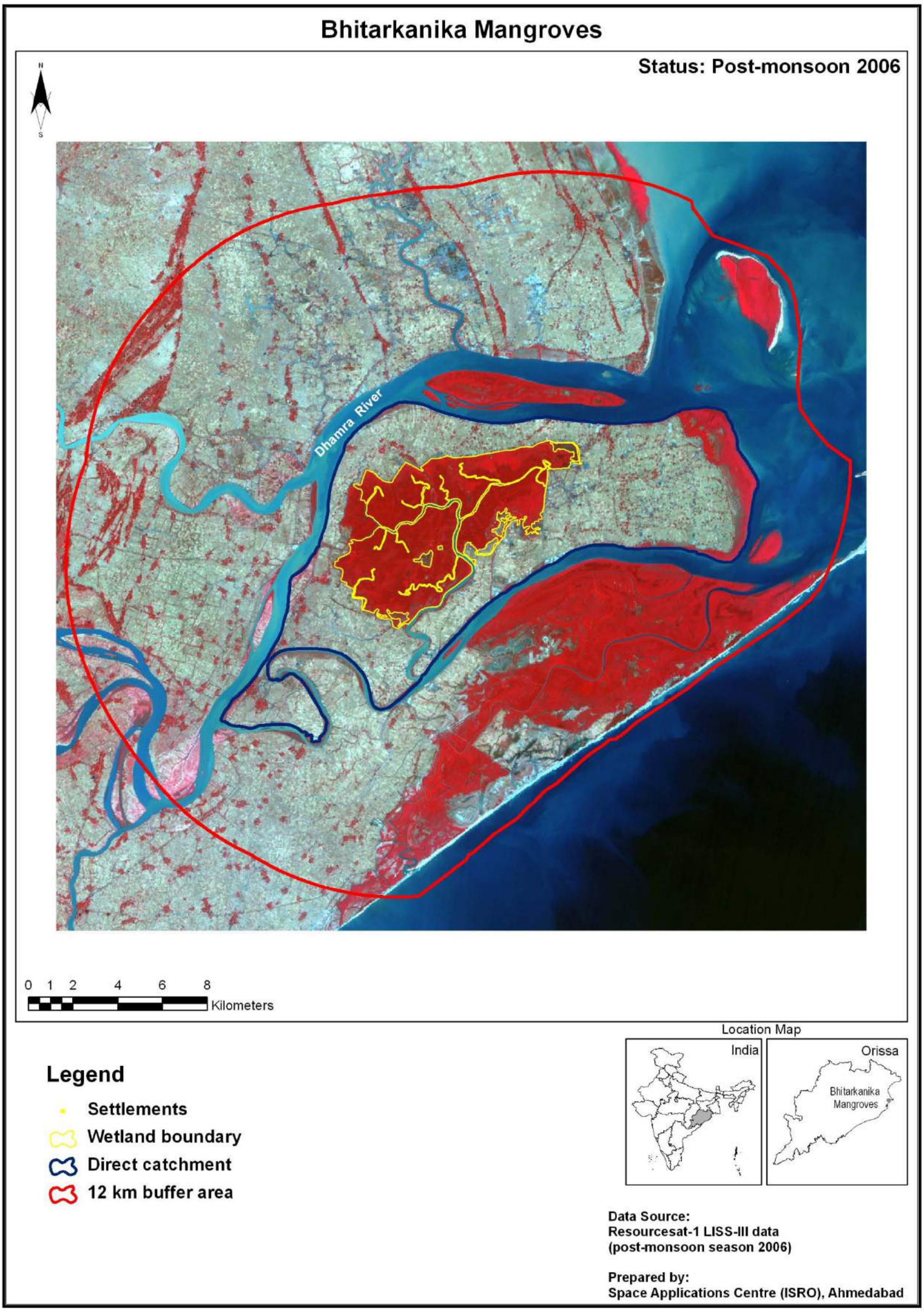

Plate 7: Bhitarkanika Mangroves and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (04-December-2006)

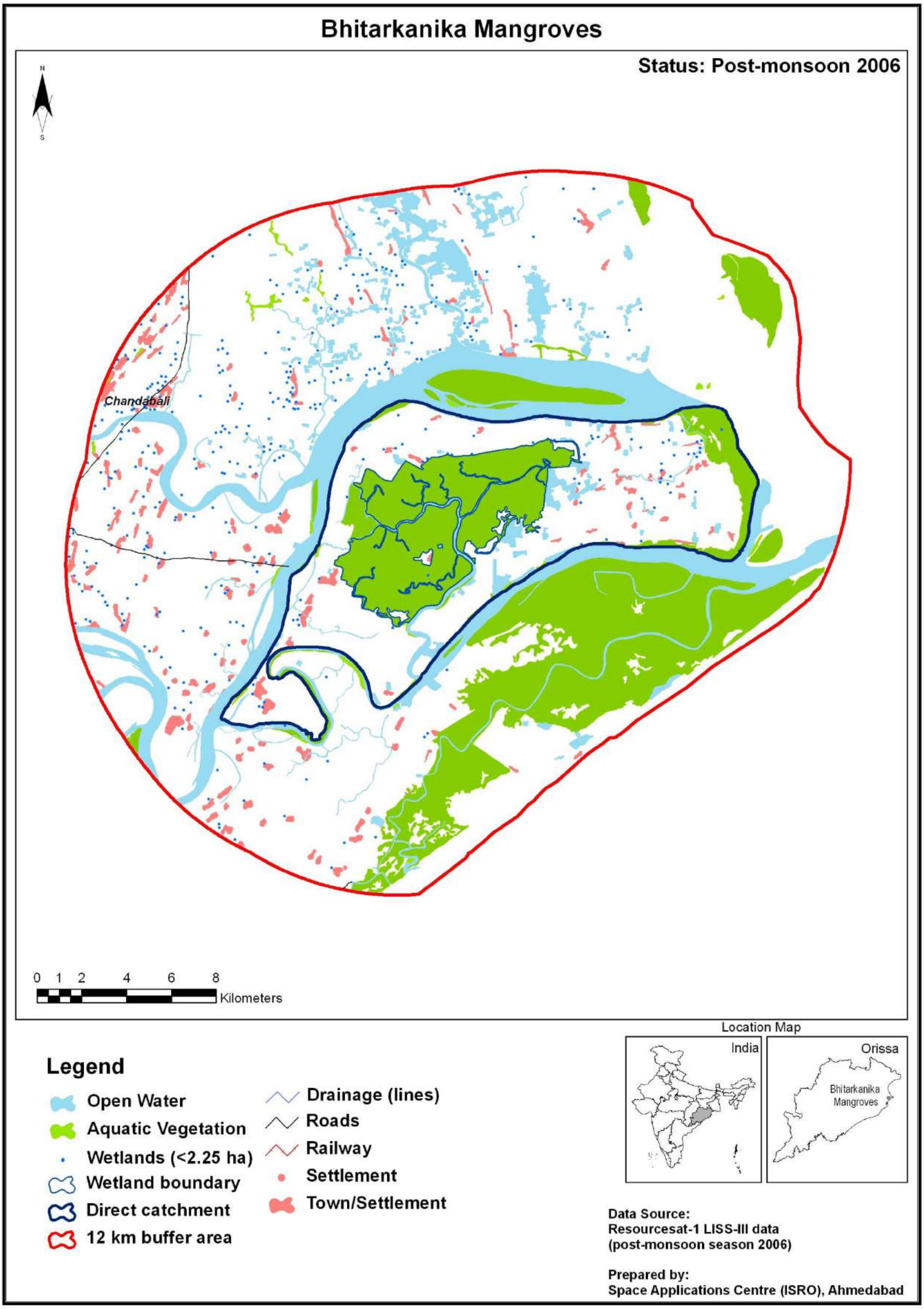

Plate 8: Open-water and vegetation status of Bhitarkanika Mangroves (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006



Plate 9: Bhitarkanika Mangroves and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon (03-April-2007)

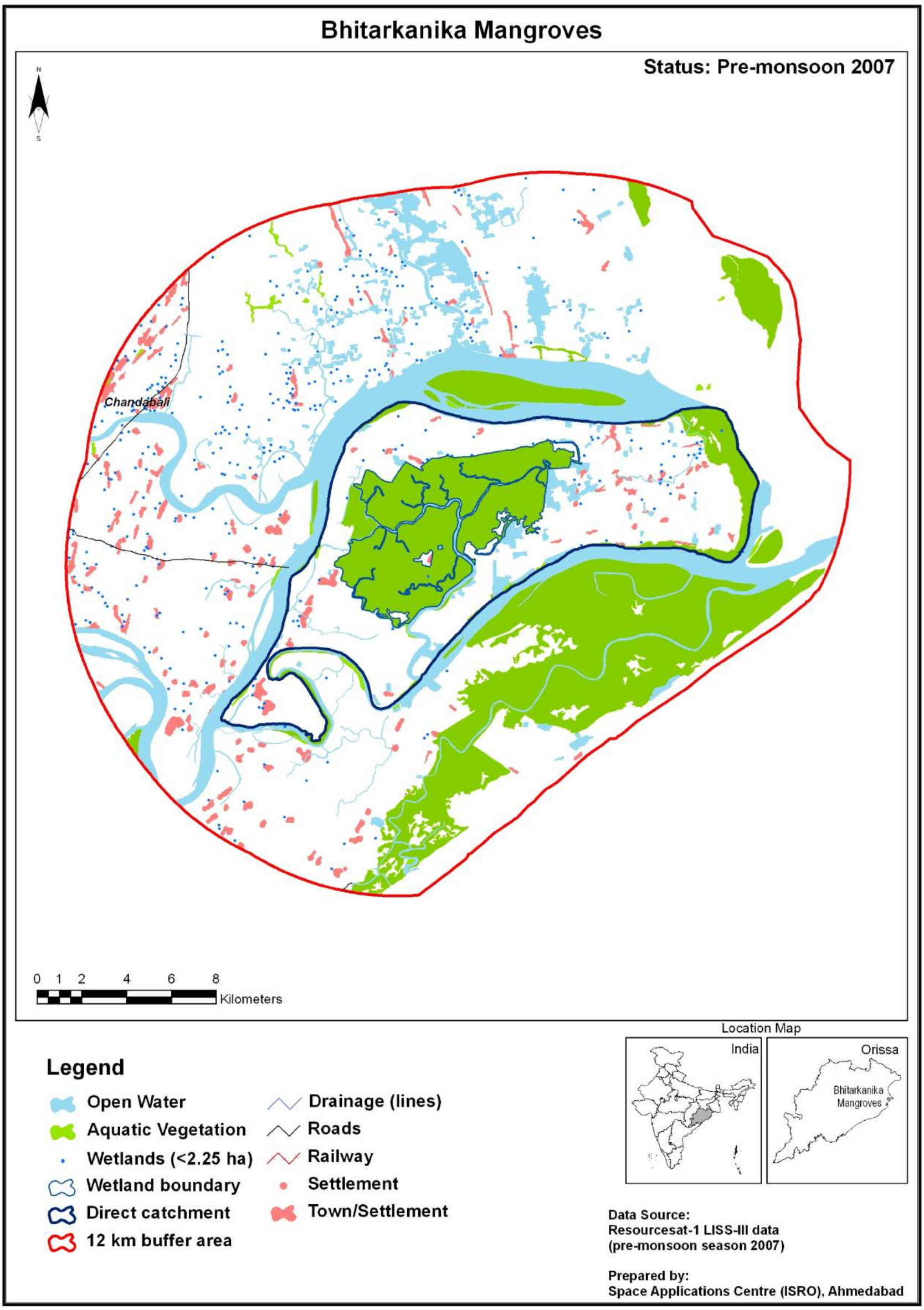

Plate 10: Open-water and vegetation status of Bhitarkanika Mangroves (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.3 Bhoj Wetland (Ramsar site no. 1206)



The Bhoj Wetland is a man made reservoir located in Bhopal City, Madhya Pradesh. It is split in two parts known as the Upper and Lower Lake. The Upper Lake was created in the 11th century by constructing an earthen dam across the Kolans River and the Lower Lake constructed nearly two centuries ago, immediate downstream of the Upper Lake. The Upper Lake is the major source of potable water to Bhopal city which is spread in the eastern part of the wetland. It was declared as Ramsar site on 19/08/2002 owing the compliance of criteria 2, 4, 5 & 6 as described below:

- Wetland supports threatened ecological communities.
- Wetland provides refuge during adverse conditions to threatened species.
- Wetland regularly supports 20, 000 or more water birds.
- Wetland regularly supports 1 % of the individuals in a population of one species or subspecies.

Bhoj wetland supports vulnerable bird species namely; Pallas Fish eagle (*Haliaectus leucoryphus*) and Sarus crane (*Grus antigone*) besides the Black necked stork, a near threatened species. More than 20,000 birds have been observed annually. More than 100-120 Sarus cranes have been observed. Around43 species of fishes are found in the lake. 10 species of Reptiles and Amphibians have been recorded. Flora comprises 106 species of Macrophytes (belonging to 87 genera of 46 families), which includes 14 rare species. 208 species of Phytoplankton and 105 species of zooplanktons, are observed in the wetland.

Macrophytes form dominant vegetation in the Upper Lake, The major ones are: *Hydrilla verticillata, Ceratophyllum demersum, Myriophyllum spathulatum, Potomageton pictinatus, Najas minor* and *Eichhornia crassipe. The* shoreline area is dominated by emergent macrophytes like *Cyperus*, *Tyhpa angustata. Eichhornia crassipes* is the major macropyhte in the Lower Lake.

Bhoj wetland as observed on Resourcesat-1 LISS-III images is given in the Figure 12.

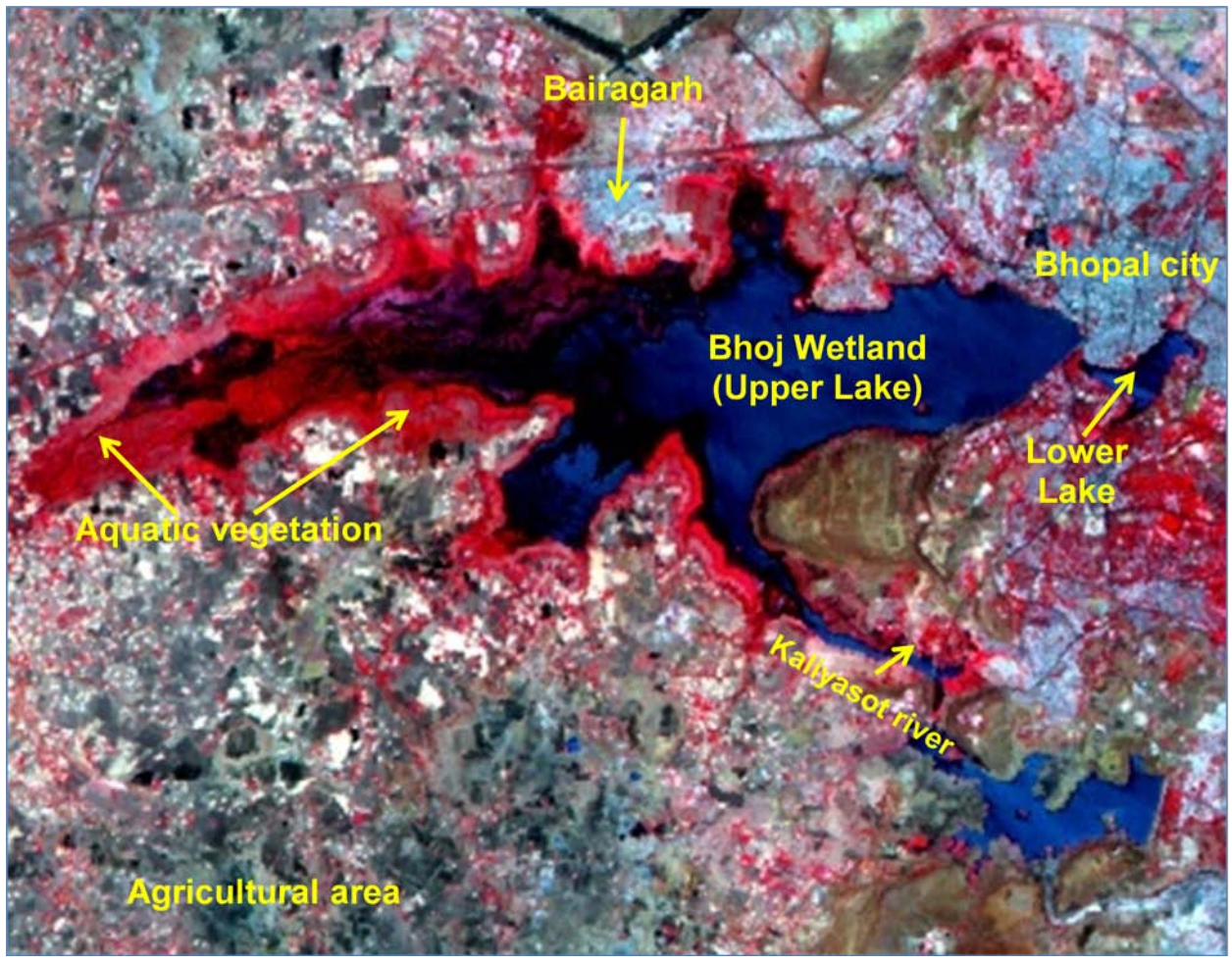

Figure 12: Bhoj wetland and its environ as seen in LISS-III FCC (06-March-2007)

Bhoj wetland is spread over 3420 ha with a perimeter of 79 km. Large areas under aquatic vegetation are observed in the Upper Lake. Significant seasonal variability has been observed in terms of open-water spread and wetland vegetation in the post-monsoon and pre-monsoon (Table 11).

Table 11: Salient observations of Bhoj wetland from satellite data

Name:	Bhoj wetland
Location:	23^0 11' 00" to 23^0 16' 43" N Latitude 77^0 14' 27" to 77^0 25' 50" E Longitude
Wetland Type:	Reservoir/Barrage
Wetland Area: Perimeter:	3420 ha 79 km
Open-water Post-monsoon: Pre-monsoon:	 3240 ha 1911 ha
Vegetation Post-monsoon: Pre-monsoon:	 Nil 1425 ha
Overall Turbidity:	Moderate to low

The area under the catchment including 12 km buffer of the wetland is 104563 ha. Agriculture land use dominates the catchment, followed by the Urban sprawl mainly of Bhopal city. A small area is under natural vegetation in the Van Vihar National Park located on the south side of Upper Lake. Around 69 wetlands of different types are observed in this area spread over 4613 ha. In addition to the Bhoj wetland, four more reservoirs are observed in this area. Wetland type-wise details for the catchment and buffer area are given in the Table 12.

Table 12: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Bhoj wetland

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1106	River/Stream	4	283	-	-	-	-
1201	Reservoir/Barrage	6	4144	4132	2230	12	1599
1202	Tank/Pond	59	186	161	38	18	36
	Total	69	4613	4293	2268	29	1635

Wetland map of the Bhoj catchment including the 12 km buffer area is given in the Plate 11. The seasonal status of open-water spread and vegetation are given in the Plates 12-15 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

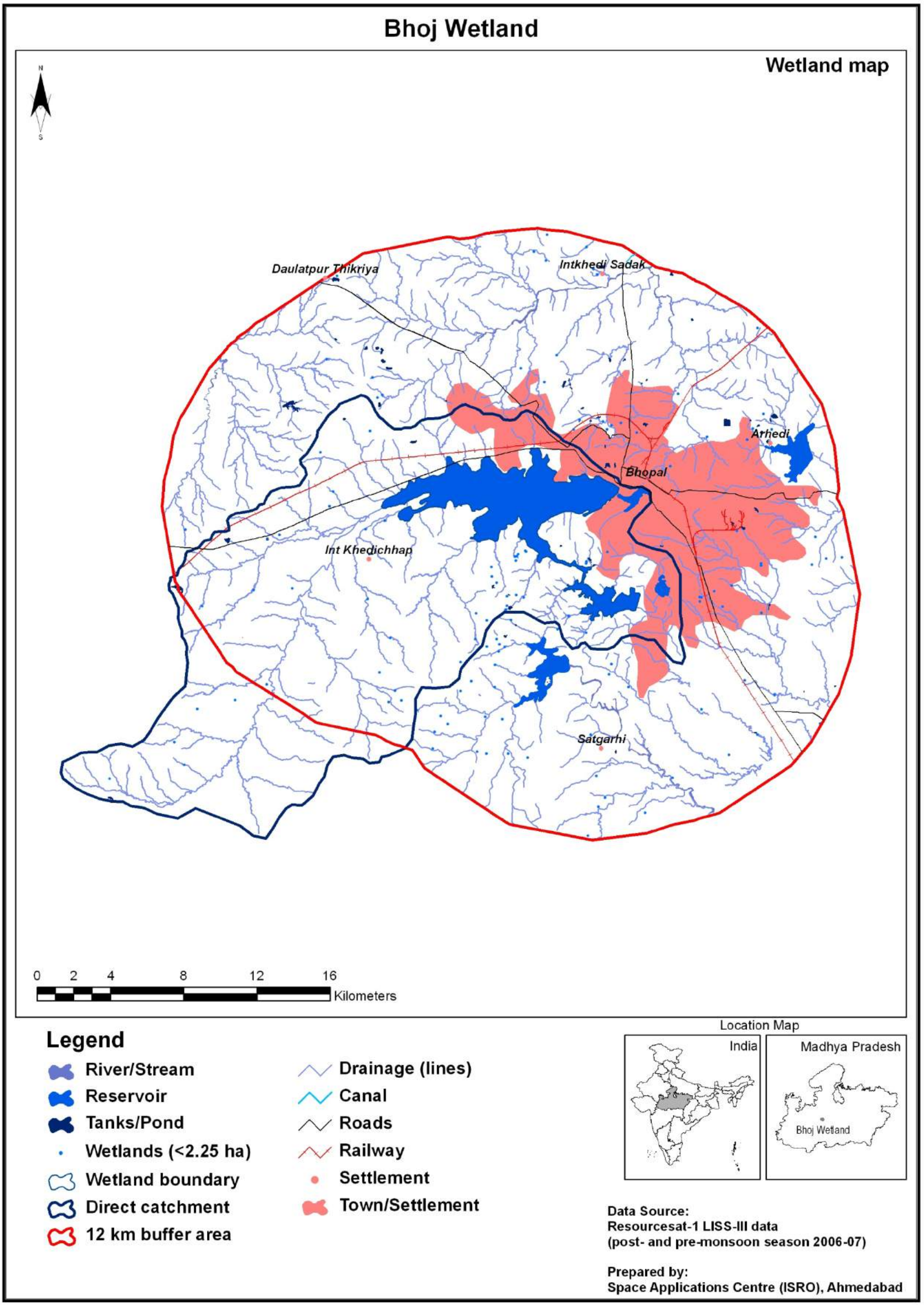

Plate 11: Wetland map of Bhoj Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

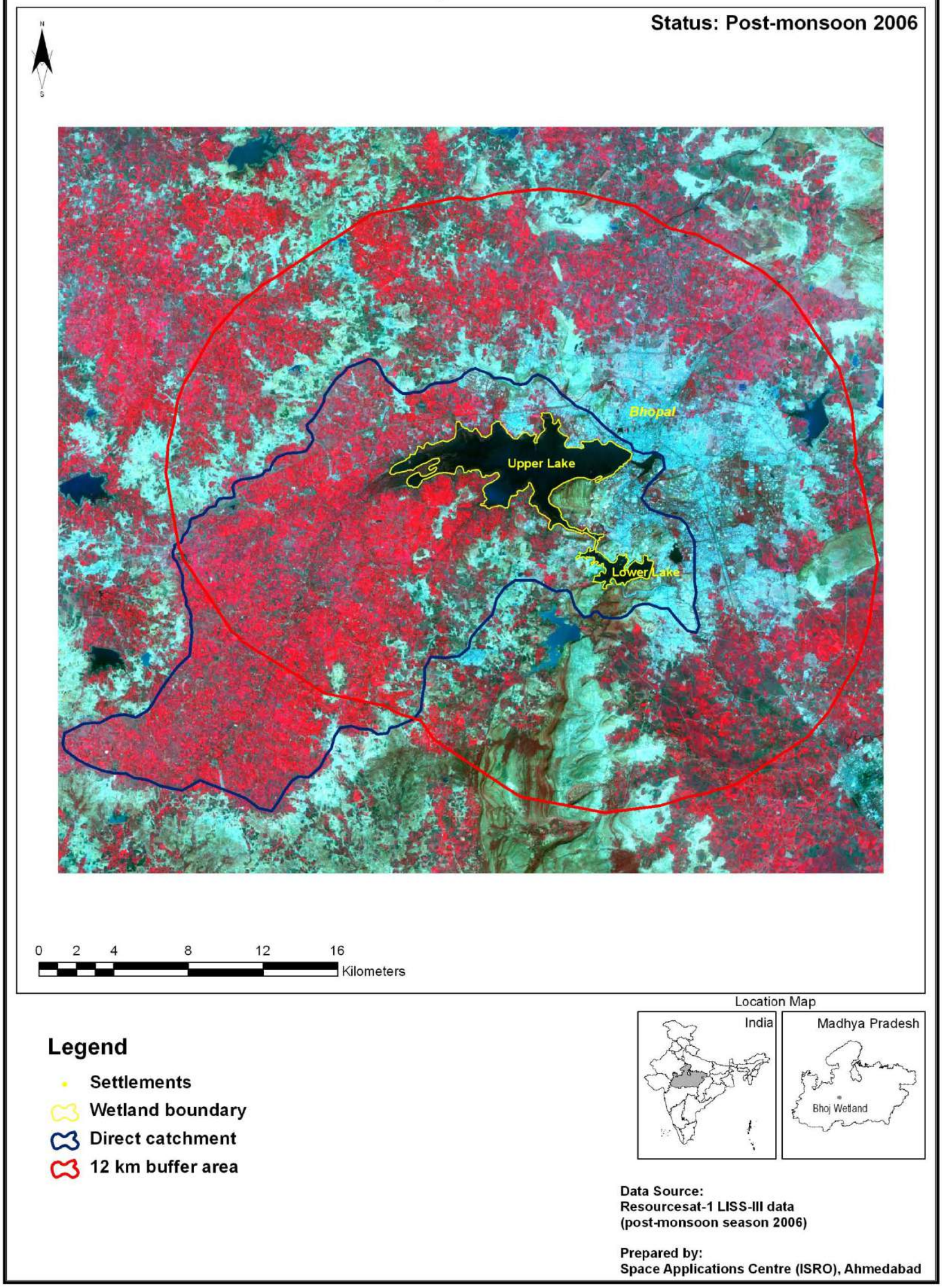

Plate 12: Bhoj Wetland and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (26-December-2006)

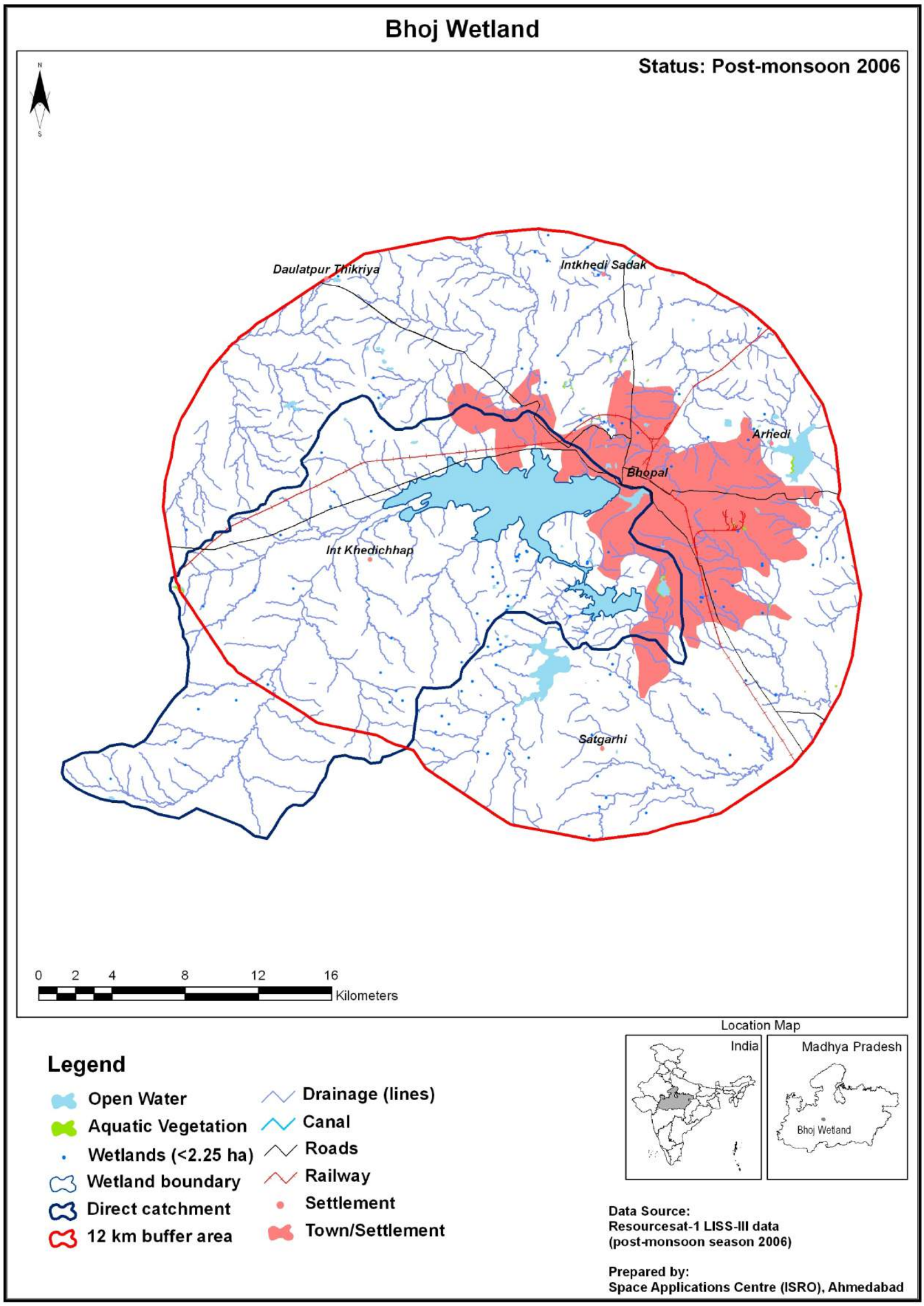

Plate 13: Open-water and vegetation status of Bhoj Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

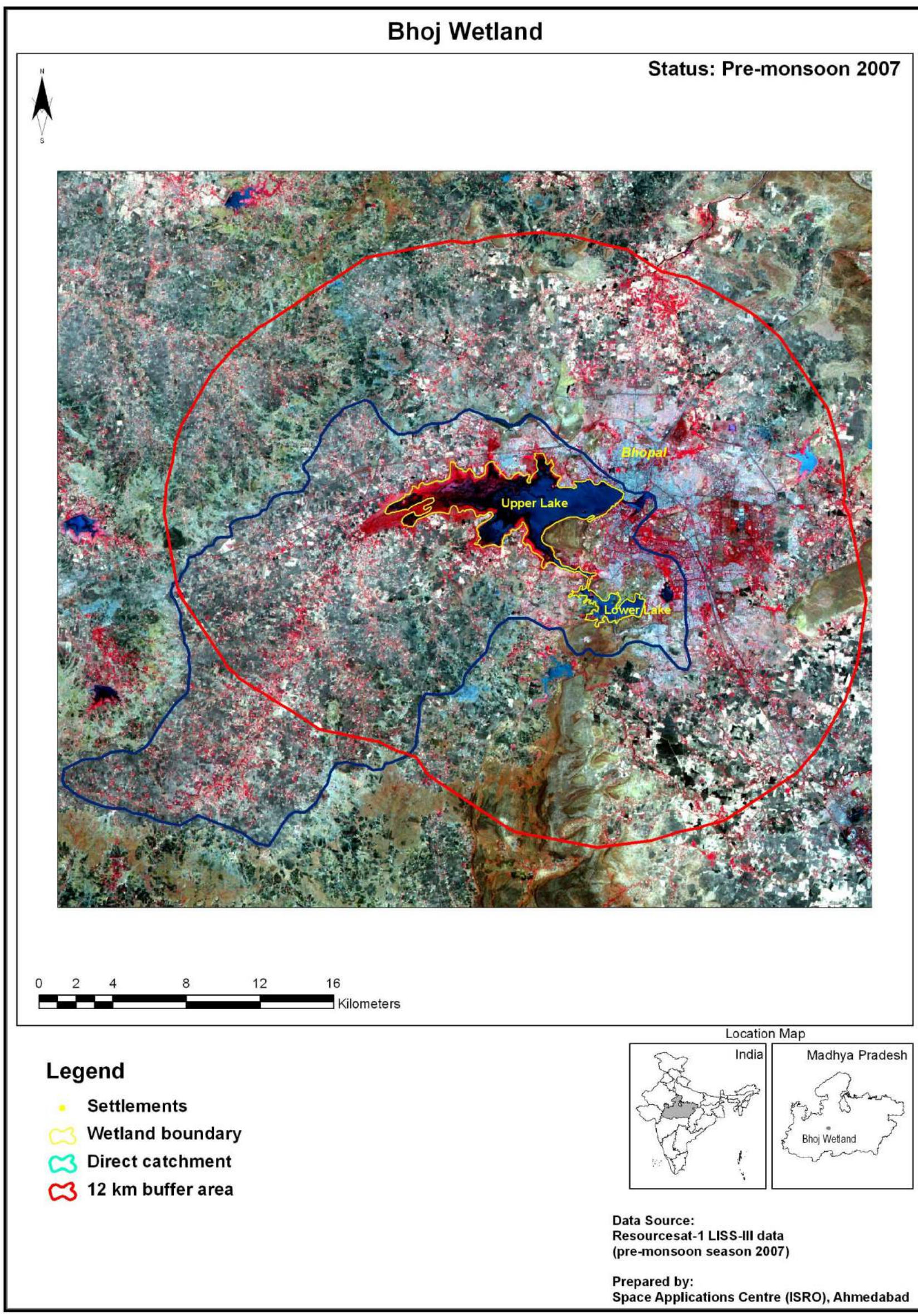

Plate 14: Bhoj Wetland and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (06-April-2007)

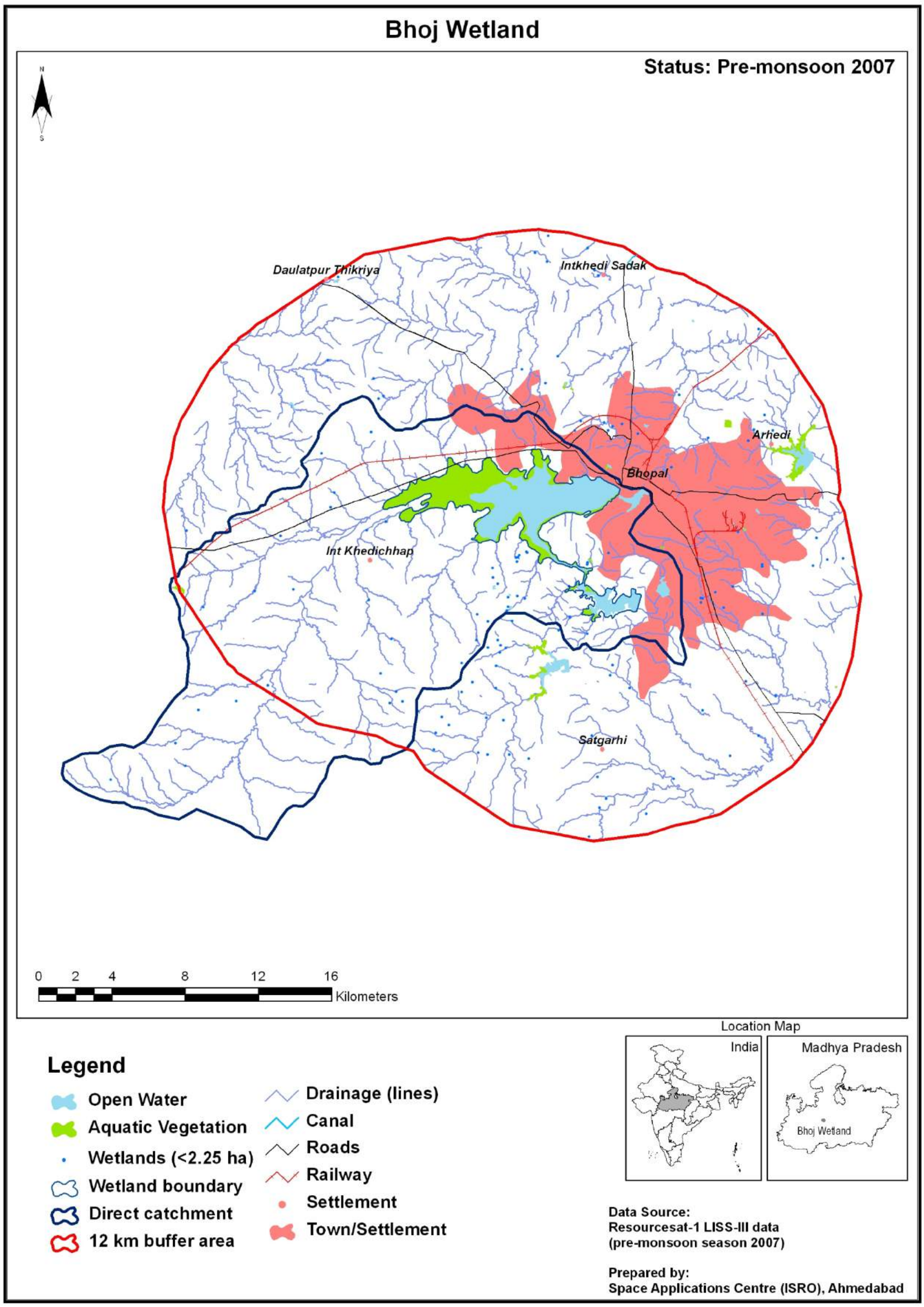

Plate 15: Open-water and vegetation status of Bhoj Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

4.2.4 Chandertal Wetland (Ramsar site no. 1569)



Chandertal is a high altitude lake on the upper Chandra valley flowing to the Chandra River. It lies near the Kunzam pass joining the Himalayan and Pir Panchal ranges. Chandertal has been declared as Ramsar site on 08/11/2005 owing the compliance of criteria 2 & 3 as described below:

- Wetland supports globally threatened ecological communities.
- Wetland supports populations of animal/plant species important for maintaining the biological diversity.

It supports CITES and IUCN Red listed Snow Leopard and is a refuge for many species like Snow Cock, Chukor, Black Ring Stilt, Kestrel, Golden Eagle, Chough, Red Fox, Himalayan Ibex, and Blue Sheep. Chandertal wetland is of special value for its endemic plant and animal species. Some of the mammals encountered in the catchment area of Chandertal are Himalayan marmot (*Marmota bobak*), Royal's vole (*Alticola roylei*), Himalayan weasel (*Mustela sibirica*), Himalayan fox (*Vulpes vulpes*), Himalayn ibex (*Capra sibirica hemalayanus*).

Chandertal wetland and its environs as observed on Resourcesat-1 LISS-IV image is shown in the Figure 13.

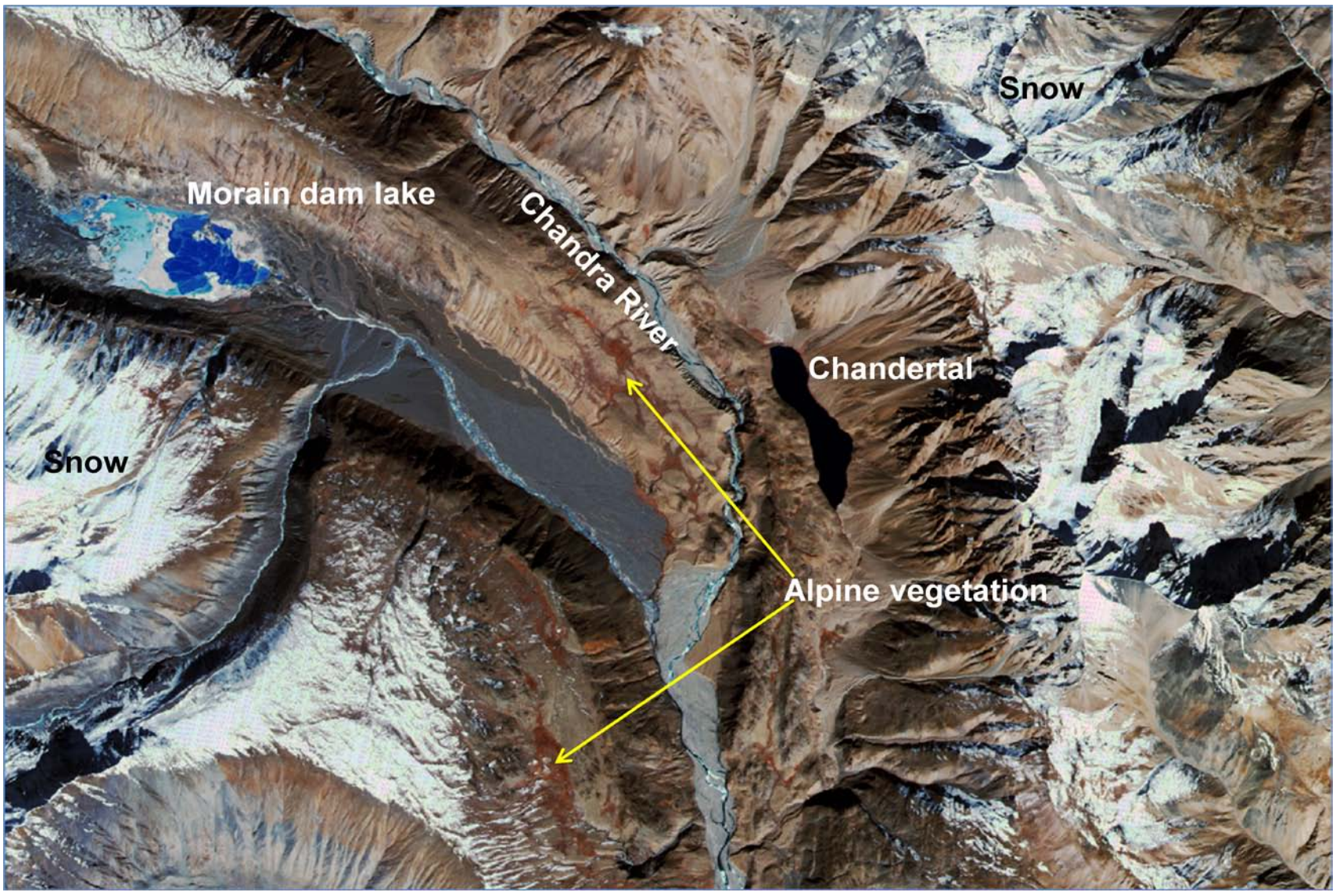

Figure 13: Chandertal and its environ as seen in LISS-IV FCC (22-November-2007)

The lake is spread over 49 ha with a perimeter of 4 km. The lake freezes in winter. Thus the open-water spread reflects the seasonality. No aquatic vegetation is detected. (Table 13).

Table 13: Salient observations of Chandertal wetland from satellite data

Name:	Chandertal Wetland
Location:	$32^0$28'26" to $32^0$29'34" N Latitude $77^0$36'32" to $77^0$37'17" E Longitude
Wetland Type:	High Altitude Wetland
Wetland Area: Perimeter:	49 ha 4 km
<u>Open-water</u> Post-monsoon: Pre-monsoon:	 43 ha 40 ha
<u>Vegetation</u> Post-monsoon: Pre-monsoon:	 Nil Nil
Overall Turbidity:	Low

The catchment falls in the alpine zone characterised by the absence of tree cover but herbaceous vegetation is detected. The catchment including the 12 km buffer zone covers an area of 49851 ha. River/stream and one reservoir is observed in this area (Table 14).

Table 14: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Chandertal

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1103	High Altitude Wetland	2	158	154	107	-	-
1106	River/Stream	2	1280	518	271	-	-
	Total	4	1438	671	378	-	-

Wetland map of the Chandertal catchment including the 12 km buffer area is given in the Plate 16. The seasonal status of open-water spread and vegetation are given in the Plates 17-20 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

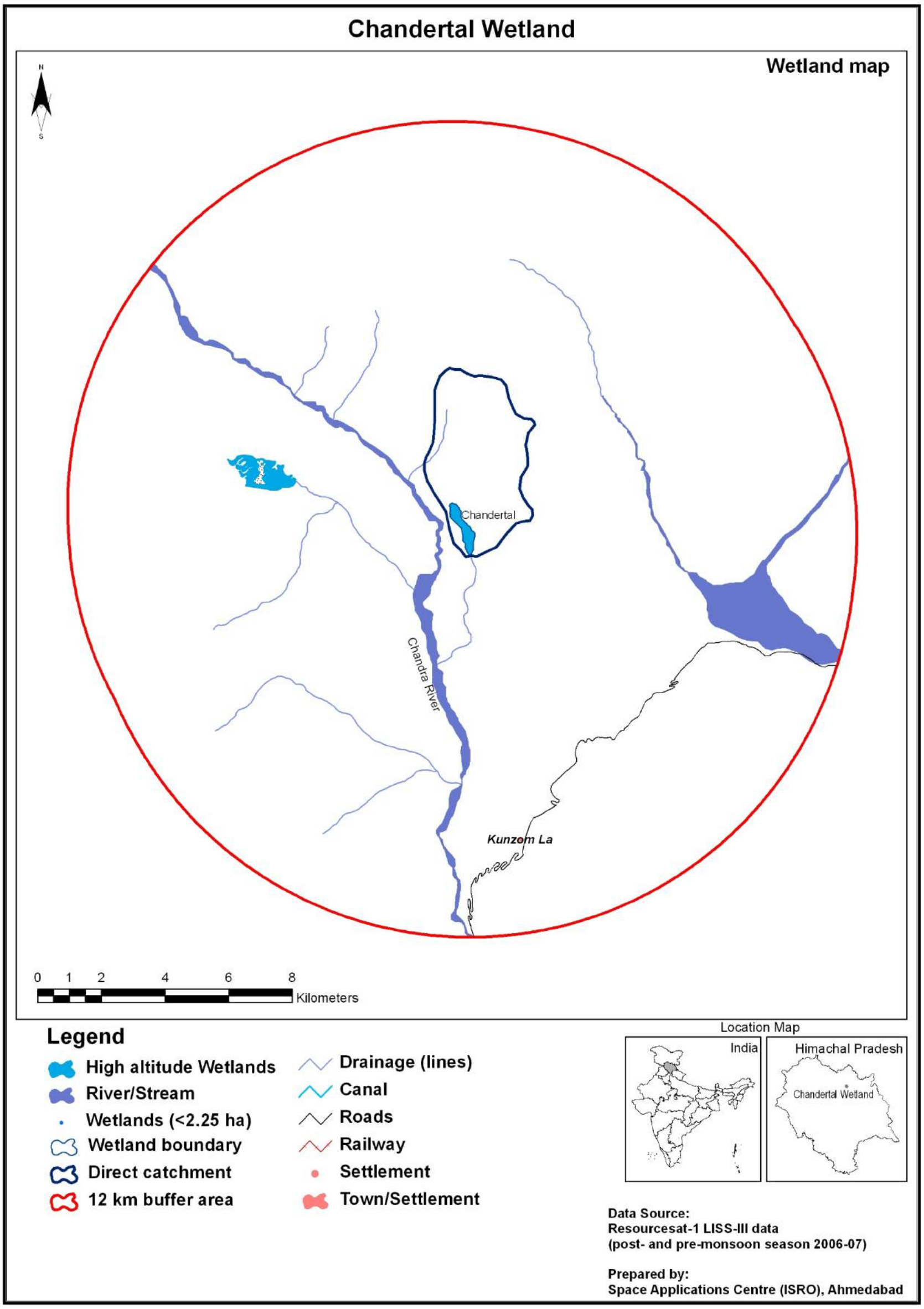

Plate 16: Wetland map of Chandertal (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

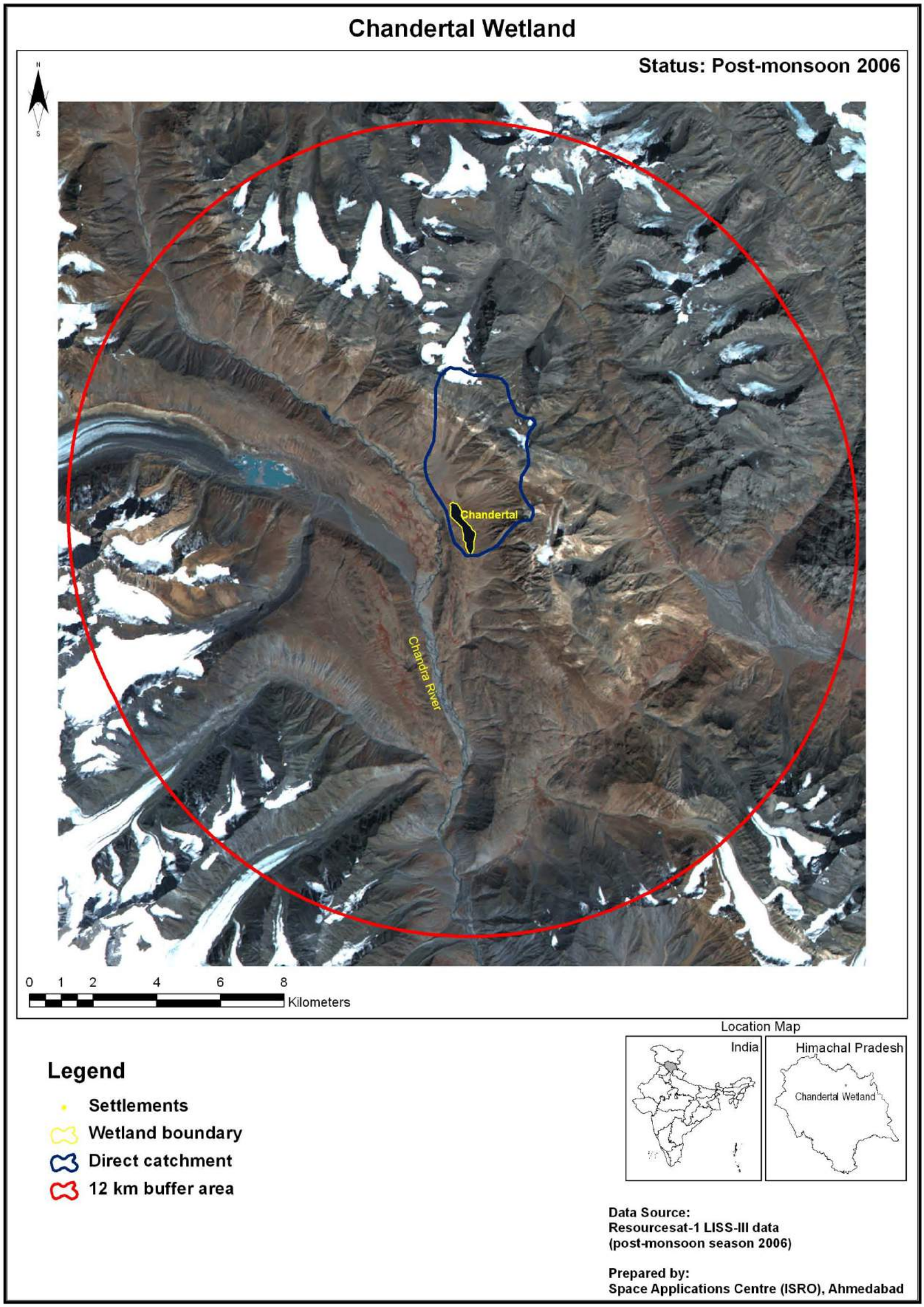

Plate 17: Chandertal and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (05-October-2006)

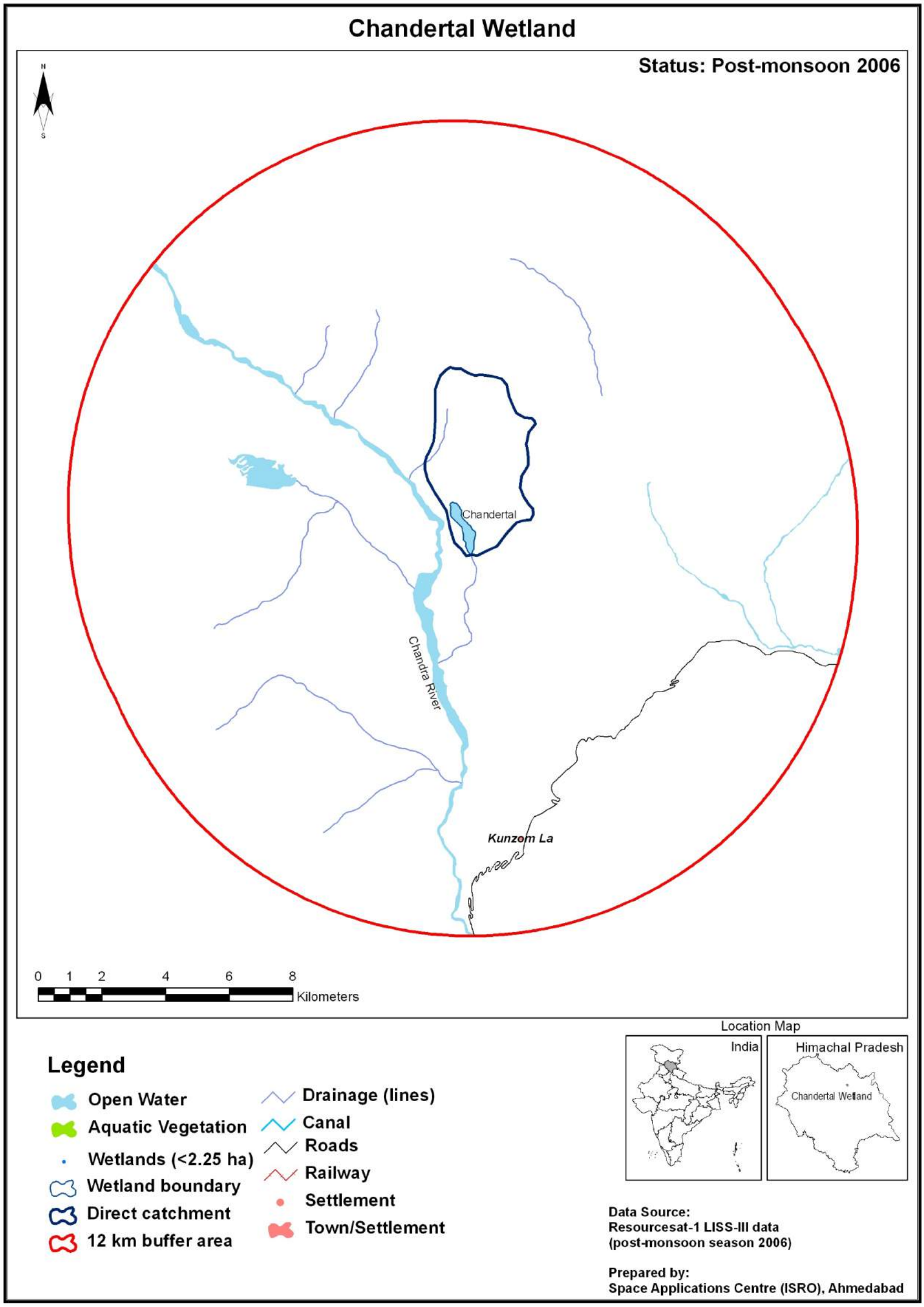

Plate 18: Open-water and vegetation status of Chandertal (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

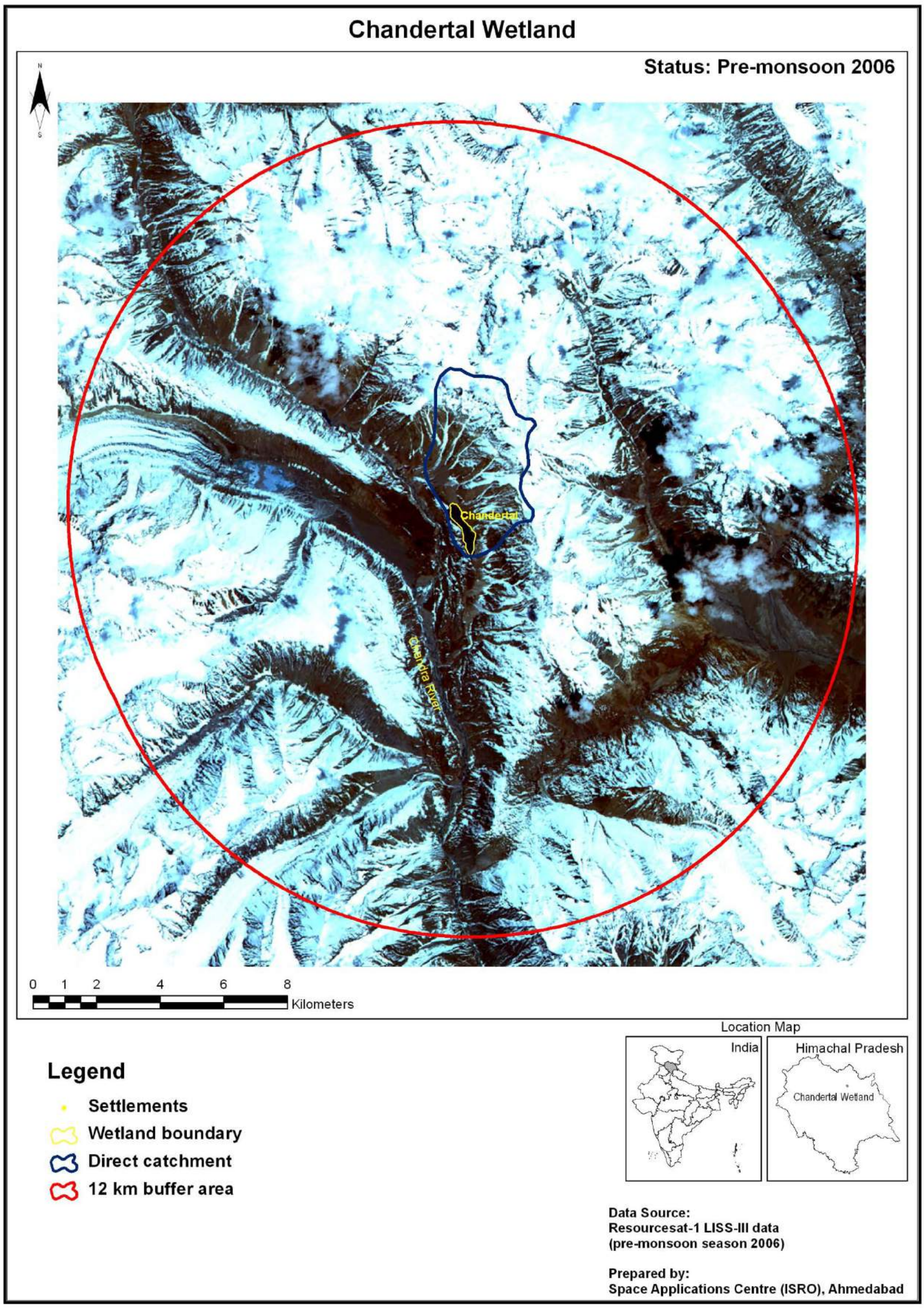

Plate 19: Chandertal and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (09-May-2007)

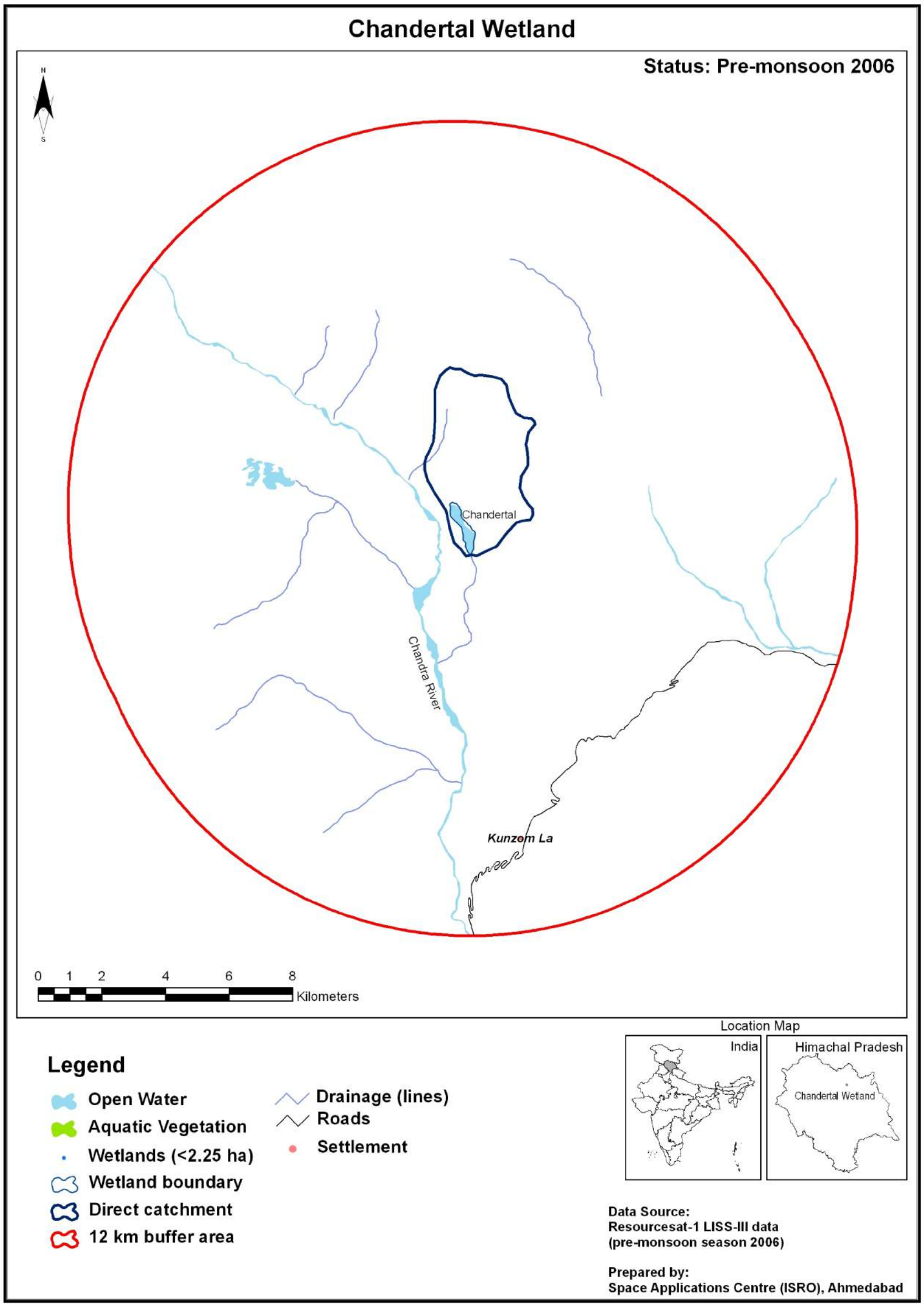

Plate 20: Open-water and vegetation status of Chandertal (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

4.2.5 Chilika Lake (Ramsar site no. 229)



Chilika is the world's second largest lagoon situated on east coast of India in Orissa state. The wetland is connected to the Bay of Bengal via a channel through a sand ridge on the north-east. Around eight rivers, prominent being Daya and Bhargavi meet the lake bringing about 375,000 cusecs of water and 13 million metric tonnes of silt annually into the wetland. This process results in extreme seasonal fluctuations in salinity in different sections of the lake. Over a period of time the opening of sea to wetland either shifts or closes as a consequence of coastal fluvial processes. In order to maintain the ecological character of the wetland a new mouth has been opened in September 2000.

Chilika is a unique ecosystem with rich biodiversity, it has been designated as a Ramsar site on 01/10/1981 owing to the compliance of criteria 2, 4, 5, 6, 8 & 9 as described below:.

- Wetland supports threatened ecological communities.
- Wetland provides refuge during adverse conditions to threatened species.
- Wetland regularly supports 20, 000 or more waterbirds.
- Wetland regularly supports 1 % of the individuals in a population of one species or subspecies.
- Wetland supports an important source of for fishes, spawning ground, nursery and/or migration path.
- Wetland supports 1 % of the population of a wetland dependent non-avian species.

The site is an important area for breeding, wintering and staging of water birds. Nearly, 225 bird species are recorded in the peak winter season. The lagoon hosts over one million migratory birds mainly ducks (Anatinae), Geese (Anserinae), Flamingos (*Phoenicopterus sp*.), Pelican (*Pelecanus sp.*), Plover (*Charadrius sp.*), Gulls (*Larus sp.*) and Terns (*Sterna sp.*). The Nalbana island located in the south-eastern part of the lake has been declared a bird sanctuary in 1987. The island gets submerged during monsoon. As it slowly emerges with withdrawal of monsoon, the island with mudflats and herbaceous vegetation becomes the hub of bird activity during winter. Chilika and its environs as observed on Resourcesat-1 LISS-III image is shown in the Figure 14.

The lake shelters the largest population (158) of endangered Irrawaddy dolphin. The lake supports around 267 species of fishes, 35 species of crabs and 29 species of shrimp and prawns, which is the livelihood of around 2 lakh fishermen living in the vicinity.

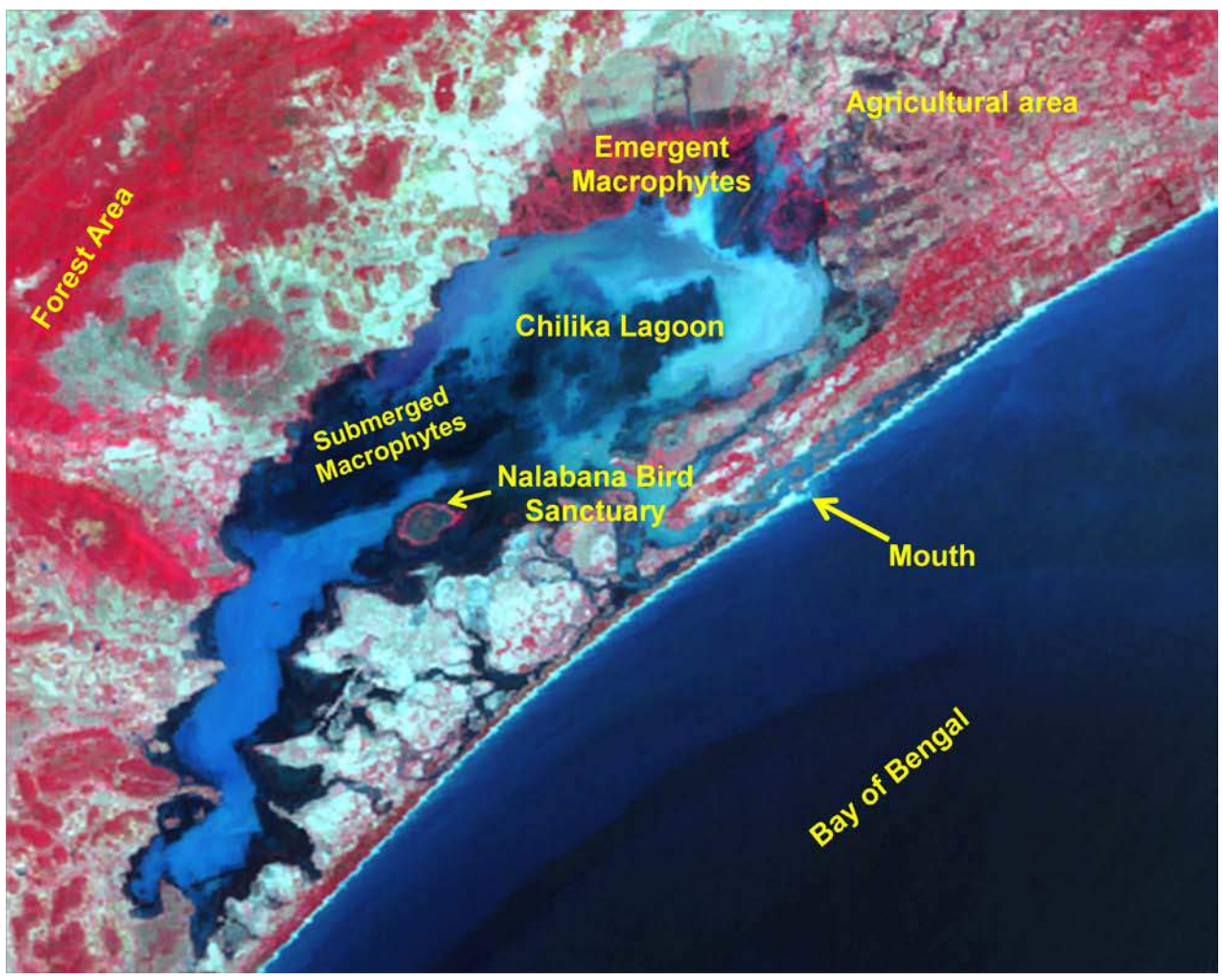

Figure 14: Chilika and its environ as seen in LISS-III FCC (16-April-2008)

Flora includes 22 species of algae and, 150 species of vascular plants in the lagoon. The dominant emergent plants are *Pragmites karka*, *Typha angustata*, *Cyperus sp*. and *Kailinga triceps*. Submerged vegetation is dominated by *Enteromorpha sp*., *Gracillaria sp*., *Cladophora sp*., *Polysiphonia sp*., *Najas sp*., *Chara sp*., *Hydrilla sp*. and *Potomageton sp*.

Chilika Lake has an area of 90894 ha with a perimeter of 585 km. The water spread shows strong seasonality, around 11 % decrease from post-monsoon (62462 ha) to pre-monsoon (55456 ha). Area under aquatic vegetation increases to around 24 per cent during pre monsoon (37225 ha) from that of post-monsoon (28432 ha) as shown in Table 15.

Table 15: Salient observations of Chilika Lake from satellite data

Name:	Chilika Lake
Location:	19°26'07" to 19°56'55" N Latitude 85°04'06" to 85°39'59" E Longitude
Wetland Type:	Lagoon
Wetland Area: Perimeter:	90894 ha 585 km
Open-water Post-monsoon: Pre-monsoon:	 62462 ha 55456 ha
Vegetation Post-monsoon: Pre-monsoon:	 28432 ha 37225 ha
Overall Turbidity:	Moderate to high

The catchment of Chilika is quite large; the land use/cover of the catchment is dominated by agriculture and forests. The huge waterlogged area in the northern part of the lake is utilised for agriculture and aquaculture. River/streams are the major wetlands in the catchment, followed by aquaculture ponds (Table 16).

Table 16: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Chilika Lake

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1104	Riverine Wetlands	2	11	11	11	-	-
1105	Waterlogged Area	34	411	125	125	287	287
1106	River/Stream	88	2807	2807	2686	0	-
1201	Reservoir/Barrage	24	908	753	609	156	299
1202	Tank/Pond	52	622	225	208	401	418
2101	Lagoon	7	89023	60699	52384	28432	37225
2103	Sand/beach	8	1115	-	-	-	-
2014	Intertidal mud-flat	63	8994	-	-	-	-
2201	Salt Pan	1	617	617	617	-	-
2202	Aquaculture Pond	65	5563	5563	5563	846	846
	Total	344	110071	70800	62203	30121	39075

Wetland map of the Chilika catchment including the 12 km buffer area is given in the Plate 21. The seasonal status of open-water spread and vegetation are given in the Plates 22-25 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

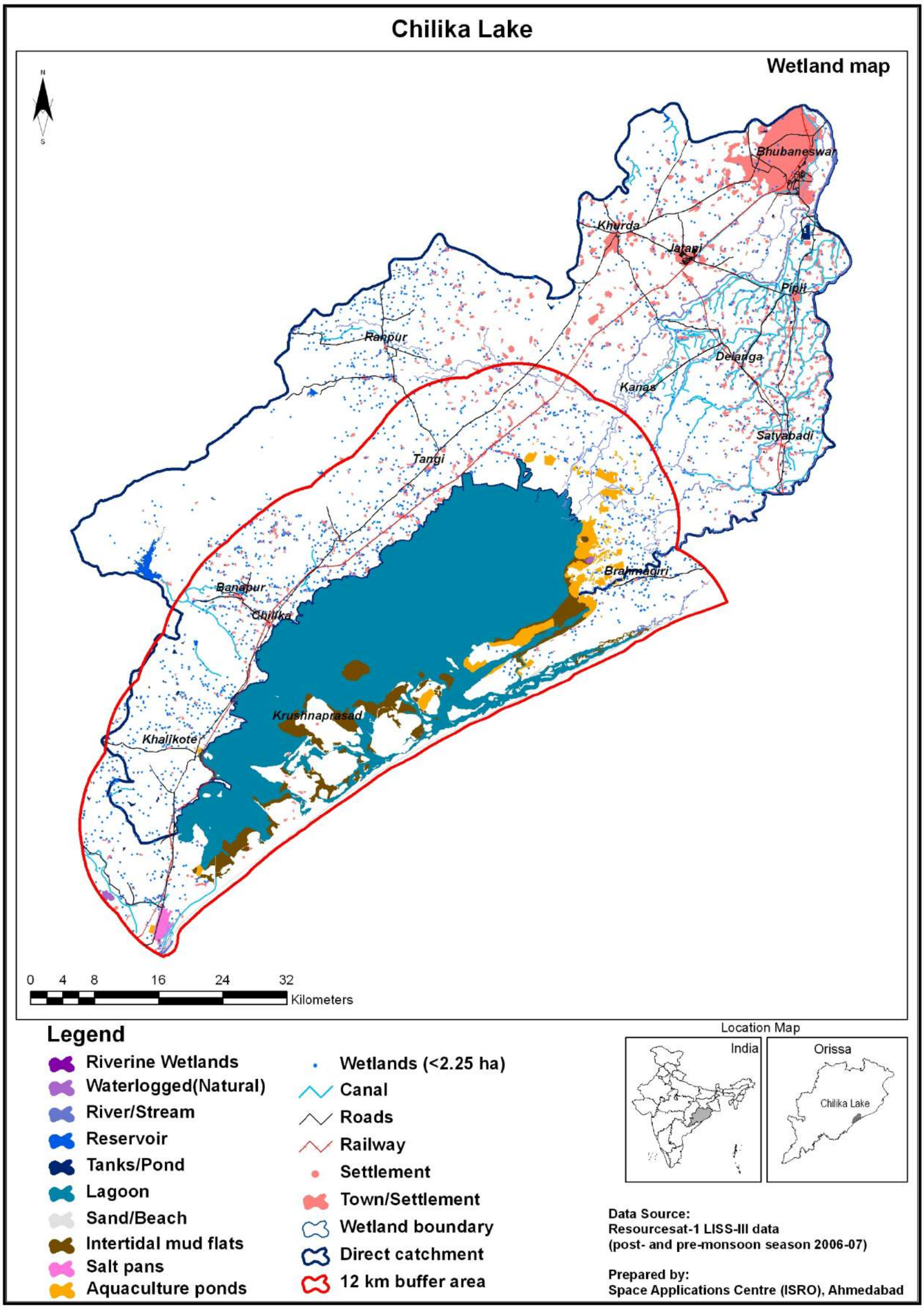

Plate 21: Wetland map of Chilika Lake (direct catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

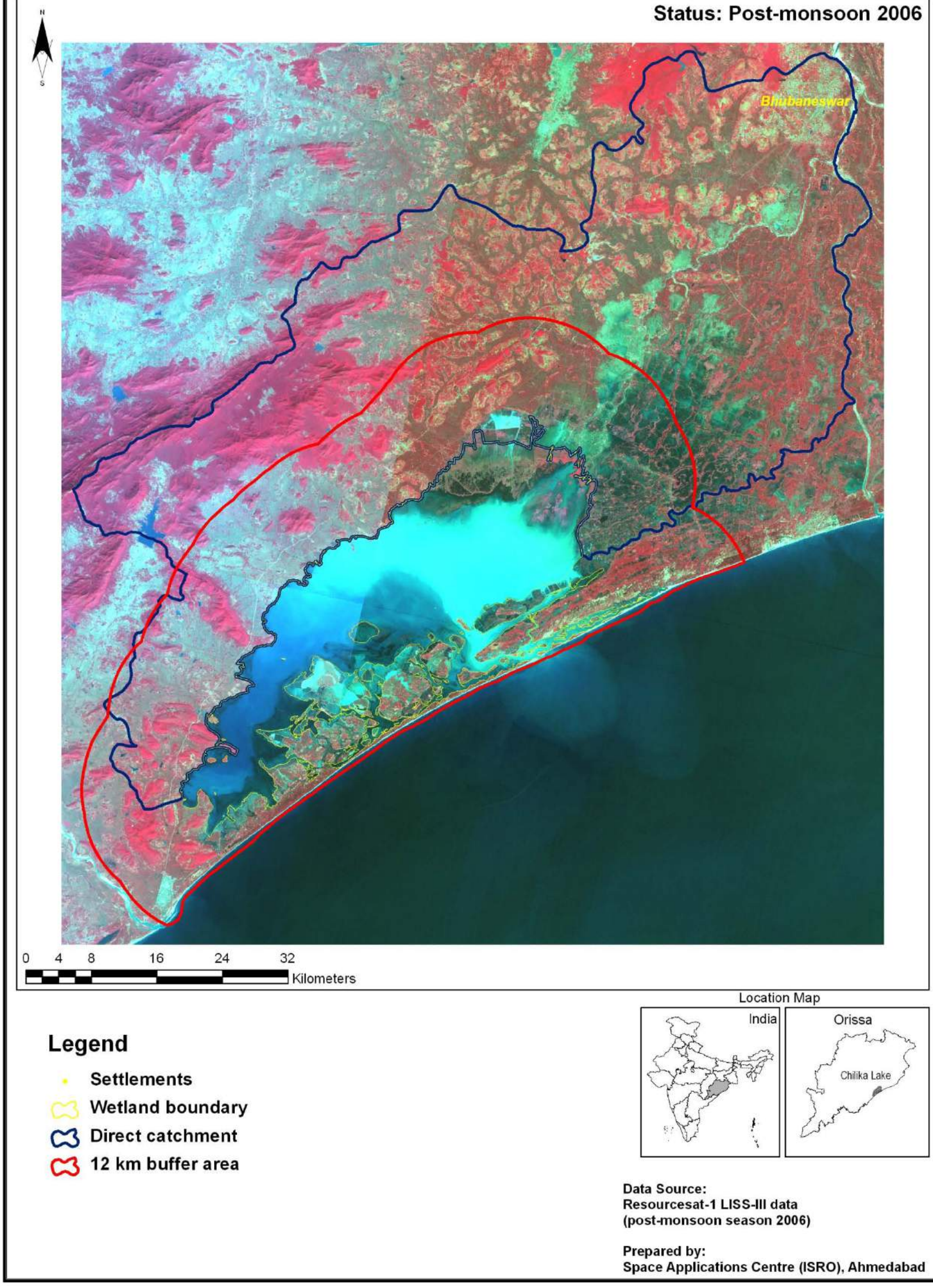

Plate 22: Chilika Lake and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (12-October-2006)

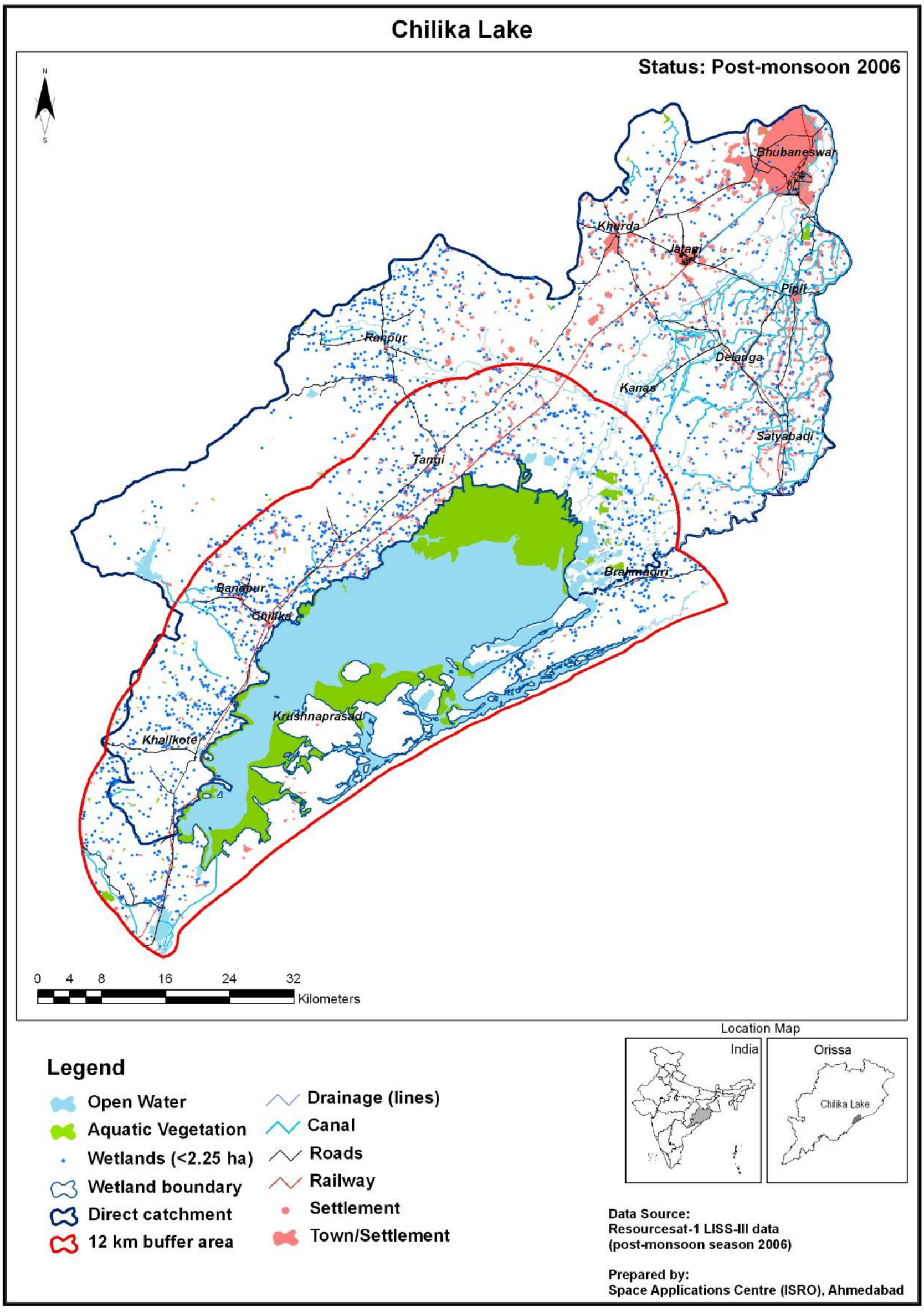

Plate 23: Open-water and vegetation status of Chilika Lake (direct catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

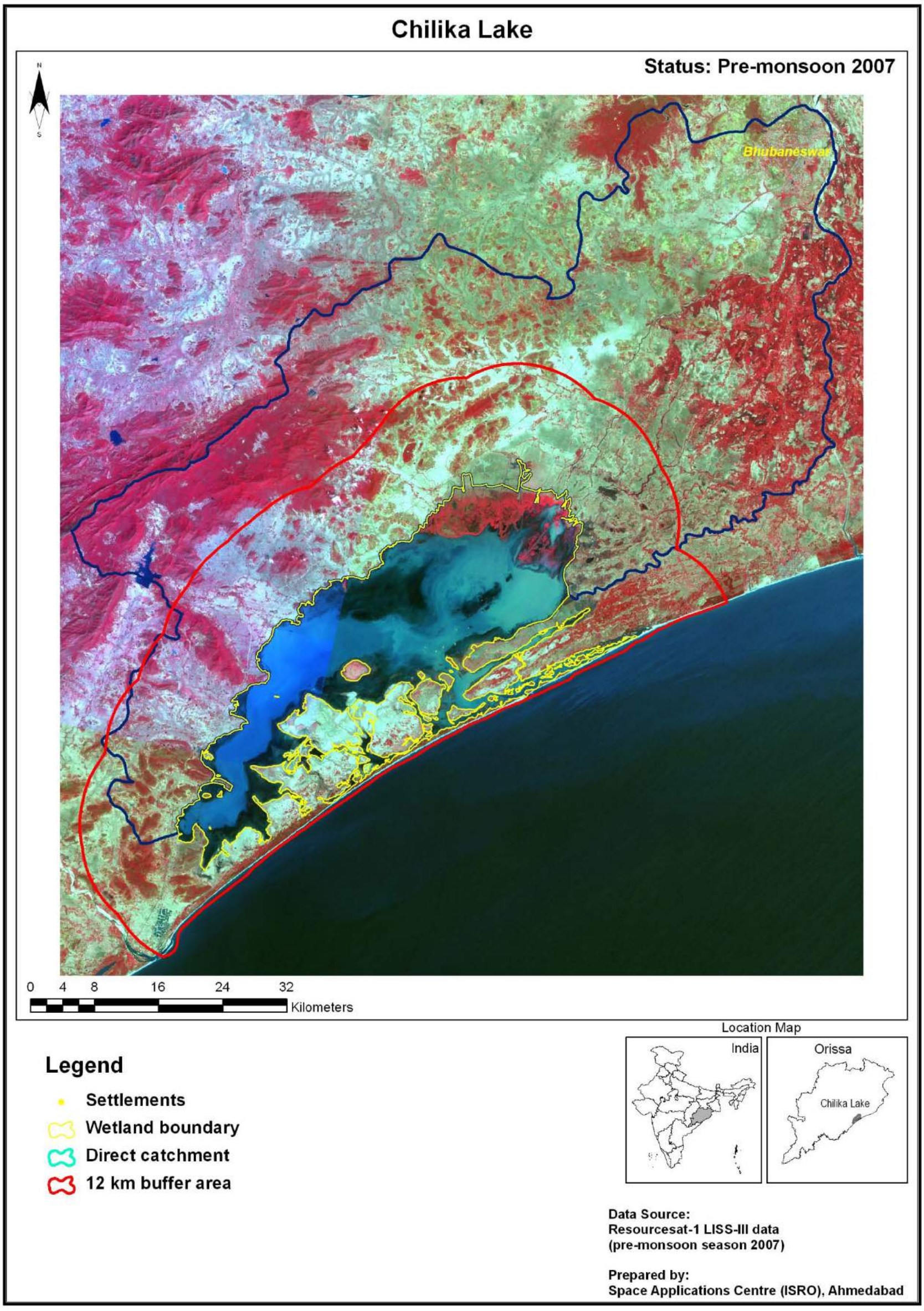

Plate 24: Chilika Lake and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (22-April-2007)

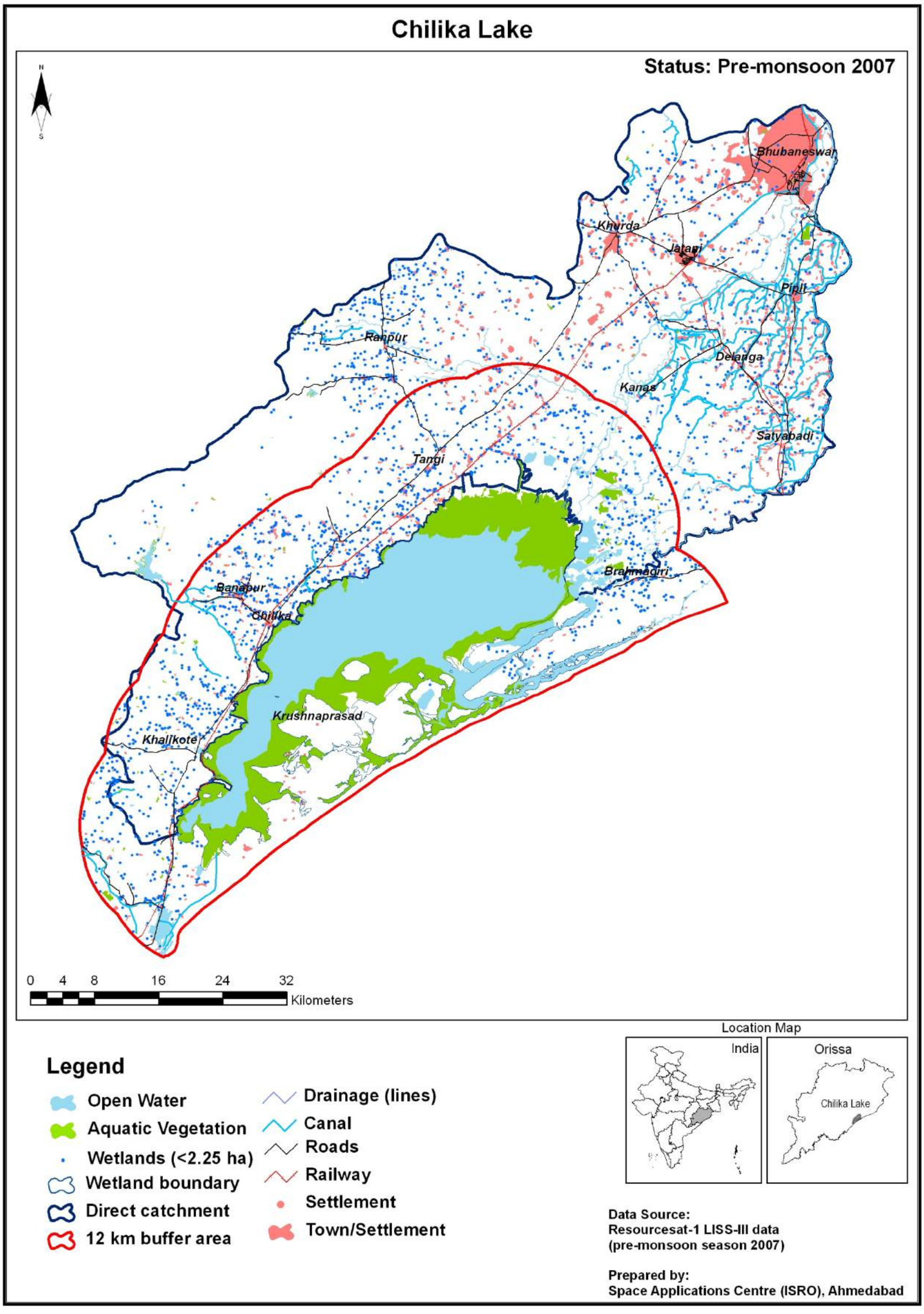

Plate 25: Open-water and vegetation status of Chilika Lake (direct catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.6 Deepor Beel (Ramsar site no. 1207)



Deepor Beel located near Guwahati city, Assam is a freshwater lake (beel in local language) formed in the abandoned channel of Brahmaputra River. It is a large natural wetland having great biological and environmental importance besides being the only major storm water storage basin for the Guwahati city. It was declared as Ramsar site on 19/08/2002 owing to the compliance of criteria 2 & 5 as described below:

- Wetland supports threatened ecological communities.
- Wetland regularly supports 20, 000 or more waterbirds.

The lake is a staging site on migratory flyways and some of the largest concentrations of aquatic birds in Assam can be seen, especially in winter. Some globally threatened birds are supported, including Spotbilled Pelican (*Pelicanus philippensis*), Lesser and Greater Adjutant Stork (*Leptoptilos javanicus* and *dubius*), and Baer's Pochard (*Aythya baeri*). Altogether 150 bird species have been recorded, of which 62 species are waterfowl. Around 414 ha area of the beel is declared as a bird sanctuary.

It supports 50 fish species belonging to 19 families. Natural breeding of some of these species takes place within the wetland itself. A large variety of tropical aquatic flora is found in the beel. The Giant Water Lily is a noteworthy species. A total of 18 genera of phytoplankton, 21 genera of zooplankton have been reported. The fish, nymphaea nuts and flowers, medicinal plants, orchid found in the lake catchment provide major revenue sources to local communities.

The lake is a shallow one, the depth of water going down to less than one meter during summer. The beel is heavily infested by water hyacinth during dry season. The Beel as observed on Resourcesat-1 LISS-III image of two seasons are given in the Figure 15.

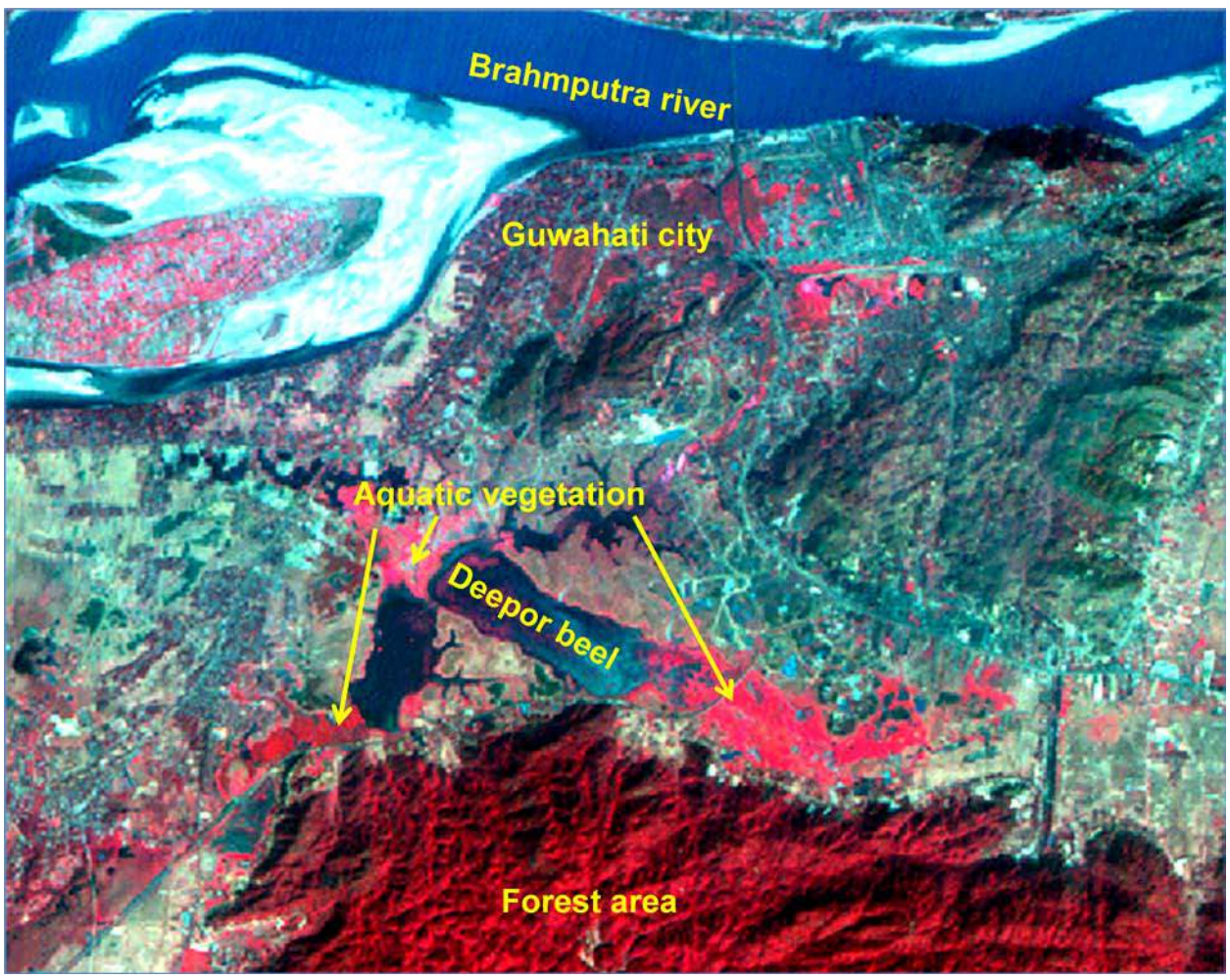

Figure 15: Deepor Beel and its environ as seen in LISS-III FCC (01-November-2006)

Deepor Beel is spread over 589 ha with a perimeter of 53 km. The water spread shows significant seasonal variation. Open-water spread reduced from 273 ha in post-monsoon (November) to 73 ha in pre-monsoon (May). On the other hand there is a 63 % increase in vegetation from 315 ha in post-monsoon to 515 ha in pre-monsoon (Table 17). Cultivation of rice crop in the dried up lake bed during dry season was observed.

Table 17: Salient observations of Deepor Beel from satellite data

Name:	Deepor Beel
Location:	26°06'02" to 26°08'34" N Latitude 91°36'29" to 91°42'24" E Longitude
Wetland Type:	Lake/Pond
Wetland Area: Perimeter:	589 ha 53 km
Open-water Post-monsoon: Pre-monsoon:	 273 ha 73 ha
Vegetation Post-monsoon: Pre-monsoon:	 315 ha 515 ha
Overall Turbidity:	Moderate to high

The catchment including 12 km buffer (65210 ha) of Deepor Beel shows the mighty Brahmaputra river in the north, the Guwahati city the Northeast, and the reserve forest area in south. The eastern side is occupied mainly by agriculture. There are few natural lakes in its vicinity. The buffer and catchment has 75 wetlands accounting for 8665 ha of area. River/Stream ranks first in terms of area (7106 ha), mainly due to the Brahmaputra, followed by 17 natural Lakes (1104 ha) including the Deepor beel. All the wetland types showed significant seasonal variation. Around 11 % reduction in open-water spread (from 4885 ha to 4327 ha), and a two-fold increase in vegetation from post-monsoon to pre-monsoon was observed (Table 18).

Table 18: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Deepor Beel

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	17	1104	669	207	434	904
1102	Ox-bow Lake/Cut-off Meander	1	41	41	41	-	-
1105	Waterlogged Area	47	402	229	132	173	270
1106	River/Stream	7	7106	3934	3934	-	-
1202	Tank/Pond	3	13	13	13	-	-
	Total	75	8665	4885	4327	607	1174

Wetland map of the Deepor Beel catchment including the 12 km buffer area is given in the Plate 26. The seasonal status of open-water spread and vegetation are given in the Plates 27-30 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

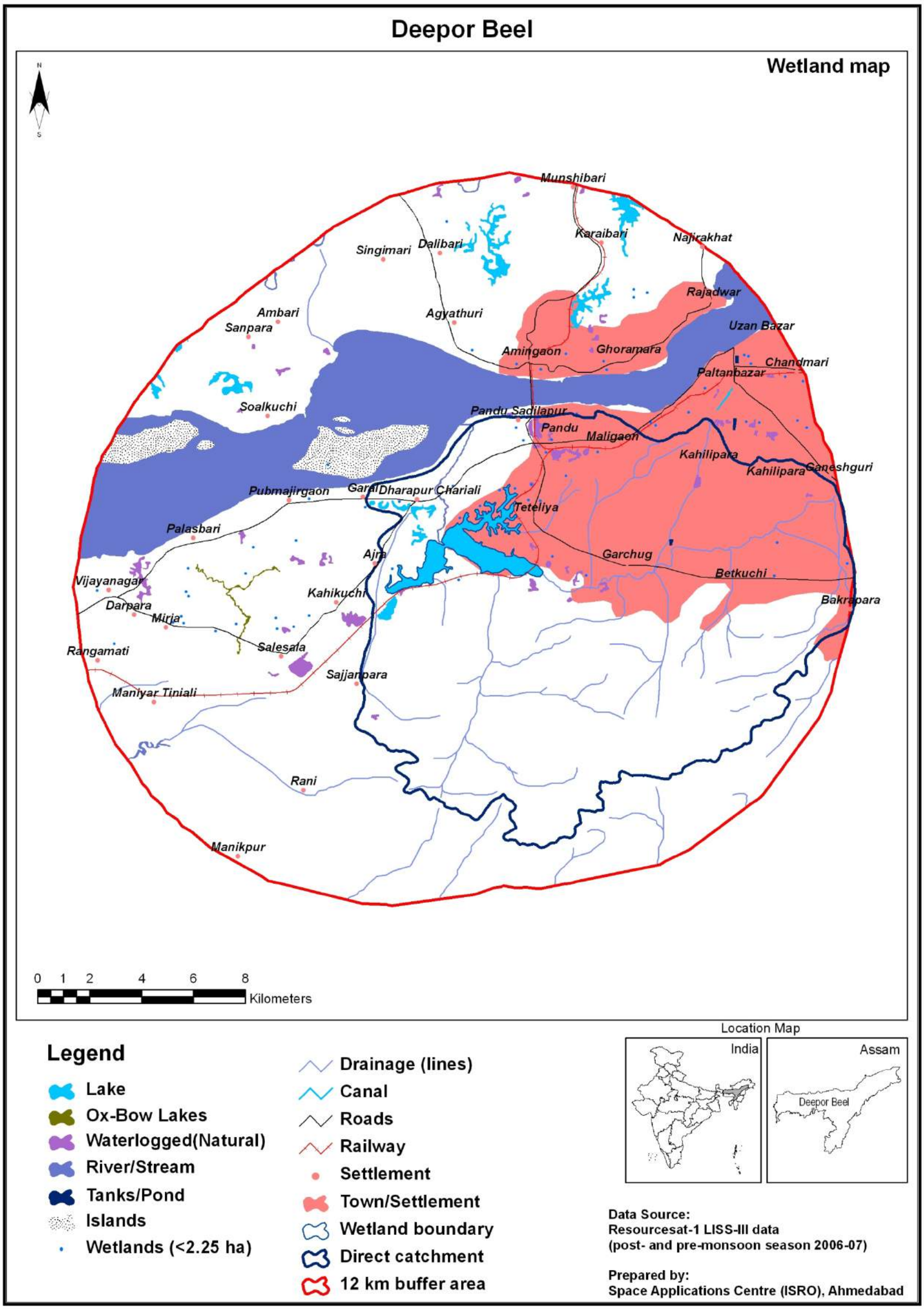

Plate 26: Wetland map of Deepor Beel (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

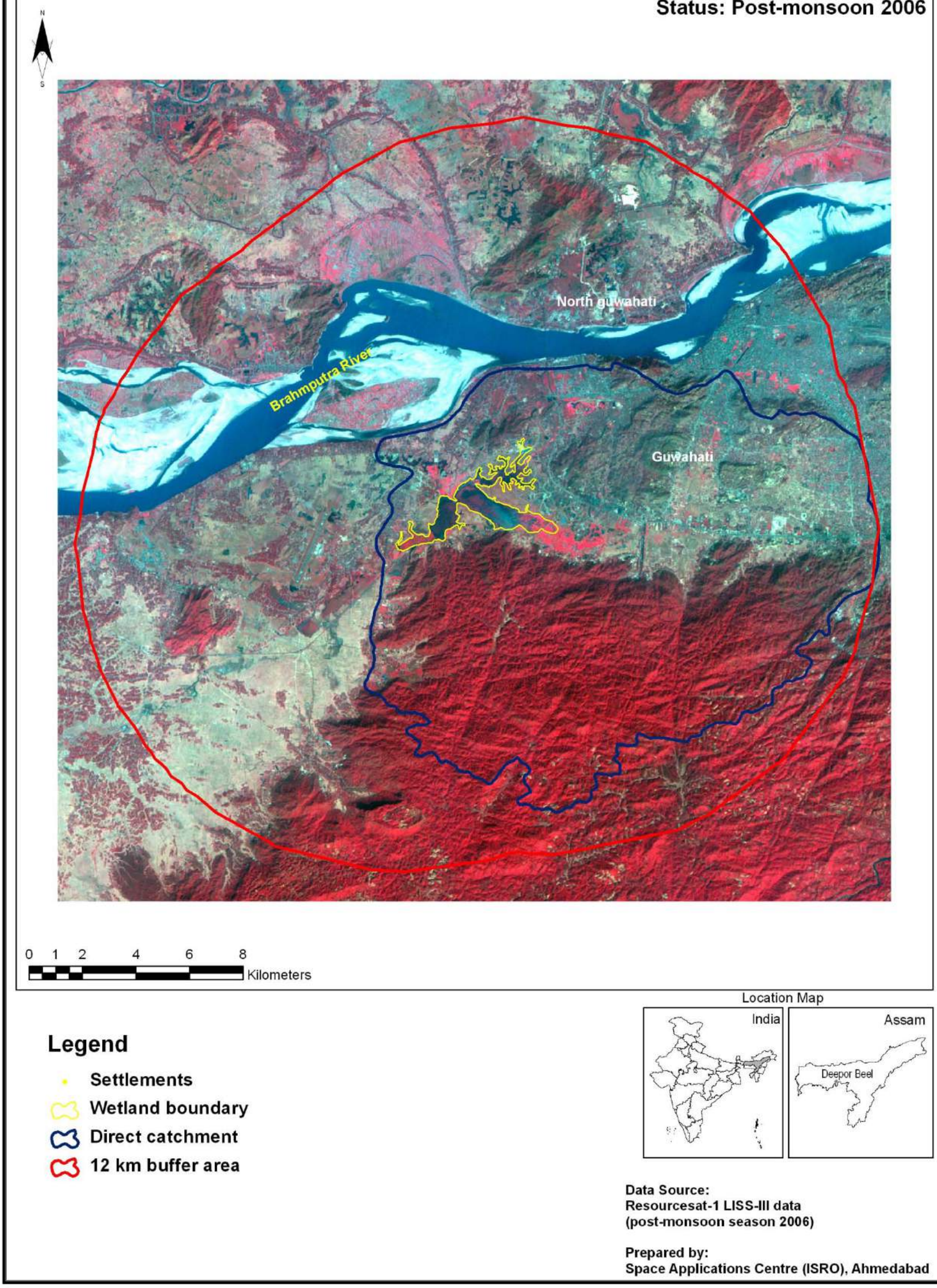

Plate 27: Deepor Beel and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (01-November-2006)

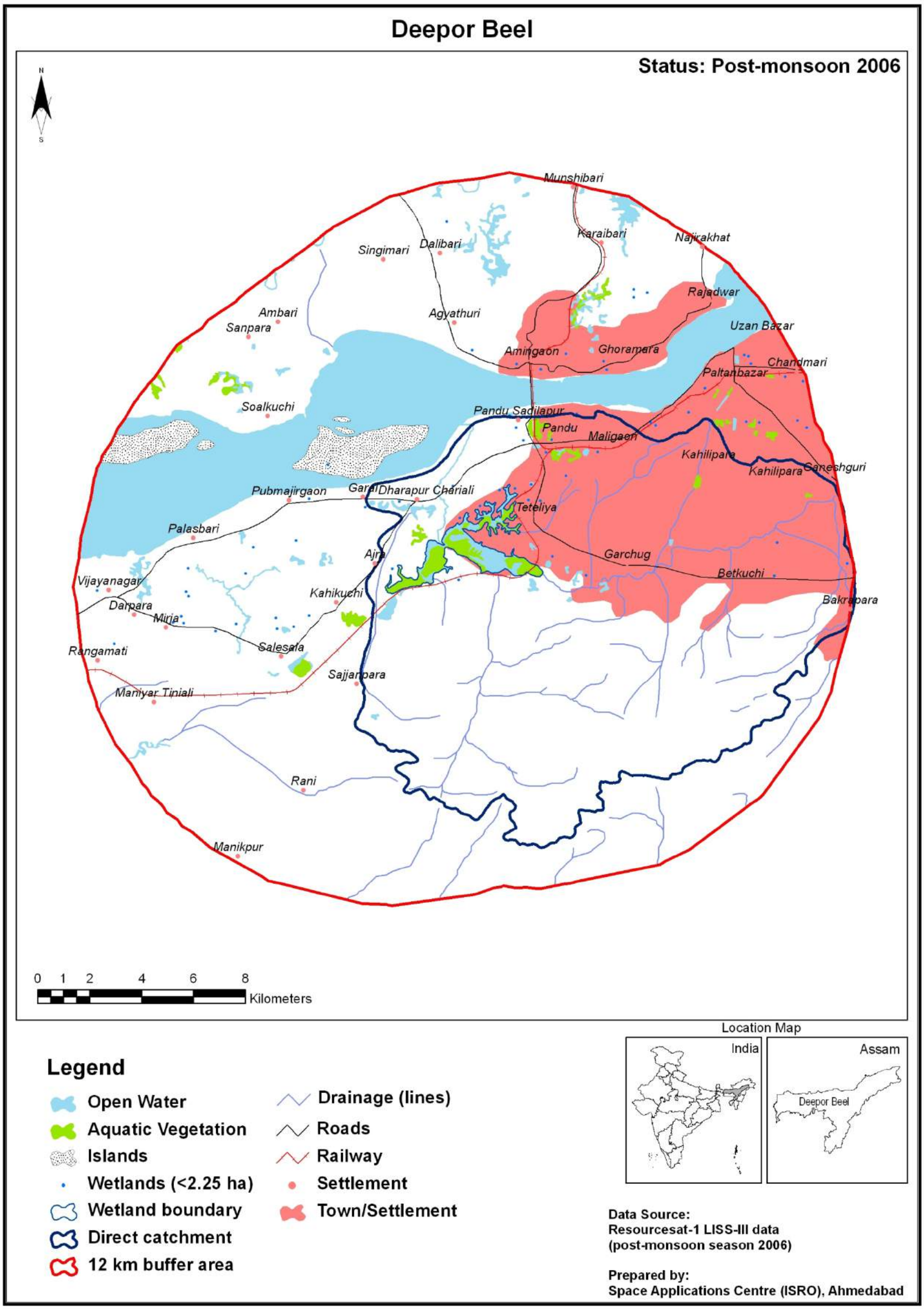

Plate 28: Open-water and vegetation status of Deepor Beel (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

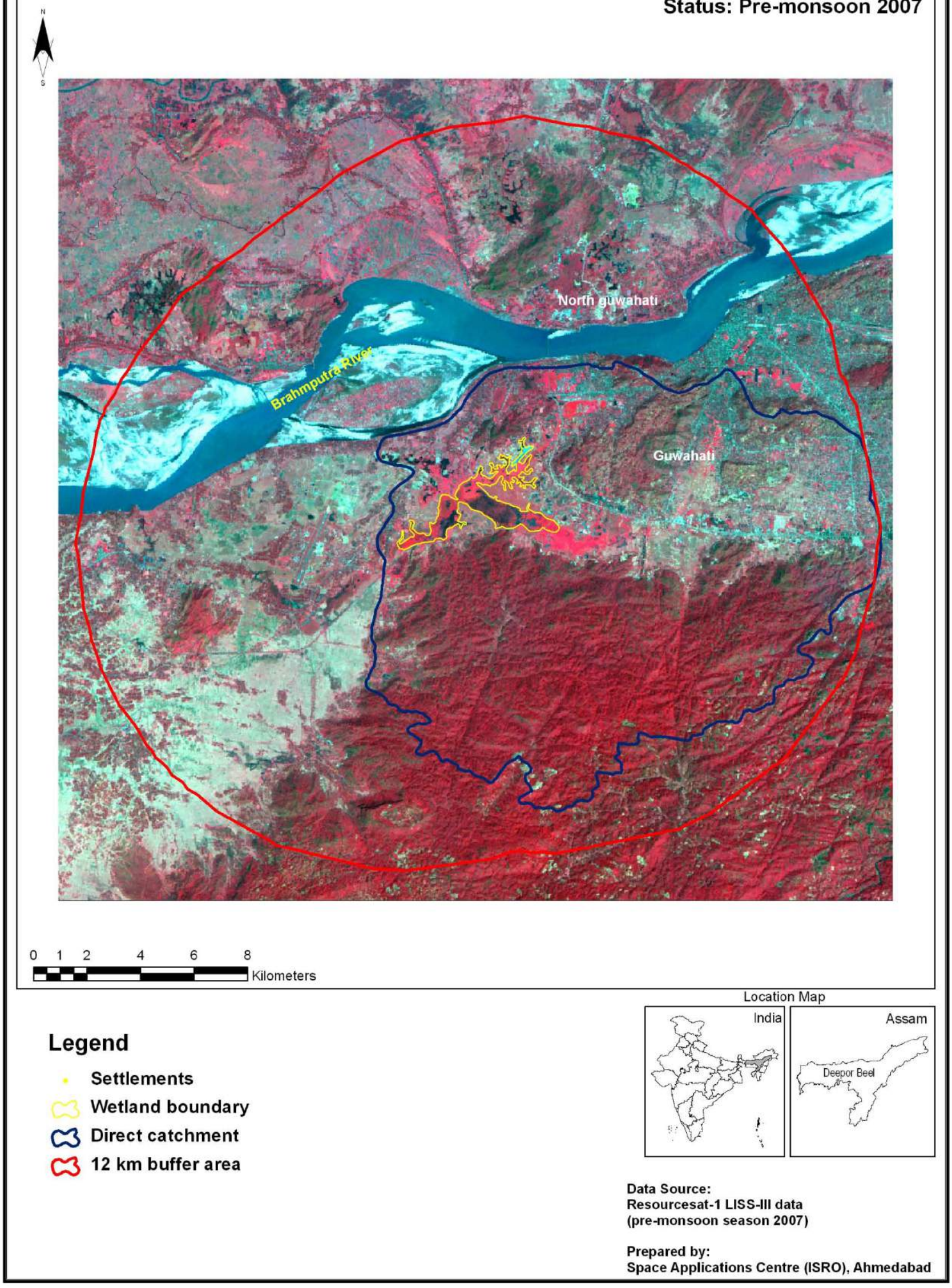

Plate 29: Deepor Beel and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (27-May-2007)

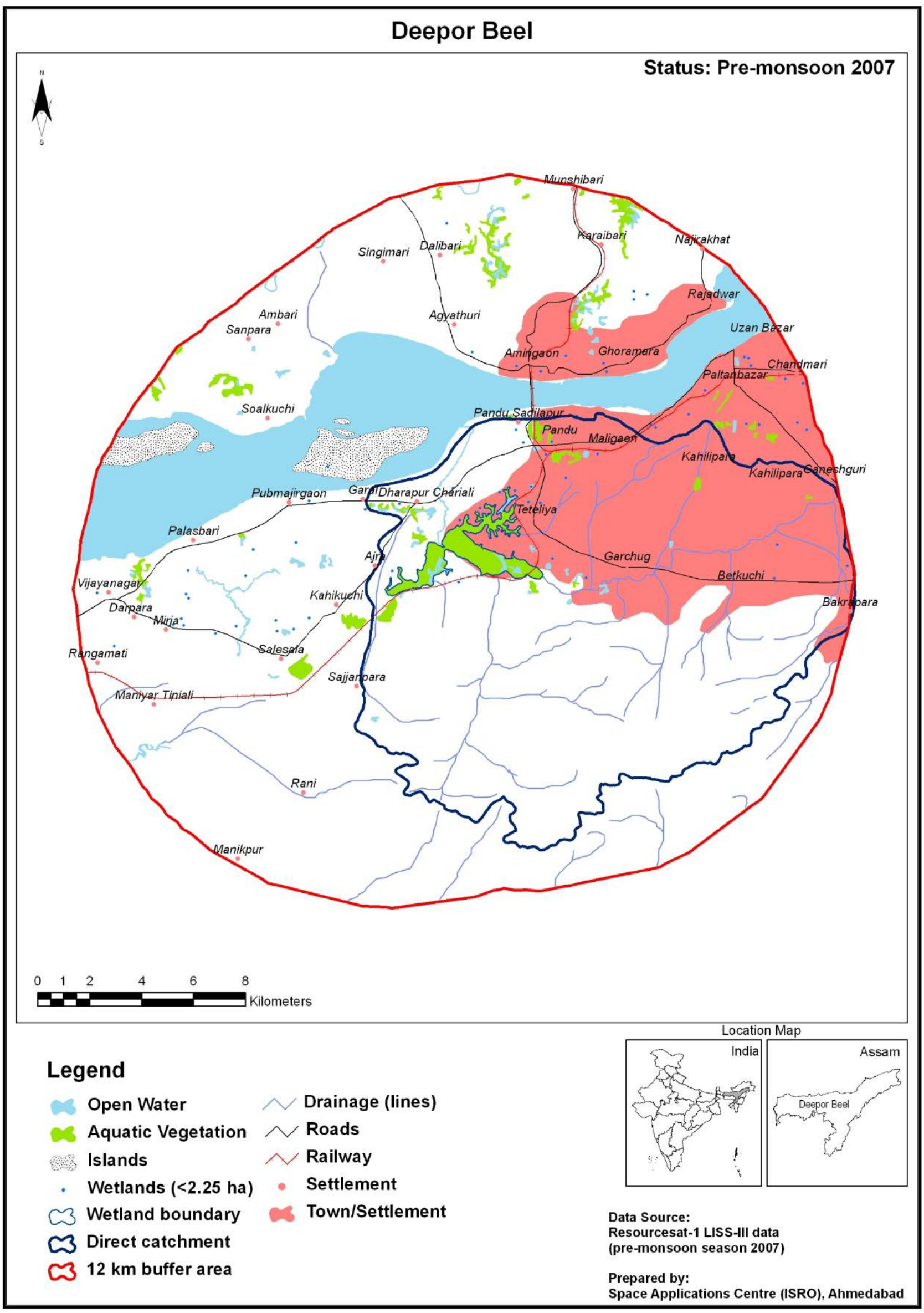

Plate 30: Open-water and vegetation status of Deepor Beel (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.7 East Calcutta Wetlands (Ramsar site no. 1208)



This is a man made wetland located east of Kolkata city, West Bengal and well known world over as "one of the rare examples of environmental protection and development management". The wetland forms an urban facility for treating the city's waste water and utilizing the treated water for pisci-culture and agriculture, through the recovery of nutrients in an efficient manner. The water flows through fish ponds covering about 4,000 ha.

East Calcutta Wetlands has been designated as a Ramsar site on 19/08/2002 owing to the compliance of criterion 1 as described below:

- Wetland represents a unique wetland type.

The wetland comprises intertidal marshes including salt marshes, salt meadows with significant waste water treatment areas like sewage farms, settling ponds, oxidation basins. It is the largest ensemble of sewage-fed fish ponds in the world in one place. The wetland provides about 150 tons of fresh vegetables daily, as well as some 10,500 tons of table fish per year, the latter providing livelihoods for more than 50,000 people directly and as many indirectly.

The wetland established over the years acts like a natural water logged area and supports diverse fauna and flora. The area harbours mammals like marsh mongoose and small Indian mongoose, palm civet and small Indian civet. More than 40 bird species comprising both local and migratory types are reported. Among these grebe, coot, darter, shag, cormorant, teals, egrets, jacanas, snipes, tern, eagle, sand piper, gulls, rails and kingfishers are significant. The wetlands as observed on Resourcesat-1 LISS-III image of two seasons are given in the Figure 16.

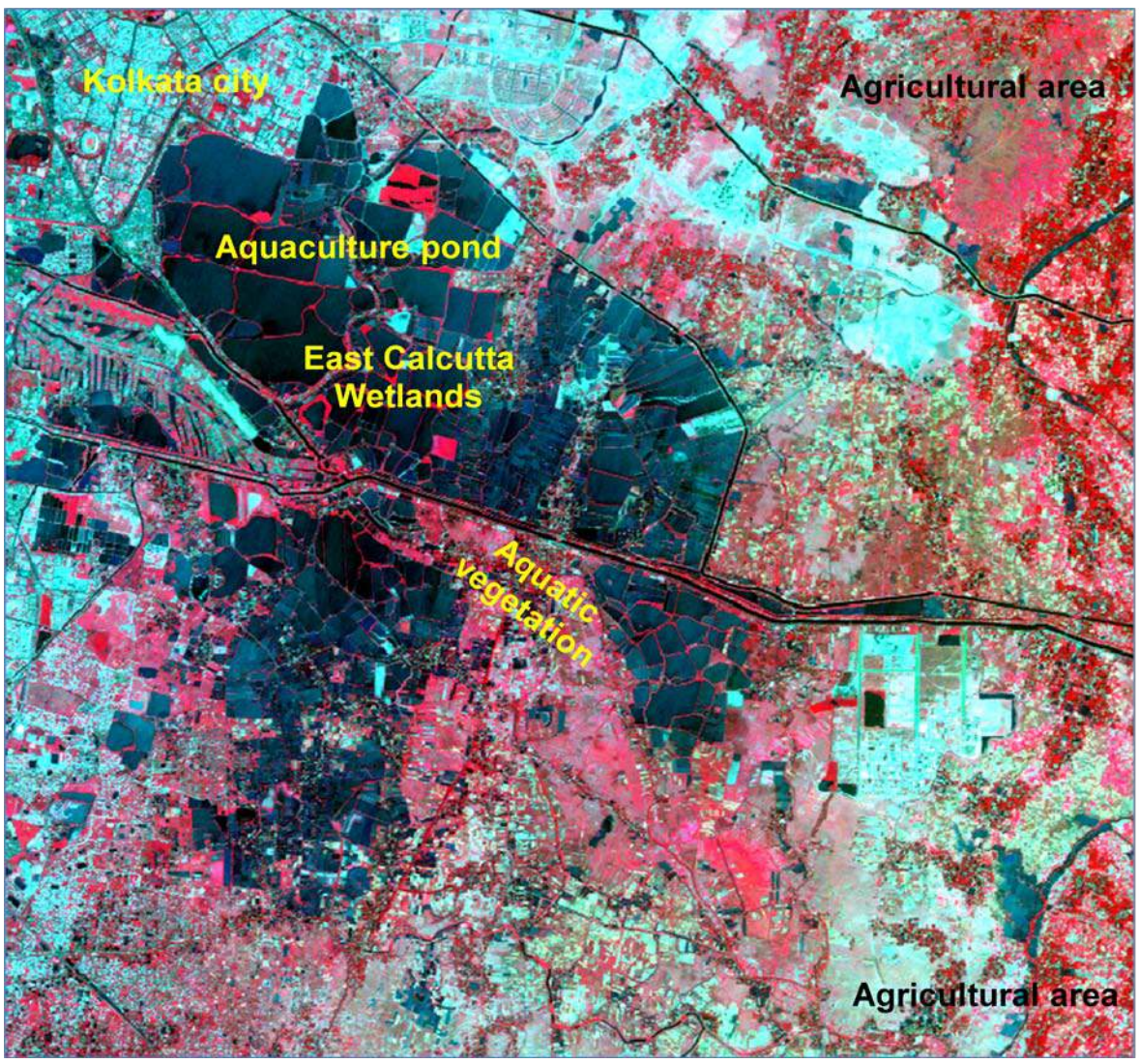

Figure 16: East Calcutta Wetlands as observed in LISS IV FCC (26-April-2008)

East Calcutta wetland encompasses the marshy area and the waste recovered land area. The total area is 12512 ha with 83 km perimeter. However, the swamp/waterlogged area is less than the 50 per cent of the area. The other area includes agricultural area developed from the waste disposal, where mainly seasonal vegetables are cultivated. Seasonal fluctuation of marshy area is negligible (Table 19).

Table 19: Salient observations of East Calcutta Wetlands from satellite data

Name:	East Calcutta Wetlands
Location:	22˚28′00” to 22˚35′18” N Latitude 88˚22′55” to 88˚30′16” E Longitude
Wetland Type:	Waterlogged (man-made)
Wetland Area: Perimeter (km):	12512 ha 83 km
Open-water Post-monsoon: Pre-monsoon:	 5775 ha 5571 ha
Vegetation Post-monsoon: Pre-monsoon:	 362 ha 65 ha
Overall Turbidity:	Moderate to high

The catchment including the 12 km buffer area of East Calcutta Wetlands is dominated by the urban sprawl of Kolkatta and Haora city. Numerous small man made ponds dot the catchment. The details for each of wetland type present in the catchment and buffer area are given in the Table 20.

Table 20: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the East Calcutta Wetlands

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	30	3393	3217	2875	138	148
1102	Ox-bow Lake/Cut-off Meander	21	245	224	186	15	35
1104	Riverine Wetland	13	94	72	58	22	19
1106	River/Stream	2	1115	1115	1115	-	-
1202	Tank/Pond	97	583	522	530	23	26
1203	Waterlogged (Man-made)	16	13630	6919	6682	364	65
	Total	179	19060	12069	11446	562	293

Wetland map of the East Calcutta Wetlands catchment including the 12 km buffer area is given in the Plate 31. The seasonal status of open-water spread and vegetation are given in the Plates 32-35 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

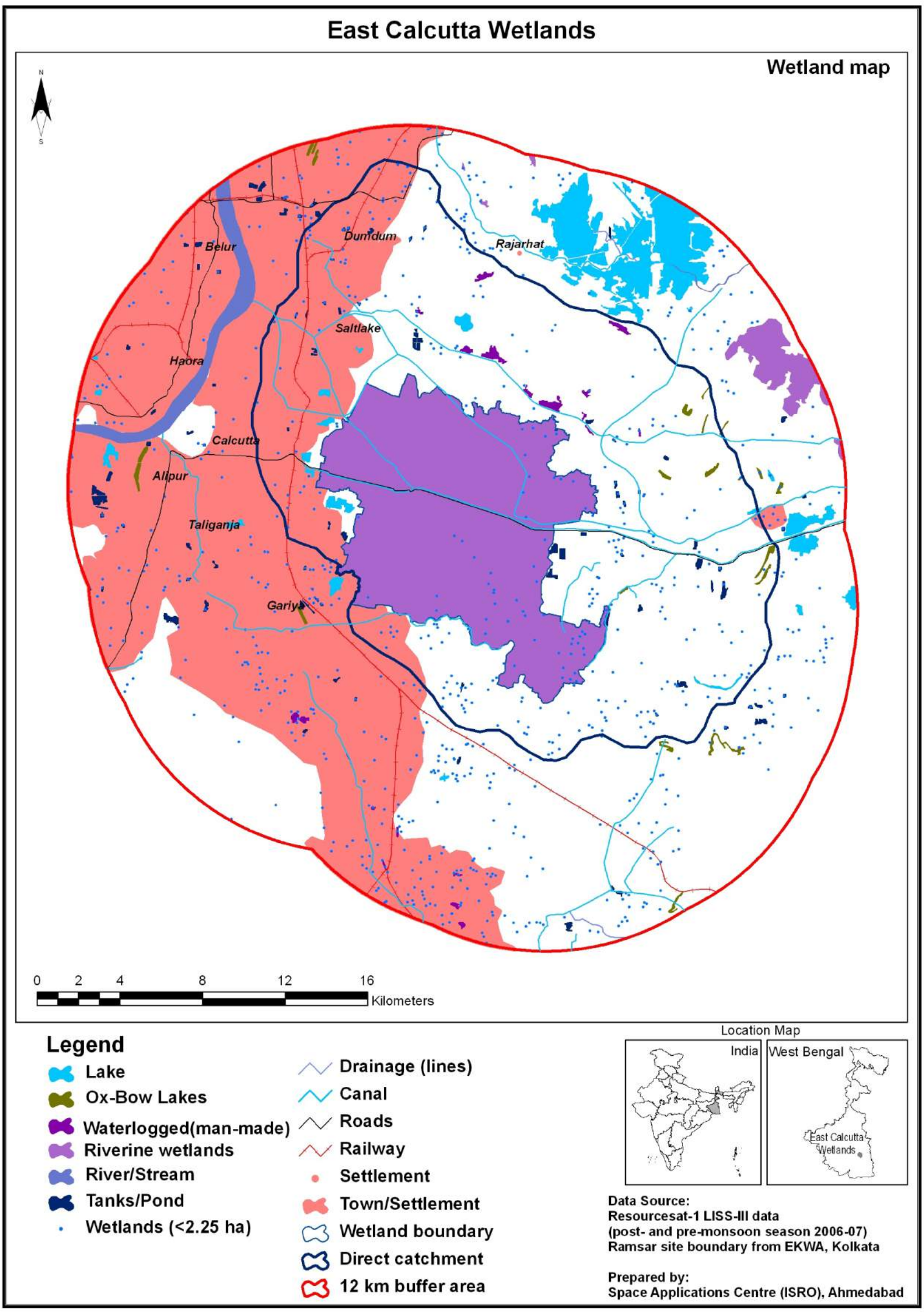

Plate 31: Wetland map of East Calcutta wetlands (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

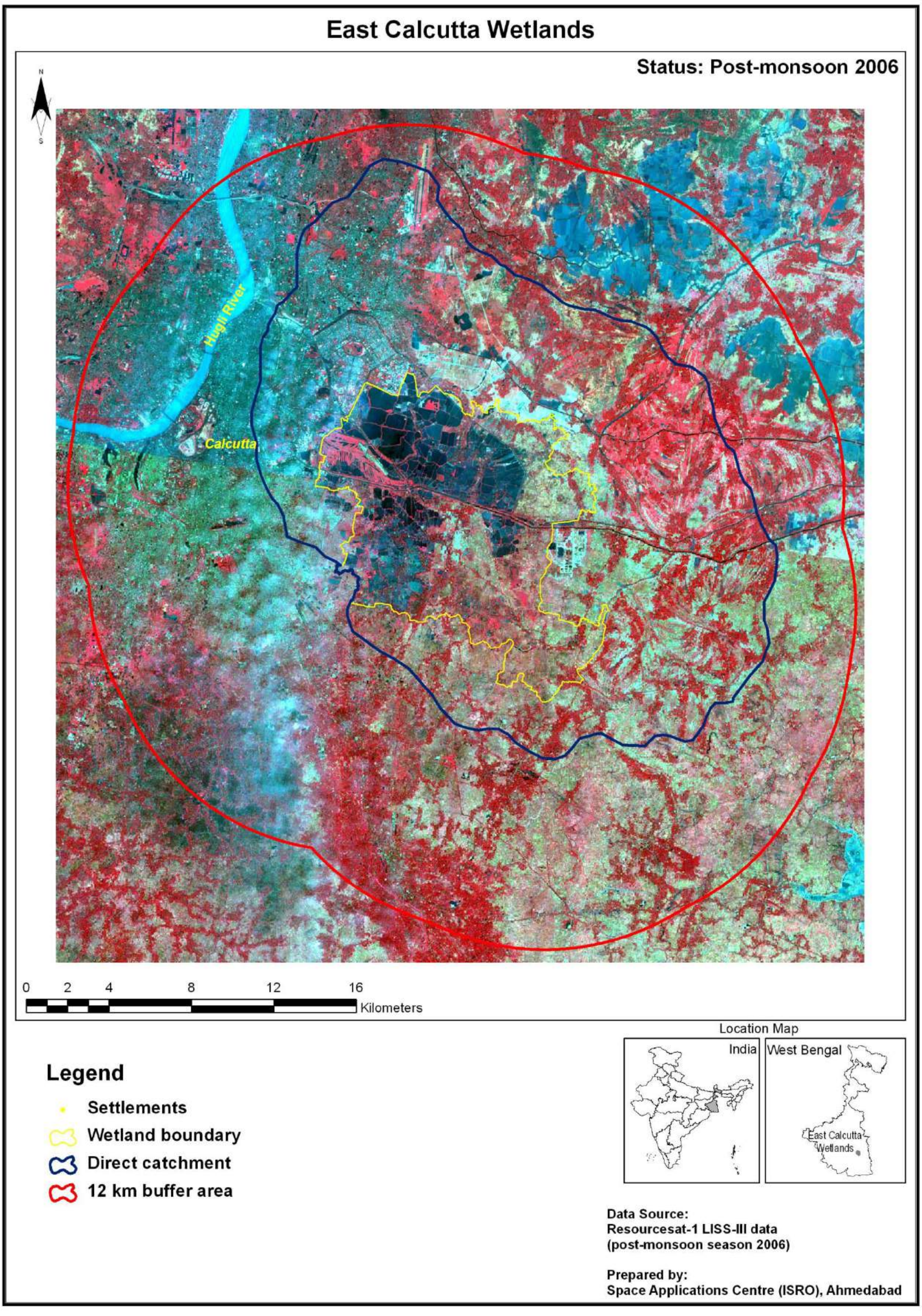

Plate 32: East Calcutta wetlands and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (09-December-2006)

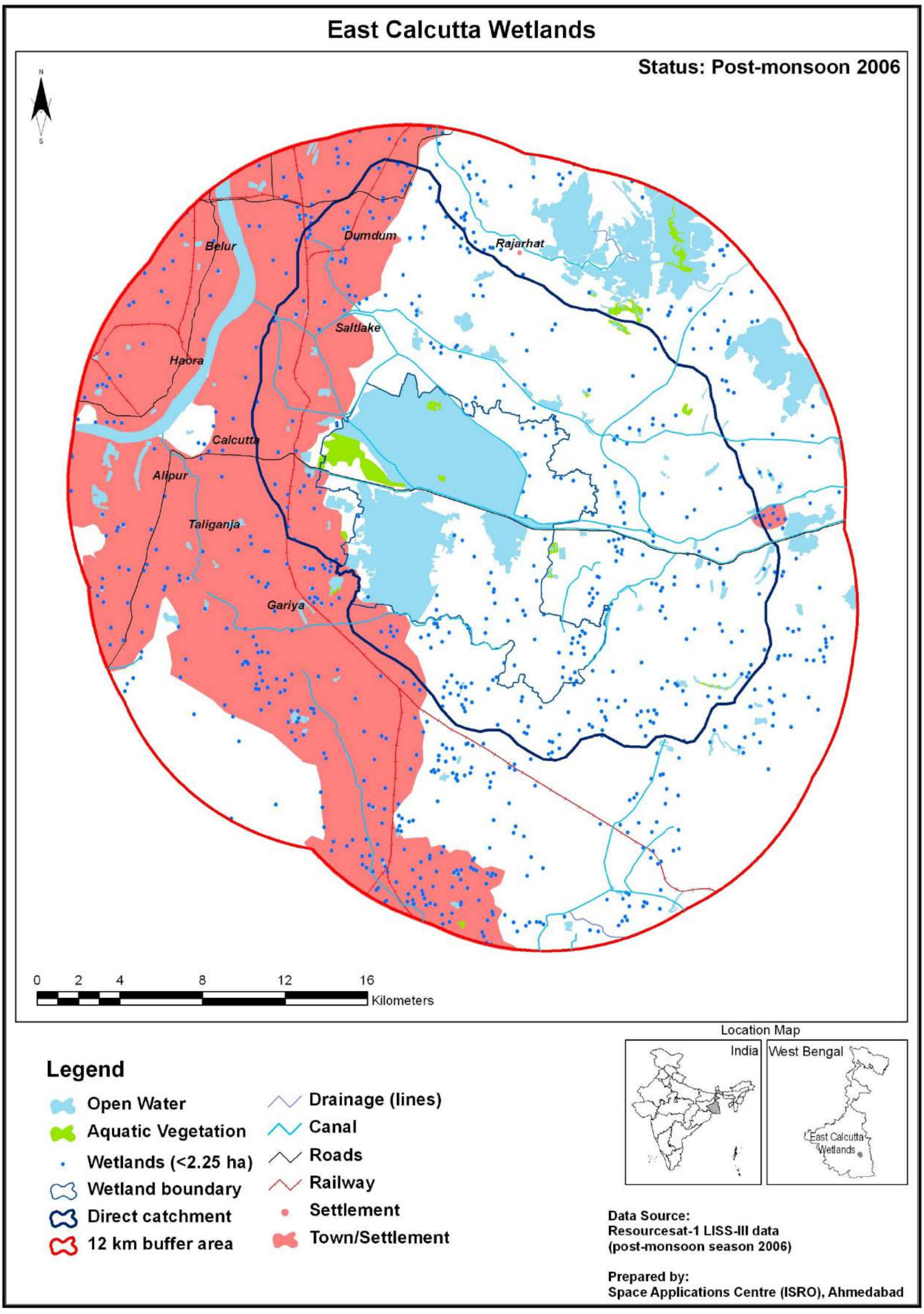

Plate 33: Open-water and vegetation status of East Calcutta wetlands (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

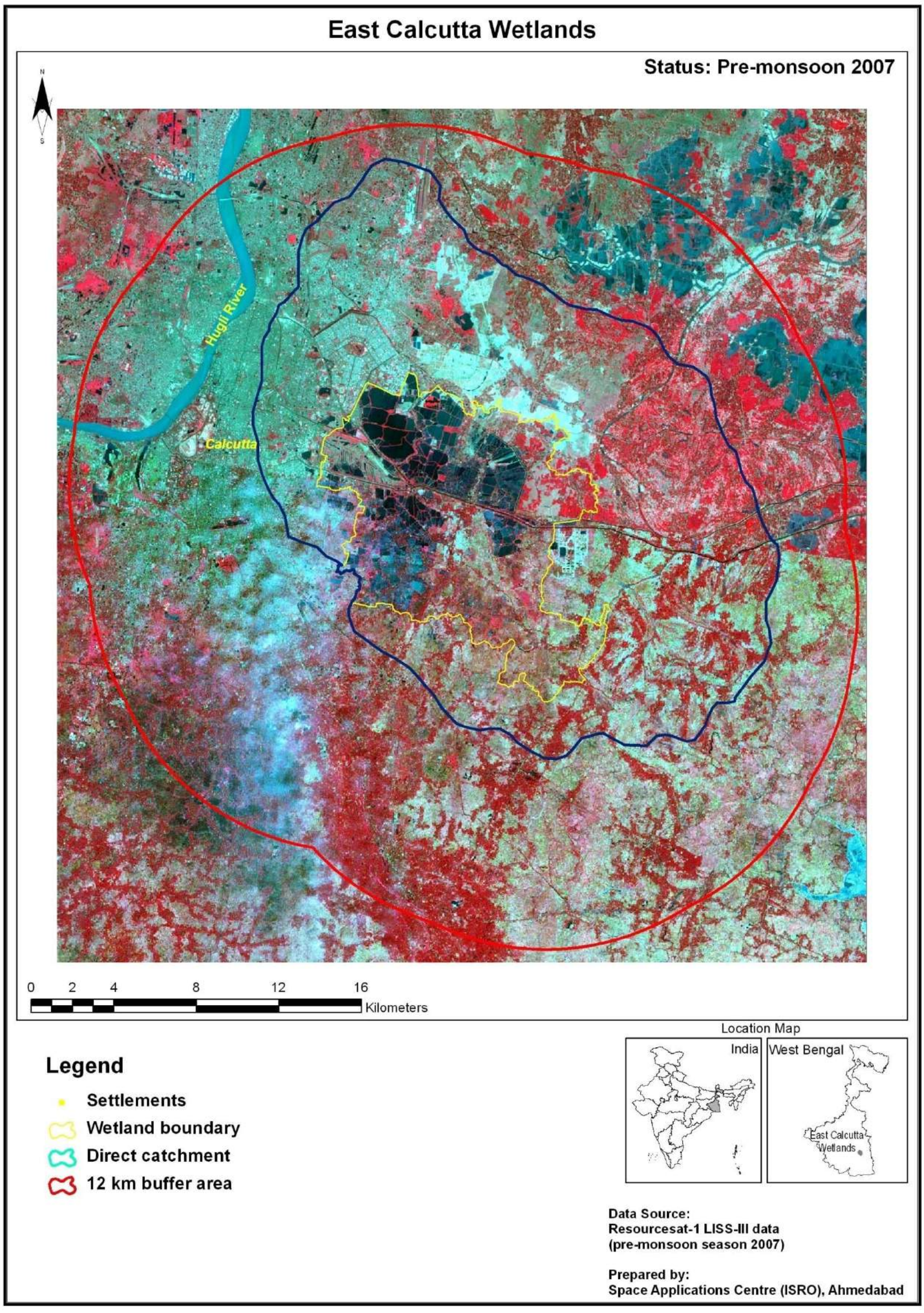

Plate 34: East Calcutta wetlands and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (08-April-2007)

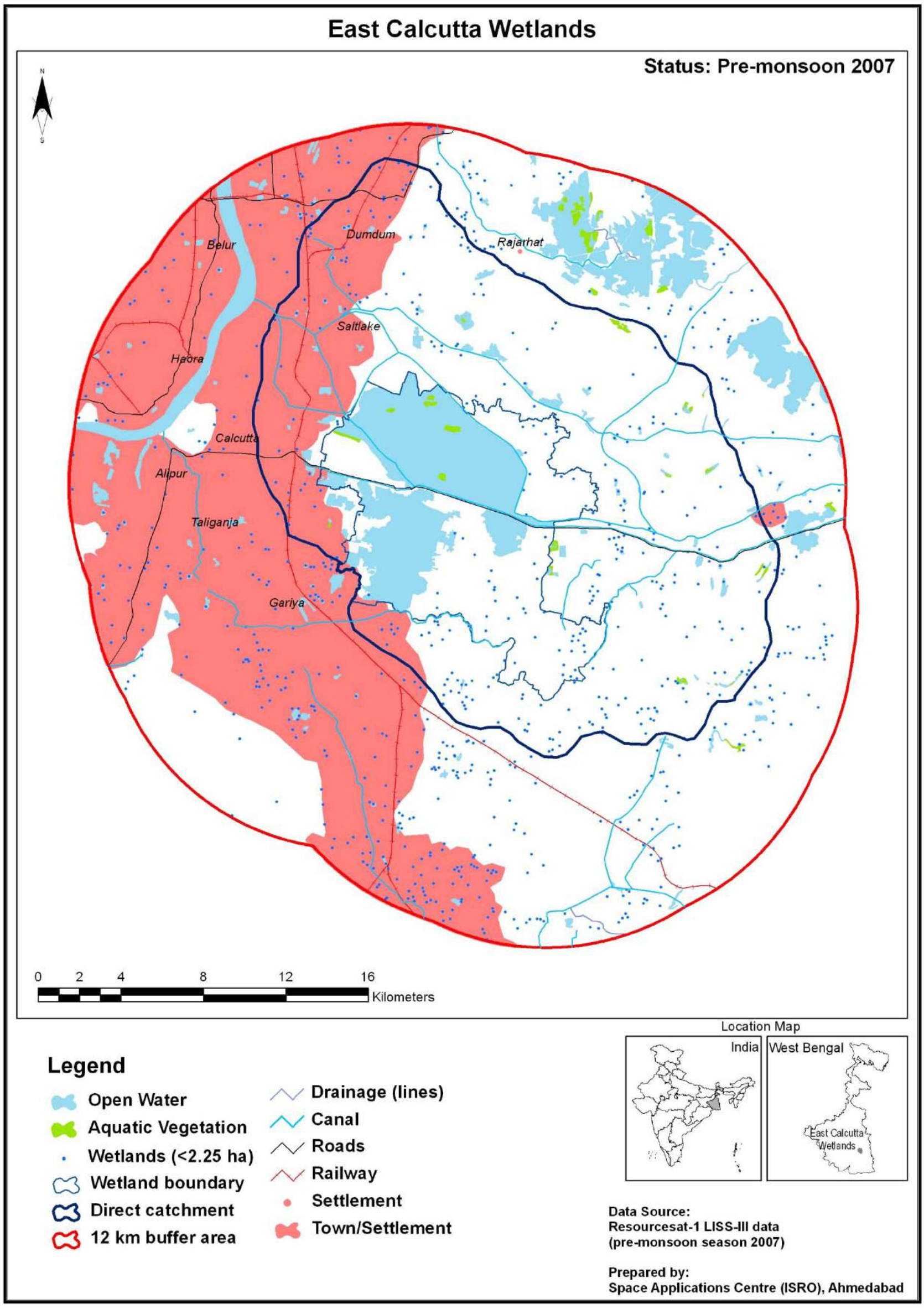

Plate 35: Open-water and vegetation status of East Calcutta wetlands (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.8 Harike Lake (Ramsar site no. 462)



The Harike Lake is a man-made impoundment built on the downstream confluence of rivers Sutlej and Beas near Harike Township, in Punjab. It is a shallow water reservoir with many islands. It was created for storage and provision of irrigation and drinking water to parts of southern Punjab and adjoining Rajasthan. Over a period of time Harike has emerged as a fine waterfowl habitat.

It was declared as a Ramsar site on 23/03/1990 owing to the compliance of criteria 2, 5 & 6 as described below:

- Wetland supports threatened ecological communities.
- Wetland regularly supports 20, 000 or more waterbirds.
- Wetland regularly supports 1 % of the individuals in a population of one species or subspecies.

The lake is an important site for breeding, wintering and staging birds, supporting over 200,000 Anatidae (ducks, geese, swans, etc.) during migration. Large populations of scaup duck, falcated teal and the white-headed stiff-tailed duck are observed here which are rarely seen elsewhere within India The area having shallow, marshy tracts serve as perfect feeding and wading habitat for waterfowl and tree covered earthen mounds are ideal nesting sites. It supports rare, vulnerable and endangered faunal species which include the Testudine turtle and the smooth Indian otter, both of which are listed in the IUCN Red list of Threatened Animals. Apart from avifauna, 7 species of turtle and 26 species of fish have been recorded

Harike Lake as observed on Resourcesat-1 LISS-III images is given in the Figure 17. One can observe the intense eutrophication of the lake. Besides the dominant *Eichornia,* extensive growth of *Typha elephantina* and *Phragmites karka* is observed along the margins of the lake. Amongst the tall grasses *Saccharum spontaneum* and *S.bengalenses* are the most common along the higher ground in the wetland area and *Tamarix diocia* is the sole woody plant truly adapted to aquatic condition.

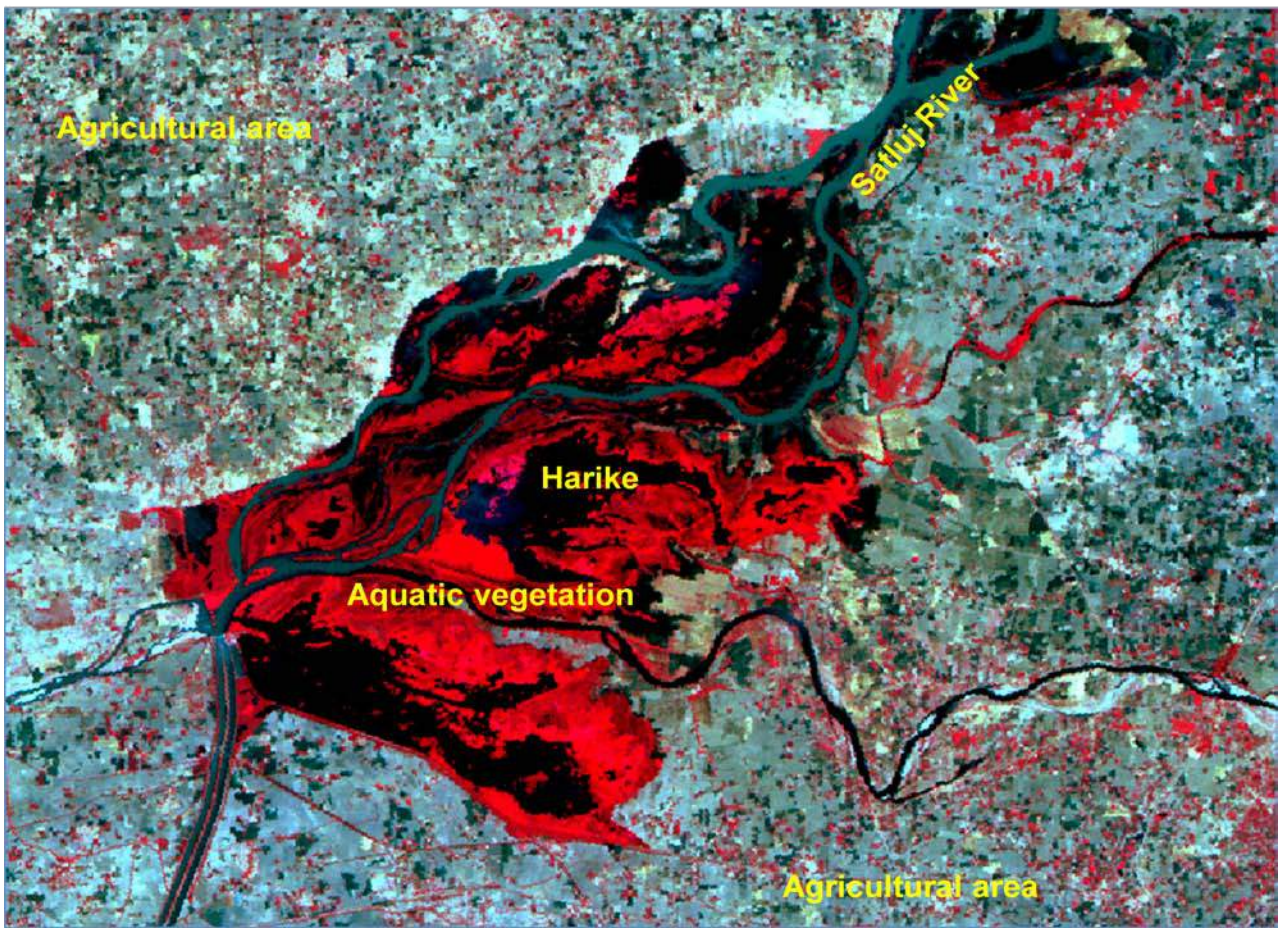

Figure 17: Harike Lake and its environ as seen in LISS-III FCC (23-May-2007)

Harike Lake has an area of 7406 ha with 67 km of perimeter. The area under open-water marginally increased (5 %) from 2425 ha in post-monsoon to 2559 ha in pre-monsoon season. On the other hand vegetation has shown a significant increase (26 %) from 4978 ha to 3667 ha across the seasons (Table 21).

Table 21: Salient observations of Harike Lake from satellite data

Name:	Harike Lake
Location:	31˚06′36” to 31˚13′04” N Latitude 74˚56′04” to 75˚05′54” E Longitude
Wetland Type:	Reservoir/Barrage
Wetland Area: Perimeter:	7406 ha 67 km
<u>Open-water</u> Post-monsoon: Pre-monsoon:	 2425 ha 2559 ha
<u>Vegetation</u> Post-monsoon: Pre-monsoon:	 4978 ha 3667 ha
Overall Turbidity:	Low to Moderate

The catchment of the lake including 12 km buffer area is 484402 ha. The land use is predominantly agriculture. The fields are cultivated during both the seasons, with rice, wheat and potato as major crops. The area is drained by seven streams including the two major rivers the Beas and Sutlej. Thus the nutrient flow along with the sediments from the intense agricultural practice of the catchment is the reason for heavy eutrophication of the wetland. The other wetlands found in the catchment are waterlogged areas, small Lake/ponds and Tanks. Most of the wetlands show intense eutrophiication during pre monsoon (Table 22).

Table 22: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Harike Lake

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	20	190	109	50	73	134
1102	Ox-bow Lake/Cut-off Meander	2	77	46	3	27	13
1105	Waterlogged Area	4	125	9	-	116	-
1106	River/Stream	20	12437	6173	4882	1637	2167
1201	Reservoir/Barrage	2	7423	2430	2560	4972	3660
1202	Tank/Pond	50	231	165	118	63	83
	Total	98	20483	8932	7613	6888	6057

Wetland map of the Harike catchment including the 12 km buffer area is given in the Plate 36. The seasonal status of open-water spread and vegetation are given in the Plates 37-40 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

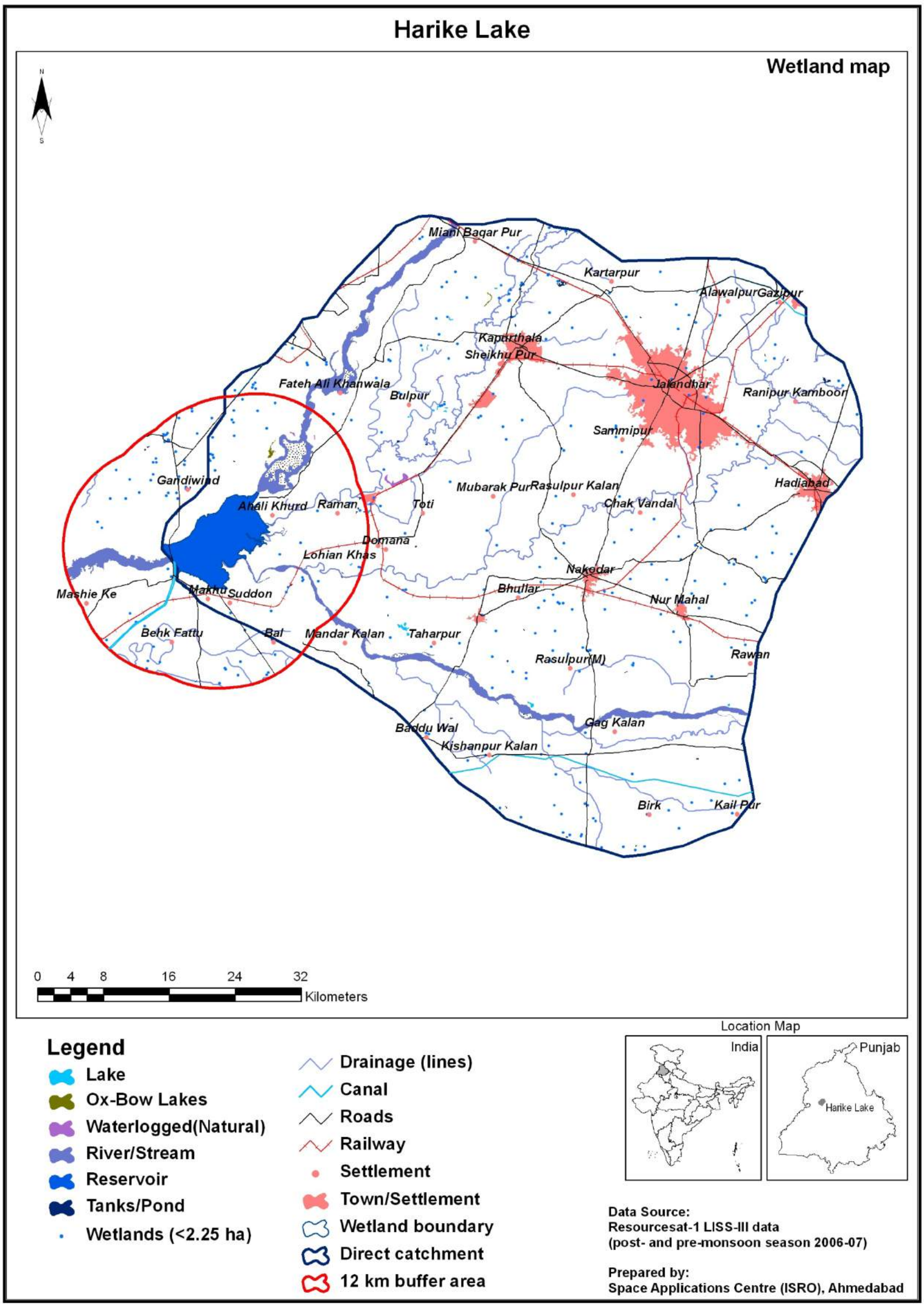

Plate 36: Wetland map of Harike Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

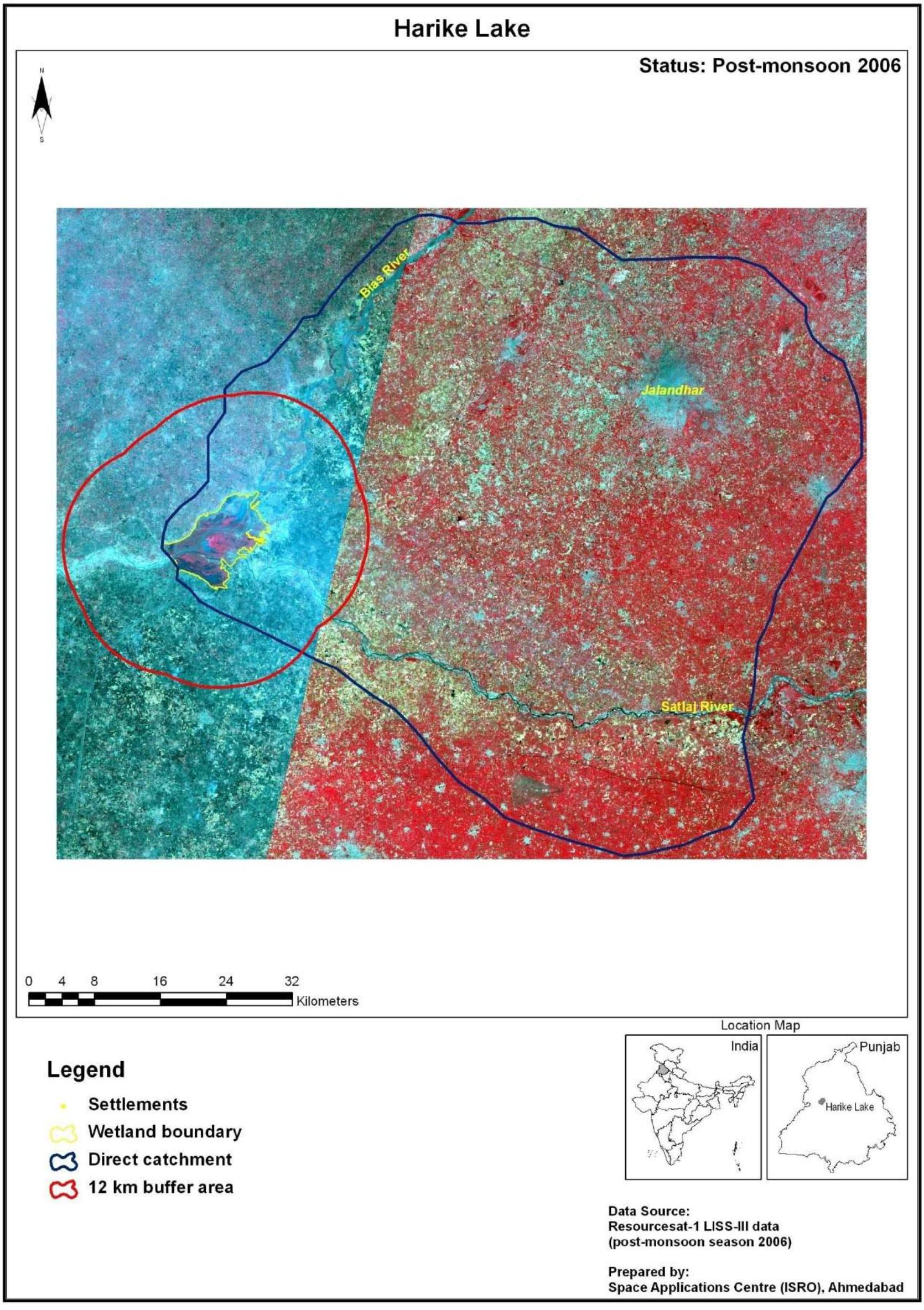

Plate 37: Harike Lake and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (19-October-2006)

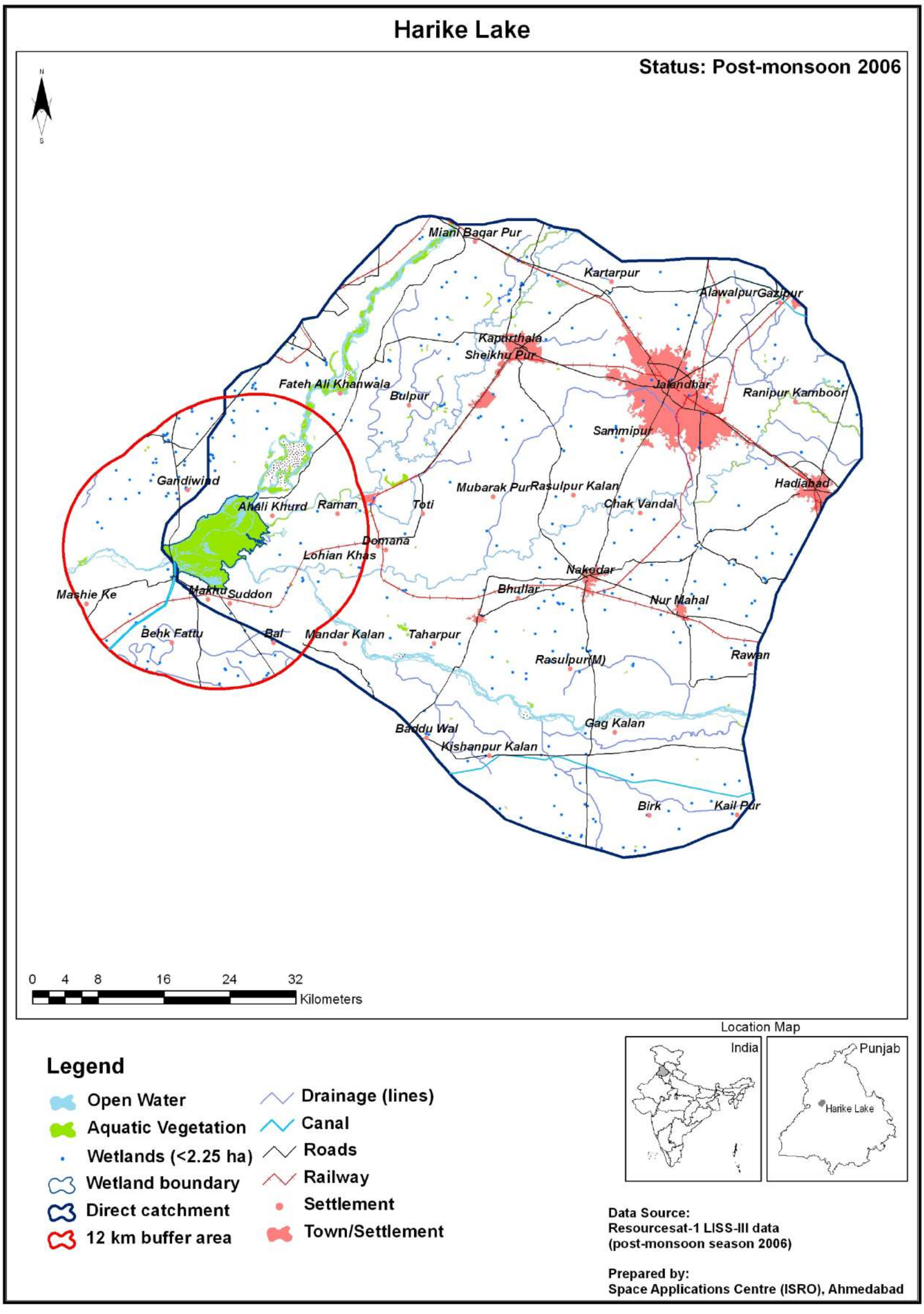

Plate 38: Open-water and vegetation status of Harike Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

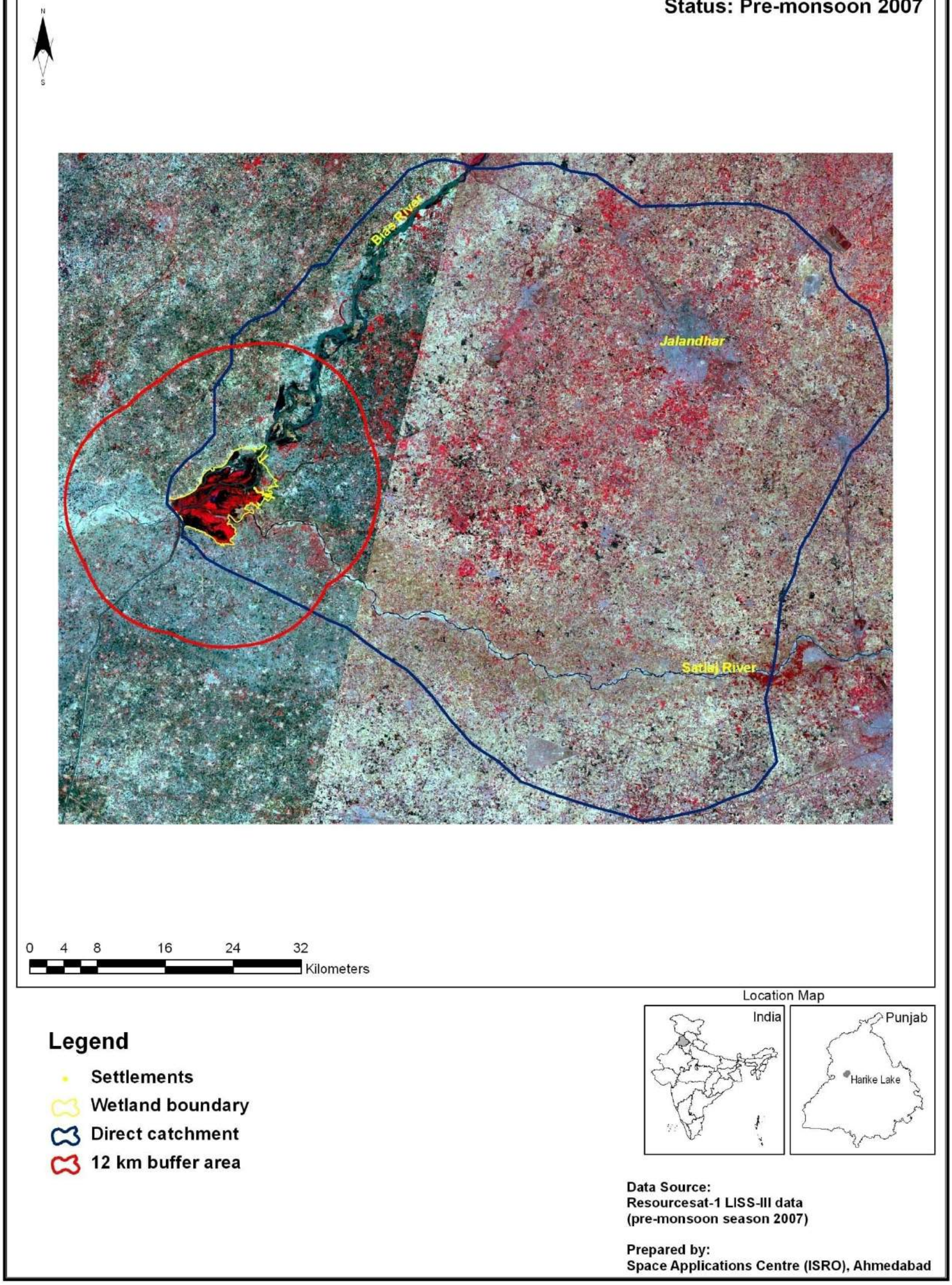

Plate 39: Harike Lake and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (23-May-2007)

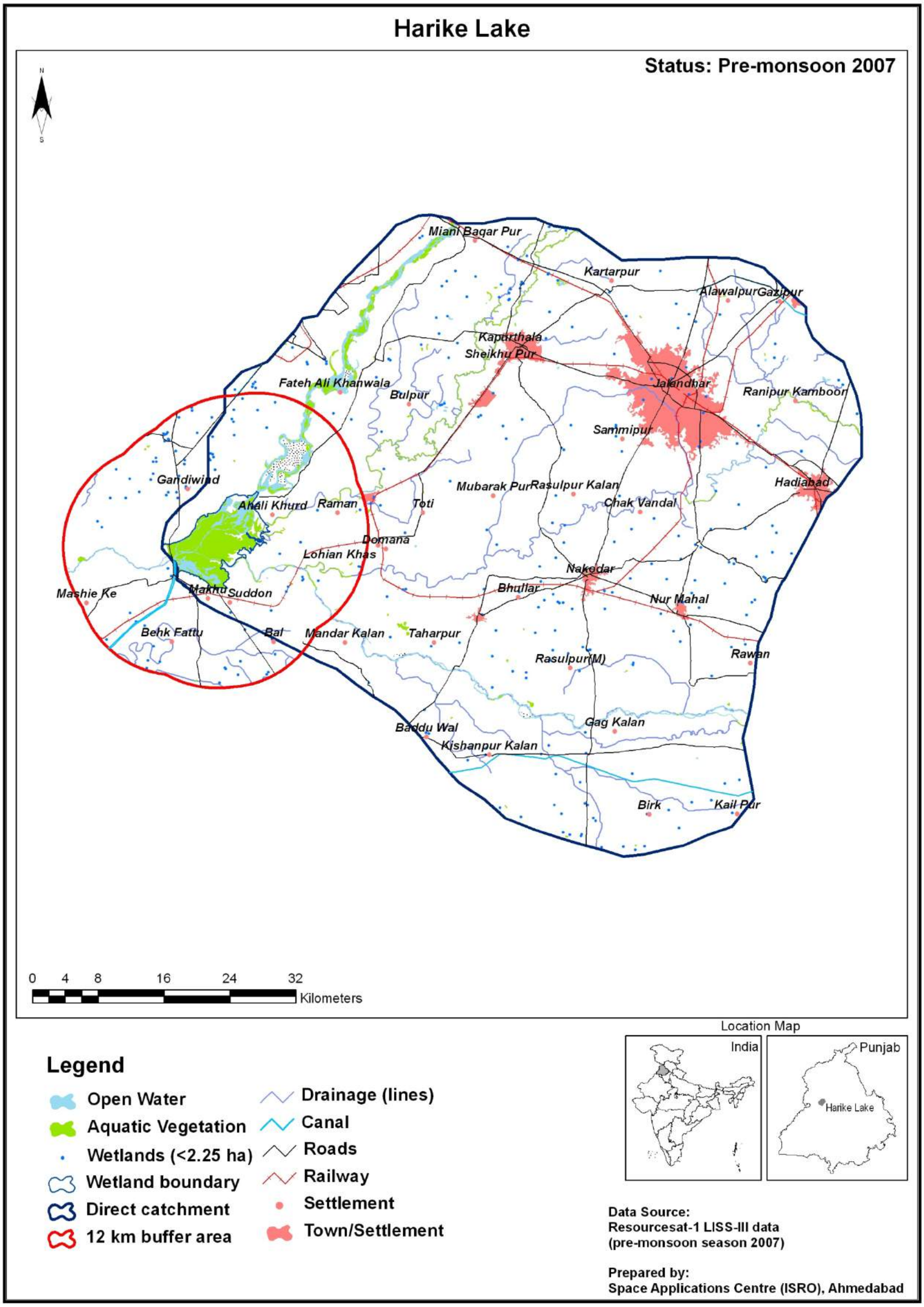

Plate 40: Open-water and vegetation status of Harike Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.9 Hokera Wetland (Ramsar site no. 1570)



Hokera is a natural riverine wetland located around 10 km from Srinagar, in Kashmir valley. It is fed by two rivers : Doodhganga and Sukhang from the southeast and northwest direction.

Hokera wetland has been designated as Ramsar site on 08/11/2005 owing to the compliance of criteria 2, 5 & 6 as described below:

- Wetland supports threatened ecological communities.
- Wetland regularly supports 20, 000 or more waterbirds.
- Wetland regularly supports 1 % of the individuals in a population of one species or subspecies.

It supports a large number of waterfowls especially the white eyed pochard (*Aythya nyroca*) enlisted in the IUCN Red list (2004). It is the only site with remaining reedbeds of Kashmir and pathway of 68 waterfowl species like Large Egret, Great Crested Grebe, Little Cormorant, Common Shelduck, Tufted Duck coming from Siberia, China, Central Asia, and Northern Europe. Around 373, 000 water fowl were reported in 2001-02

It is an important source of food, spawning ground and nursery for fishes, besides offering feeding and breeding ground to a variety of water birds. It is an important spawning ground for fishes; offering feeding and breeding ground to a variety of waterfowl both resident and migratory.

Hokera wetland provides lucrative harvests such as fish, fodder and water nuts. During spring the fish, migrate up to Hokera from the river Jhelum for stocking. Thus a sizable fish stock is available that feeds the avifauna. Owing to its characteristics, the vegetation is a prominent part of this wetland.

In the southern part the marginal shallow water puddles are dominated by *Typha, Phragmites, Eleocharis etc.* Many species of *Nymphoides* are found in the open water, when the shallow water areas dry up during summer, the vegetation is replaced by ephemeral species like *Batrachium trichophyllum* etc. In the north-western parts of the wetlands, large numbers of floating gardens are found. Hokera wetland as observed on Resourcesat-1 LISS-III image is given in the Figure 18.

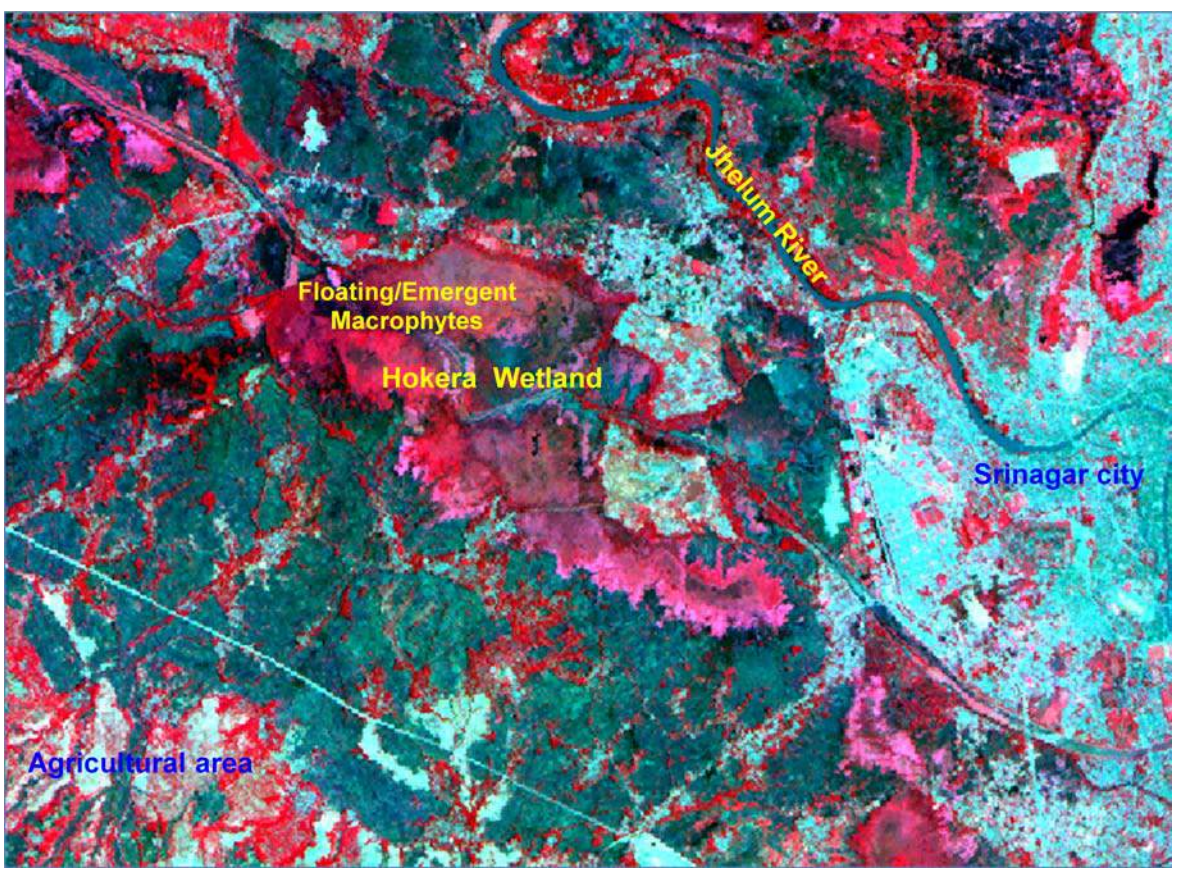

Figure 18: Hokera wetland and its environ as seen in LISS-III FCC (18-May-2007)

Hokera wetland has an extent of 1371 ha with 31 km perimeter. The water spread of the wetland depends on the discharge from the Dudhganga spill channel. The lake is shallow one, attaining maximum depth of 2.5 m during the snow melt period and dries up to <1 m during autumn. The wetland is observed to be completely under vegetation such that the open-water is not detectable during October. However, during May, there is 65 ha of open-water spread (Table 23).

Table 23: Salient observations of Hokera wetland from satellite data

Name:	Hokera Wetland
Location:	34˚03′57” to 34˚07′04” N Latitude 74˚40′12” to 74˚45′14” E Longitude
Wetland Type:	Riverine Wetland
Wetland Area: Perimeter:	1371 ha 31 km
Open-water Post-monsoon: Pre-monsoon:	 Nil 65 ha
Vegetation Post-monsoon: Pre-monsoon:	 1371 ha 1306 ha
Overall Turbidity:	Low to Moderate

The catchment of Hokera wetland including 12 km buffer constitutes 70323 ha area. Agricultural area mainly used for rice cultivation adjoins the western part of the lake. Except, the rivers/steams, there are no other wetland in its catchment. However, in the 12 km buffer area there are many riverine wetlands and natural lakes. The wetlands accounts for 9244 ha. However, there is marginal reduction (about 4 %) in the vegetation from post-monsoon to pre-monsoon (Table 24).

Table 24: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Hokera wetland

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	7	1505	991	1074	547	386
1104	Riverine Wetland	26	6647	33	278	6619	6450
1106	River/Stream	6	1089	1001	1084	-	-
1202	Tank/Pond	1	3	3	3	-	-
	Total	40	9244	2028	2439	7166	6836

Wetland map of the Hokera catchment including the 12 km buffer area is given in the Plate 41. The seasonal status of open-water spread and vegetation are given in the Plates 42-45 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

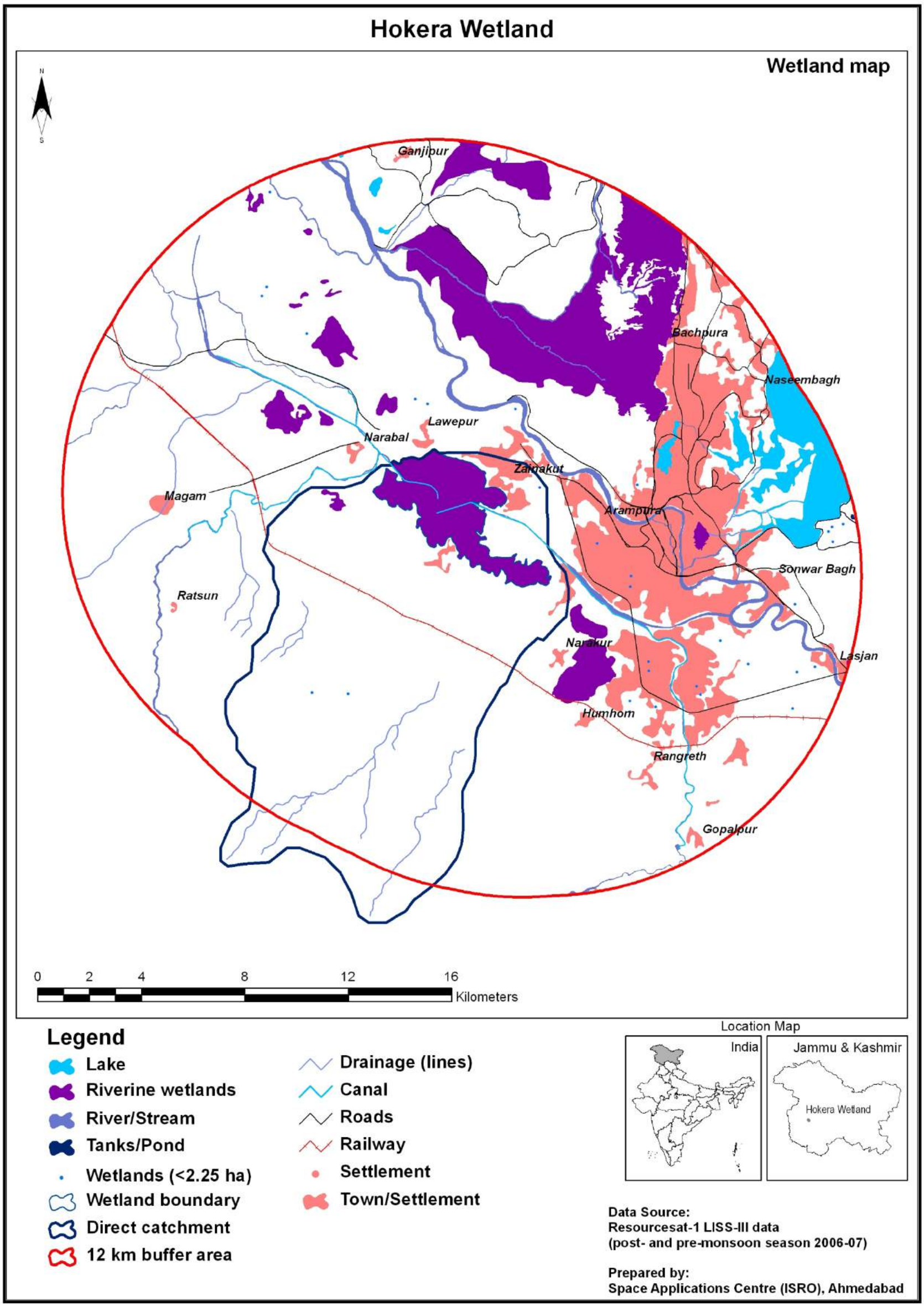

Plate 41: Wetland map of Hokera Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

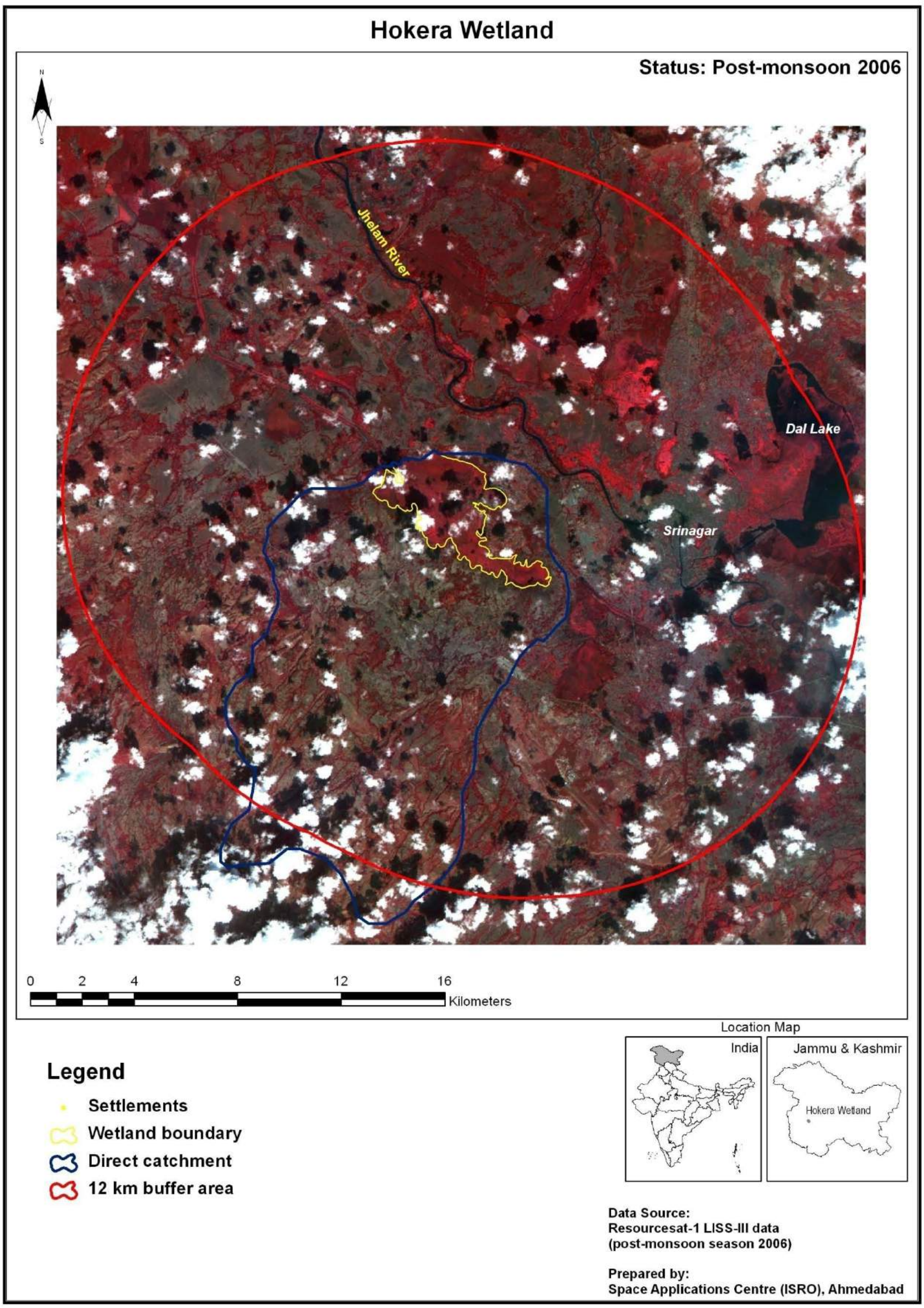

Plate 42: Hokera Wetland and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (14-October-2006)

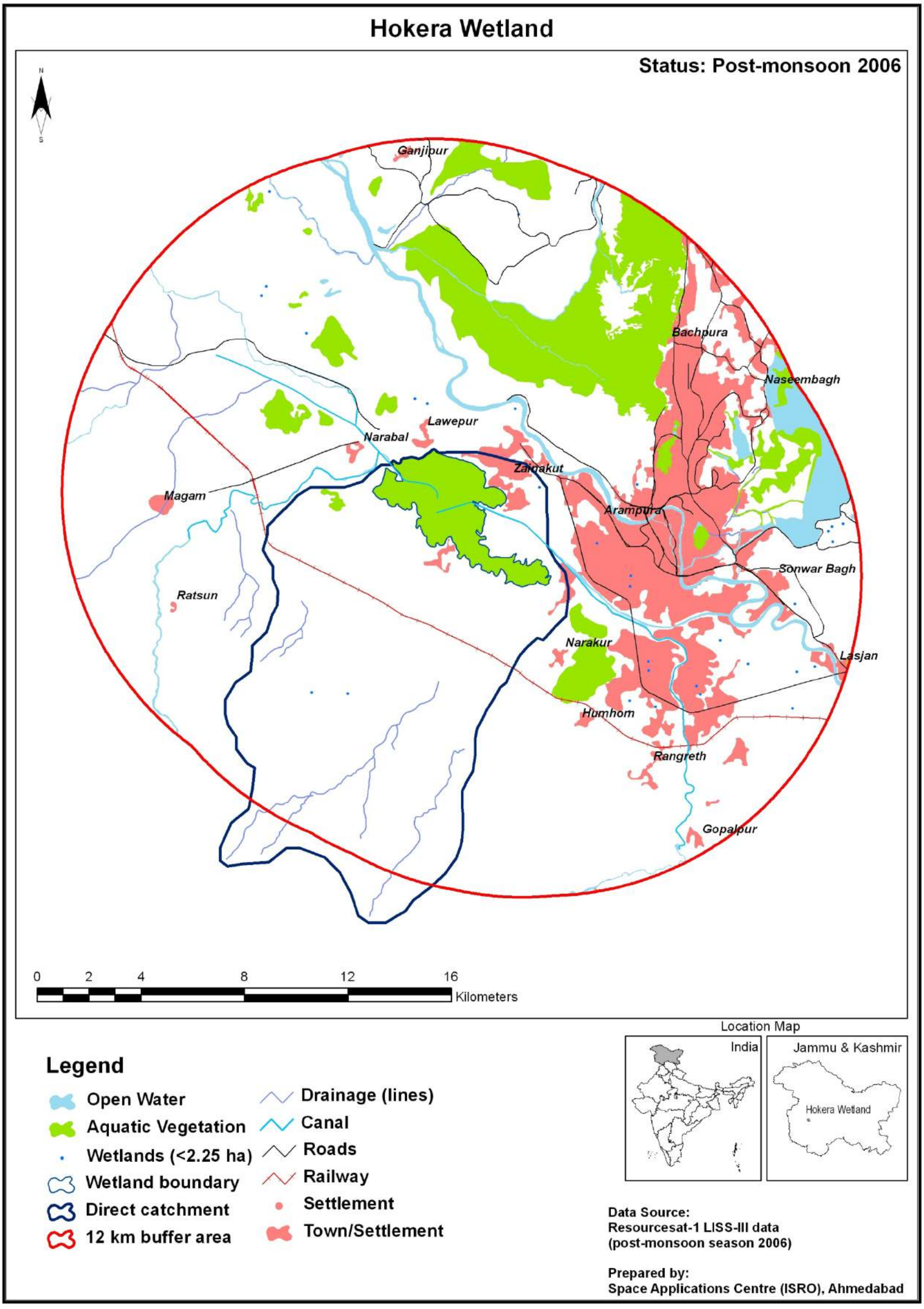

Plate 43: Open-water and vegetation status of Hokera Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

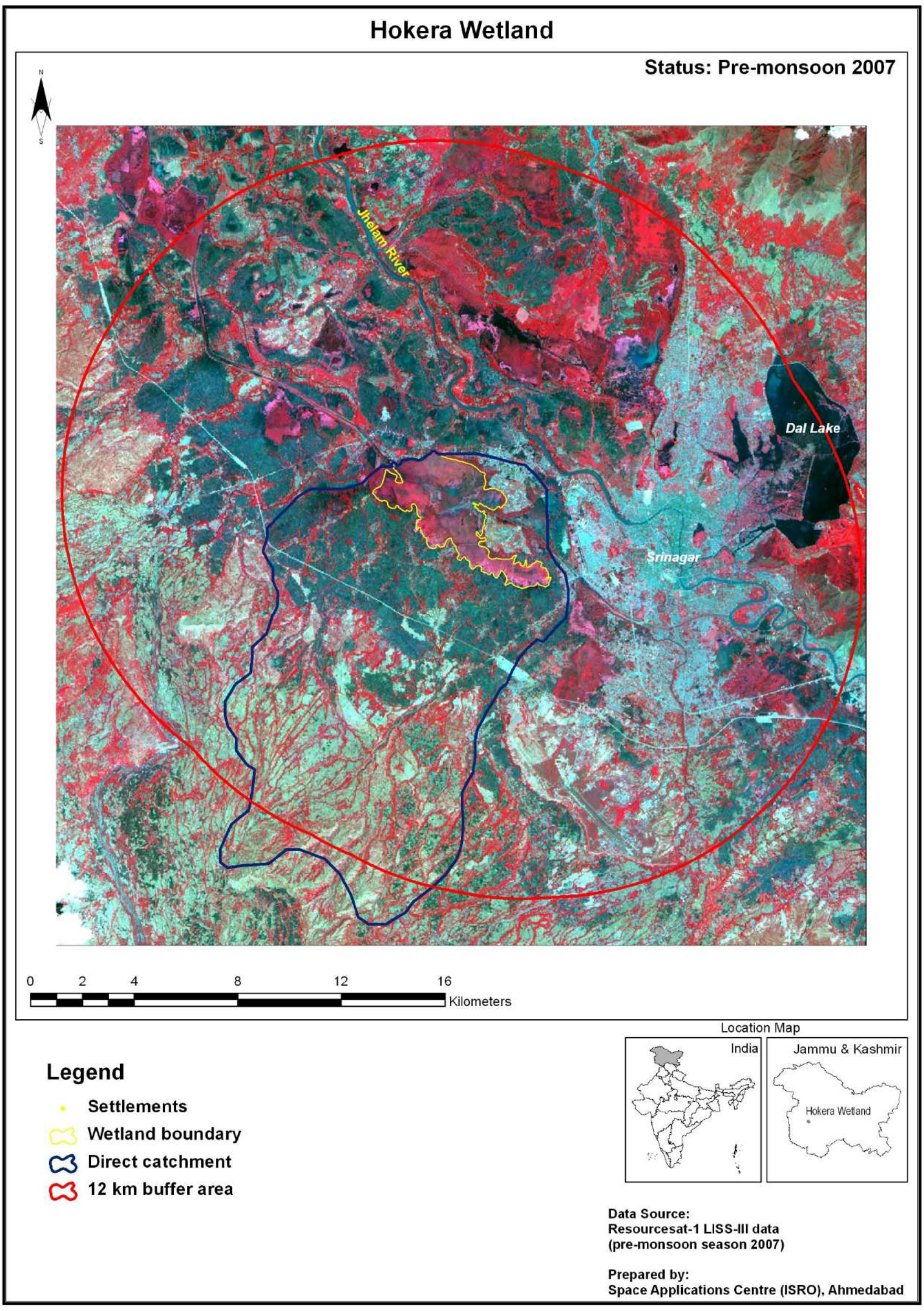

Plate 44: Hokera Wetland and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (18-May-2007)

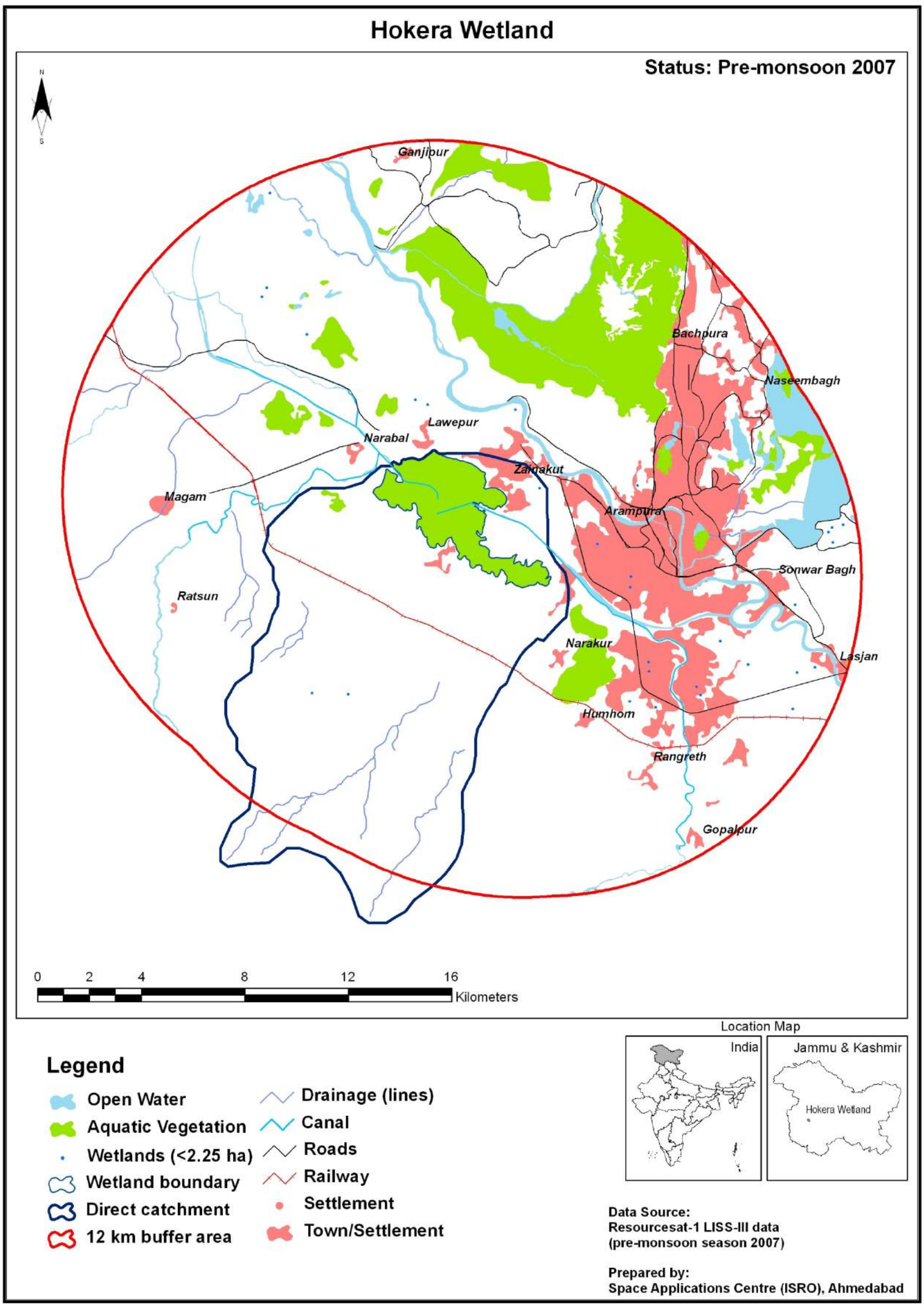

Plate 45: Open-water and vegetation status of Hokera Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.10 Kanjli (Ramsar site no. 1160)



This wetland is a man made impoundment of water. It was created by construction of a small barrage on the Kali Bein, an important tributary of river Beas in 1870. The purpose was to create a water storage area for irrigation of crops. It is located near Kanjli village in Kapurthala district of Punjab. Kali Bein ultimately joins Harike wetland present in the downstream after a distance of about 20 km. Kanjli wetland was designated as a Ramsar Site on 22/01/2002.

The site fulfils Criteria 3 because of its importance in supporting a considerable diversity of aquatic, mesophytic, and terrestrial flora and fauna in the biogeographical region,

Kanjli wetland supports diverse aquatic flora besides mesophytes. The aquatic flora include *Chara sp., Hydrilla sp., Vallesnaria sp., Potomageton sp., Nelumbo sp., Nymphea sp., Eichhornia crassipes, Cyperus sp., Trapa sp., Typha angustata* and *T. elephantine*. The water comprises 34 species of zooplankton from Protozoa, Rotifera, Nematoda, Ostracada, Copepoda, Oligotheta, Cladocera. There are 15 species of recorded macro invertebrates and 17 species of fishes.

Kanjli acts as a transitory stopover for migratory birds on their way to Harike besides supporting a large number of resident birds. Commonly observed migratory birds of Kanjli are various species of goose, white eyed pochard, wigeon, tufted pochard, common teal, large whistling teal, pintail, mallard and shovler.

Kanjli wetland as observed on Resourcesat-1 LISS-IV image is given in the Figure 19.

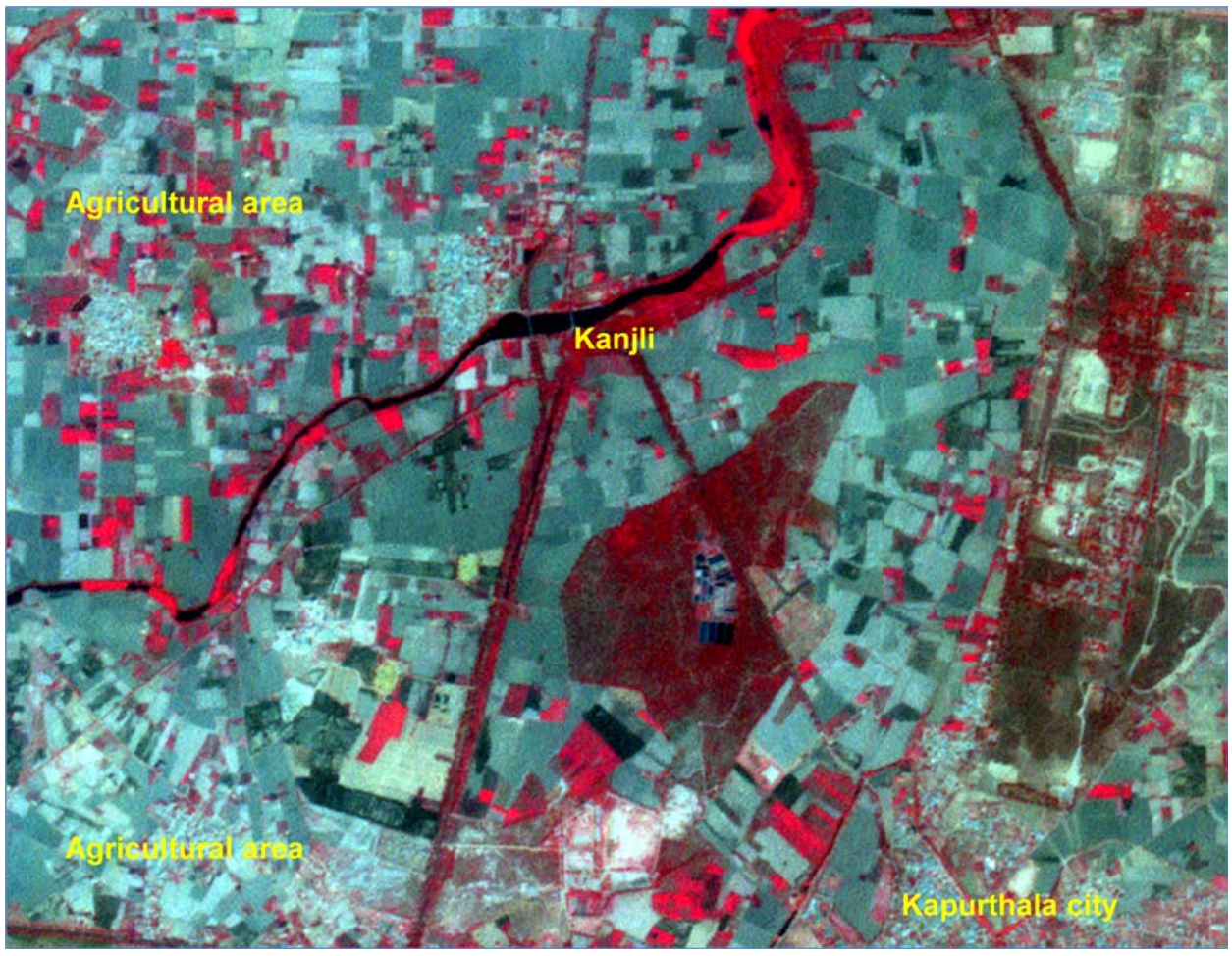

Figure 19: Kanjli wetland and its environ as seen in LISS-IV FCC (14-May-2006)

Kanjli wetland is man made reservoir with an extent of 17 ha. The perimeter of the wetland is 2 km. Open-water spread in post-monsoon is 5 ha out of 17 ha revealing the fact that the wetland is highly vegetated (Table 25). The vegetation is 12 ha in post-monsoon and has shown a reduction in pre-monsoon (5 ha).

Table 25: Salient observations of Kanjli wetland from satellite data

Name:	Kanjli
Location:	31˚24′36” to 31˚24′52” N Latitude 75˚22′33” to 75˚23′04” E Longitude
Wetland Type:	Reservoir/Barrage
Wetland Area: Perimeter:	17 ha 2 km
<u>Open-water</u> Post-monsoon: Pre-monsoon:	 5 ha Nil
<u>Vegetation</u> Post-monsoon: Pre-monsoon:	 12 ha 5 ha
Overall Turbidity:	Moderate

The catchment of Kanjli wetland including 12 km buffer area is estimated to be 47508 ha which constitutes 23 wetlands with an estimated area of 545 ha, including Kanjli. River/Stream ranks first in the area (418 ha). The open-water spread has shown a reduction of about 64 % from post-monsoon (221 ha) to pre-monsoon (79 ha). On the other hand there is an increase in the extent of vegetation by about 2.8 times from post-monsoon to pre-monsoon (Table 26). Wetland type-wise area estimates and seasonal changes in terms of open-water and vegetation are given in Table 26.

Table 26: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Kanjli

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	4	25	12	9	7	15
1102	Ox-bow Lake/Cut-off Meander	1	22	3	-	18	13
1105	Waterlogged	1	5	-	-	5	-
1106	River/Stream	8	418	155	32	67	291
1201	Reservoir/Barrage	1	17	5	-	12	5
1202	Tank/Pond	8	58	45	38	13	16
	Total	23	545	221	79	122	340

Wetland map of the Kanjli catchment including the 12 km buffer area is given in the Plate 46. The seasonal status of open-water spread and vegetation are given in the Plates 47-50 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

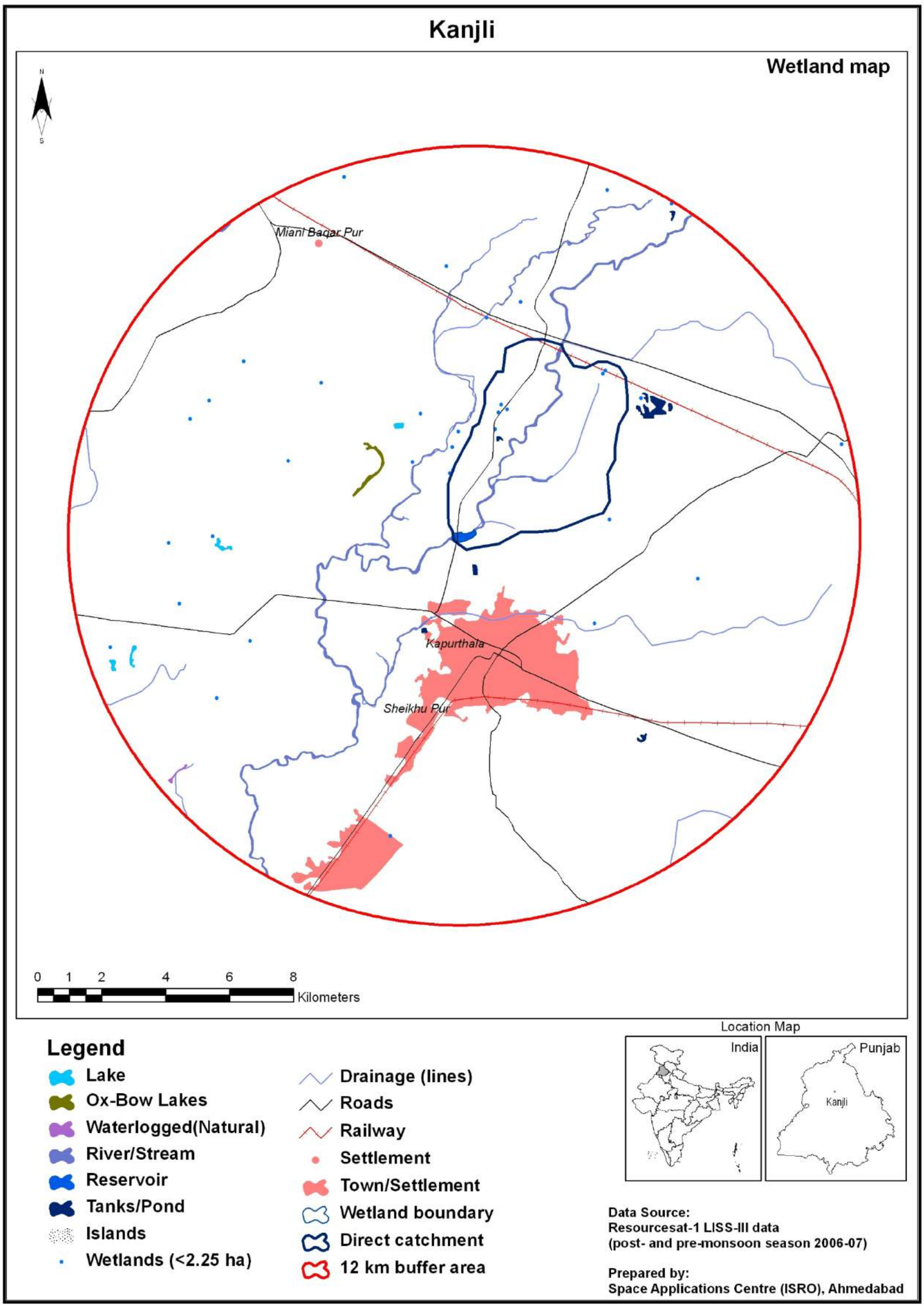

Plate 46: Wetland map of Kanjli Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

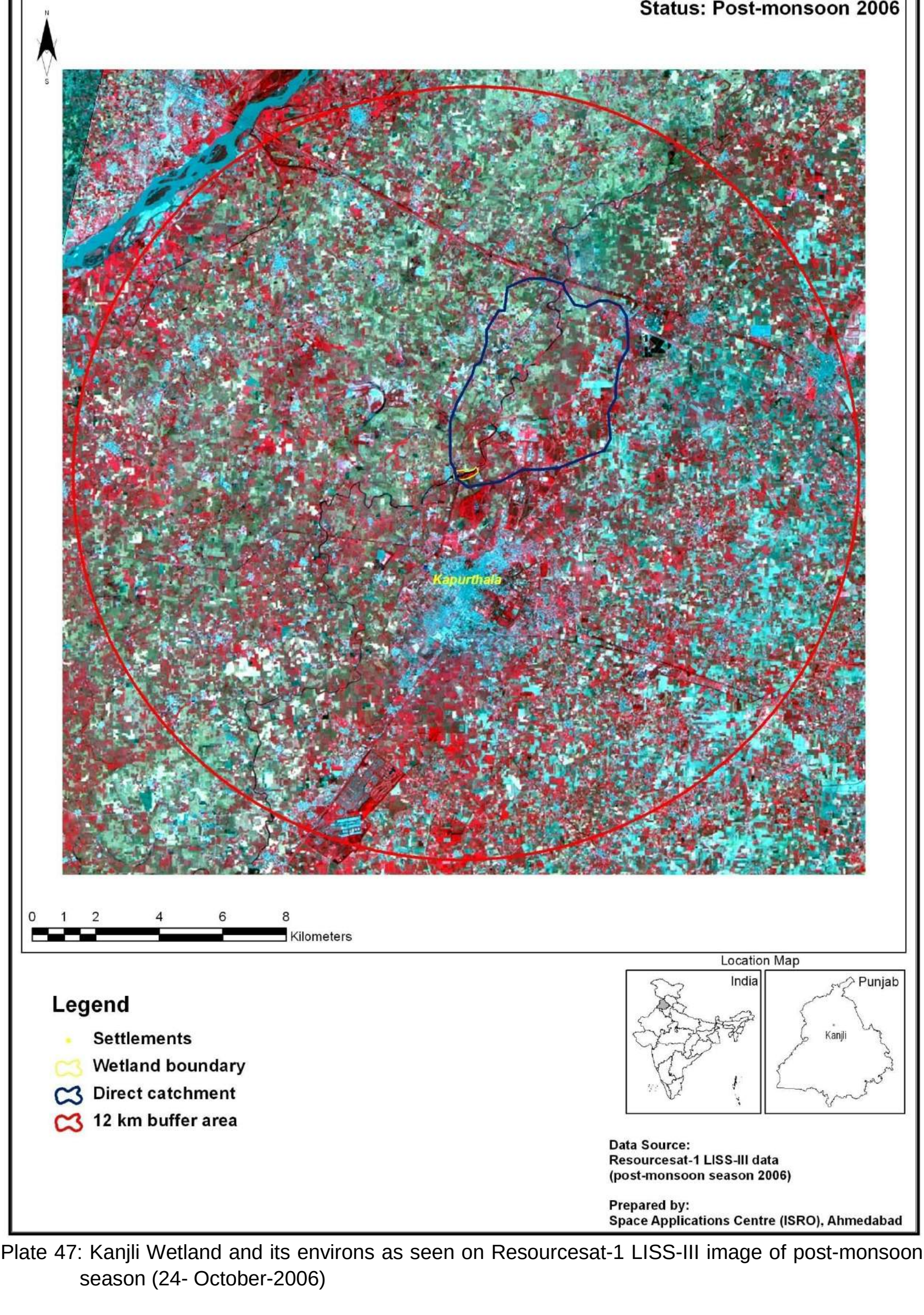

Plate 47: Kanjli Wetland and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (24- October-2006)

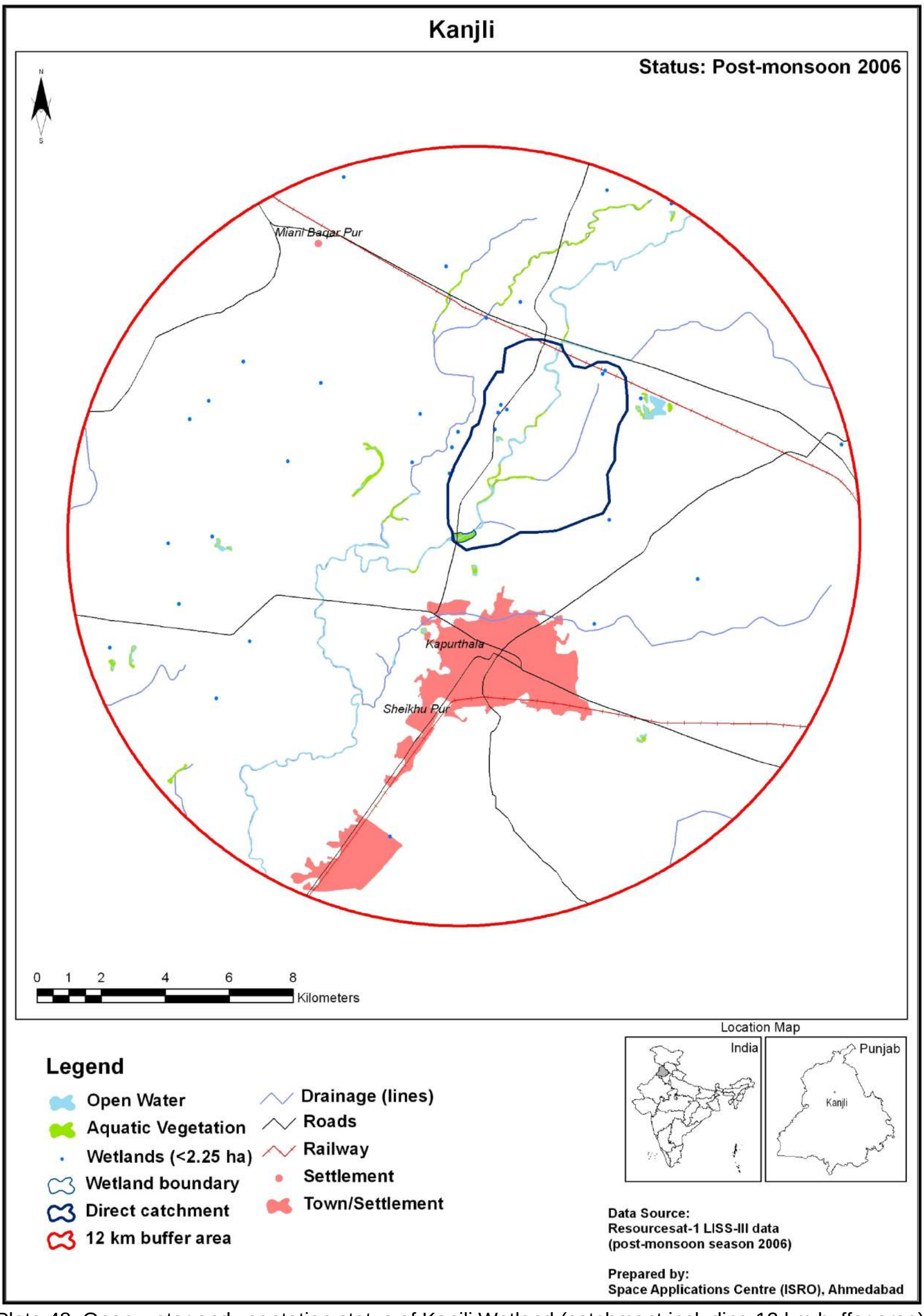

Plate 48: Open-water and vegetation status of Kanjli Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

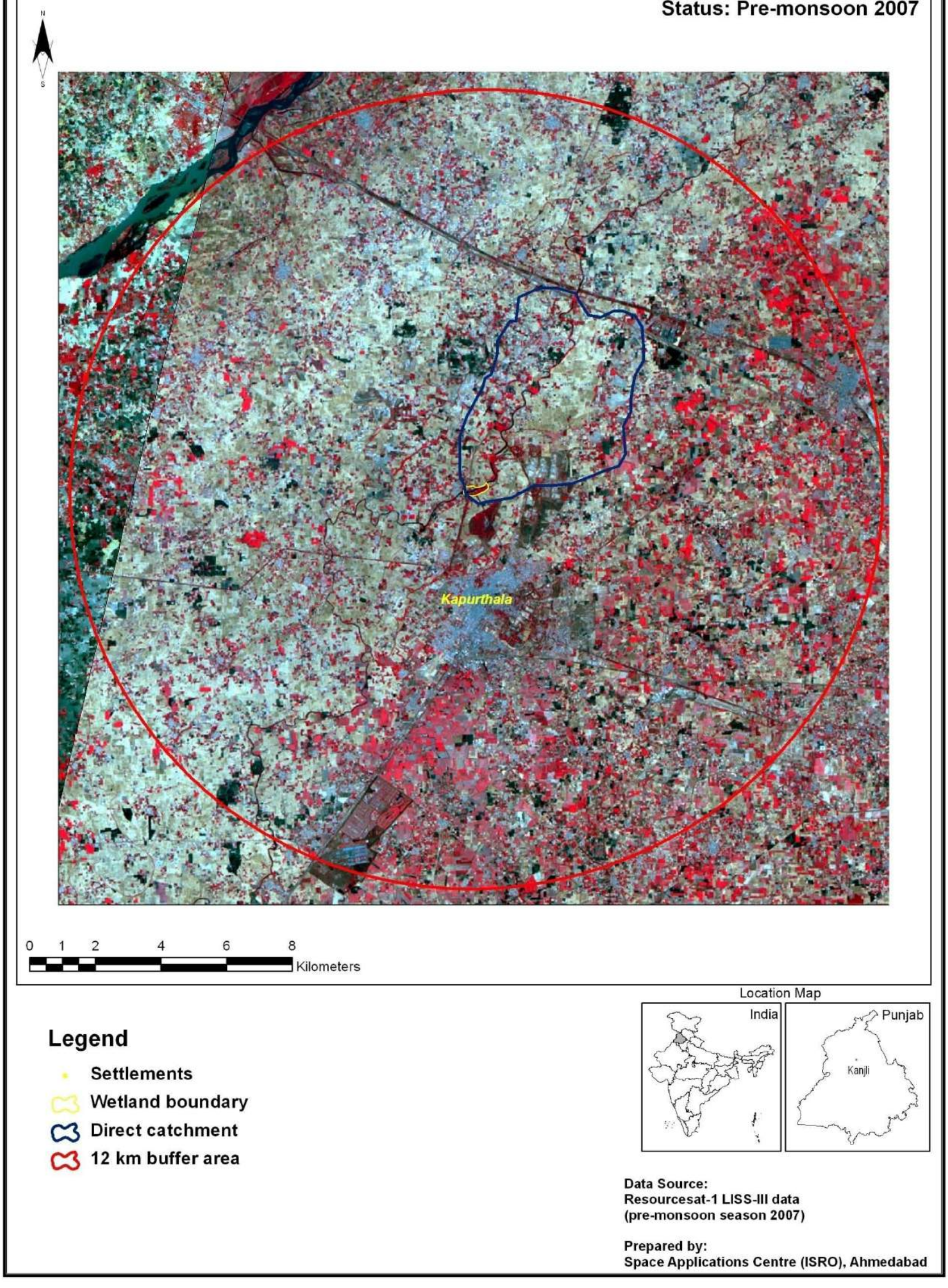

Plate 49: Kanjli Wetland and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (10-April-2007)

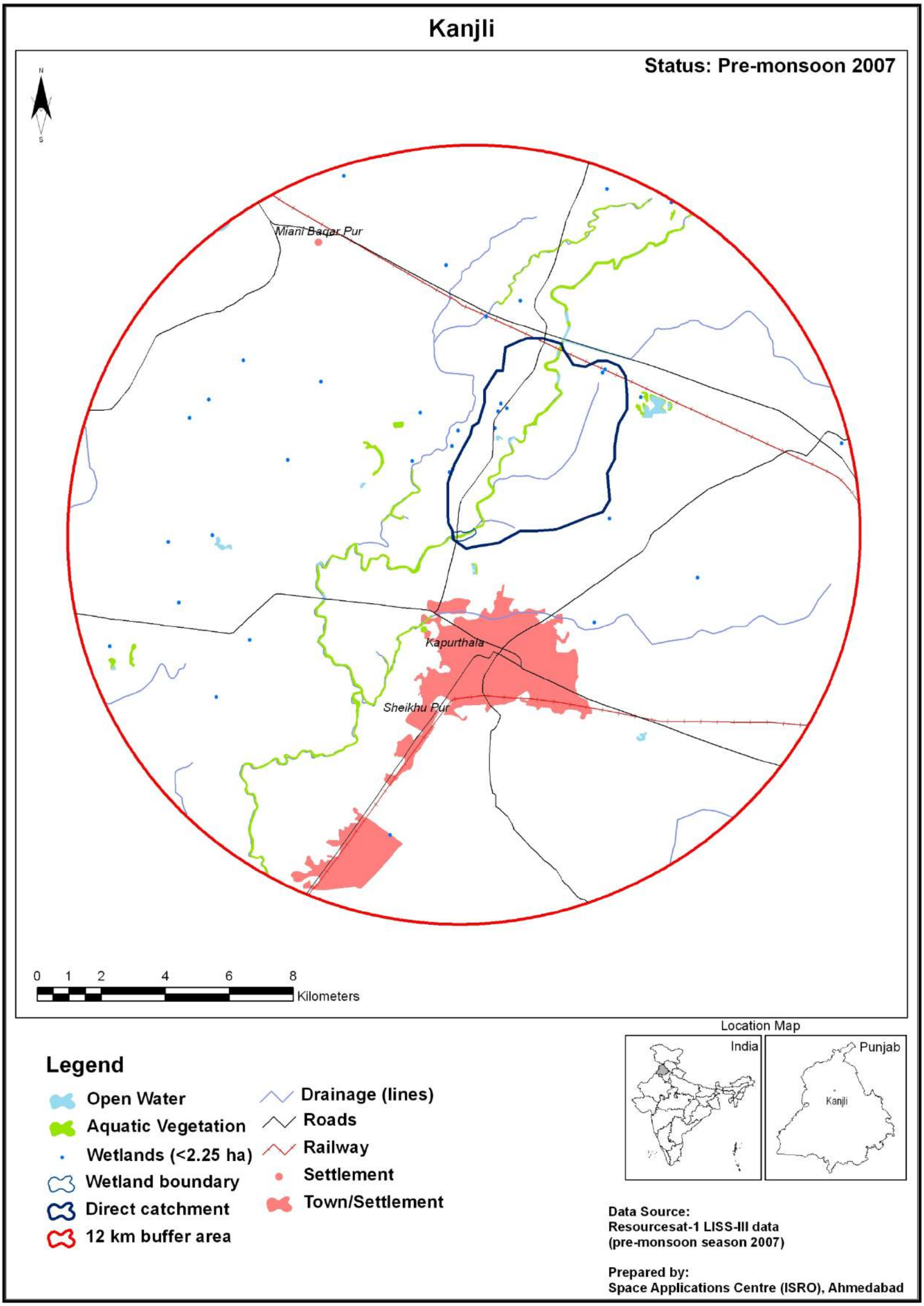

Plate 50: Open-water and vegetation status of Kanjli Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.11 Keoladeo National Park (Ramsar site no. 230)



Keoladeo National Park, popularly known as the Bharatpur Bird Sanctuary is located in the Bharatpur district, Rajasthan, The origin of this wetland is due to artificial flooding of a natural depression. The construction of Ajan Bandh, a temporary reservoir, about one km from the Park some 250 years ago led to the flooding of this depression creating a waterfowl habitat. Subsequently, a number of earthen bunds and sluice gates were constructed to regulate the water. The Park receives water through a canal from the dam.

This wetland has been recognised as a World Heritage site in 1985. This wetland became a Ramsar Site on 01/10/1981 owing to the compliance of criteria 2, 5 & 6 as described below:

- Wetland supports threatened ecological communities.
- Wetland regularly supports 20, 000 or more waterbirds.
- Wetland regularly supports 1 % of the individuals in a population of one species or subspecies.

The park supports more than 350 bird species. The park supports enormous congregations of migratory waterfowl in winter. More than 25 species of ducks and goose like coots, brahminy duck, mallard, gadwal, wigeon, shoveller, pintail duck, bar-headed goose, greylag goose and others are known to winter here annually. The park is the only wintering ground for the highly endangered Siberian crane. Other key fauna in the park are the Cheetal, Sambhar, blue bull, wild boar, golden jackel etc. Apart from the aquatic vegetation that florish during good monsoon years, the other vegetation is characteristic of semi-arid zone dominated by *Acacia nilotica, Zyziphus mauritiana, Prosopis cineraria, Salvadora etc.* Keoladeo National Park as observed on Resourcesat-1 LISS-III images is given in the Figure 20.

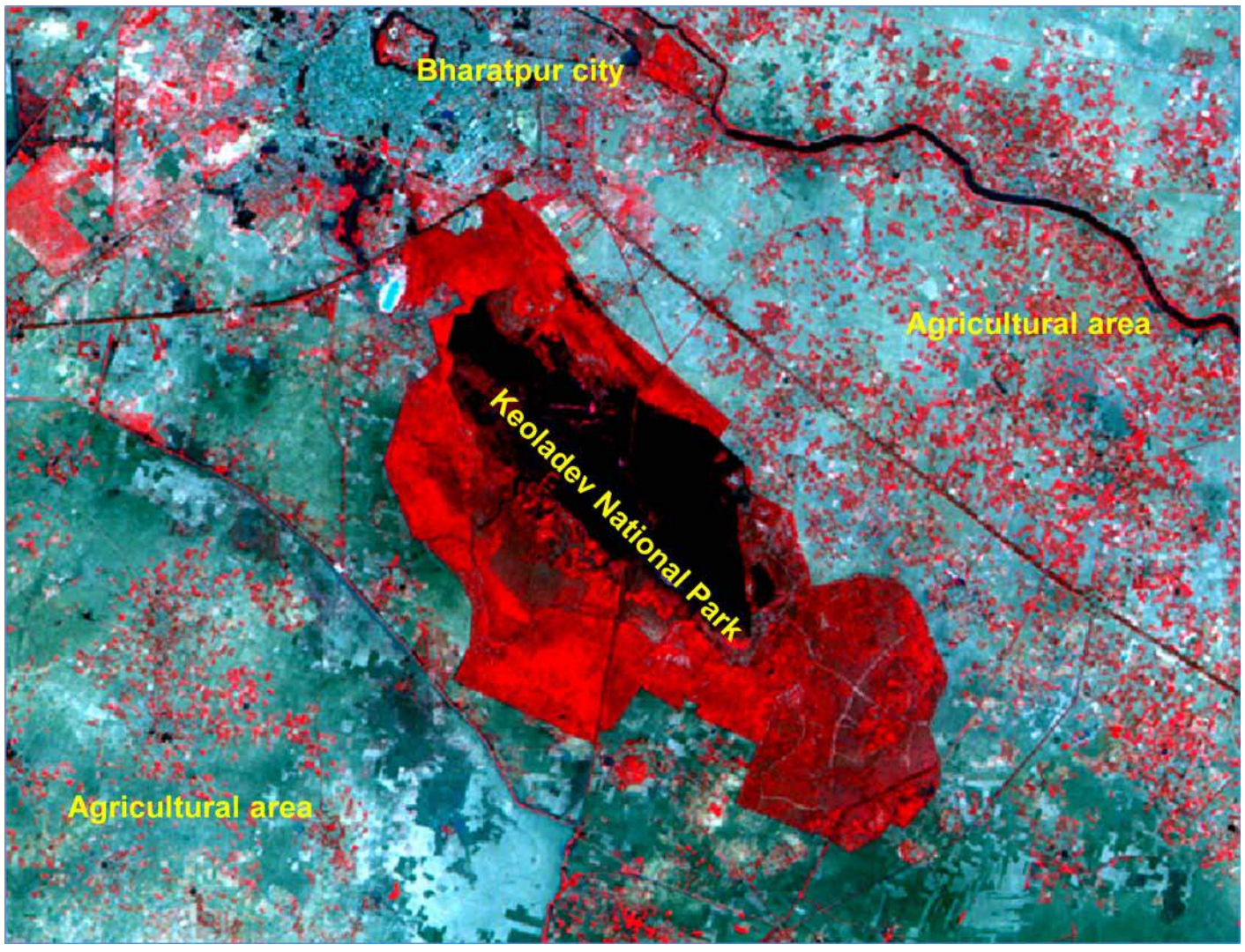

Figure 20: Keoladeo National Park and its environ as seen in LISS-III FCC (10-October-2006)

Keoladeo National Park has an area of 2912 ha with a perimeter of 30 km. The open-water spread in post-monsoon is 744 ha which has shown a reduction (about 65 %) in pre-monsoon to 253 ha (Table 27). The vegetation extent has also shown a decrease from 2168 ha to 1230 ha which is about 43 %.

Table 27: Salient observations of Keoladeo National Park from satellite data

Name:	Keoladeo National Park
Location:	27˚07′29” to 27˚12′28” N Latitude 77˚29′11” to 77˚33′44” E Longitude
Wetland Type:	Waterlogged (Man-made)
Wetland Area: Perimeter:	2912 ha 30 km
<u>Open-water</u> Post-monsoon: Pre-monsoon:	 744 ha 253 ha
<u>Vegetation</u> Post-monsoon: Pre-monsoon:	 2168 ha 1230 ha
Overall Turbidity:	Moderate

The catchment including 12 km buffer area (101583 ha) predominantly comprises agricultural land use. Other than the Park, there are hardly any large wetlands in the catchment (Table 28.).

Table 28: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Keoladeo National Park

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1106	River/Stream	5	370	191	3	-	-
1202	Tank/pond	24	169	100	38	6	-
1203	Waterlogged	3	2998	767	257	2219	1230
	Total	32	3537	1058	298	2225	1230

Wetland map of the Keoladeo National Park catchment including the 12 km buffer area is given in the Plate 51. The seasonal status of open-water spread and vegetation are given in the Plates 52-55 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

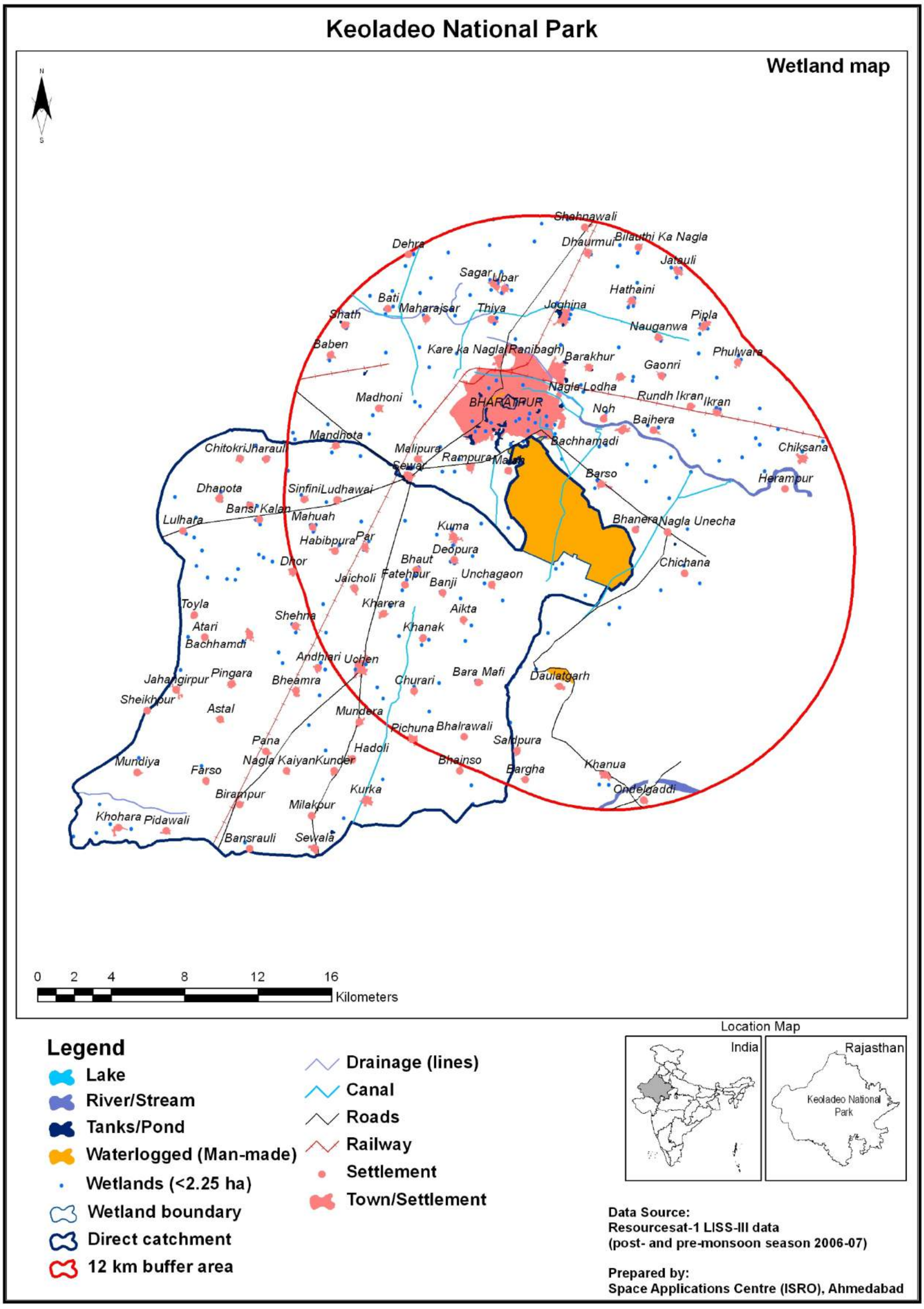

Plate 51: Wetland map of Keoladeo National Park (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

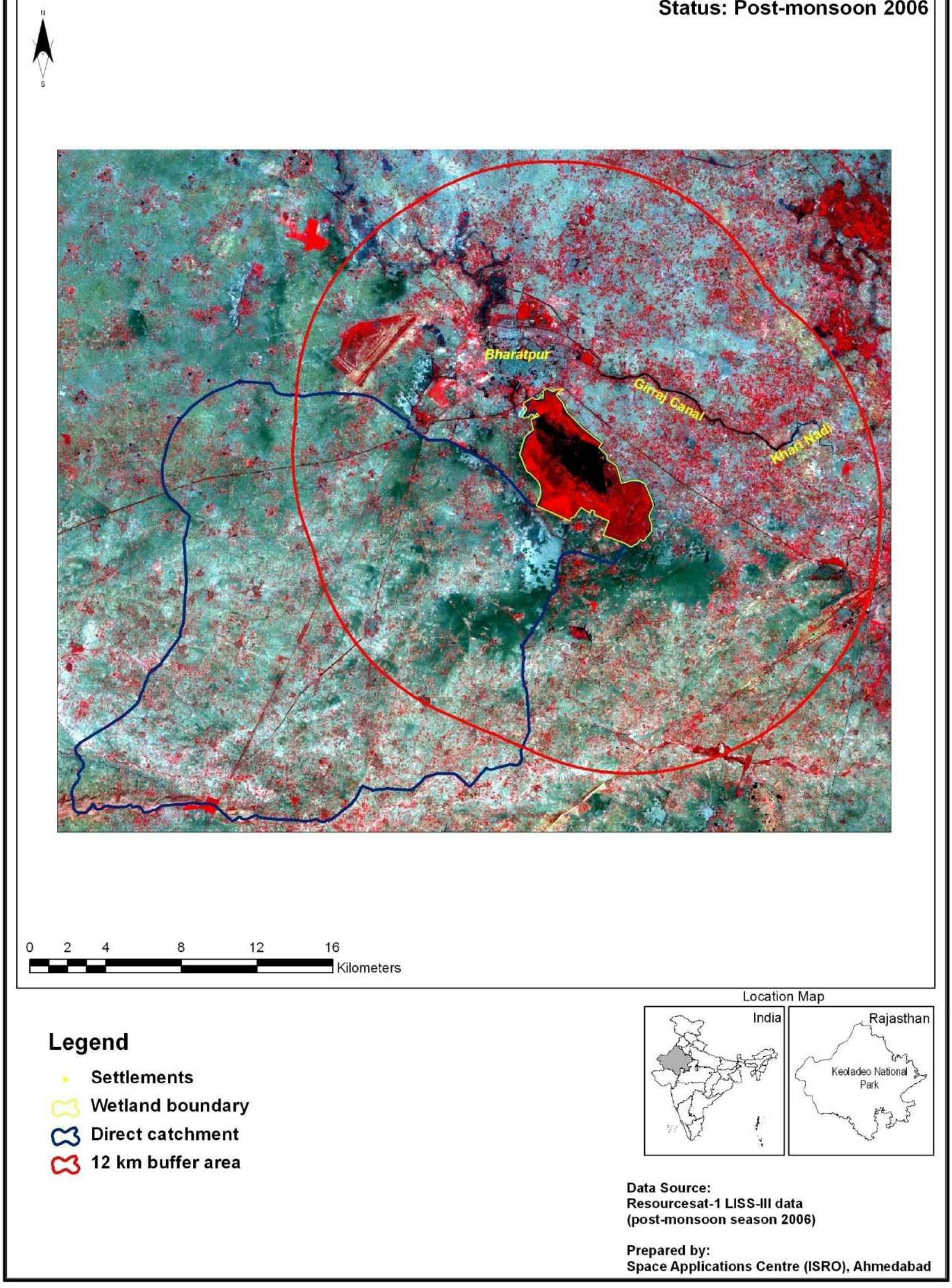

Plate 52: Keoladeo National Park and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (10- October-2006)

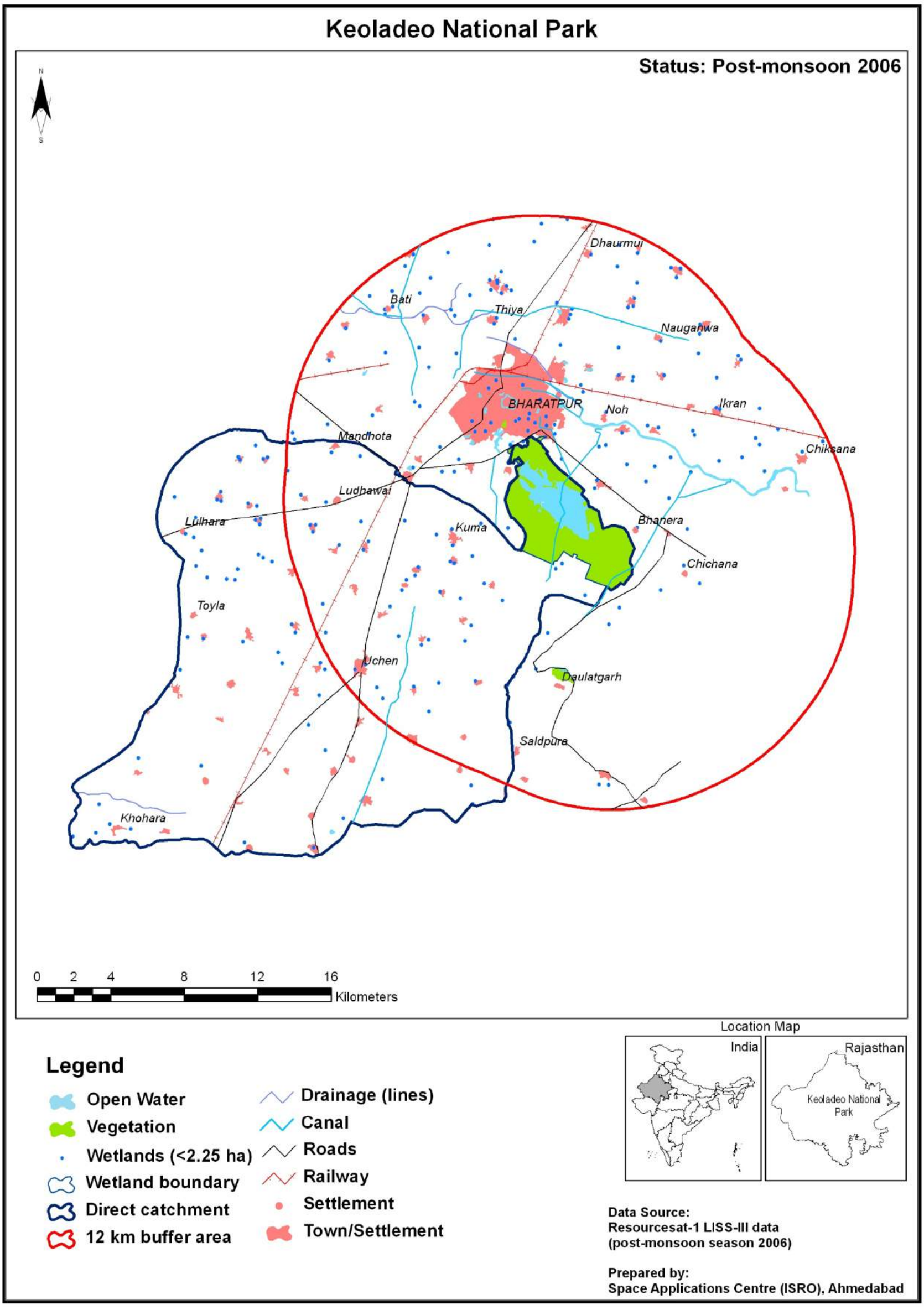

Plate 53: Open-water and vegetation status of Keoladeo National Park (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

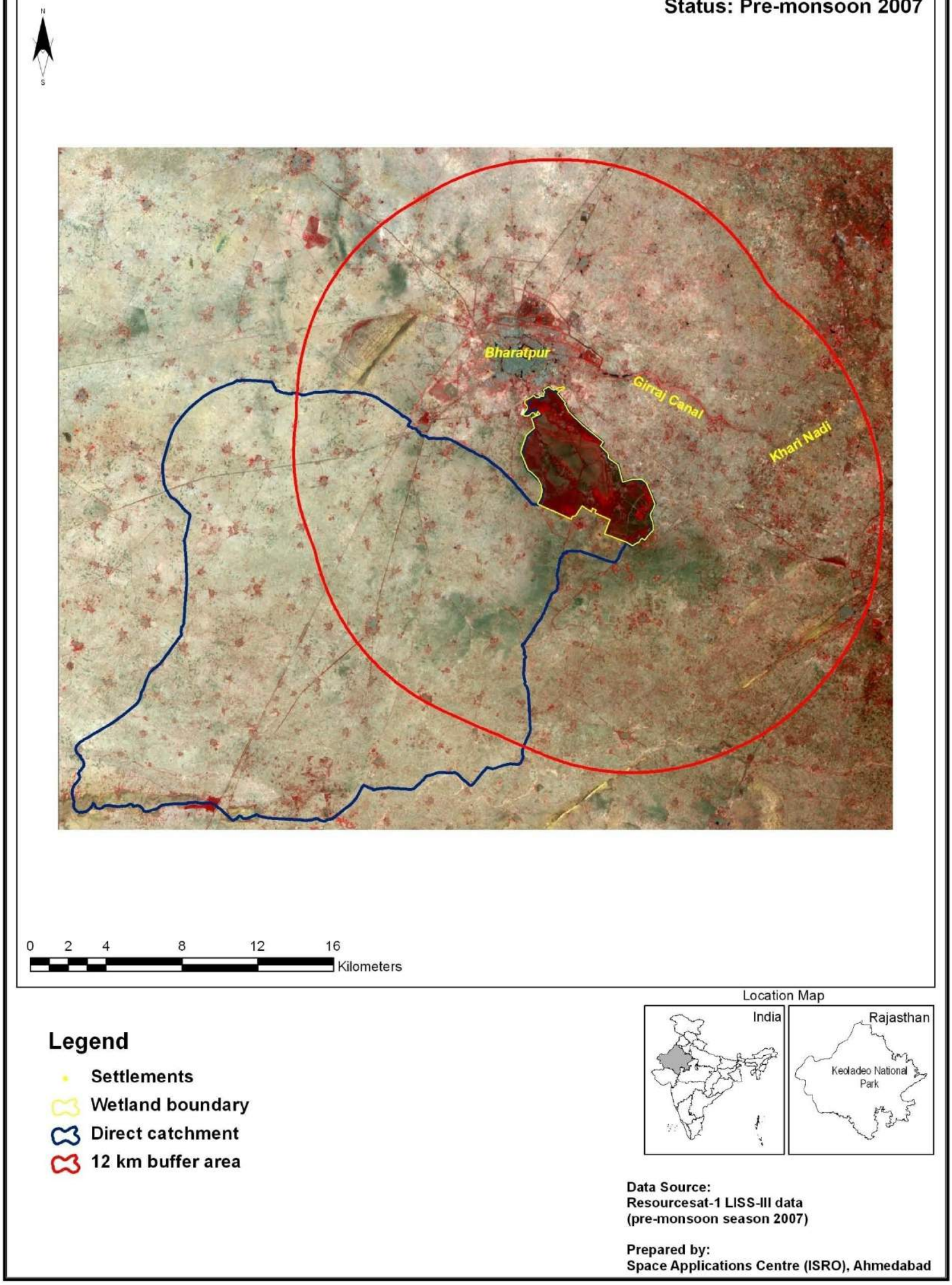

Plate 54: Keoladeo National Park and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (14-May-2007)

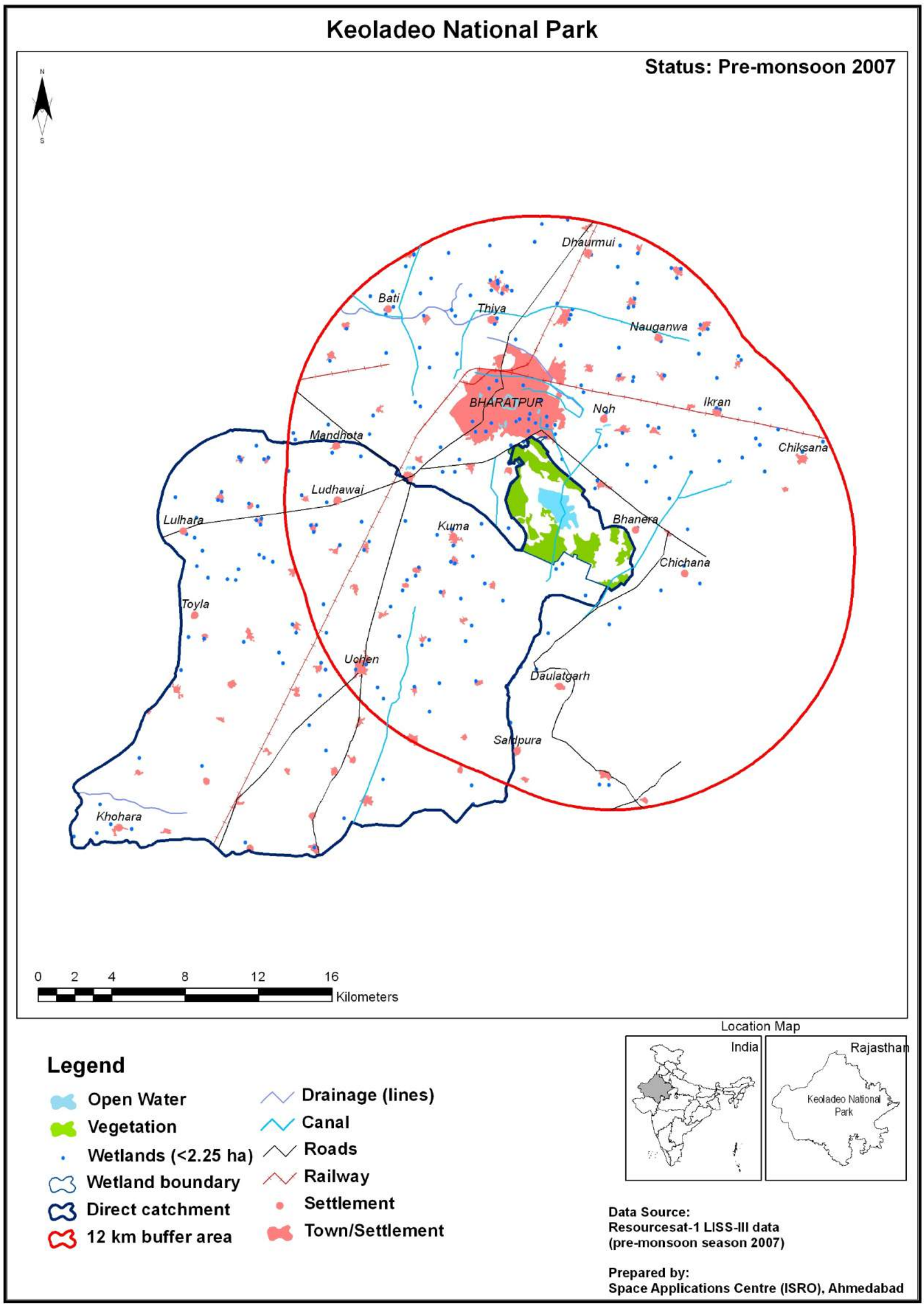

Plate 55: Open-water and vegetation status of Keoladeo National Park (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.12 Kolleru Lake (Ramsar site no. 1209)



Kolleru Lake is a fresh water lake situated between the Krishna and the Godavari rivers in the coastal region of Andhra Pradesh. It is a shallow lake and entirely depends on monsoon runoff from over 30 channels of which Budameru Ramileru and Thammileru are prominent. The lake drains to the Bay of Bengal through Upputeru River. The surface overflow of the lake reaches the Bay of Bengal through Upputeru River and also receives saline back water from the sea.

Kolleru Lake has been designated as a Ramsar Site on 19/08/2002 owing to the compliance of criteria 2, 4, 5 & 6 as described below:

- Wetland supports threatened ecological communities.
- Wetland provides refuge during adverse conditions to threatened species.
- Wetland regularly supports 20, 000 or more waterbirds.
- Wetland regularly supports 1 % of the individuals in a population of one species or subspecies.

The site is known to have about 160 species of birds. The lake supports more than 50,000 waterfowl which includes a variety of resident and migratory birds. The most abundant duck reported was the Garganey with upto 10,000 which was about 3.0 per cent of the population in South Asia..

Around 63 species of fish including some endemic ones have been reported from the lake. Of late extensive aquaculture ponds characterise the lake. Kolleru Lake as observed on Resourcesat-1 LISS-III image is given in the Figure 21.

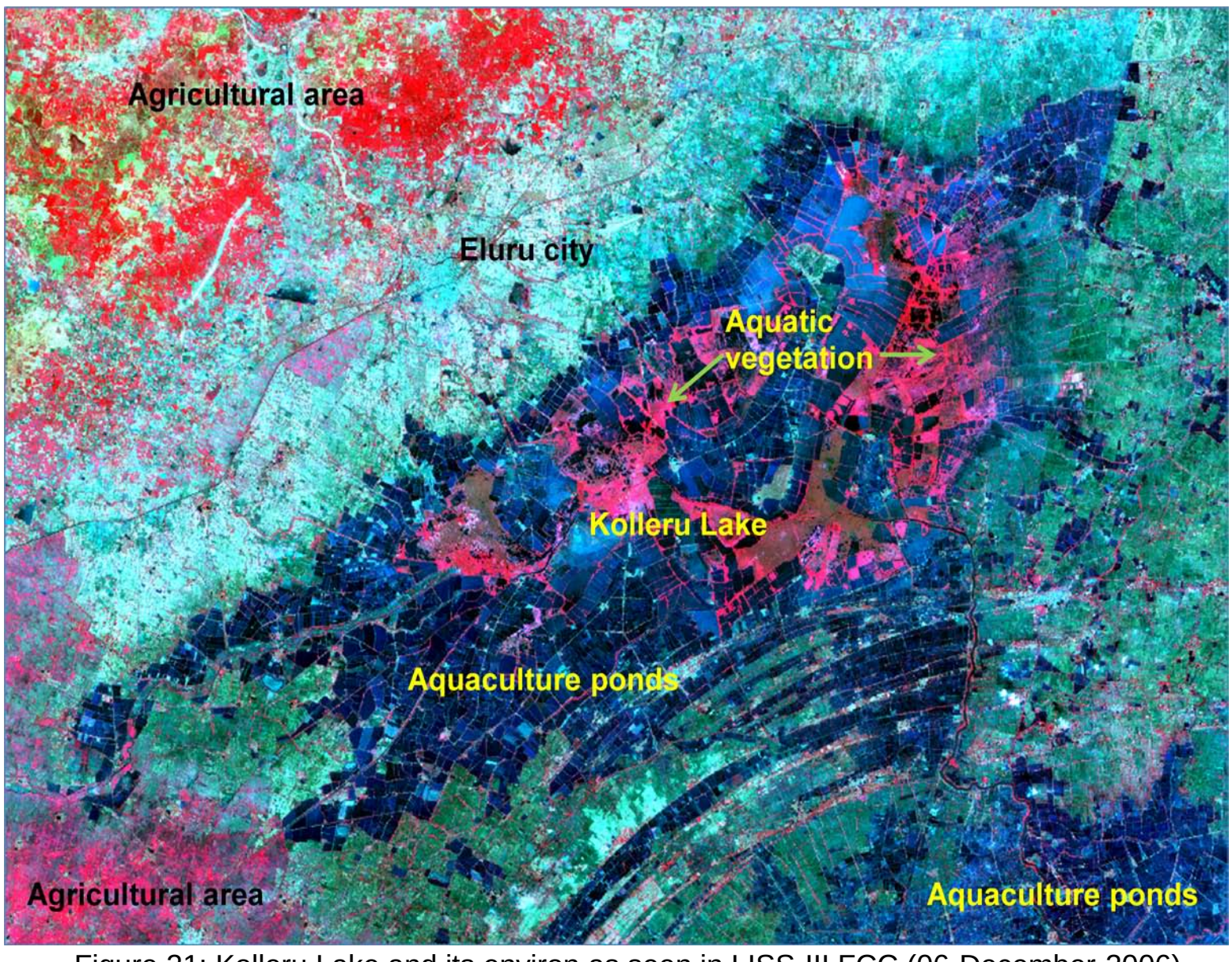

Figure 21: Kolleru Lake and its environ as seen in LISS-III FCC (06-December-2006)

Kolleru Lake is spread over 83501 ha with a perimeter of 362 km. Around 78 per cent of the lake is under aquaculture ponds. The lake is highly vegetated, Vegetation has increased from 15305 ha (post-monsoon) to 31027 ha (pre-monsoon) which slightly more than double (Table 29).

Table 29: Salient observations of Kolleru Lake from satellite data

Name:	Kolleru Lake
Location:	16˚24′14” to16˚48′40” N Latitude 80˚55′17” to 81˚27′32” E Longitude
Wetland Type:	Lake/Pond
Wetland Area: Perimeter :	83501 ha, Lake (18019 ha), Aquaculture ponds (65490 ha) 362 km
Open-water Post-monsoon: Pre-monsoon:	 58973 ha 22699 ha
Vegetation Post-monsoon: Pre-monsoon:	 15305 ha 31027 ha
Overall Turbidity:	Low to Moderate

The catchment of the lake including the 12 km buffer area is spread over 649259 ha. Agriculture is the predominant land use of the catchment with intensive cultivation practice. The lake is the dominant wetland of this area accounting about 72 percent of the total wetland area. The other major wetland is aquaculture pond located south of the lake(Table 30).

Table 30: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Kolleru Lake

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	5	18353	378	2524	15315	31075
1106	River/Stream	9	2085	1472	797	-	-
1201	Reservoir/Barrage	49	2371	1962	856	252	898
1202	Tank/pond	397	4254	3391	1924	583	1070
1203	Waterlogged	2	94	24	23	70	-
2202	Aquaculture Pond	209	88672	81476	63661	-	3
	Total	671	115829	88703	69785	16220	33046

Wetland map of the Kolleru catchment including the 12 km buffer area is given in the Plate 56. The seasonal status of open-water spread and vegetation are given in the Plates 57-60 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

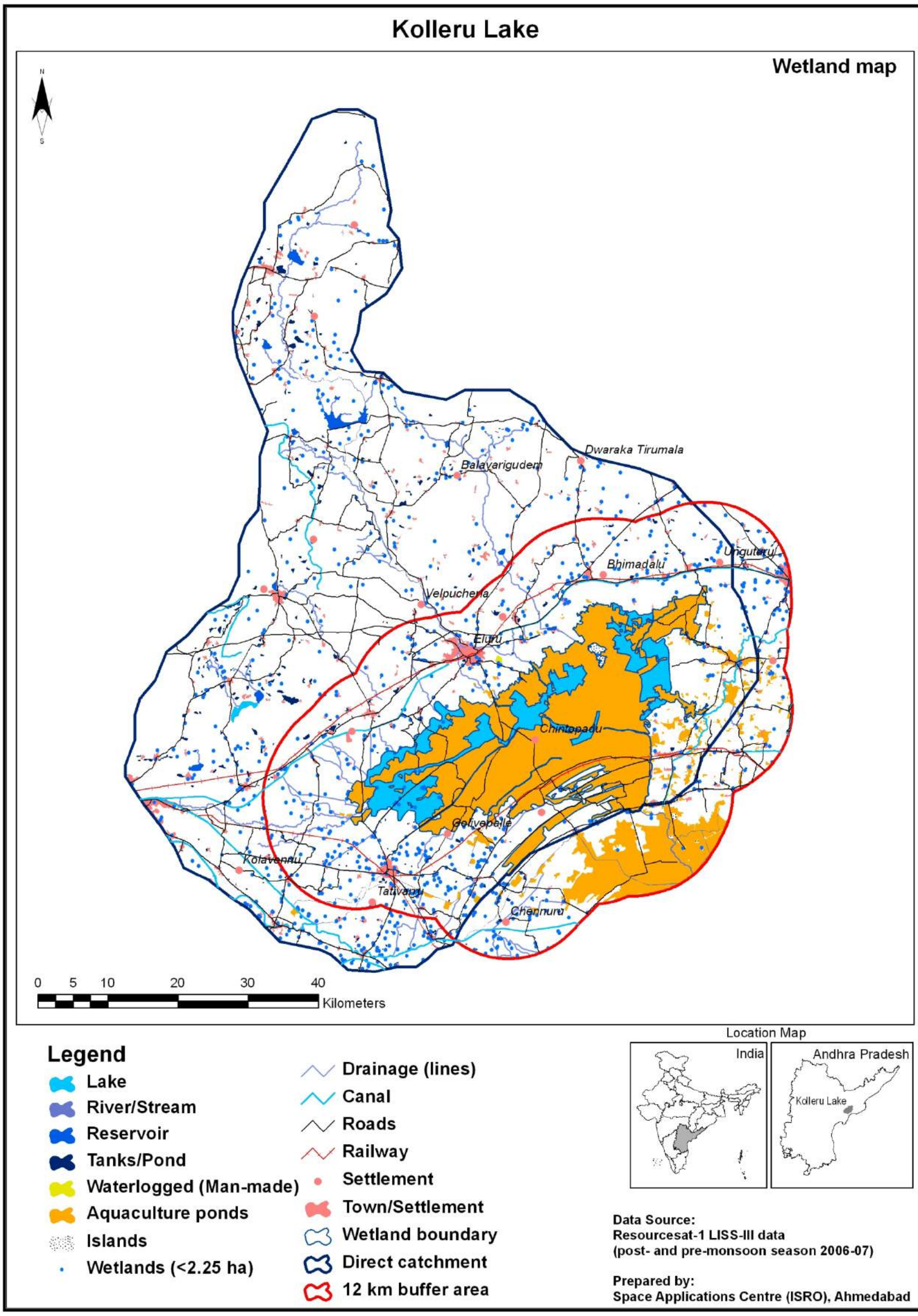

Plate 56: Wetland map of Kolleru Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

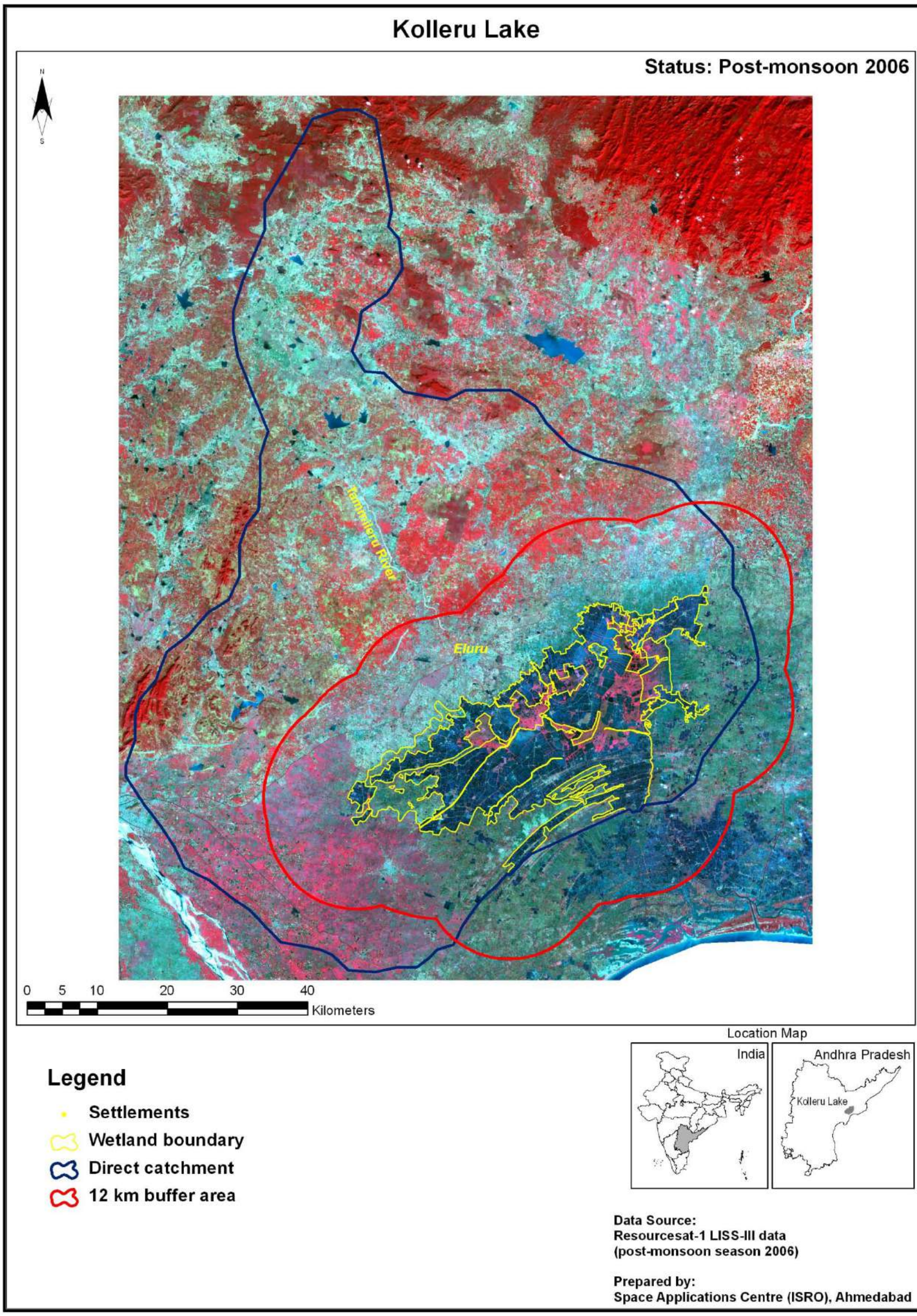

Plate 57: Kolleru Lake and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (06-December-2006)

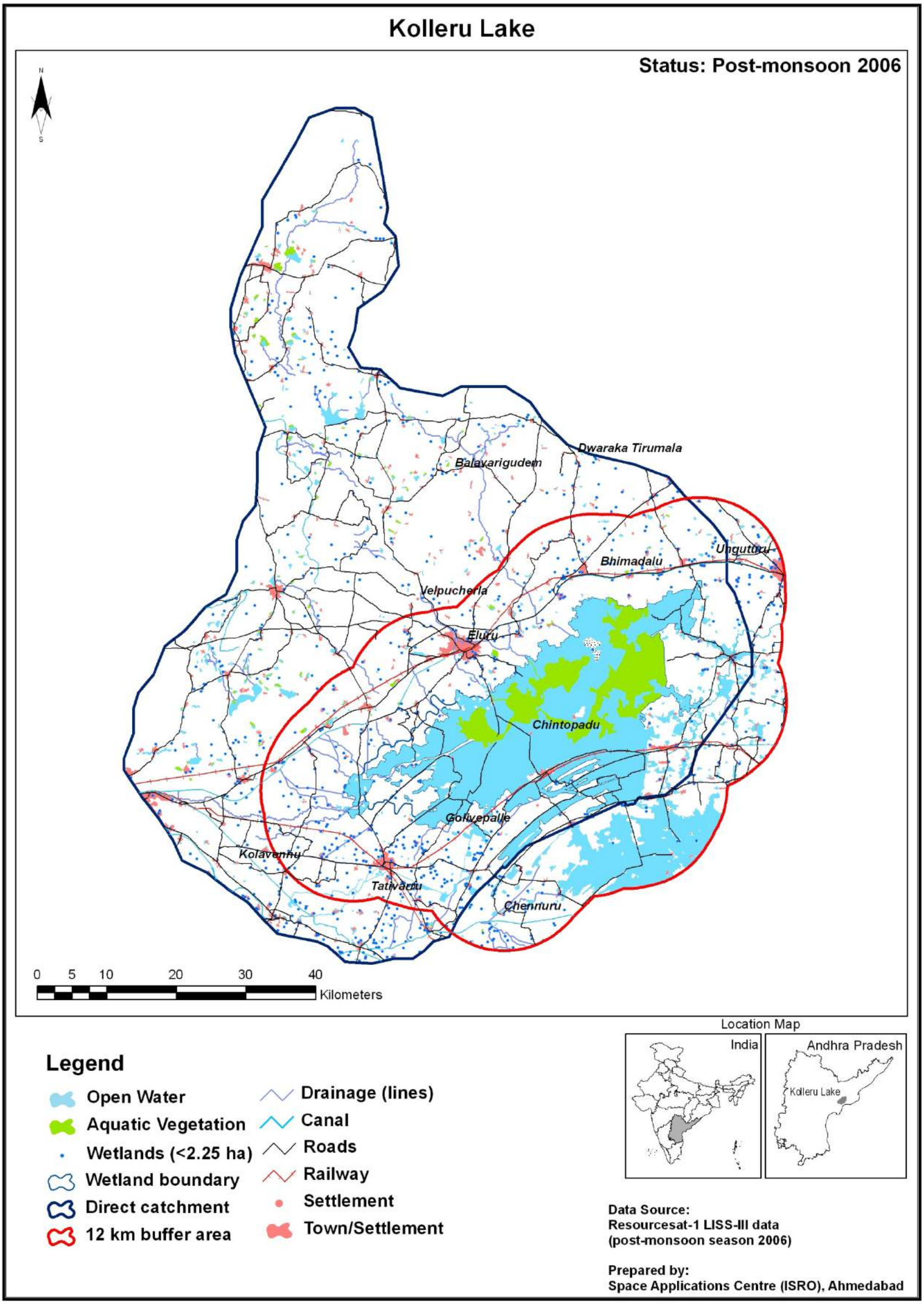

Plate 58: Open-water and vegetation status of Kolleru Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

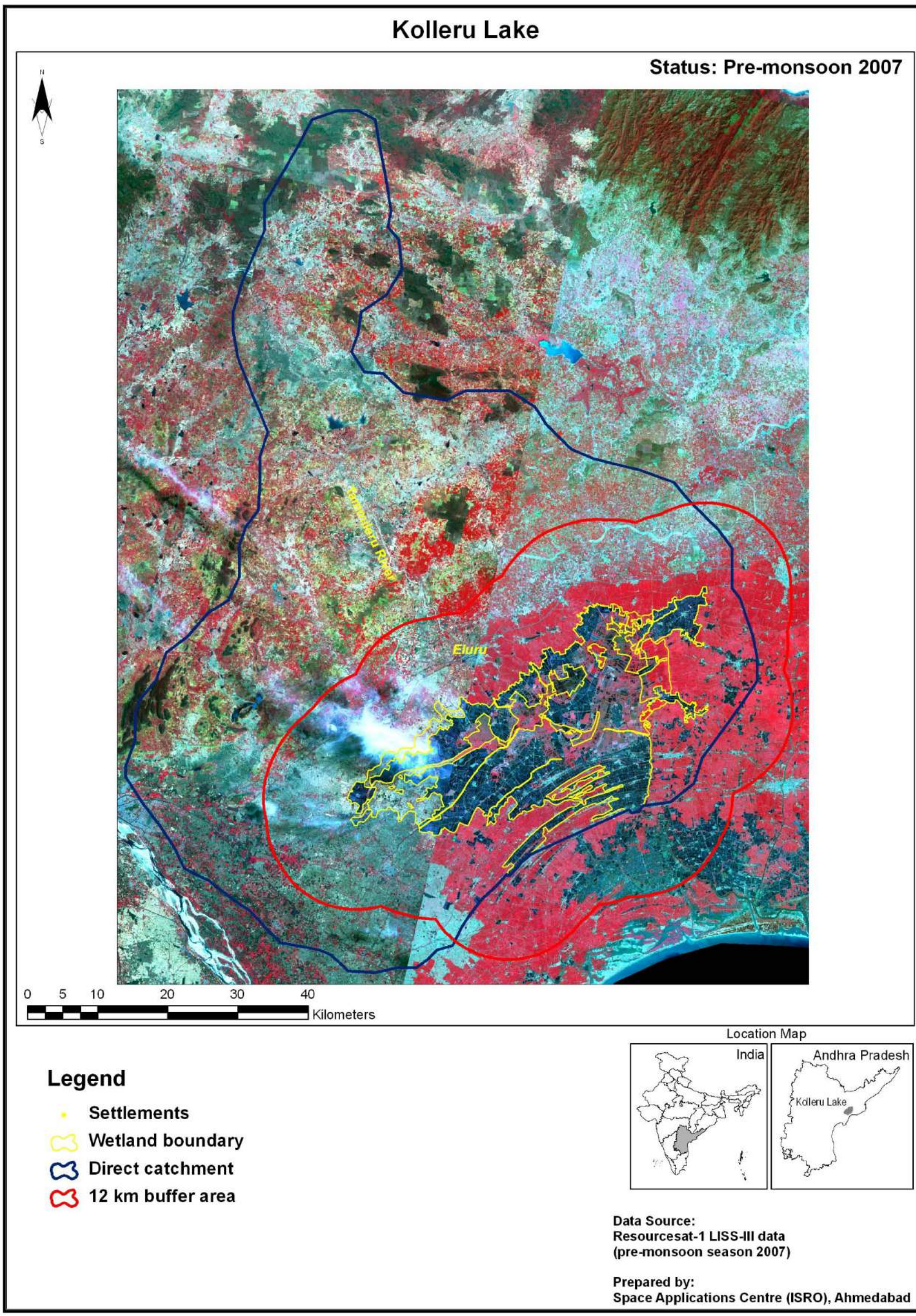

Plate 59: Kolleru Lake and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (25-May-2007)

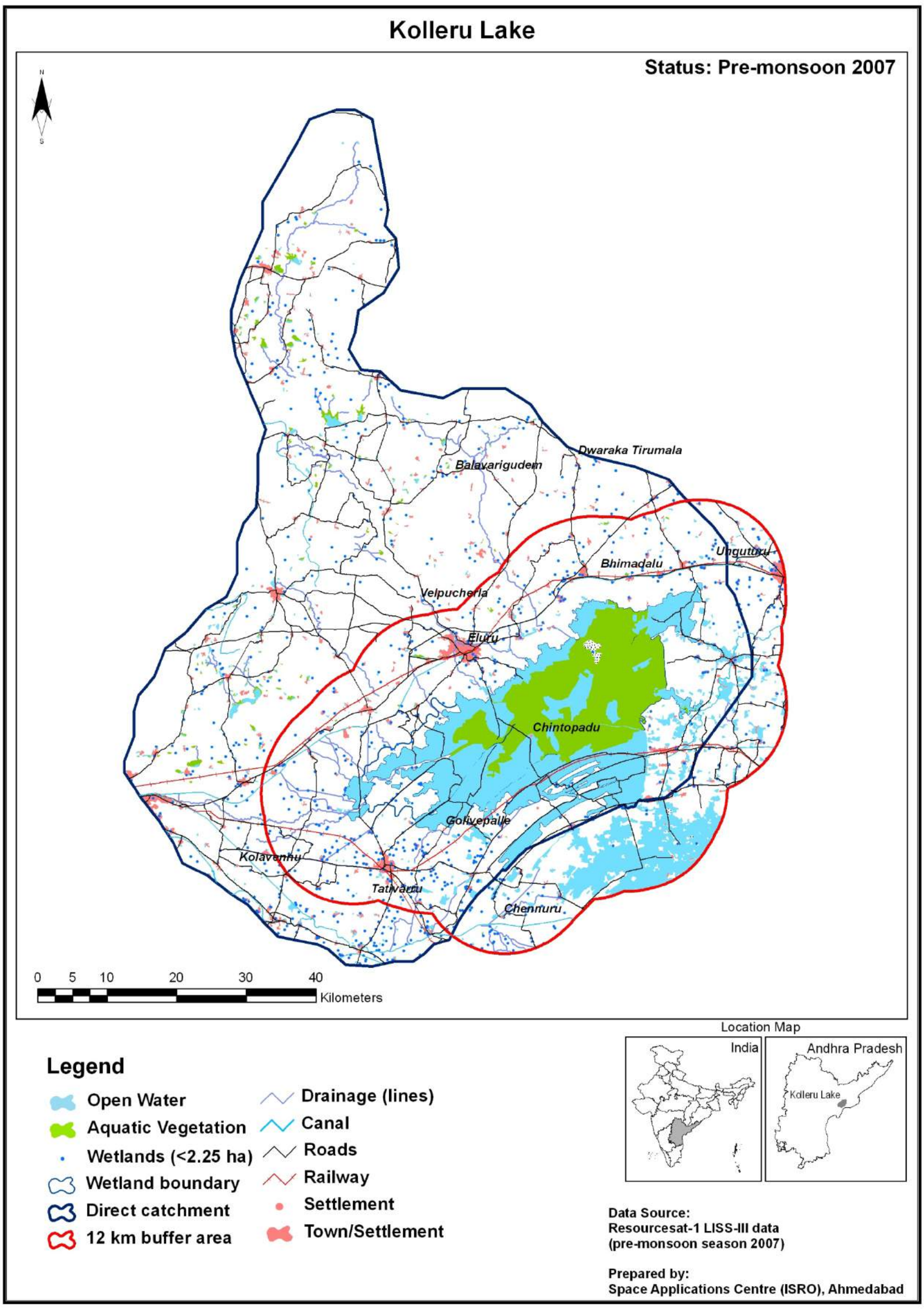

Plate 60: Open-water and vegetation status of Kolleru Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.13 Loktak Lake (Ramsar site no. 463)



Loktak Lake is the largest natural lake of North-eastern India situated on the west of Imphal city in Manipur state. It is also known as the floating lake due to the floating *phumdis* (heterogeneous mass of vegetation, soil, and organic matters at various stages of decomposition).

Loktak Lake was declared as Ramsar site on 23/03/1990 owing to the compliance of criteria 2, 5 & 6 as described below:

- Wetland supports globally threatened ecological communities.
- Wetland regularly supports 20, 000 or more waterbirds
- Wetland regularly supports 1 % of the individuals in a population of one species or subspecies.

The lake supports around 116 species of birds including 21 species of migratory waterfowl. Globaly threatened species like the Spot-billed Pelican and the Greater Spotted Eagle have been reported from the lake. Keibul Lamjao National Park, which is the last natural refuge of the endangered 'Sangai' or Manipur brow-antlered deer (*Cervus eldi eldi*) is situated in the southeastern shores of this lake. It is a large continuous mass of swamp composed of decaying vegetation of >1.5 m thick. *Zizania latifolia is one of the vegetation found only in this lake in India.*

There are small hillocks within the lake which provide refuse to large mammals during wet season. Including the barking deer. Loktak Lake as observed on satellite image is shown in Figure 22.

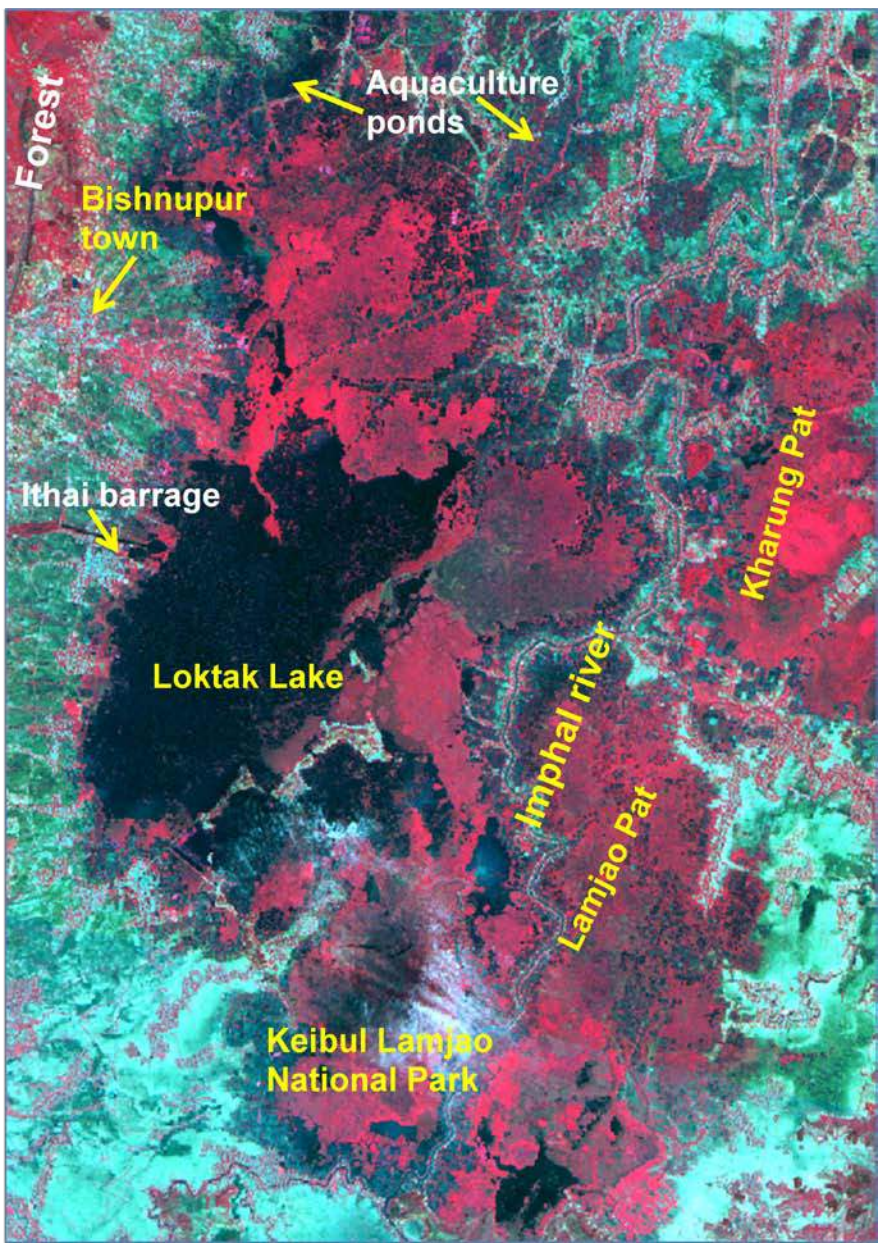

Figure 22: Loktak Lake and its environ as seen in LISS-III FCC (03-May-2007)

Loktak Lake has an extent of 24672 ha with a perimeter of 167 km. The open-water spread shows around 3 per cent reduction from post-monsoon (14460 ha) to pre-monsoon (13918 ha). The vegetation has registered marginal increase (about 5%) from 10212 ha in post-monsoon to 10754 ha in pre-monsoon seasons (Table 31).

Table 31: Salient observations of Loktak Lake from satellite data

Name:	Loktak Lake
Location:	24˚21′37” to 24˚43′02” N Latitude 93˚44′44” to 94˚00′47” E Longitude
Wetland Type:	Lake/Pond
Wetland Area: Perimeter :	24672 ha 167 km
Open-water Post-monsoon: Pre-monsoon:	 14460 ha 13918 ha
Vegetation Post-monsoon: Pre-monsoon:	 10212 ha 10754 ha
Overall Turbidity:	Moderate-High

The catchment including the 12 km buffer area (188957 ha) is predominantly of agricultural land use followed by forest. Wetlands occupy an area of 45750 ha, Loktak Lake accounting for about 54 per cent of wetland area (24672 ha). The major wetland types in the catchment are Lake/pond, waterlogged areas and rivers/streams. Significant fluctuation of vegetation is observed in case of waterlogged areas and lakes (Table 32).

Table 32: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Loktak Lake

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	14	38959	22136	17178	16119	21885
1102	Ox-bow Lake/Cut-off Meander	4	27	27	27	-	-
1105	Waterlogged	41	2382	2157	1344	110	1057
1106	River/Stream	3	1622	1622	1622	-	-
1201	Reservoir/Barrage	1	43	43	36	-	-
1202	Tank/Pond	19	75	75	75	-	-
2202	Aquaculture Pond	11	2642	2383	2339	230	303
	Total	93	45750	28444	22622	16459	23245

Wetland map of the Loktak Lake catchment including the 12 km buffer area is given in the Plate 61. The seasonal status of open-water spread and vegetation are given in the Plates 62-65 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

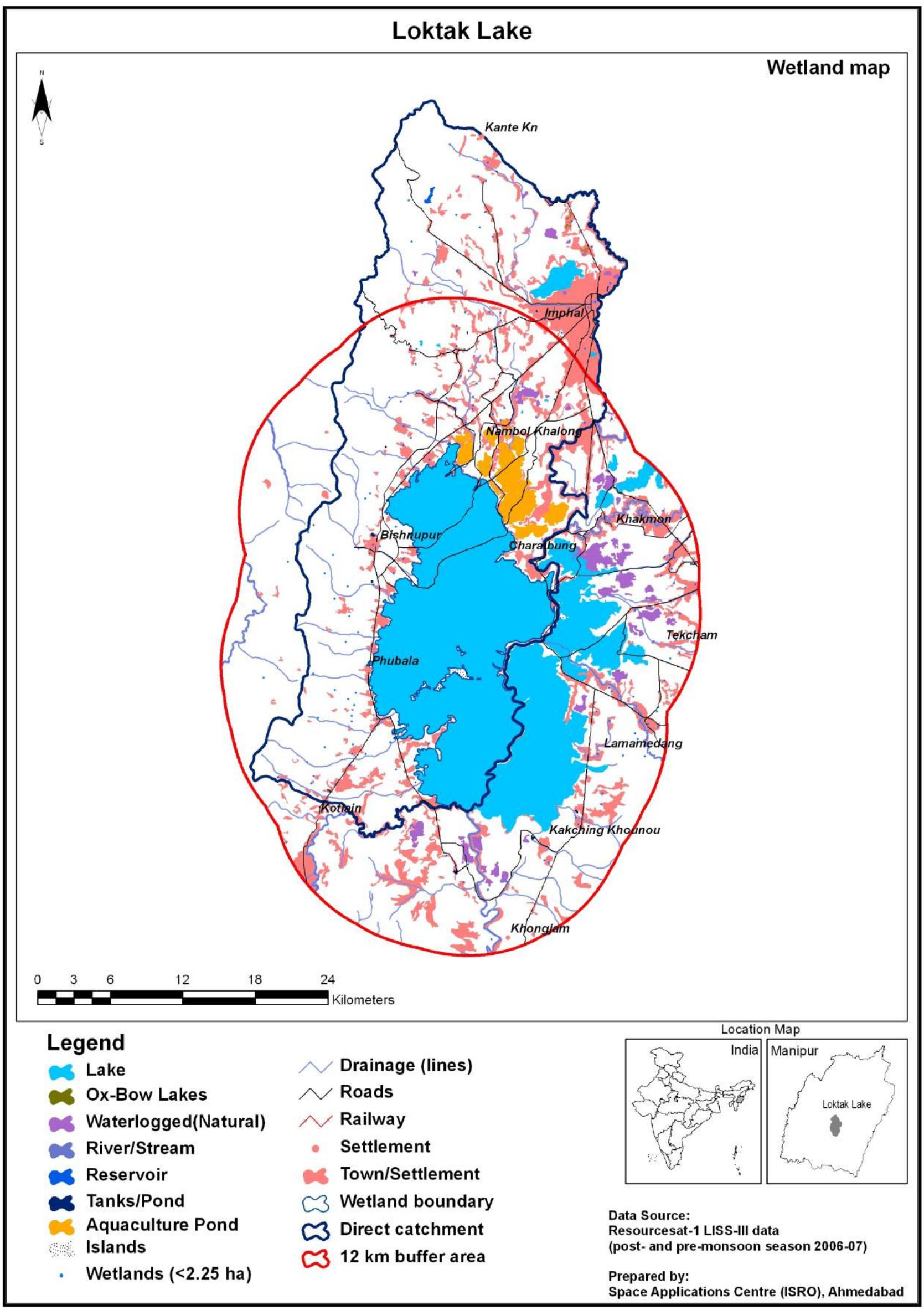

Plate 61: Wetland map of Loktak Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

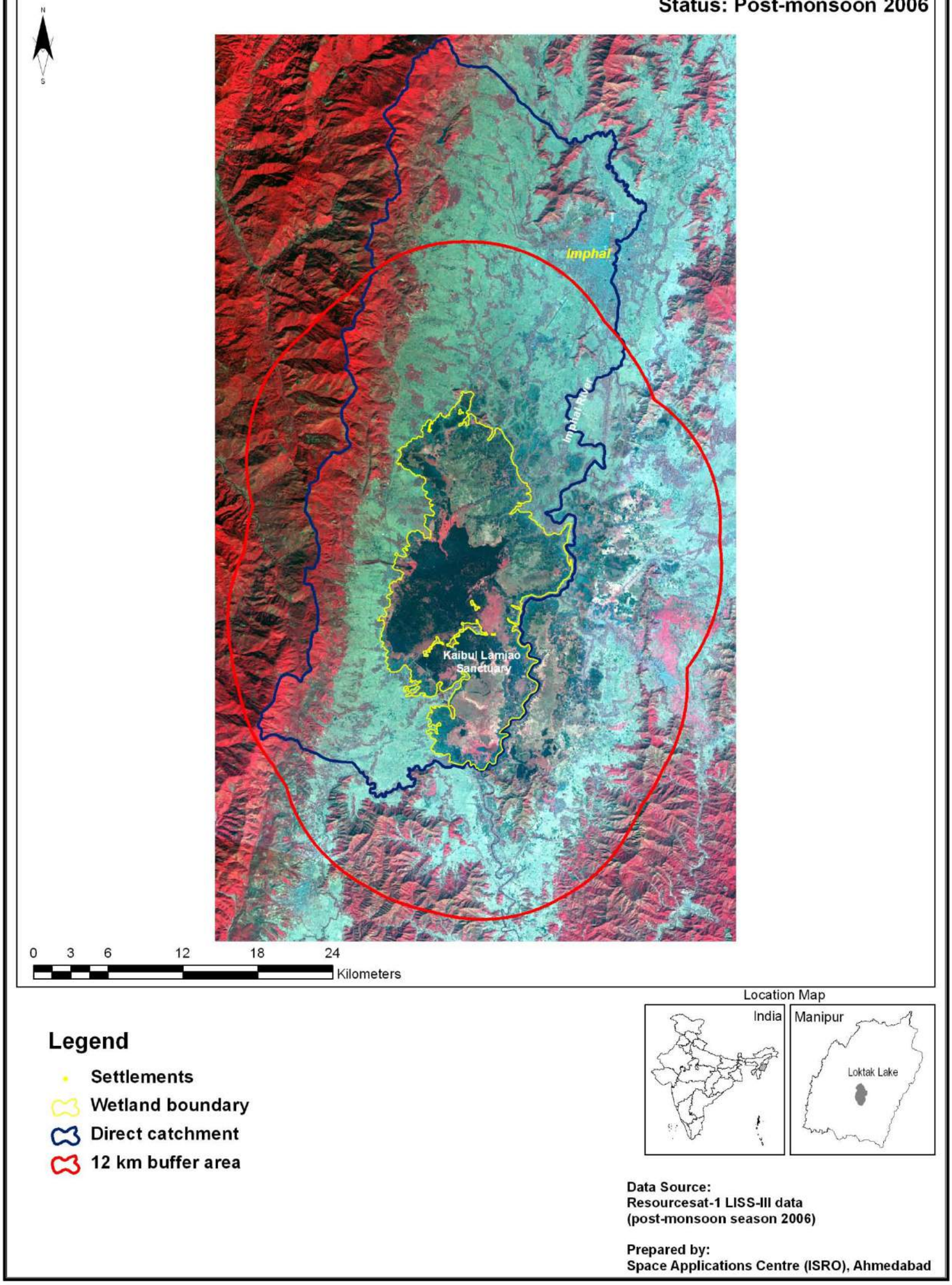

Plate 62: Loktak Lake and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (05-December-2006)

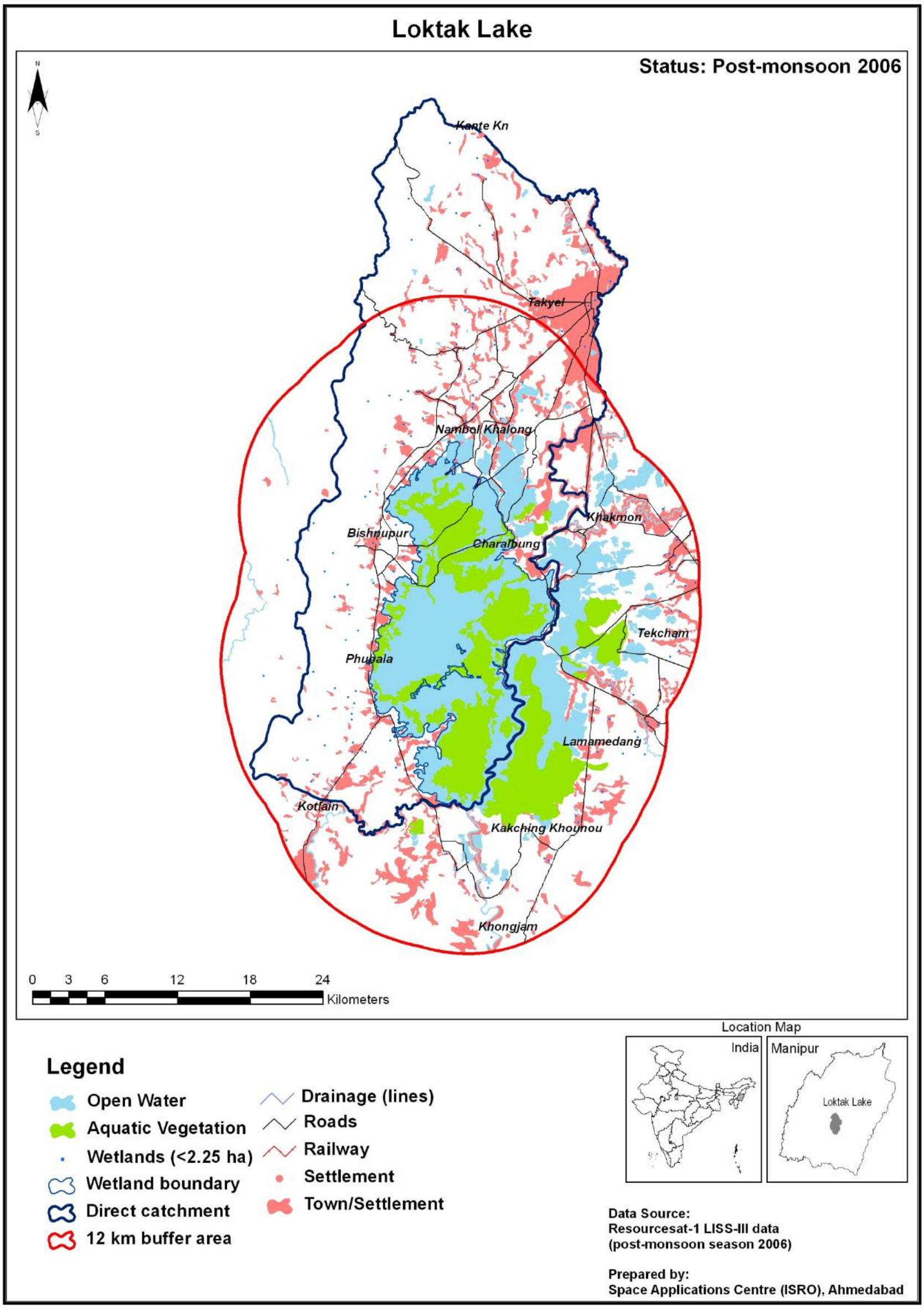

Plate 63: Open-water and vegetation status of Loktak Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

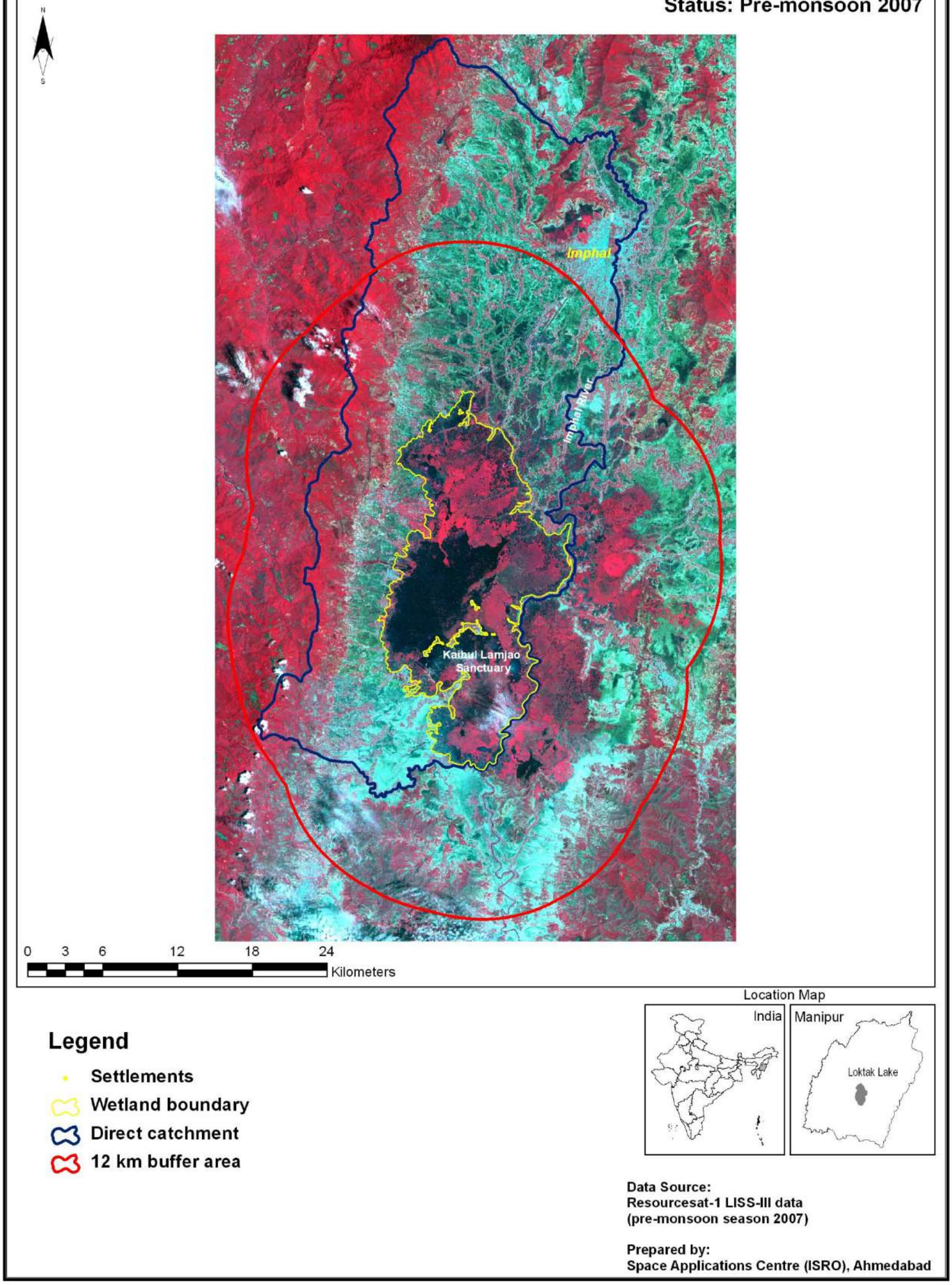

Plate 64: Loktak Lake and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (07-May-2007)

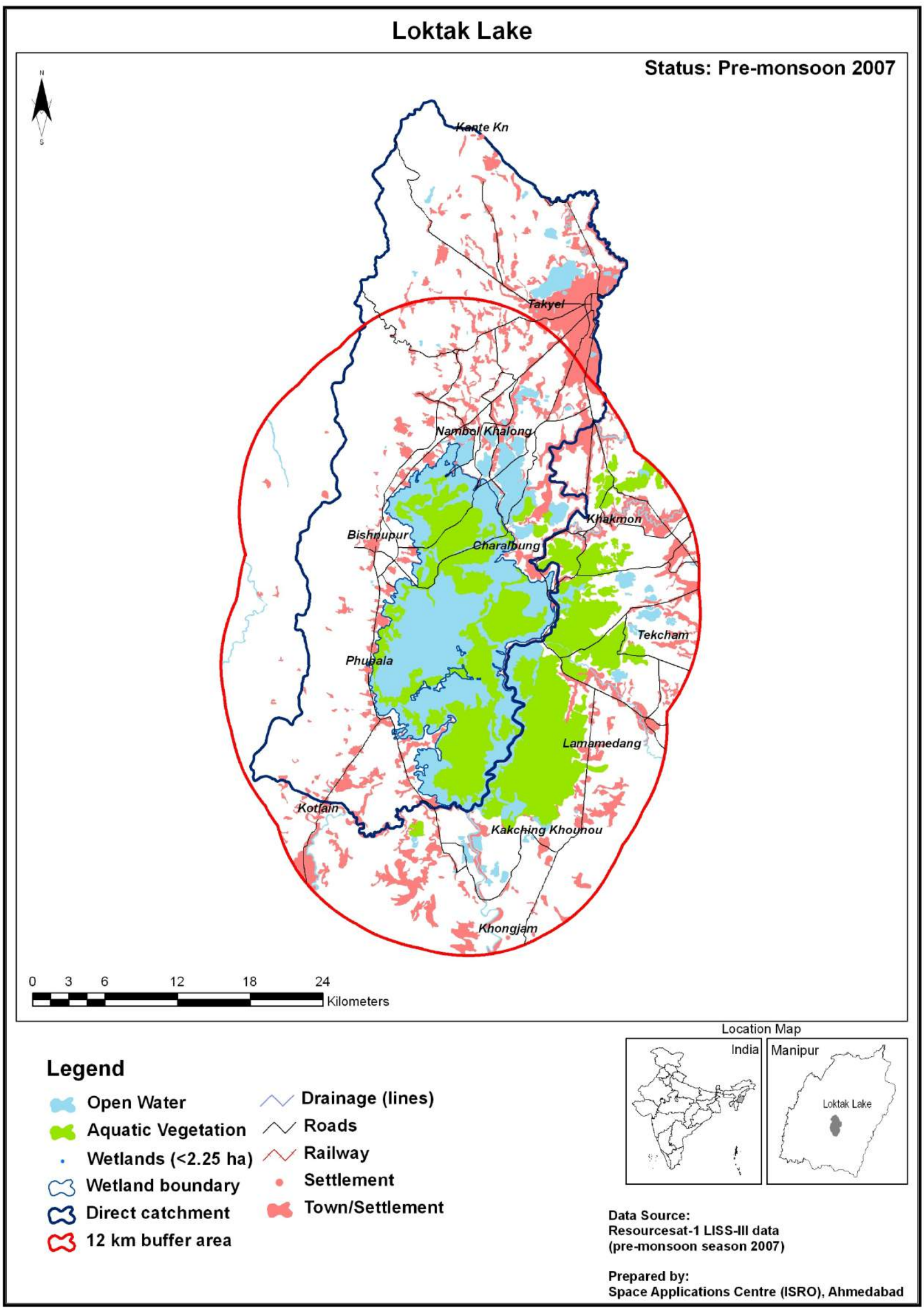

Plate 65: Open-water and vegetation status of Loktak Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.14 Nalsarovar Bird Sanctuary (Ramsar site no. 2078)



Nalsarovar is a naturalinland lake situated in Gujarat state.. Nalsarovar is the largest protected inland wetland habitats of the state and is amongst the notified wetlands of the country, identified by the National Wetland, Mangroves and Coral Reefs Committee.

It is the most recent one identified as Ramsar site on 24/09/2012 owing to the compliance of criteria 2, 5 & 6 as described below:

- Wetland supports globally threatened ecological communities.
- Wetland regularly supports 20, 000 or more waterbirds
- Wetland regularly supports 1 % of the individuals in a population of one species or subspecies.

The wetland supports 306 recorded species of birds, out of which 46 species are of terrestrial birds, 260 species are of waterfowls. The lake registers the largest population of waterfowl that occurs here in the state. Many ducks and waders are found in large numbers easily crossing the 1 per cent threshold bio-geographic population. The lake supports 4 species listed in the schedule-1 of the Wildlife (Protection) Act, 1972. The threatened bird species include the Dalmatian Pelican, the Pallas's Fish-eagle, and the Indian Skimmer.

The lake is a shallow one. Though it is fresh water, it turns saline at many places during summer. This characteristic gives rise to a wide variety of flora. Emergent vegetation like *Typha, Cyperus* are found on the shoreline and in the islands. Nalsarovar as observed on satellite image is given in Figure 23.

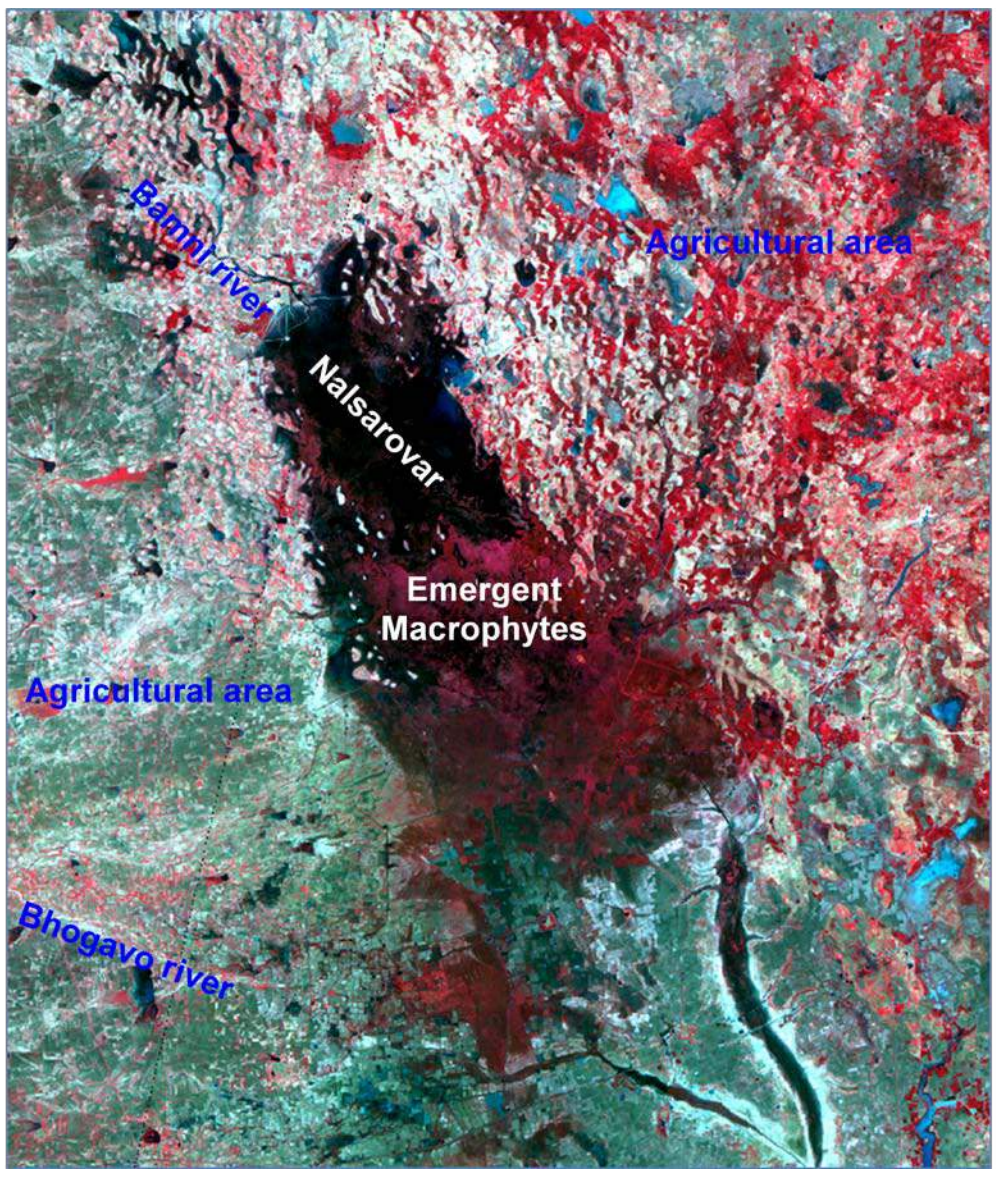

Figure 23: Nalsarovar Bird Sanctuary and its environ as seen in LISS-III FCC (19-October-2006)

Nalsarovar has an aerial extent of 14673 ha with a perimeter of 145 km. The open-water spread show very significant seasonal fluctuation from 2618 ha in post-monsoon to 424 ha in pre-monsoon (Table 33). On the other hand the extent of vegetation has decreased from 12056 ha to 2865 ha which is about 97 %.

Table 33: Salient observations of Nalsarovar Bird sanctuary from satellite data

Name:	Nalsarovar Bird Sanctuary
Location:	$22^0$39'05" to $22^0$53'03" N Latitude $71^0$57'58" to $72^0$10'22" E Longitude
Wetland Type:	Lake/Pond
Wetland Area: Perimeter:	14673 ha 145 km
<u>Open-water</u> Post-monsoon: Pre-monsoon:	 2618 ha 424 ha
<u>Vegetation</u> Post-monsoon: Pre-monsoon:	 12055 ha 2865 ha
Overall Turbidity:	Low-Moderate

The catchment together with 12 km buffer area (216162 ha) of Nalsarovar is mainly under agricultural land use. Around 169 wetlands with an aerial extent of 22043 ha are found in this area, out of which Nalsarovar accounts for about 67 per cent of the wetland area. The seasonality is quite prominent in all the wetlands of the area reflected in reduction in water spread and in vegetation (Table 34).

Table 34: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Nalsarovar Bird Sanctuary

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	5	15536	3350	424	12187	2865
1105	Waterlogged (natural)	35	2478	885	136	1593	101
1106	River/Stream	9	2123	155	20	-	-
1201	Reservoir/Barrage	8	360	222	112	139	24
1202	Tank/Pond	110	1319	575	251	744	209
1203	Waterlogged (man-made)	2	227	200	4	27	-
	Total	169	22043	5387	947	14689	3199

Wetland map of the Nalsarovar catchment including the 12 km buffer area is given in the Plate 66. The seasonal status of open-water spread and vegetation are given in the Plates 67-70 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

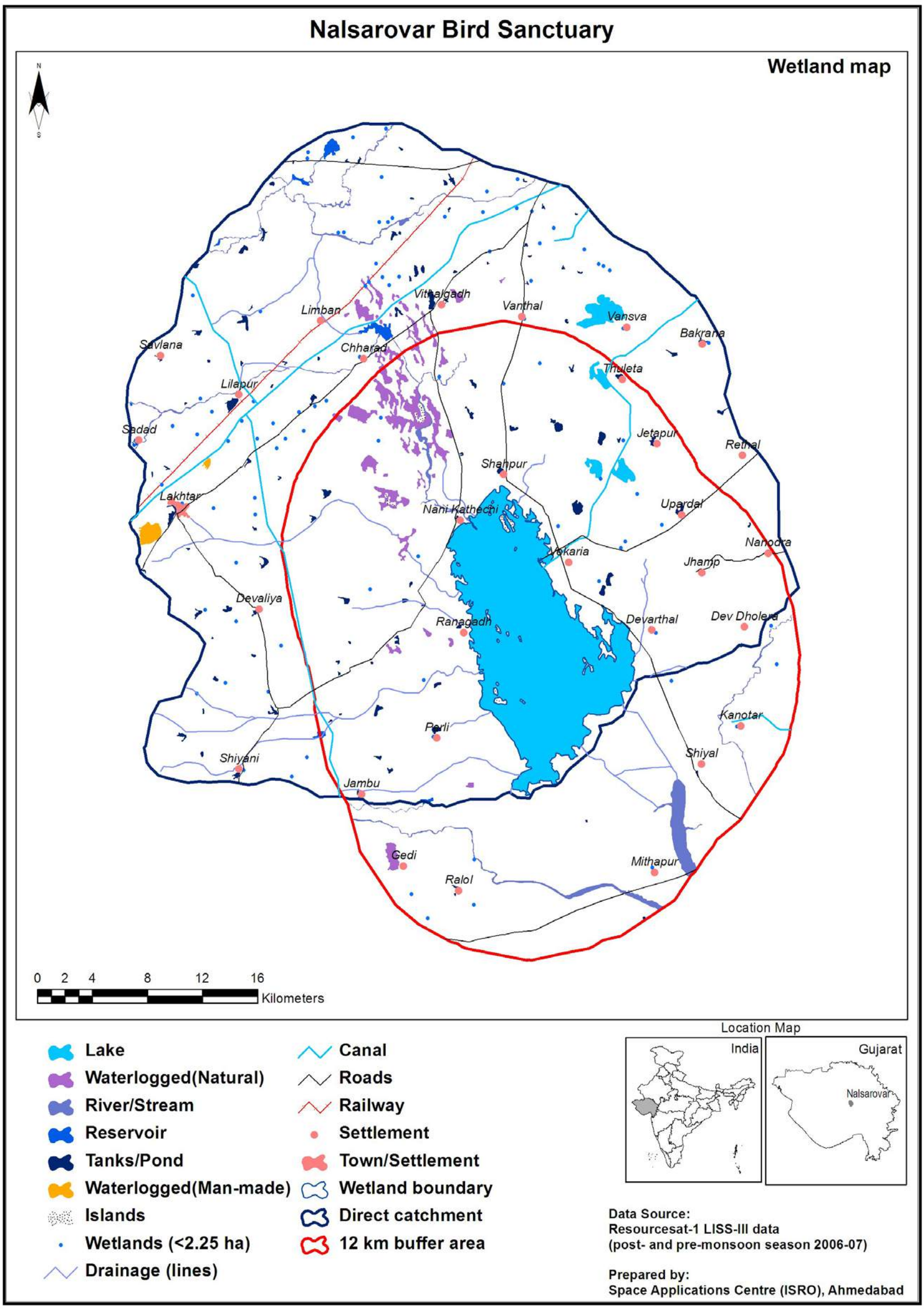

Plate 66: Wetland map of Nalsarovar Bird Sanctuary (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

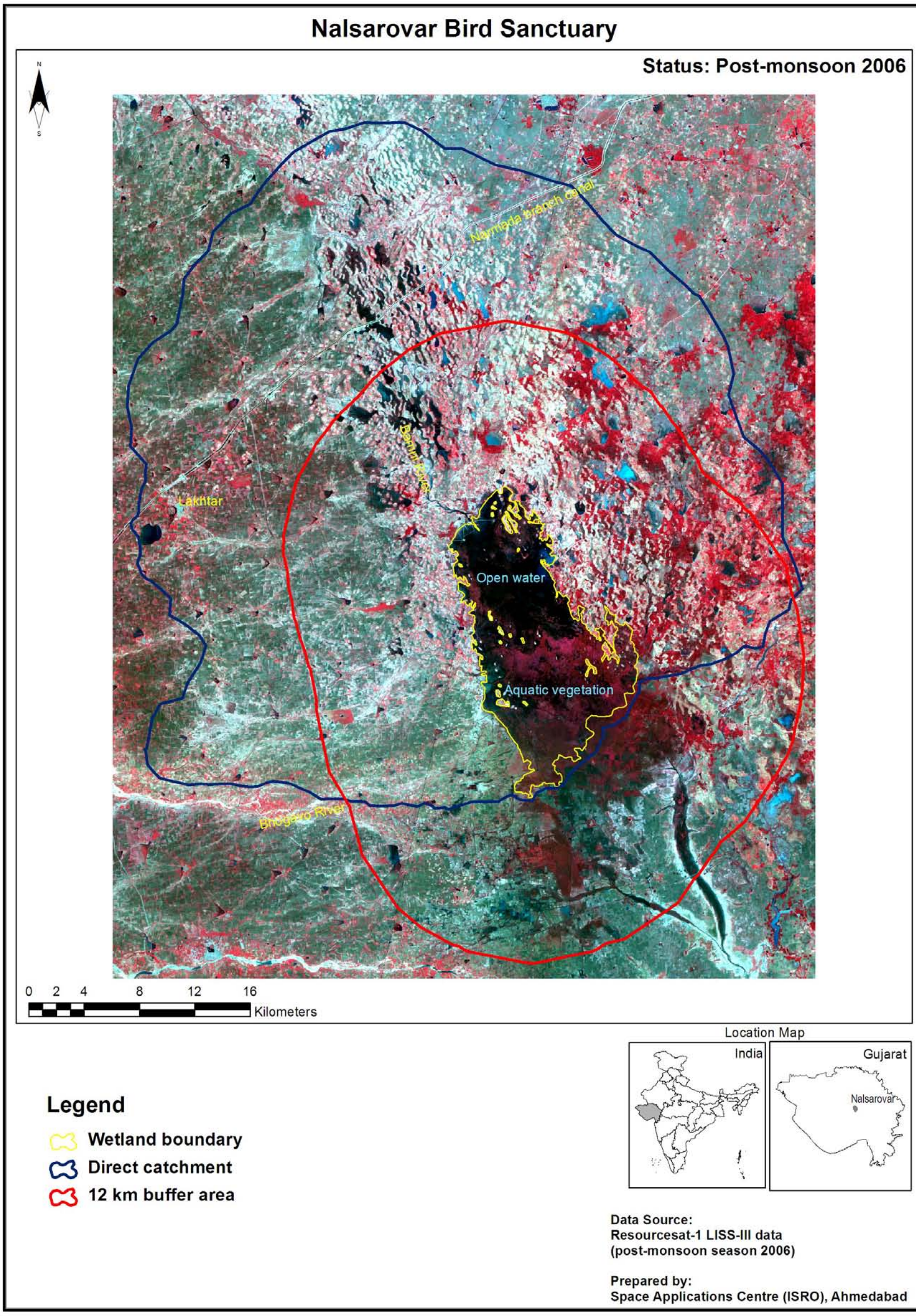

Plate 67: Nalsarovar Bird Sanctuary and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (19-October-2006)

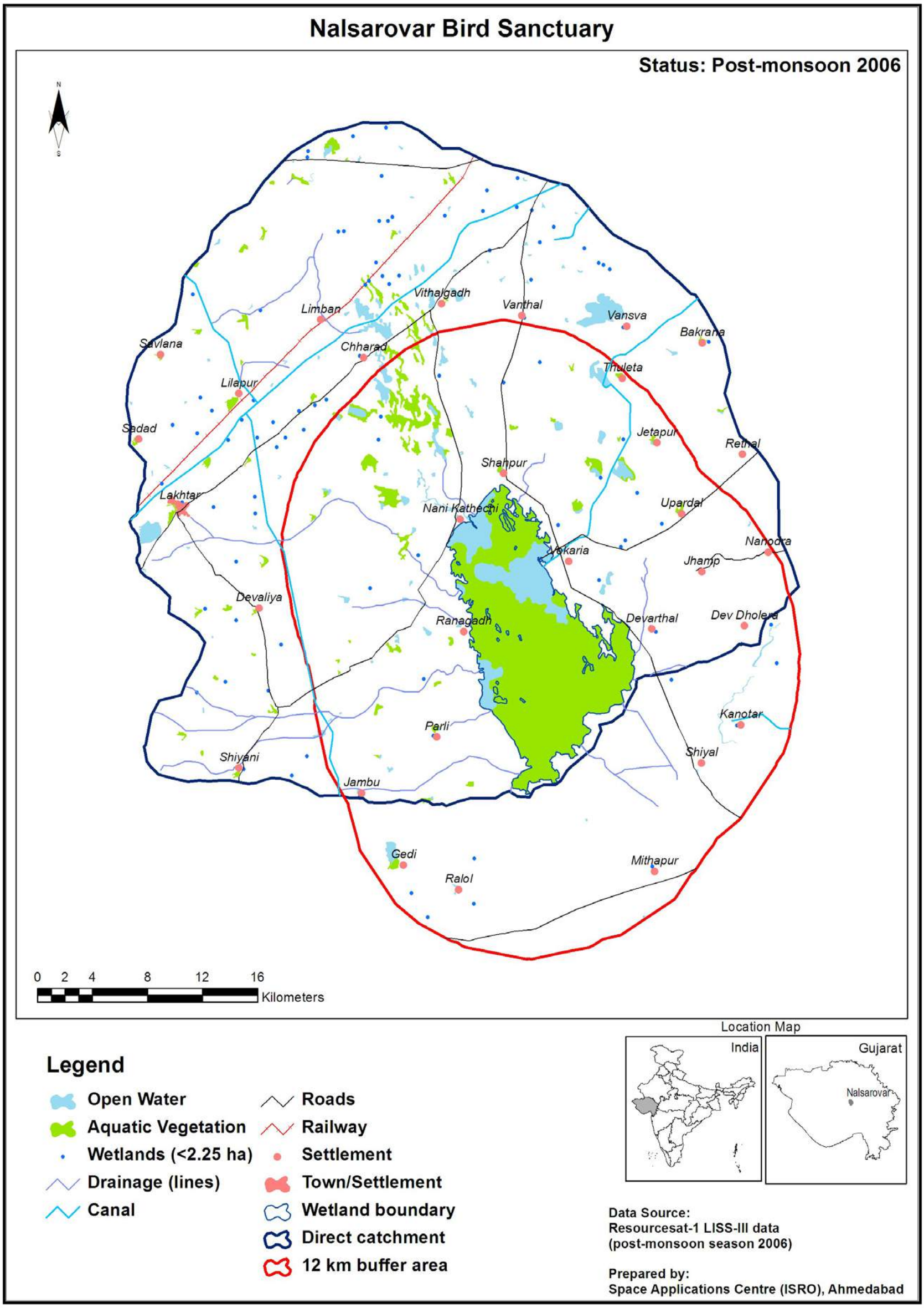

Plate 68: Open-water and vegetation status of Nalsarovar Bird Sanctuary (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

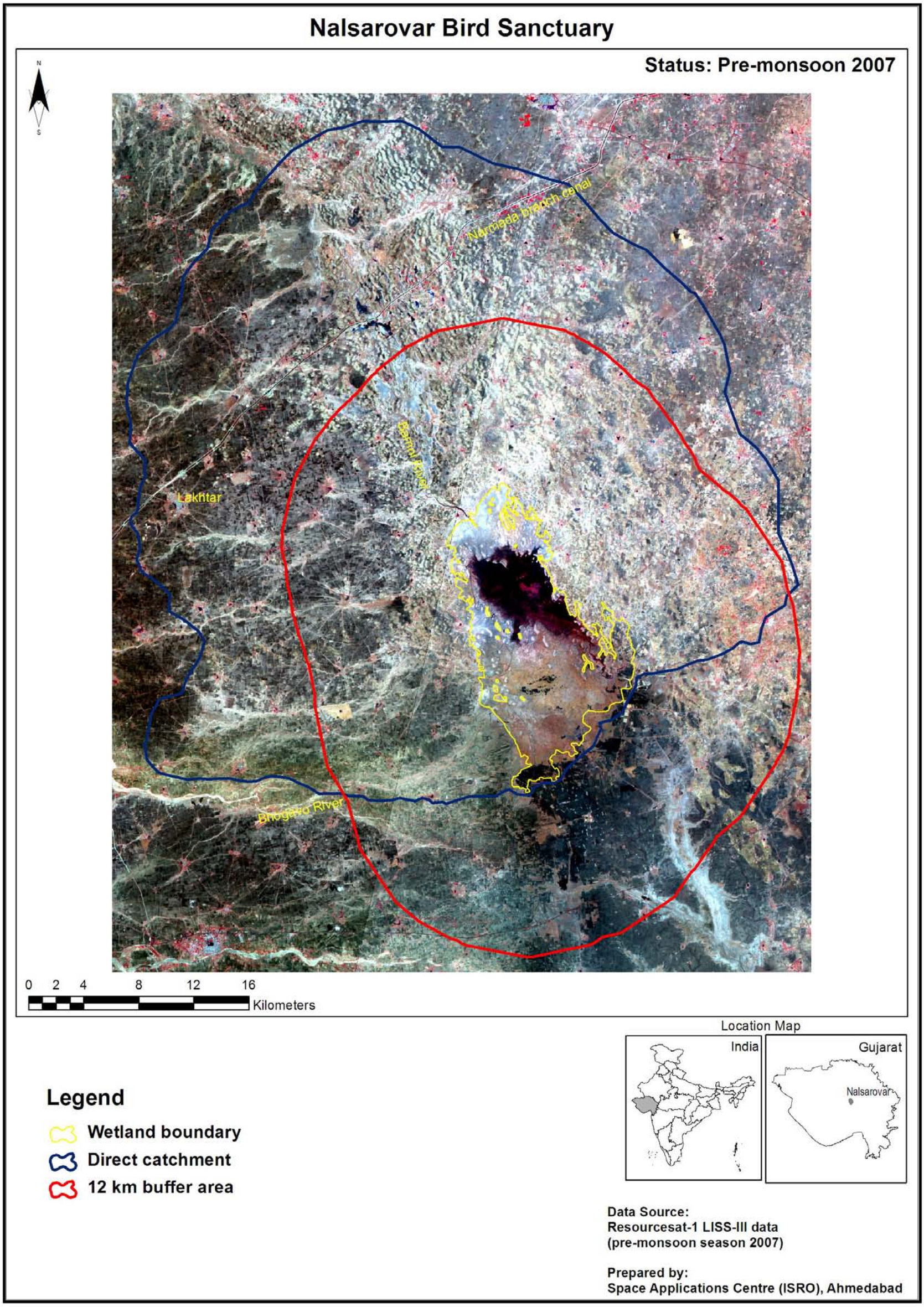

Plate 69: Nalsarovar Bird Sanctuary and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (23-May-2007)

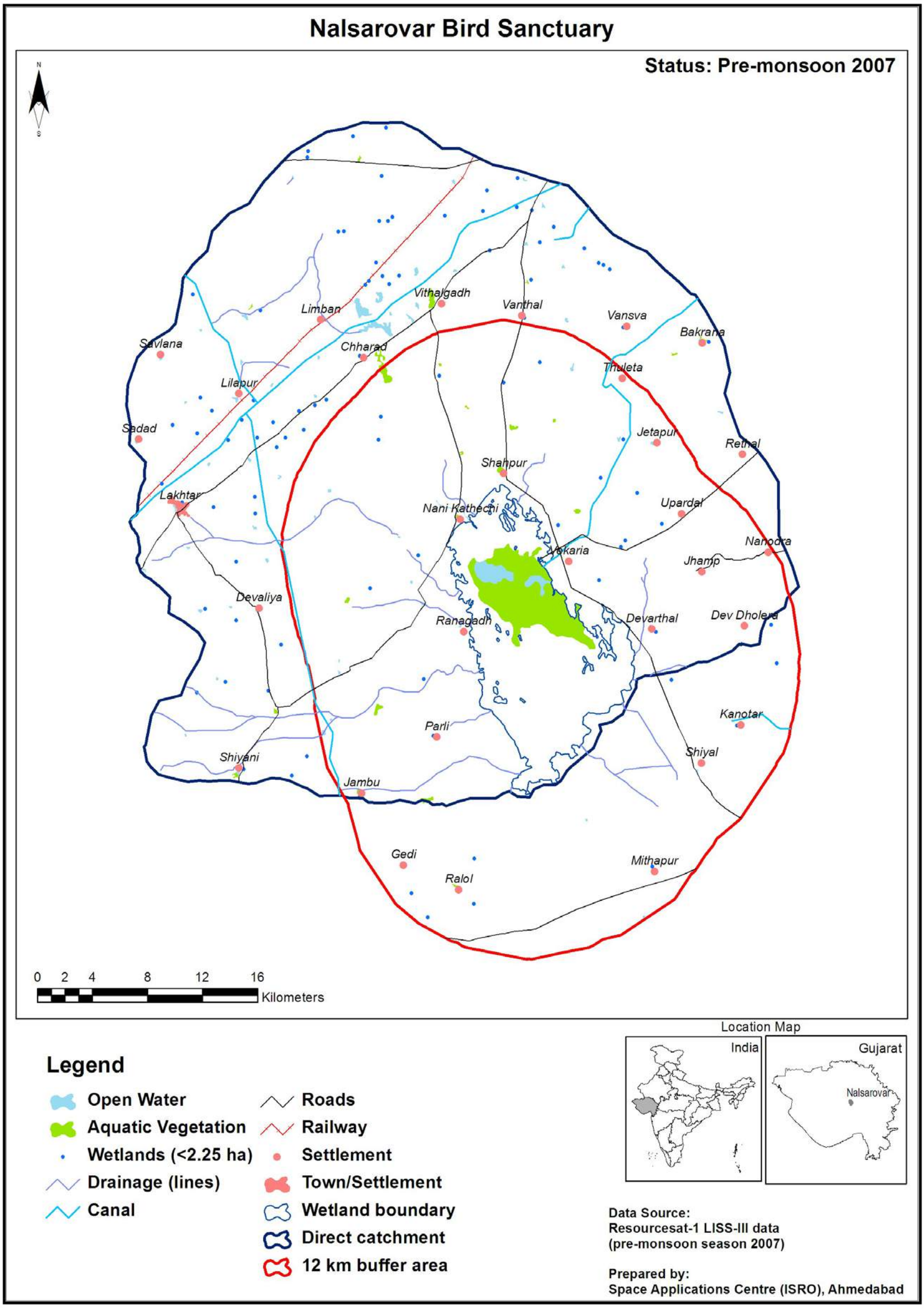

Plate 70: Open-water and vegetation status of Nalsarovar Bird Sanctuary (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.15 Point Calimere Wildlife and Bird Sanctuary (Ramsar site no. 1210)



This site is situated at the southern end of Nagappattinam district, Tamil Nadu. Point Calimere is actually a complex wetland composed of creek, forest, swamps, and intertidal mudflats. The sanctuary may be divided into three divisions: the Point Calimere Forest; Great Vedaranyam Swamp (GVS), which includes the mangrove forests at Muthupet and the mangroves of Talaignayar Reserve Forest (TRF).

It was declared as Ramsar site in 19/08/2002 owing to the compliance of criteria 2, 4 & 5 as described below:

- Wetland supports globally threatened ecological communities.
- Wetland provides refuge during adverse conditions to threatened species.
- Wetland regularly supports 20, 000 or more water birds.

This site is rich in birds both waterfowls and forest birds. The sanctuary is an important staging and wintering ground for migratory birds like flamingos, ducks, gulls and terns. As high as 28,000 flamingos and 100,000 Garganey have been reported in this site. The swamps and saltpans harbour as many as 110 species of birds. The threatened Spot-billed Pelican also occur here. The wetland supports the vulnerable species like sandpiper and grey pelican listed in the IUCN Red List. The wetland is the breeding ground for many species of marine fishes which are vital to the fisheries of the coast. GVS is the spawning ground for commercially important prawns, crabs and harbours 23 fish species, whereas the Mullipalam Lagoon harbours 20 species marine species of fish. Mangroves are dominated by *Avicennia marina.* Twenty nine species of reptiles and eight species of amphibians are reported from here. Point Calimere Wildlife and Bird Sanctuary as observed on Resourcesat-1 LISS-III image is given in the Figure 24.

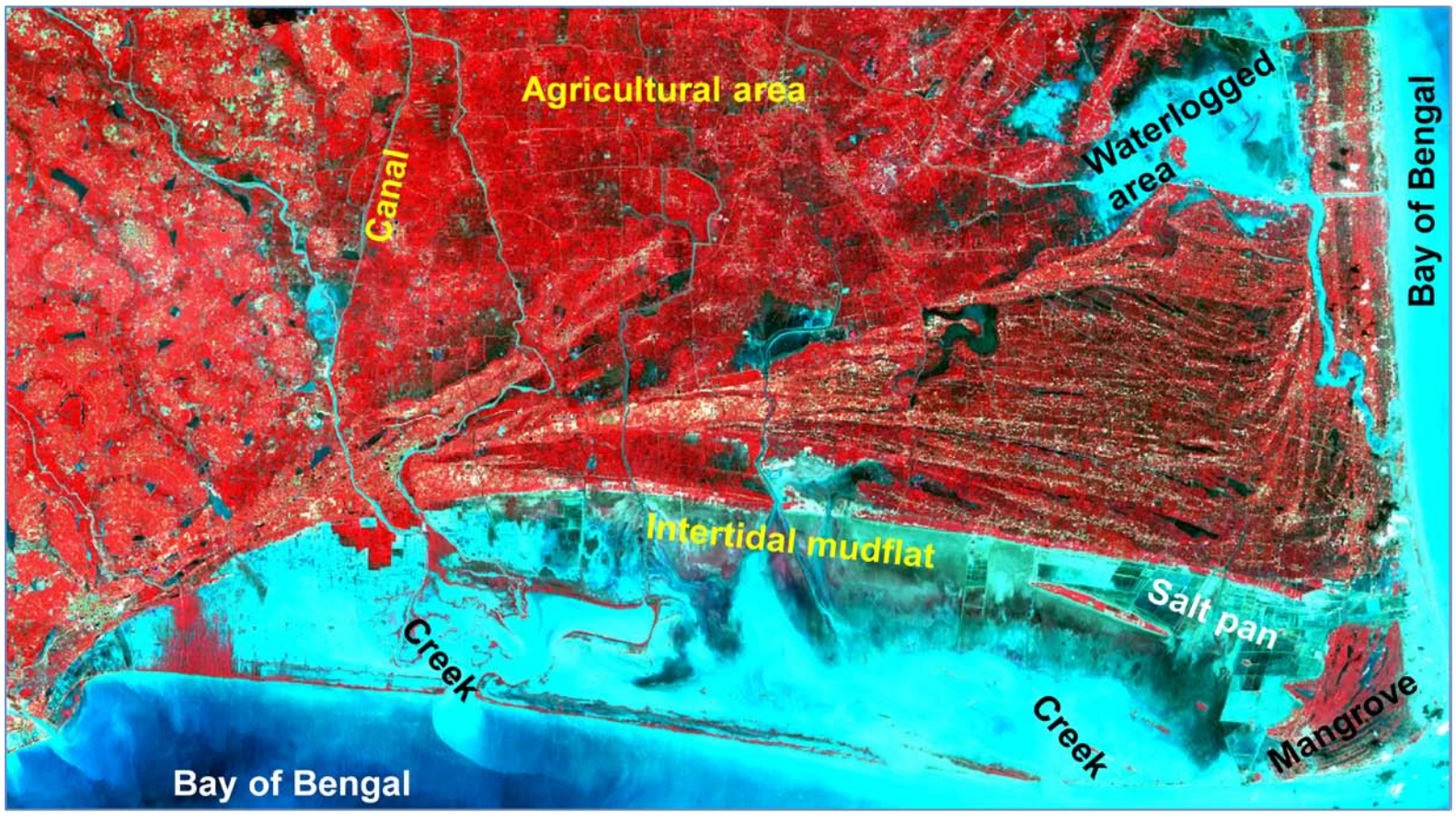

Figure 24: Point Calimere Wildlife and Bird Sanctuary and its environ as seen in LISS-III FCC (08-December-2006)

Point Calimere Wildlife and Bird Sanctuary includes many of the coastal wetland types making it complex. Together the site has an aerial estimate of 44882 ha. The open-water spread in post-monsoon is 23179 ha which was found to have increased marginally to 23300 ha in pre-monsoon. The vegetation comprising mangroves remained unchanged in both the seasons (Table 35).

Table 35: Salient observations of Point Calimere Wildlife and Bird Sanctuary from satellite data

Name:	Point Calimere Wildlife and Bird Sanctuary
Location:	10˚15′46” to 10˚23′44” N Latitude 79˚21′19” to 79˚53′04” E Longitude
Wetland Type:	Coastal wetland complex
Wetland Area: Perimeter:	44882 ha Creek(15085 ha), Intertidal mud-flat (18004 ha), Mangrove (4509 ha), Salt pan (7284 ha) 246 km
<u>Open-water</u> Post-monsoon: Pre-monsoon:	 23179 ha 23300 ha
<u>Vegetation</u> Post-monsoon: Pre-monsoon:	 4504 ha 4504 ha
Overall Turbidity:	High

The catchment including the 12 km buffer area extends over 200530 ha. The area under wetlands is estimated to be 61284 ha. The open-water spread in post-monsoon (36412 ha) was found to have reduced to 32369 ha in pre-monsoon which is about 11%. The vegetation has shown an increase of about 1.6 times from post-monsoon (6258 ha) to pre-monsoon (10426 ha). Wetland type-wise area estimates and seasonal changes in terms of open-water and vegetation are given in Table 36.

Table 36: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Point Calimere Wildlife and Bird Sanctuary

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	29	2582	1836	214	571	2202
1105	Waterlogged	4	1223	1092	825	124	398
1106	River/Stream	9	4519	4400	4471	23	49
1201	Reservoir/Barrage	1	7	2	-	5	7
1202	Tank/Pond	252	2259	1342	180	858	2071
1203	Waterlogged	10	4908	4738	3674	168	1190
2102	Creek	2	15084	15079	15084	-	-
2103	Sand/Beach	1	131	-	-	-	-
2104	Intertidal Mud-flat	10	18004	-	-	-	-
2105	Salt Marsh	1	235	235	235	-	-
2106	Mangrove	17	4509	-	-	4509	4509
2201	Salt Pan	12	7823	7685	7684	-	-
2202	Aquaculture Pond	1	3	3	3	-	-
	Total	349	61284	36412	32369	6258	10426

Wetland map of the Point Calimere Wildlife and Bird Sanctuary catchment including the 12 km buffer area is given in the Plate 71. The seasonal status of open-water spread and vegetation are given in the Plates 72-75 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

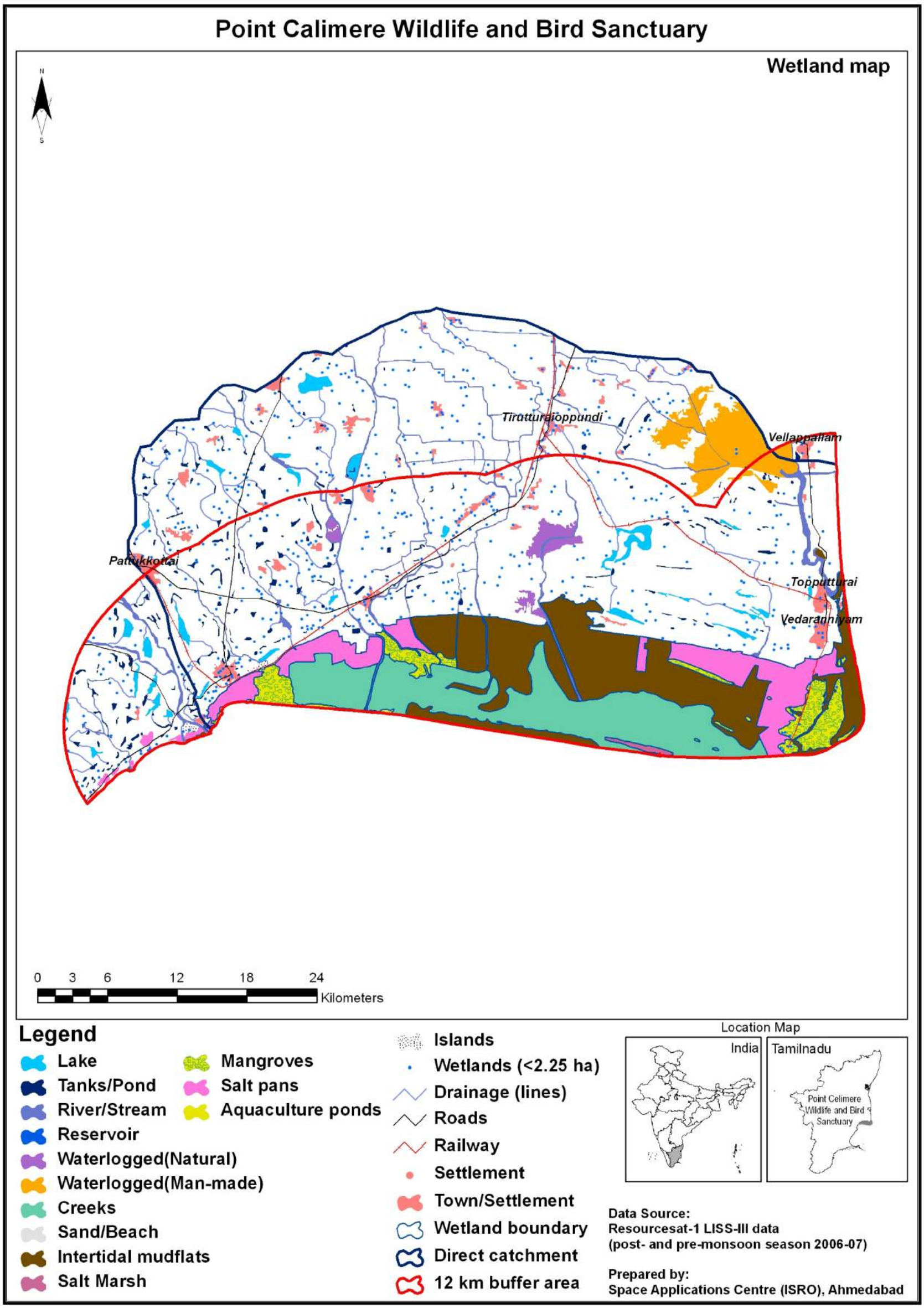

Plate 71: Wetland map of Point Calimere Wildlife and Bird Sanctuary (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)



Plate 72: Point Calimere Wildlife and Bird Sanctuary and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (08-December-2006)

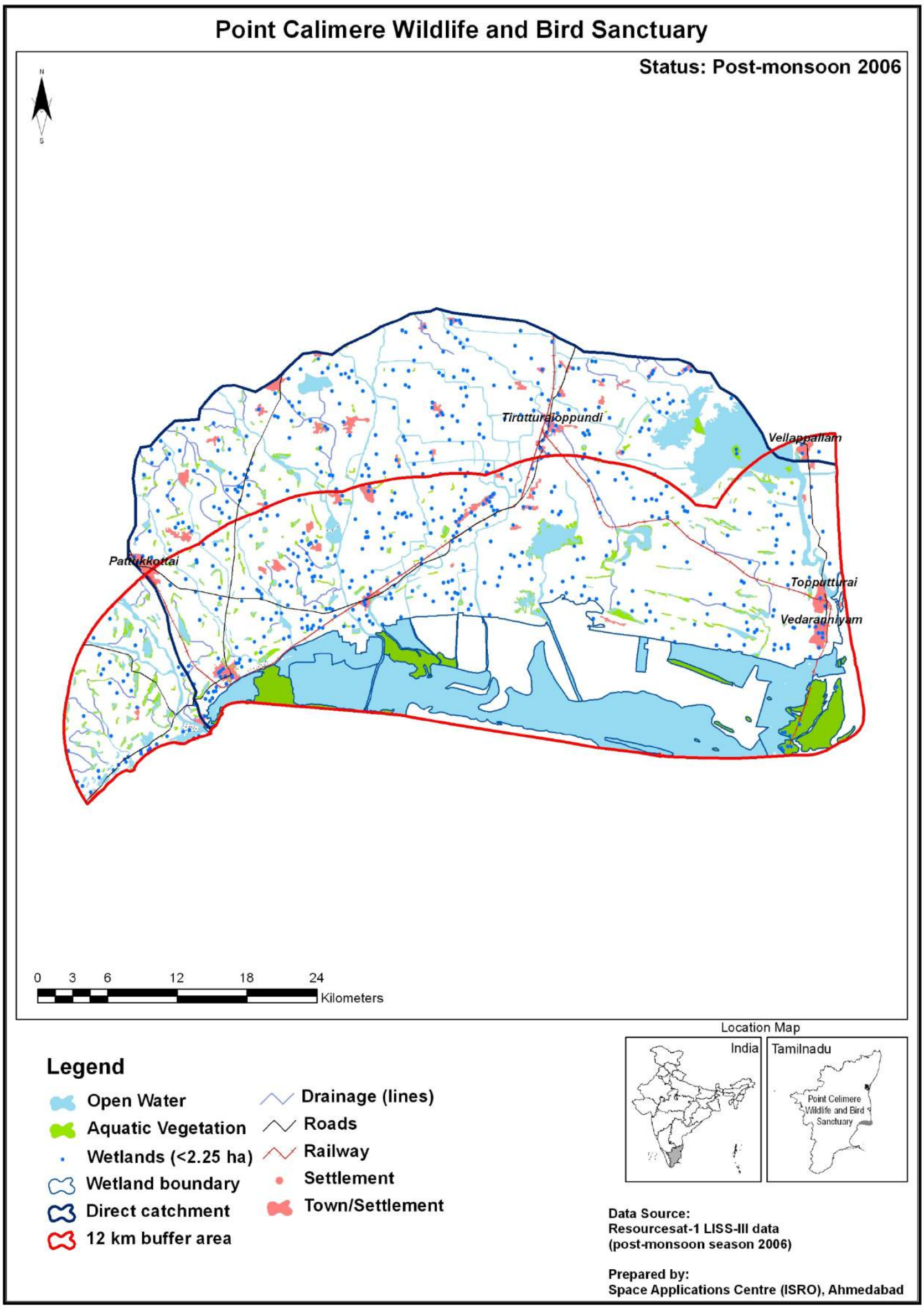

Plate 73: Open-water and vegetation status of Point Calimere Wildlife and Bird Sanctuary (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon 2006

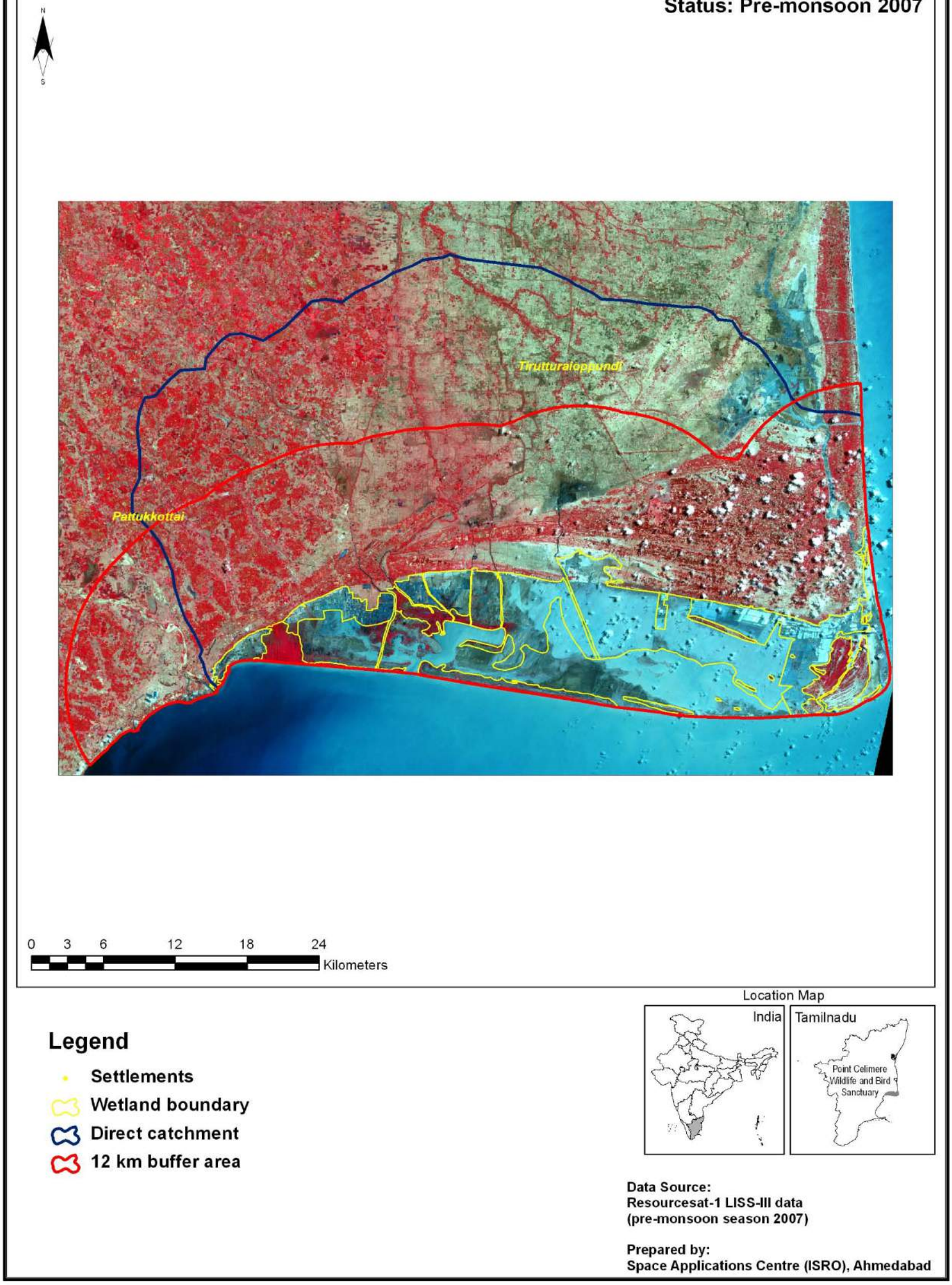

Plate 74: Point Calimere Wildlife and Bird Sanctuary and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (20-May-2007)

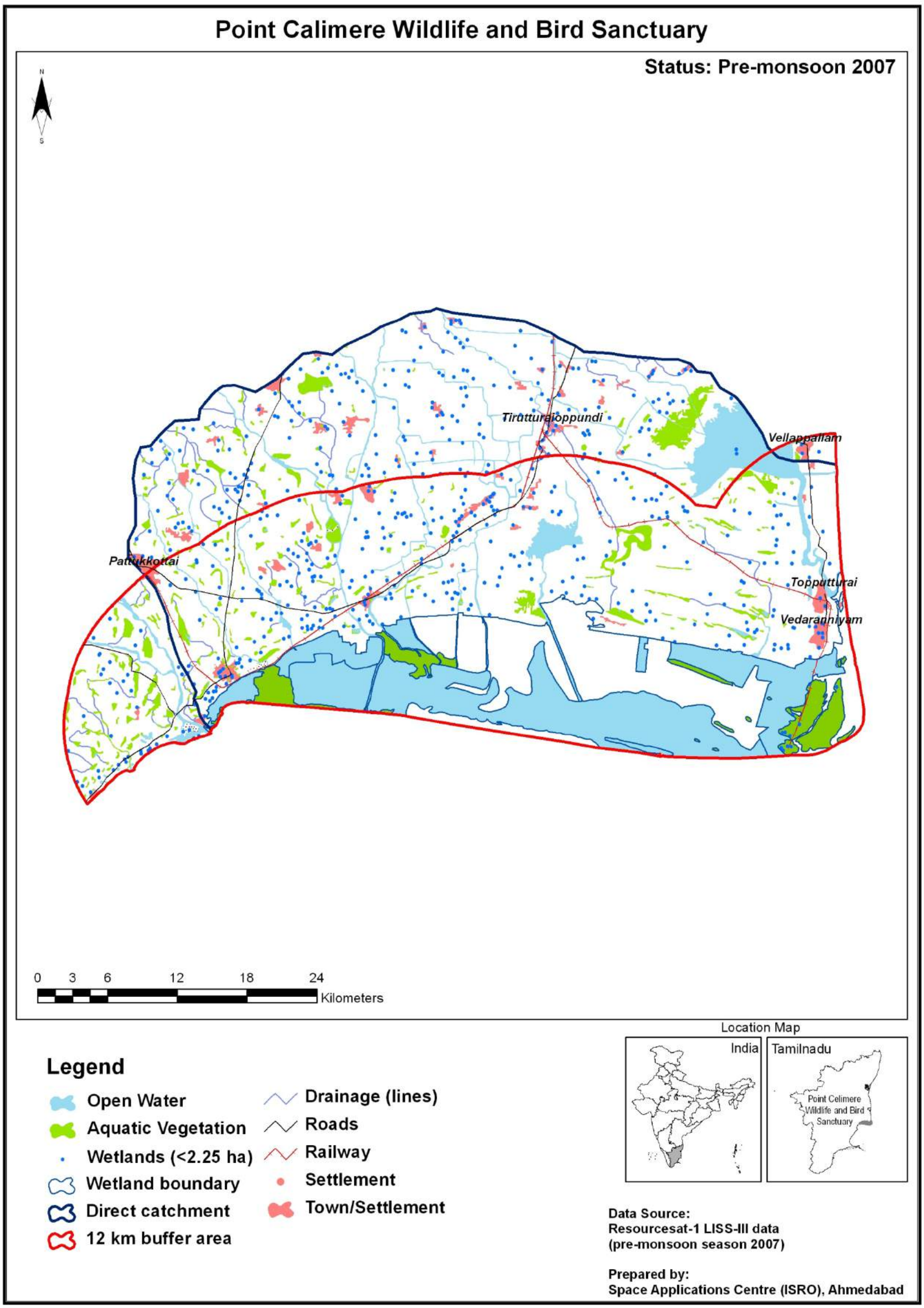

Plate 75: Open-water and vegetation status of Point Calimere Wildlife and Bird Sanctuary (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon 2007

4.2.16 Pong Dam Lake (Ramsar site no. 1211)



Pong Dam Lake is a reservoir by damming of the River Beas in the foothills of the Himalayas in the state of Himachal Pradesh. It is also known as the Maharana Pratap Sagar. Built primarily for irrigation purpose, it became a significant habitat of migratory birds and declared as Wildlife Sanctuary in 1986.

This wetland was declared as Ramsar site on 19/08/2002 owing to the compliance of criteria 2, 5 & 6 as described below:

- Wetland supports globally threatened ecological communities.
- Wetland regularly supports 20, 000 or more waterbirds.
- Wetland supports 1 % of individuals in a population of one species or subspecies.

Around 220 avian species are recorded from this wetland belonging to 54 families. The reservoir is an important wintering ground for waterfowl mainly barheaded geese, northern lapwing, ruddy shelduck, common teal, mallard and coot. Concentration of wintering waterfowl is as high as 75,000. More than 30, 000 Bar-headed Gees have been reported during peak season, which is around 33 per cent of the known population. The red necked grebe has been recorded from this wetland for the first time, which attaches national as well as international importance for the conservation of several waterfowls. The black headed gull, great black headed gull and herring gull species which are uncommon from coast in India, but visit this wetland in each winter.

The reservoir is a rich source of fish. Fish diversity comprises of 25 species belonging to 6 families. Golden masher, Snow trout and *Labeo dero* are some of the indigenous fish of the lake.. Pong Dam Lake as observed on Resourcesat-1 LISS-III image is given in the Figure 25.

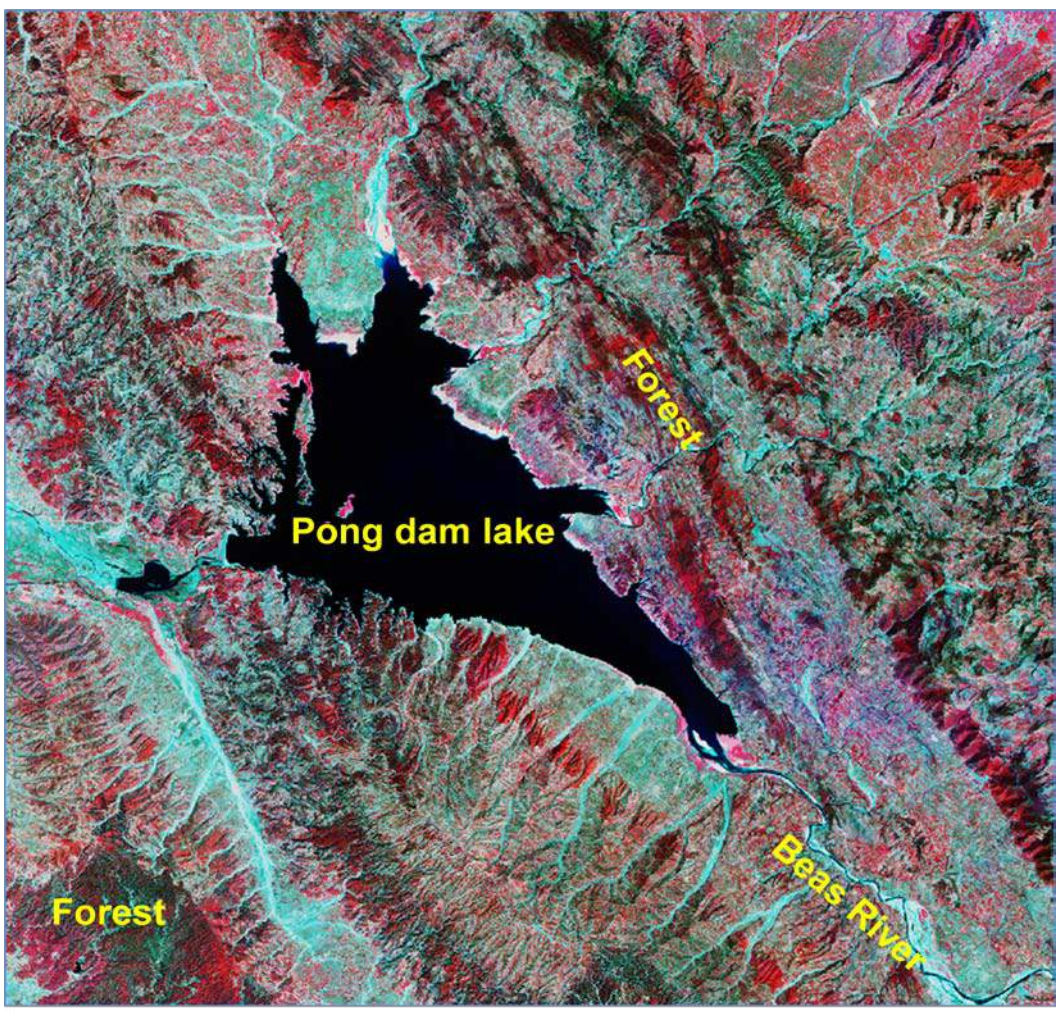

Figure 25: Pong Dam Lake and its environ as seen in LISS-III FCC (10-April- 2007)

Pong dam Lake has an aerial extent of 24532 ha with a perimeter of 322 km. The extent of open-water spread has showed seasonal variation of 24508 ha to 20286 ha from post to pre monsoon. Aquatic vegetation has been noticed during pre-monsoon season in the swampy areas where water has receded (Table 37).

Table 37: Salient observations of Pong Dam Lake from satellite data

Name:	Pong Dam Lake
Location:	31˚50′03” to 32˚08′58” N Latitude 75˚56′00” to 76˚15′55” E Longitude
Wetland Type:	Reservoir/Barrage
Wetland Area: Perimeter :	24532 ha 322 km
<u>Open-water</u> Post-monsoon: Pre-monsoon:	 24508 ha 20286 ha
<u>Vegetation</u> Post-monsoon: Pre-monsoon:	 Nil 3731 ha
Overall Turbidity:	Low-Moderate

Pong Dam Lake has a catchment area of 614167 ha including the 12 km buffer with predominance of natural forest. River/streams are the dominant wetlands in the catchment. The reservoir accounts for about 73 per cent of the total wetland extent (24532 ha) as shown in Table 38.

Table 38: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Pong Dam Lake

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1106	River/Stream	18	9156	3701	2584	-	-
1201	Reservoir/Barrage	2	24589	24508	20307	-	3731
1203	Waterlogged	1	3	3		-	-
	Total	21	33748	28212	22891	-	3731

Wetland map of the Pong Dam lake catchment including the 12 km buffer area is given in the Plate 76. The seasonal status of open-water spread and vegetation are given in the Plates 77-80 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

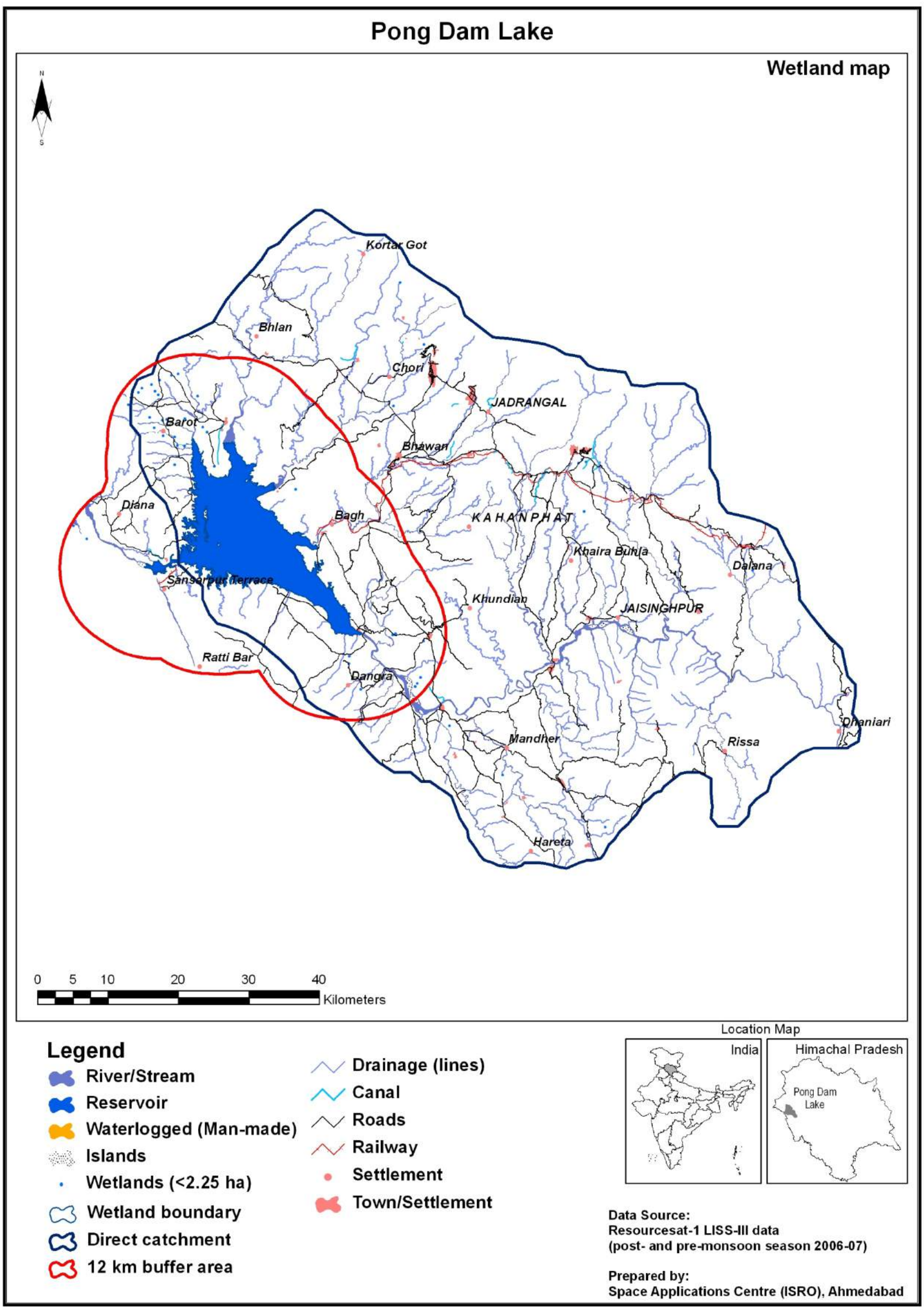

Plate 76: Wetland map of Pong Dam Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

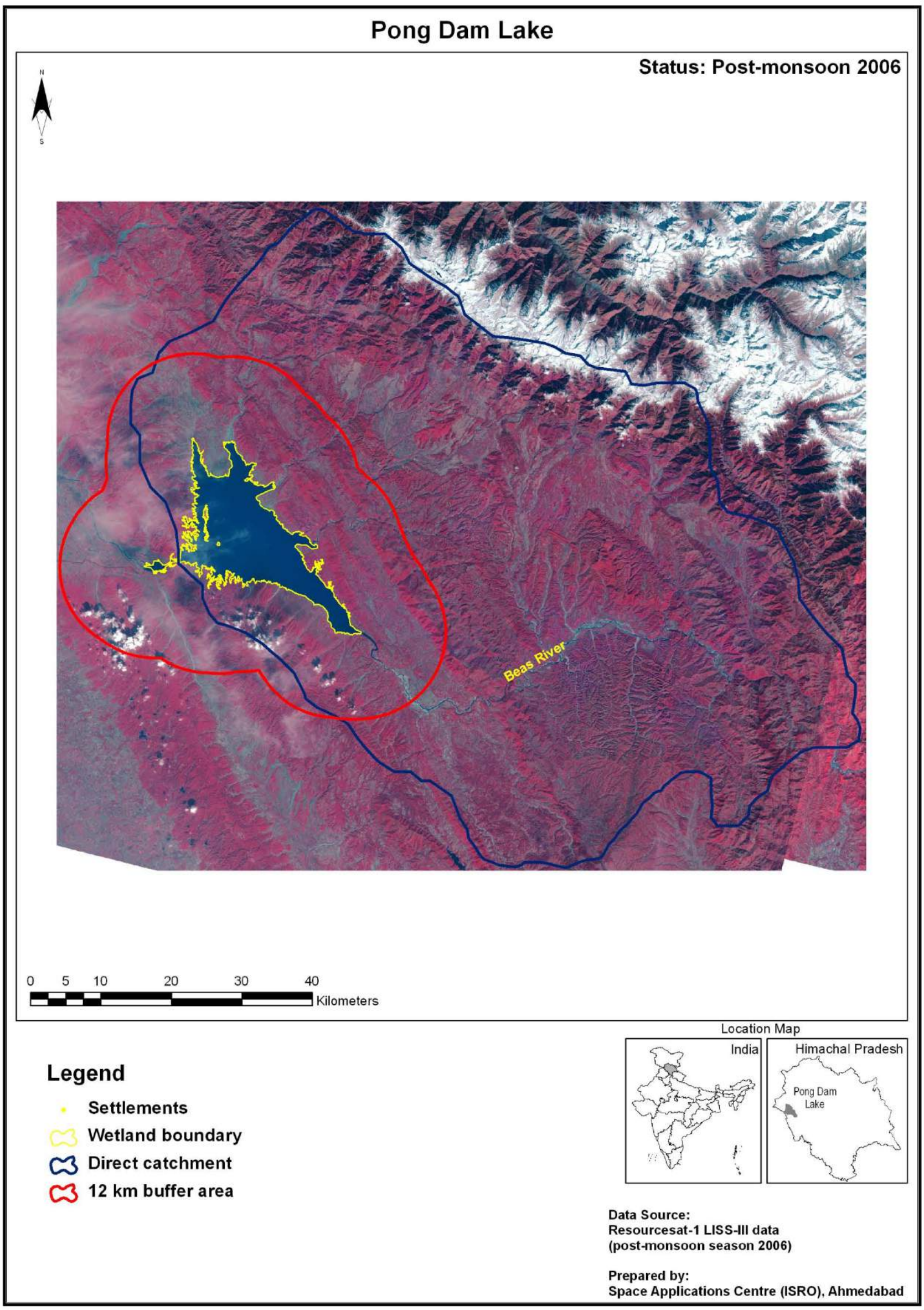

Plate 77: Pong Dam Lake and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (24-October-2006)

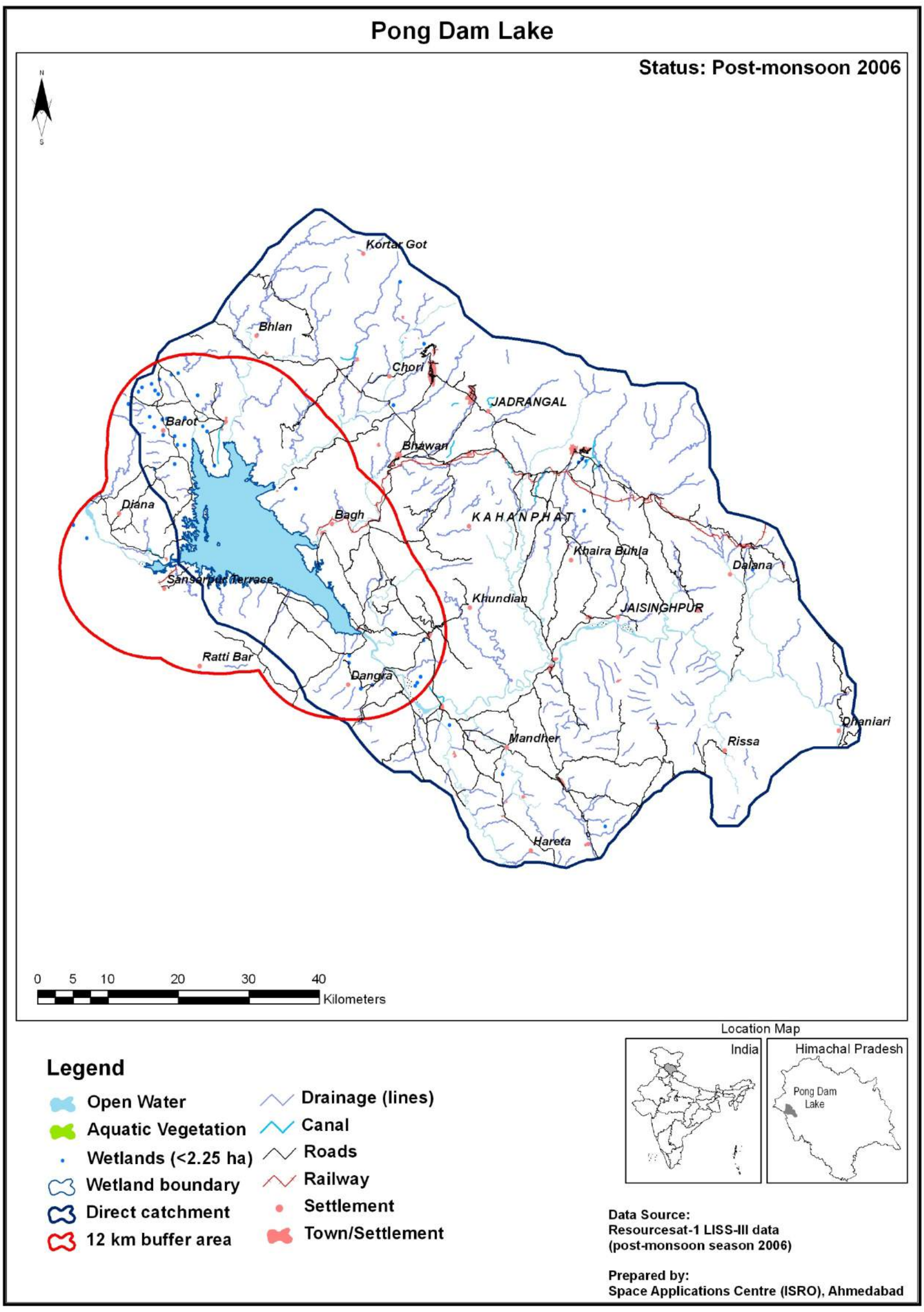

Plate 78: Open-water and vegetation status of Pong Dam Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

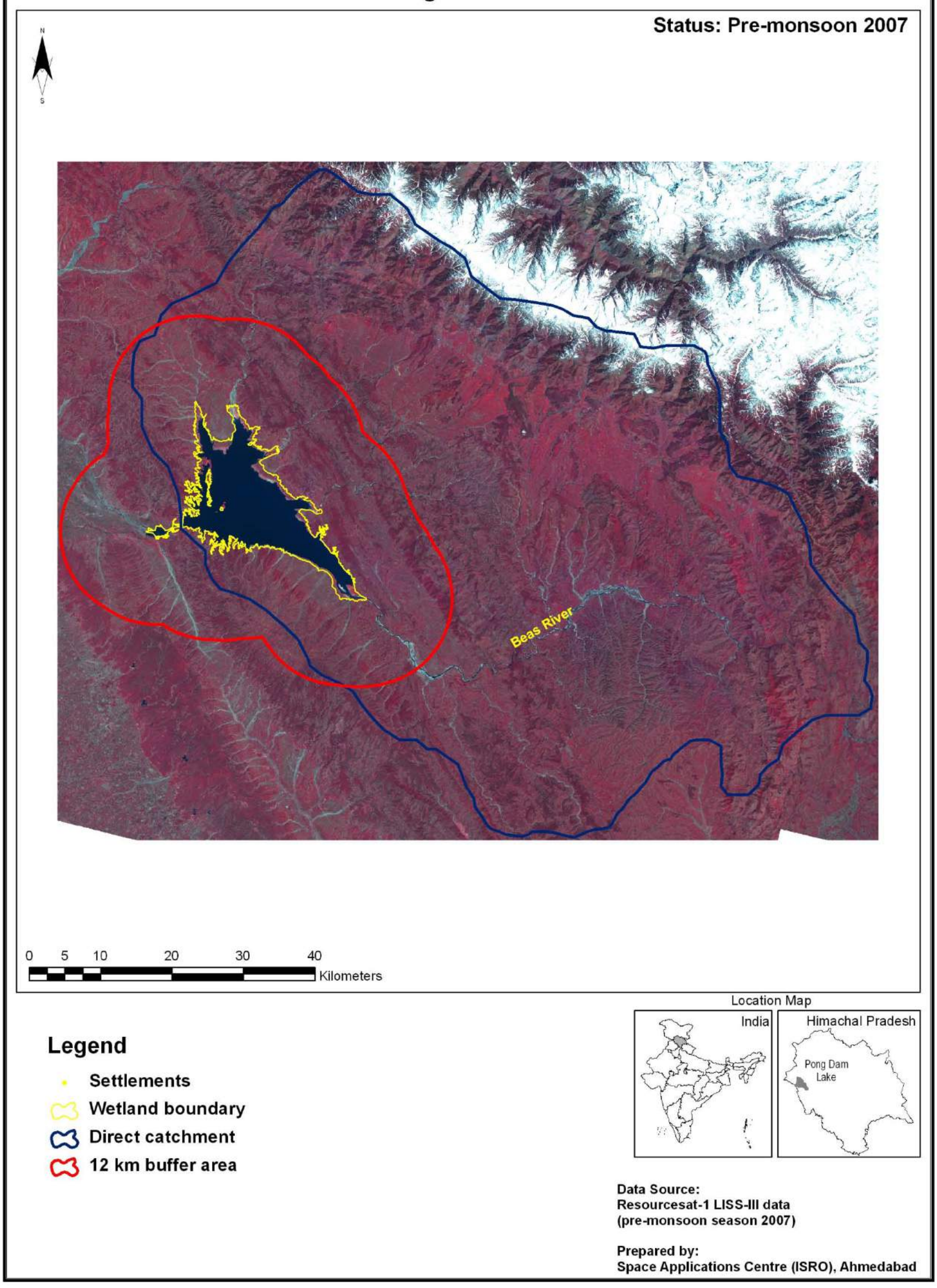

Plate 79: Pong Dam Lake and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (10-April-2007)

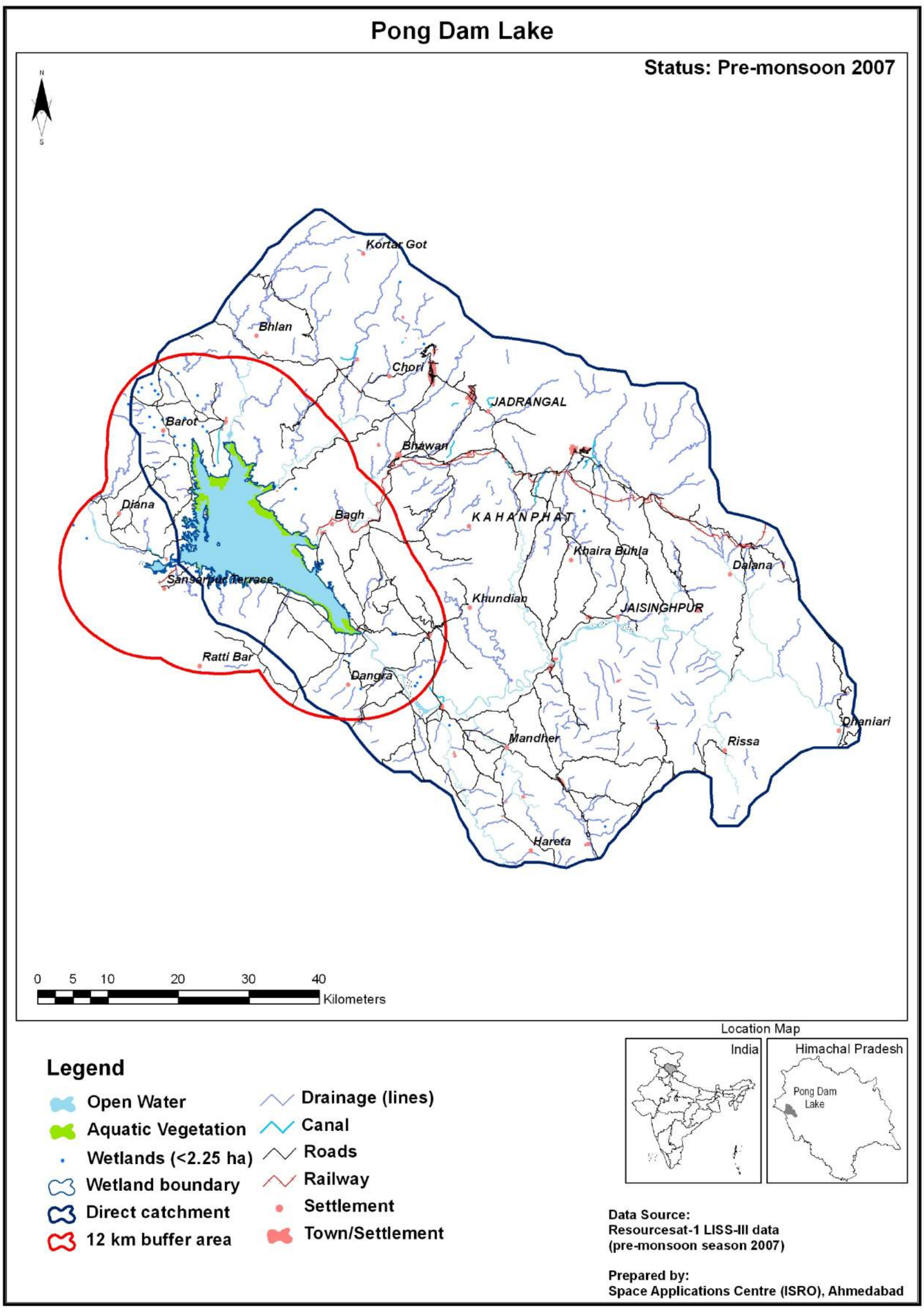

Plate 80: Open-water and vegetation status of Pong Dam Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.17 Renuka Wetland (Ramsar site no. 1571)



Renuka wetland is a small natural lake situated in the Sirmaur district of Himachal Pradesh. It is fed by a small stream arising from lower Himalayan hills. The hills that surround the Renuka Lake are covered with dense sub-tropical forests. It is known for its rich biodiversity besides being important religious place of worship.

It was declared as Ramsar site on 08/11/2005 owing to the compliance of criteria 3 & 4 as described below:

- Wetland supports populations of animal/plant species important for maintaining biological diversity.
- Wetland providing refuge to wildlife during adverse condition.

The lake and its surrounding area is a Wild life sanctuary. According to faunal survey, Renuka Lake has 443 species of animals ranging from protozoa to mammals.

The lake has grasslands, marshy area, rocky area and open-water that form different habitats for flora and fauna. Even though the extent is small; it has considerable depth (maximum 13). Nineteen species of fishes are reported from this wetland. Avifauna includes 103 species out of which 66 are resident and rest are migratory in nature. The lake environs being very picturesque attracts large number of tourists. Renuka wetland as observed on satellite image is given in Figure 26.

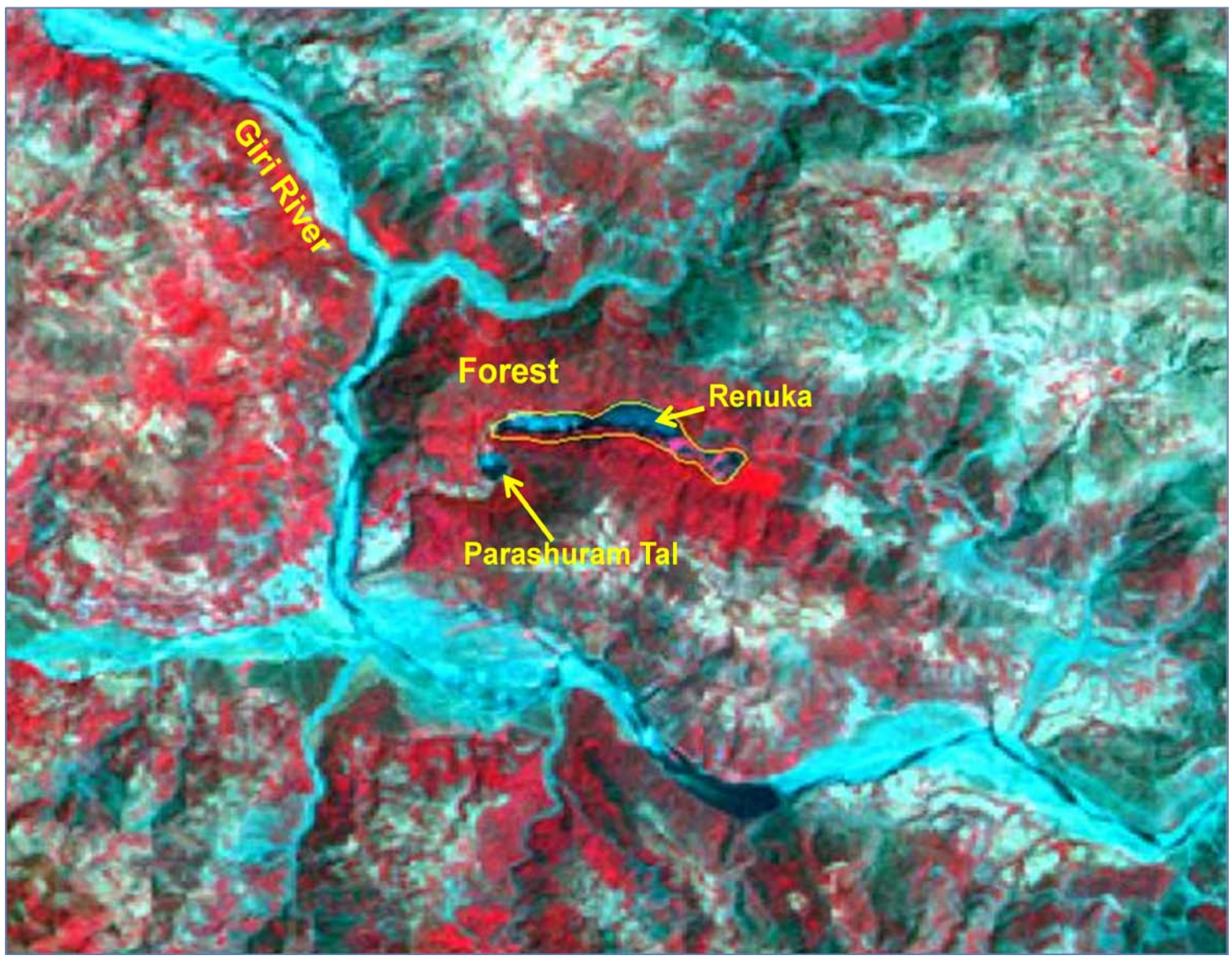

Figure 26: Renuka wetland and its environ as seen in LISS-III FCC (09-May-2007)

Renuka wetland is a small natural lake with an extent of 29 ha and a perimeter of 4 km. The extent of open-water show significant seasonal variation. The wetland is devoid of vegetation in post monsoon. However, pre-monsoon image shows vegetation to the extent of 6 ha (Table 39).

Table 39: Salient observations of Renuka wetland from satellite data

Name:	Renuka Wetland
Location:	30^0 36' 22" to 30^0 36' 51" N Latitude 77^0 26' 54" to 77^0 27' 04" E Longitude
Wetland Type:	Lake/Pond
Wetland Area: Perimeter:	29 ha 4 km
Open-water Post-monsoon: Pre-monsoon:	 29 ha 16 ha
Vegetation Post-monsoon: Pre-monsoon:	 Nil 6 ha
Overall Turbidity:	Low

The catchment of the Renuka wetland is 49490 ha including the 12 km buffer area is predominated by natural forest. Around 10 wetlands belonging to three types are found in the area. Out of the three wetland types present in the catchment and buffer area, River/Stream dominates the aerial extent with 1860 ha. (Table 40).

Table 40: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Renuka wetland

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/pond	2	33	33	17	-	6
1106	River/Stream	7	1860	1145	318	-	-
1201	Reservoir/Barrage	1	154	-	8	-	-
	Total	10	2047	1178	343	-	6

Wetland map of the Renuka catchment including the 12 km buffer area is given in the Plate 81. The seasonal status of open-water spread and vegetation are given in the Plates 82-85 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

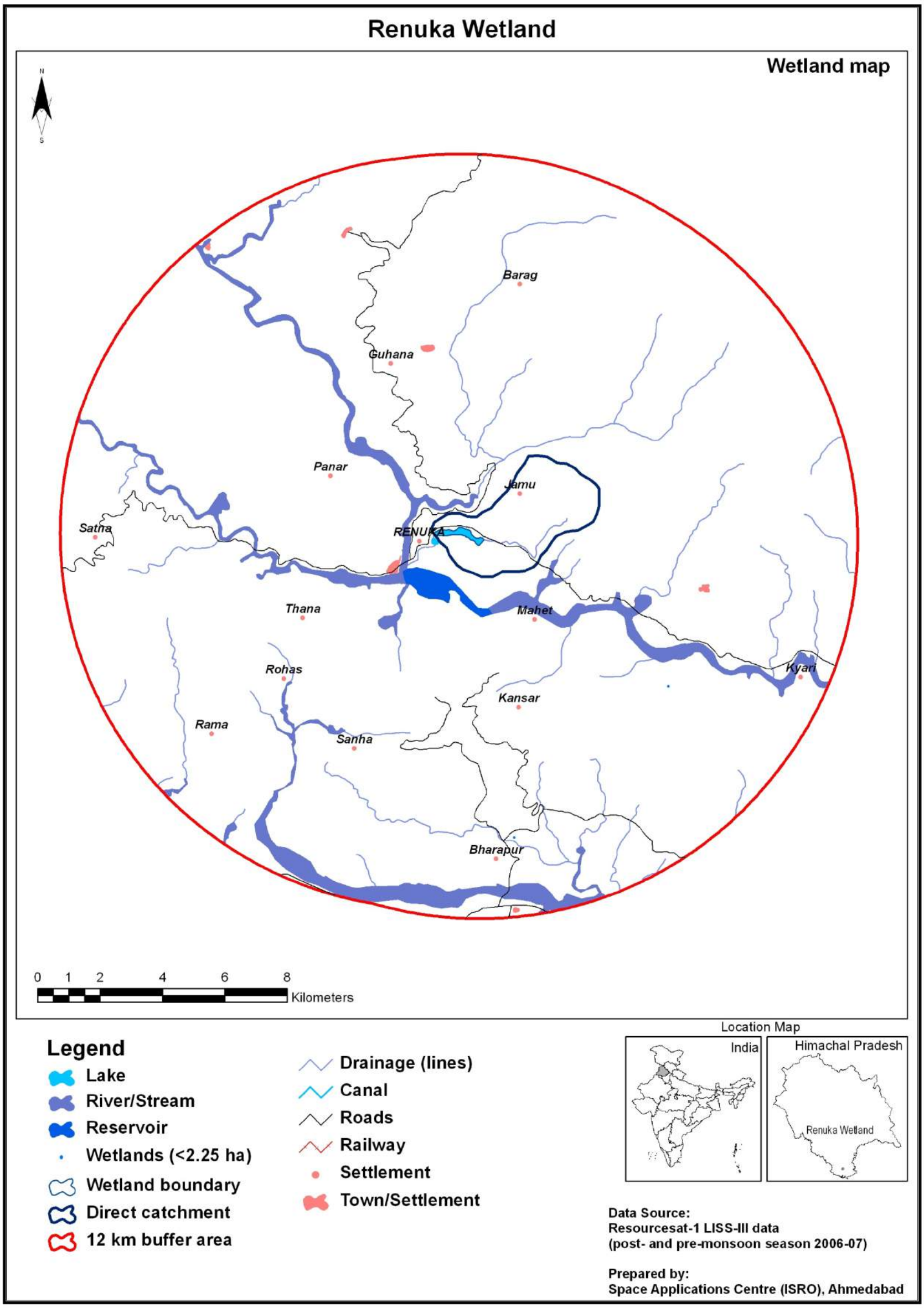

Plate 81: Wetland map of Renuka Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

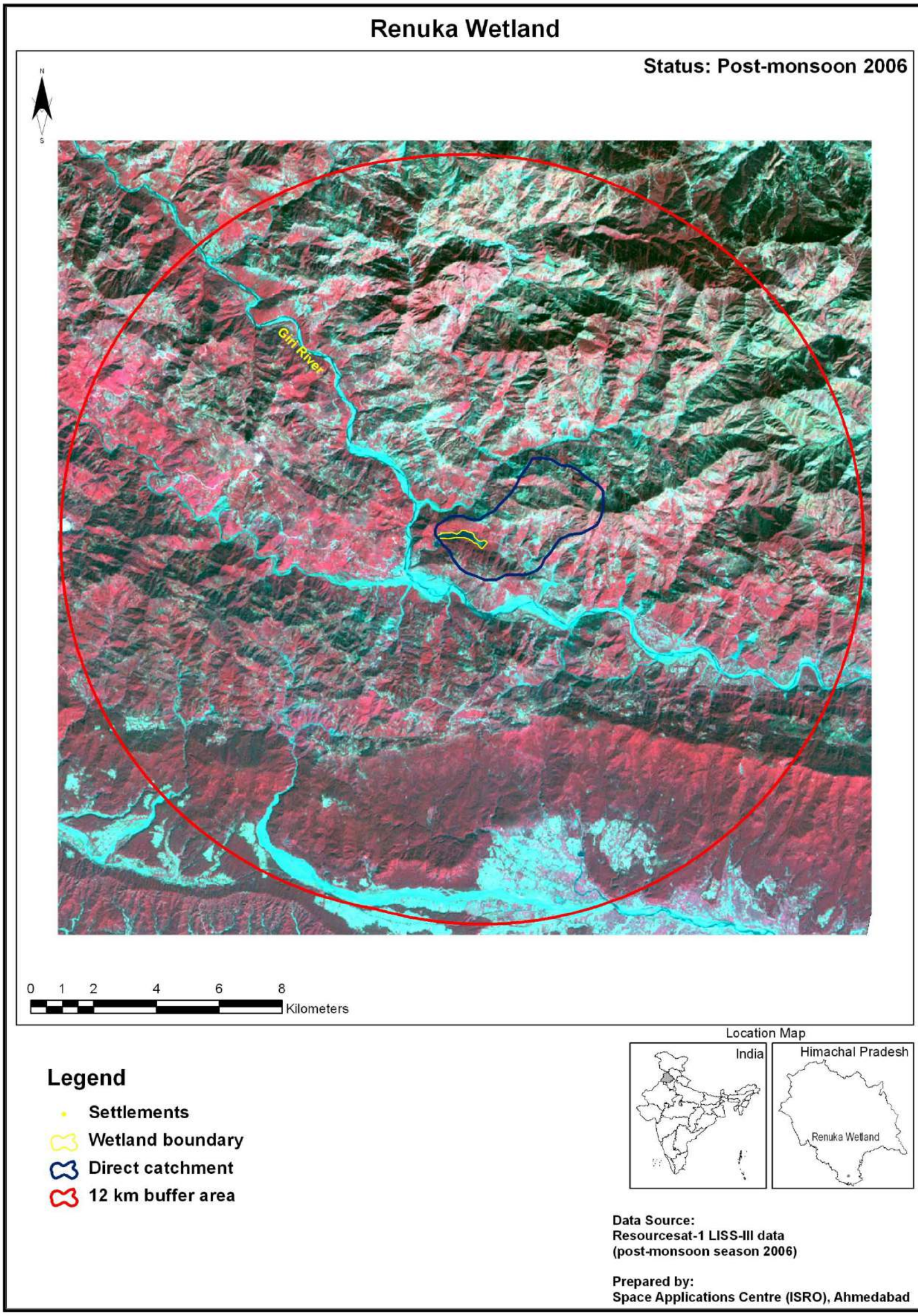

Plate 82: Renuka Wetland and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (05-October-2006)

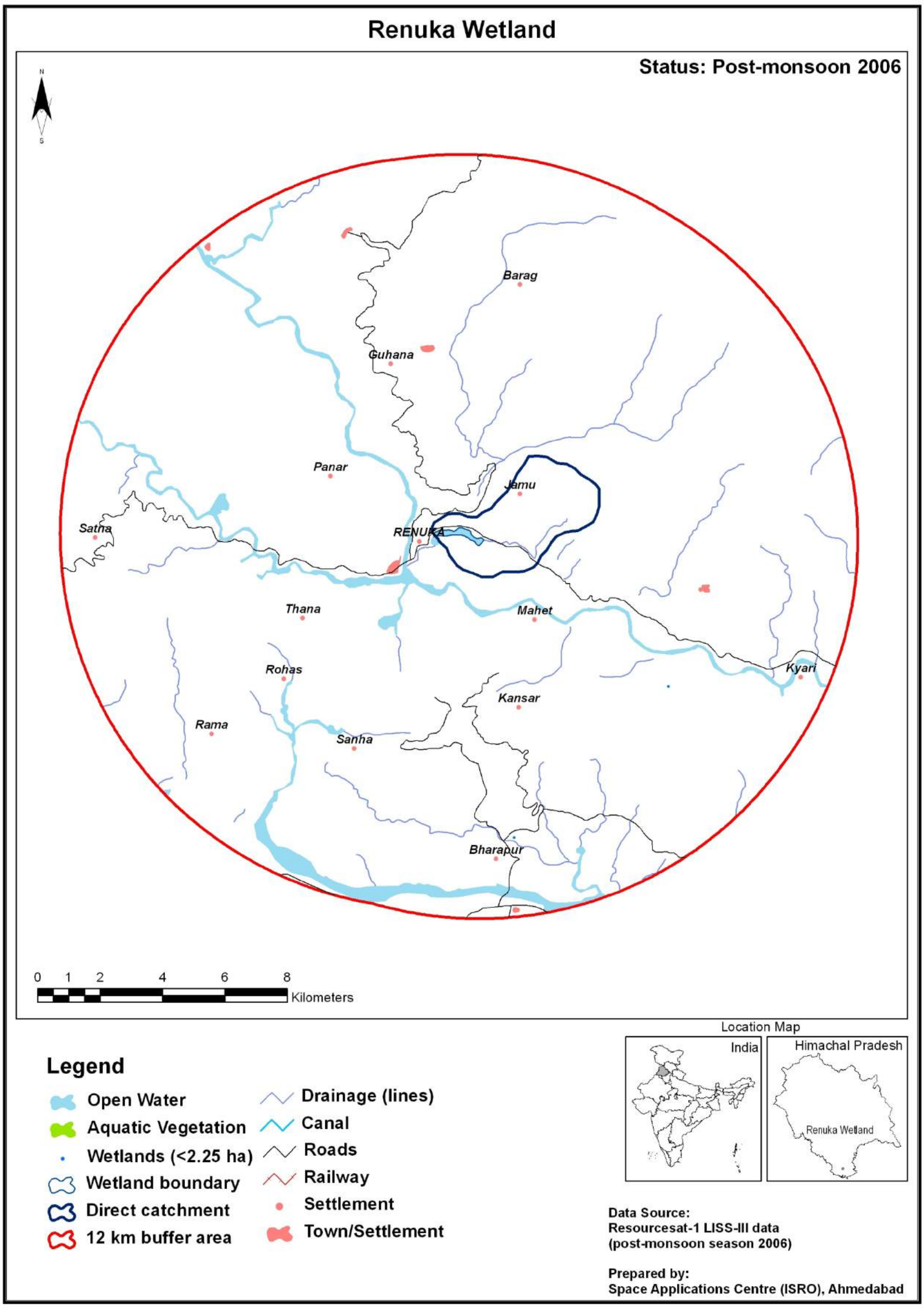

Plate 83: Open-water and vegetation status of Renuka Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

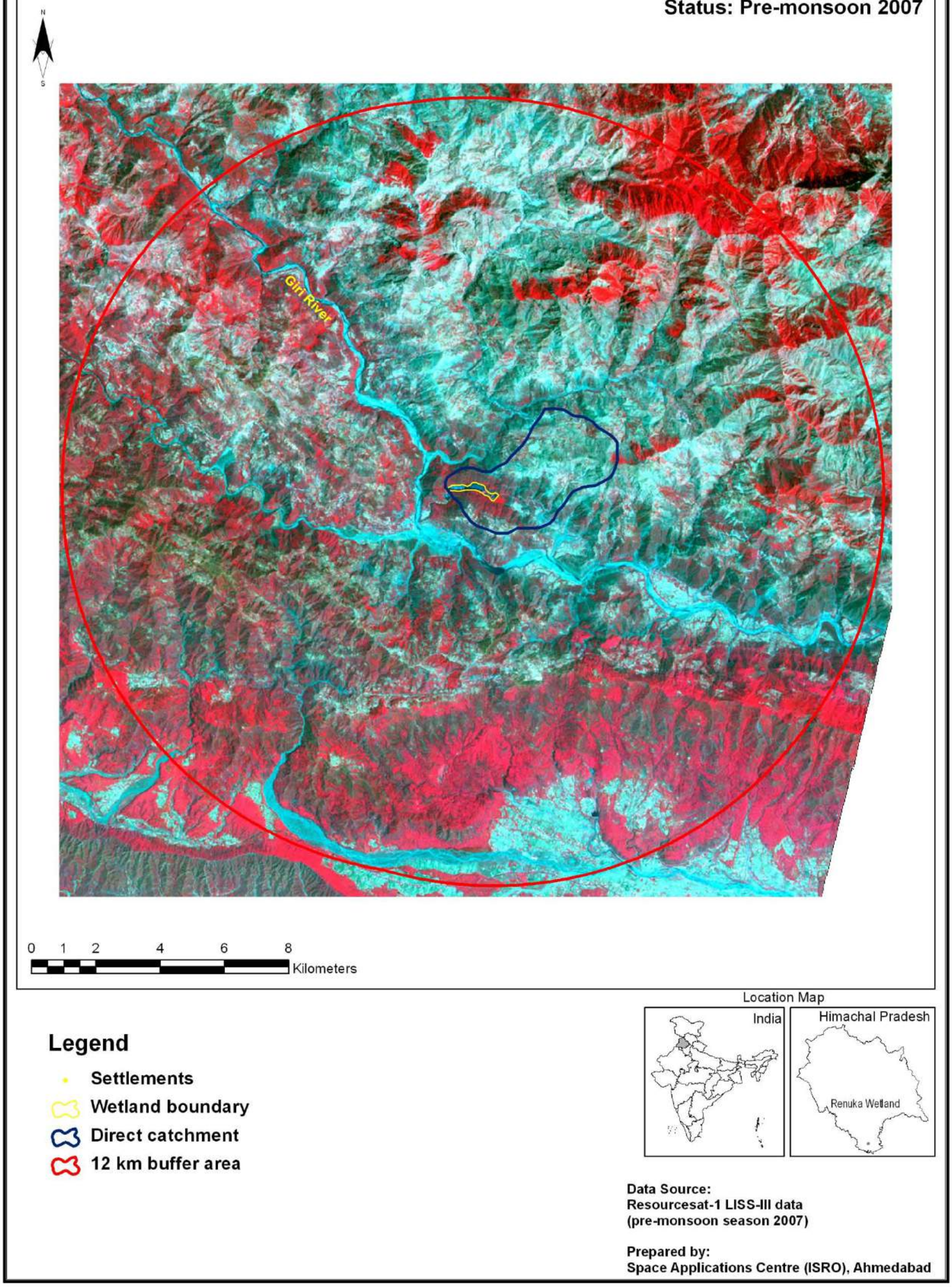

Plate 84: Renuka Wetland and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (09-May-2007)

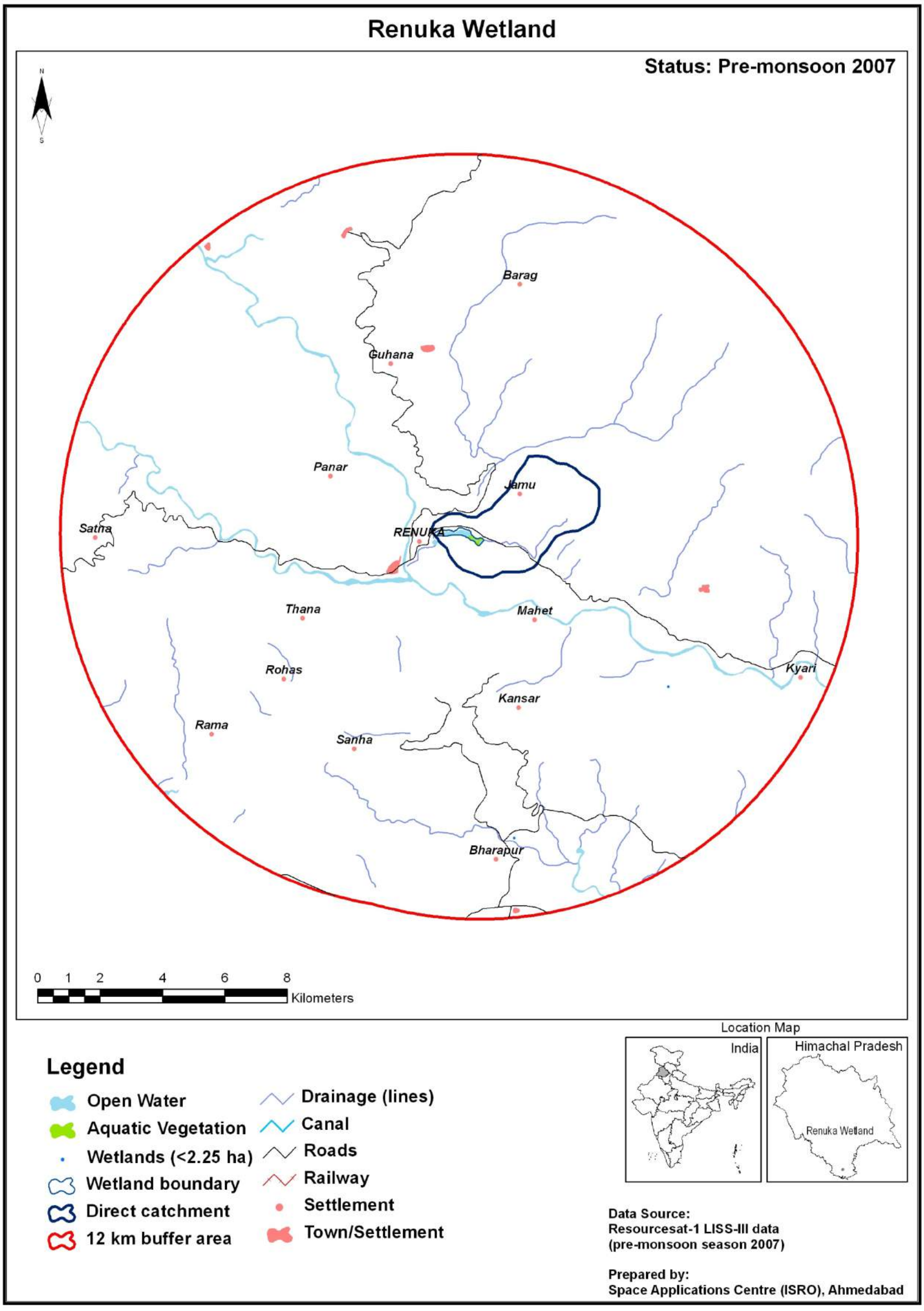

Plate 85: Open-water and vegetation status of Renuka Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.18 Ropar (Ramsar site no. 1161)



Ropar is a man-made impoundment formed after the construction of head regulator on the Sutlej near Ropar town in Punjab. With the construction of main barrage the water is diverted to Bist Doab canal resulting reduced level of impoundment, the depth varying from 0.5 m t0 6.0 m.

Ropar is designated as Ramsar site on 22/01/2002 owing to the compliance of criteria 5 & 6 as described below:

- Wetland regularly supports 20, 000 or more waterbirds.
- Wetland regularly supports 1 % of the individuals in a population of one species or subspecies.

Around 154 species of birds have been recorded. It is an important staging ground for a number of migratory birds. It provides habitat to the endangered turtle *Chitra indica* and threatened snake *Python molurus*. It is also an important breeding site for the globally vulnerable otter *Lutrogale perspicillata* and “at lower risk” mammals such as deer *Axis porcinus* and Indian pangolin. The nationally protected deer *Cervus unicolor* also breeds here.

Ropar wetland observed on Resourcesat-1 LISS-III image is given in the Figure 27.

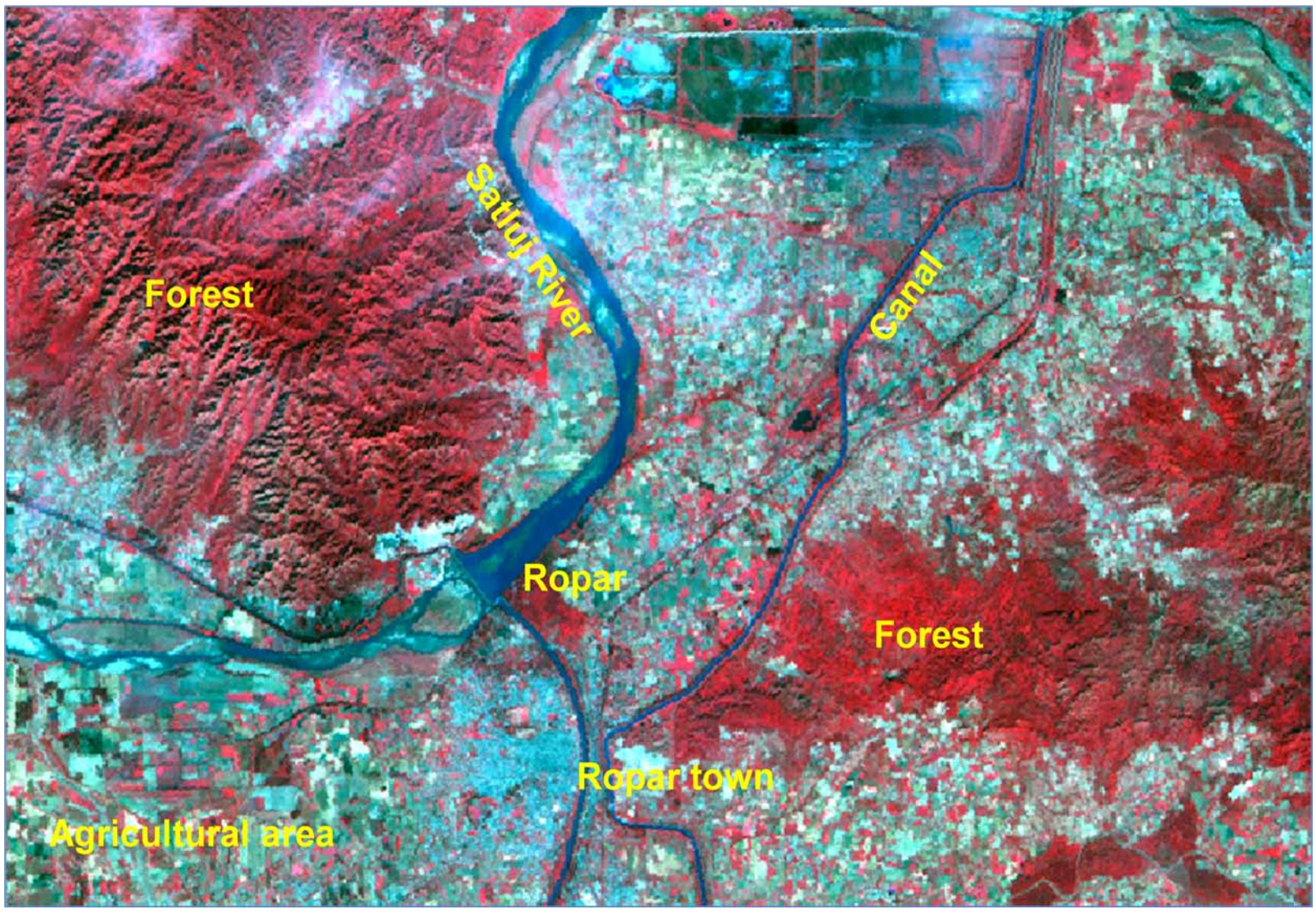

Figure 27: Ropar wetland and its environ as seen in LISS-III FCC (24-December-2006)

Ropar wetland has an extent of 144 ha with 9 km perimeter. Extent under open-water remained unchanged in both the seasons. The extent under vegetation in post-monsoon (3 ha) ha was observed to be completely devoid in pre-monsoon (Table 41).

Table 41: Salient observations of Ropar wetland from satellite data

Name:	Ropar
Location:	$30^0$59'00" to $31^0$00'47" N Latitude $76^0$30'47" to $76^0$32'33" E Longitude
Wetland Type:	Reservoir/Barrage
Wetland Area: Perimeter:	144 ha 9 km
Open-water Post-monsoon: Pre-monsoon:	 141 ha 141 ha
Vegetation Post-monsoon: Pre-monsoon:	 3 ha Nil
Overall Turbidity:	Moderate-High

Ropar wetland has a catchment of 55818 ha including the 12 km buffer area is dominated by hills and agricultural area. River/Stream dominates the wetland types in terms of aerial extent (2135 ha) including the Ropar itself (Table 42).

Table 42: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Ropar wetland

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	3	21	13	9	7	9
1106	River/Stream	11	2135	1173	885	-	-
1201	Reservoir/Barrage	1	144	141	142	3	-
1202	Tank/Pond	10	138	58	74	3	11
	Total	25	2438	1385	1110	13	20

Wetland map of the Ropar catchment including the 12 km buffer area is given in the Plate 86. The seasonal status of open-water spread and vegetation are given in the Plates 87-90 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

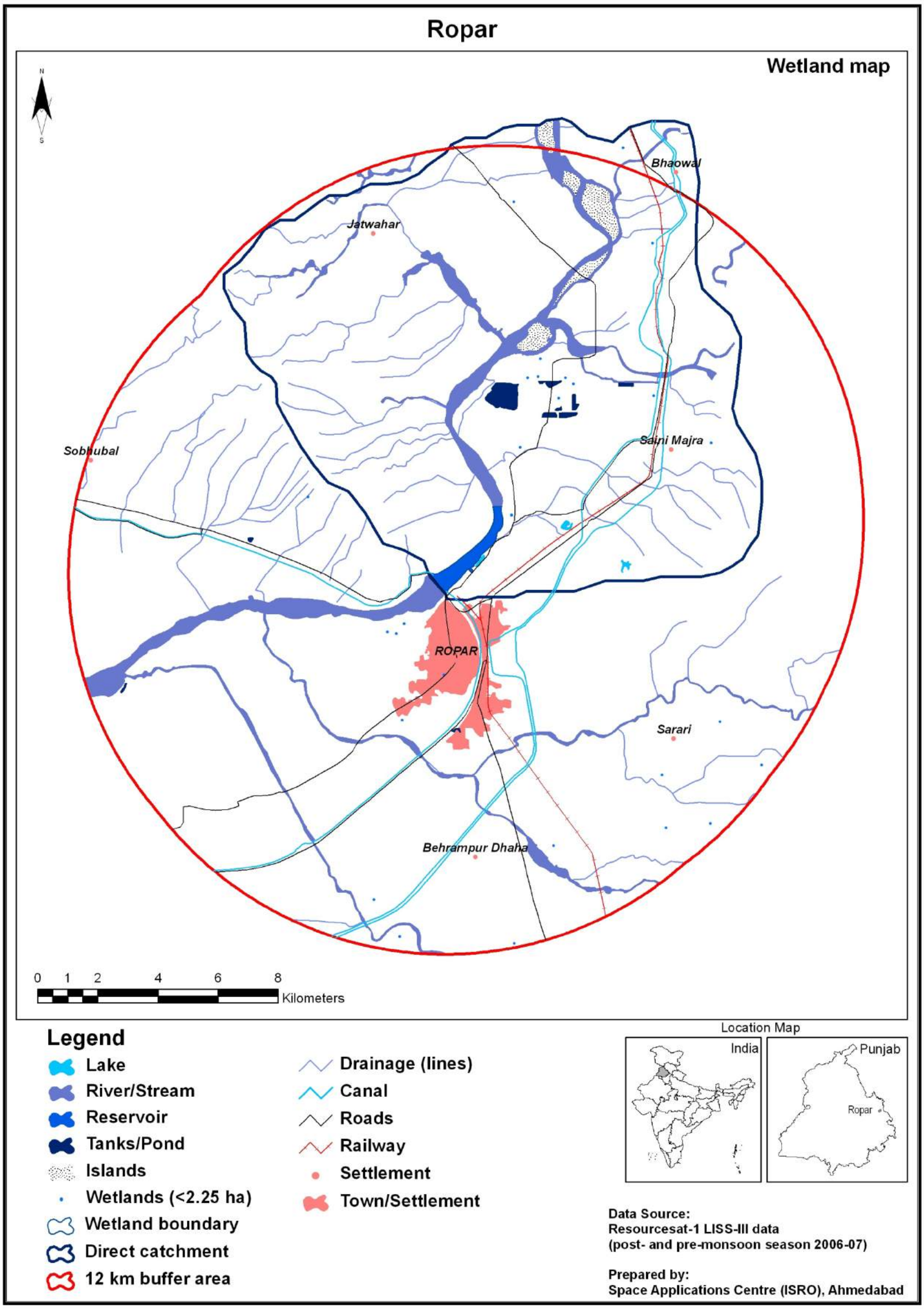

Plate 86: Wetland map of Ropar Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

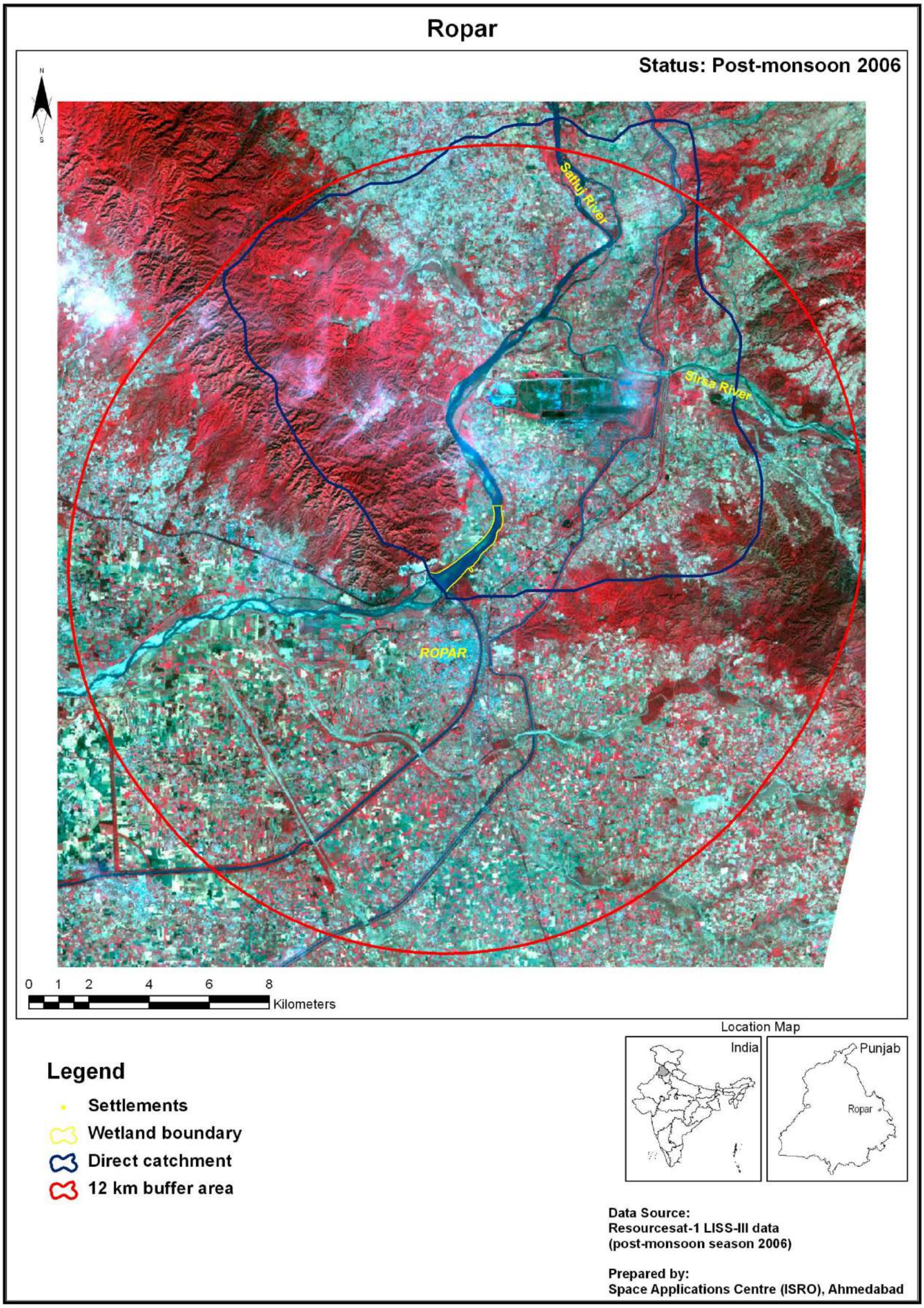

Plate 87: Ropar Wetland and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (24-October-2006)

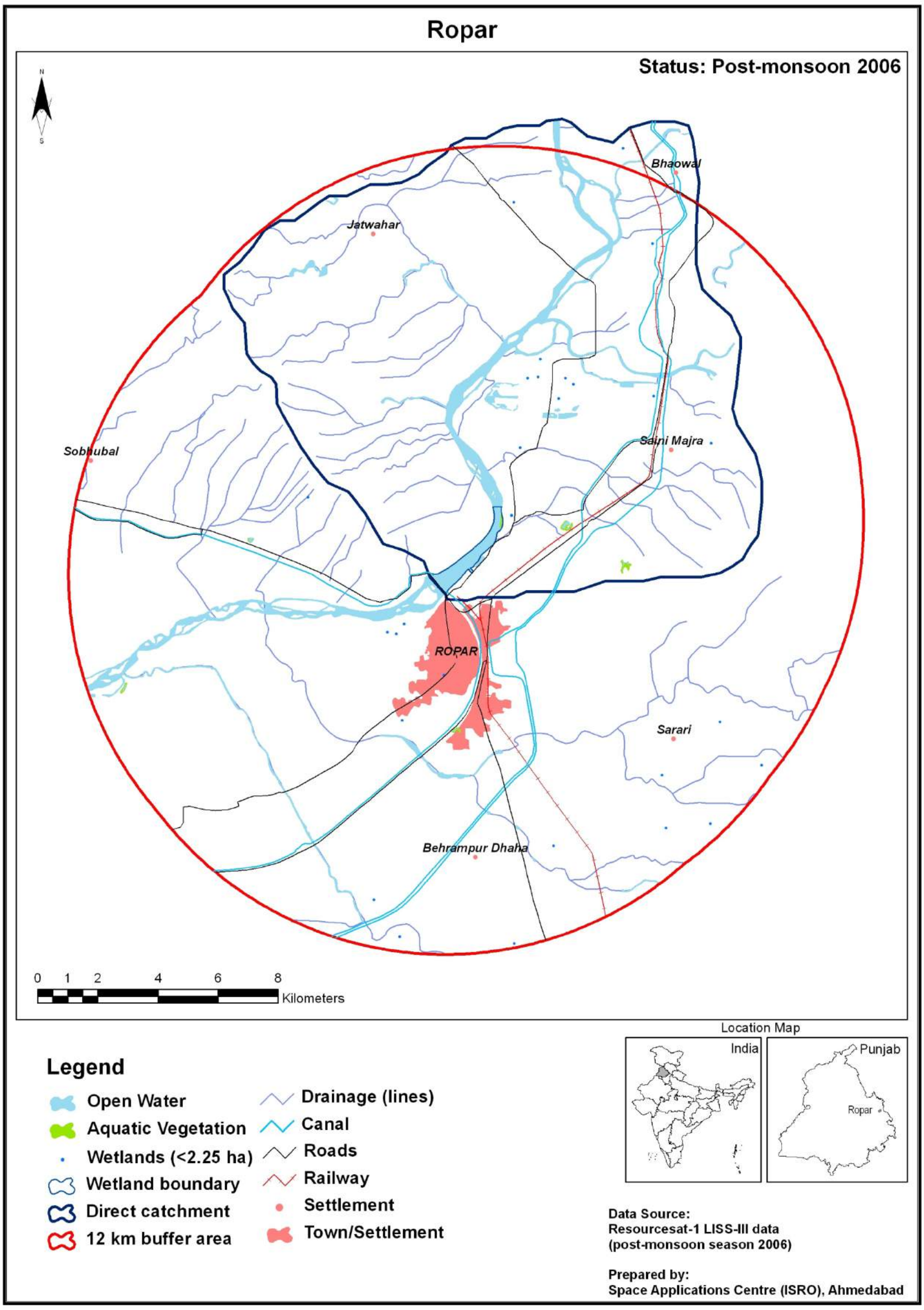

Plate 88: Open-water and vegetation status of Ropar Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

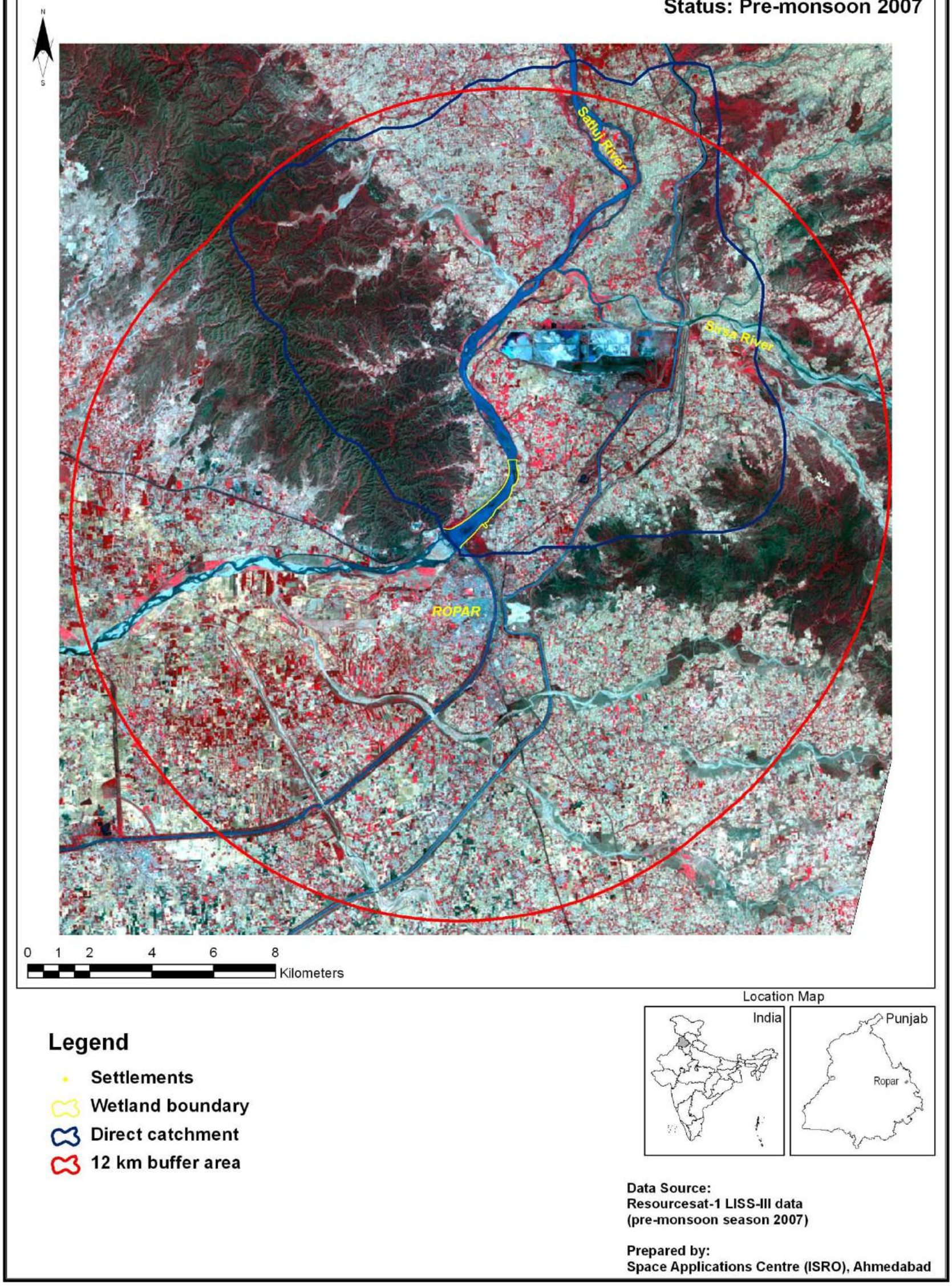

Plate 89: Ropar Wetland and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (10-April-2007)

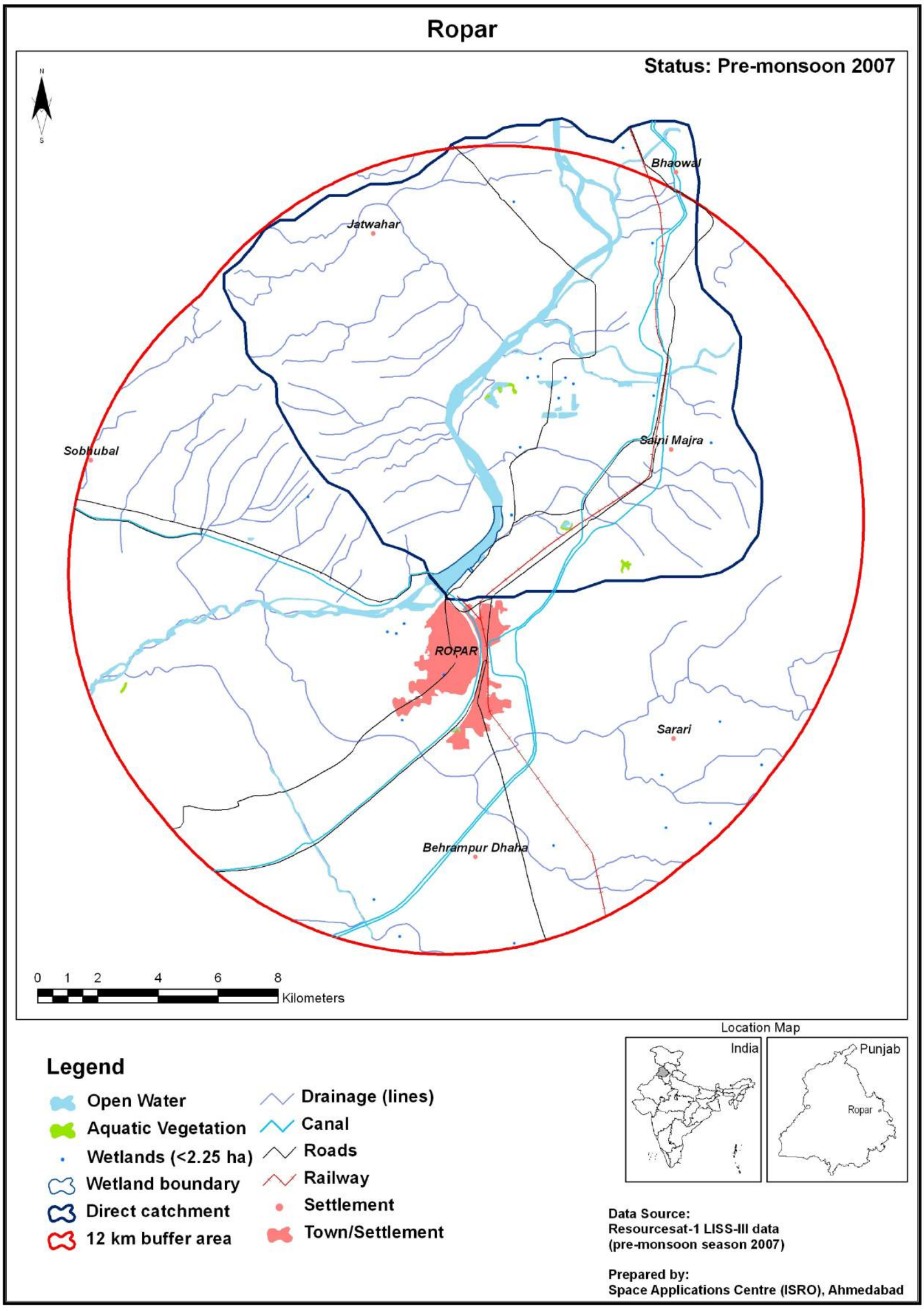

Plate 90: Open-water and vegetation status of Ropar Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.19 Rudrasagar Lake (Ramsar site no. 1572)



Rudrasagar is a natural depression receiving flows from perennial streams. Located about 50 km from Agartala in West Tripura district, Tripura state. Three main streams feed the water to the lake namely; Oacherra, Durlavnaraya Cherra and Kemtali Cherra. The overflow gets discharged through Kachigang into the Gumati River. The lakebed is formed of silt deposition.

It was declared as Ramsar site on 08/11/2005 owing to the compliance of criteria 2, 3 & 8 as described below:

- Wetland supports globally threatened ecological communities.
- Wetland supports populations of animal/plant species important for maintaining biological diversity.
- Wetland supports source of food for fishes.

The wetland is a unique habitat for certain fishes. It comprises of six rare species namely; *Botia* sp*., Cyclinia* sp*., Kachuga* sp*., Macrobrachium* sp*., Notopterus chitala, Oxygstus* sp*.* and nine endangered species namely; *Channa marulius, Cirrhinus reba, Labeo bata, Macrobrachium rosenbergii, M. rude, Mystus aor, M. gulio, Notopterus chitala* and *Ompak paba. The lake support diverse aquatic vegetation.* The lake having perennial connection with one of the major rivers facilitates the natural breeding ground for fish, freshwater turtle and tortoise. The wetland supports IUCN Red listed endangered Three-striped Roof turtle (*Kachuga dhongka*).. Rudrasagar Lake as observed on Resourcesat-1 LISS-IV image is given in the Figure 28.

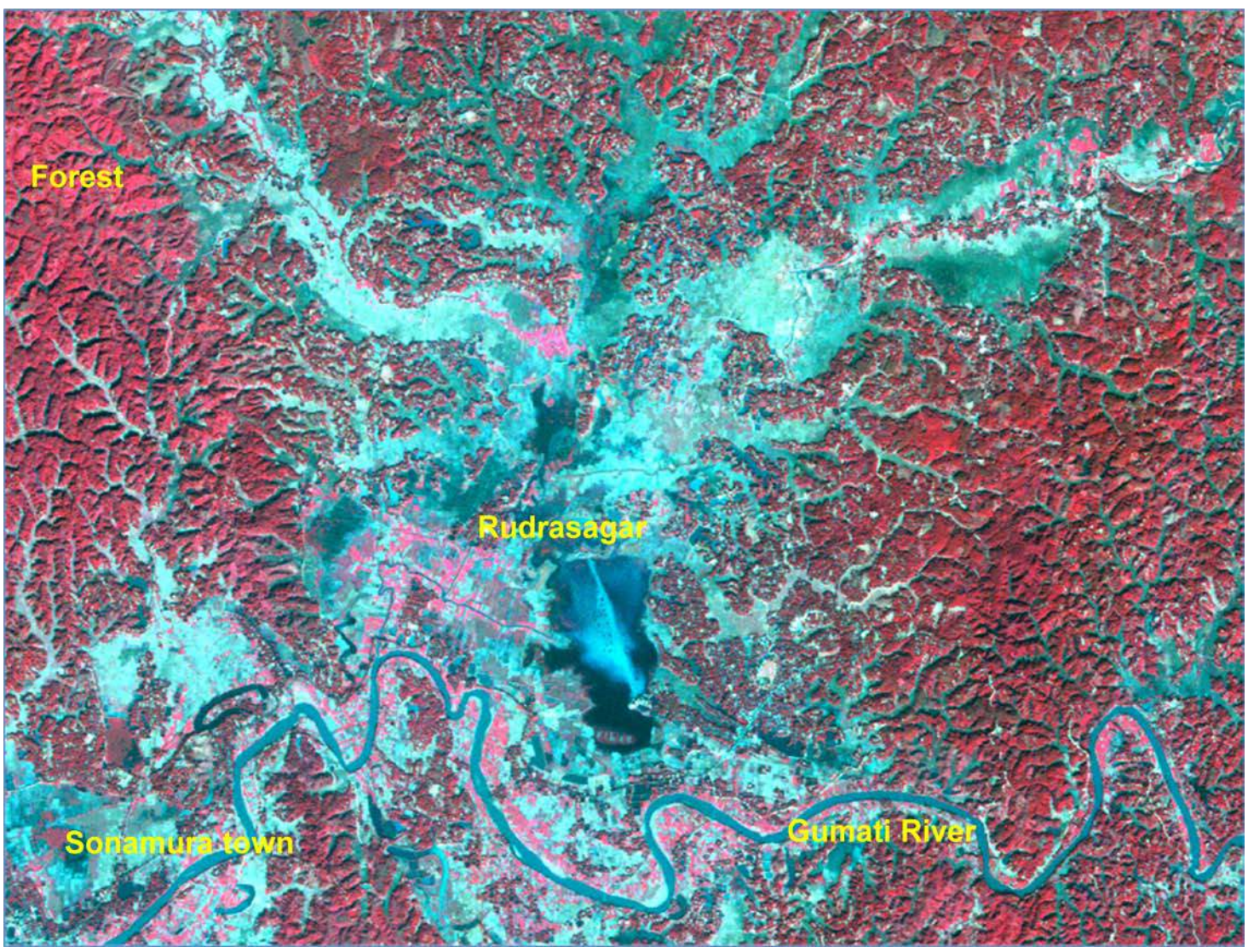

Figure 28: Rudrasagar Lake and its environ as seen in LISS-IV FCC (29-December-2007)

Rudrasagar Lake has an extent of 688 ha with a perimeter of 68 km. The area under open-water got reduced to 145 ha in the pre-monsoon compared to the extent in the post-monsoon (547 ha). Vegetation has almost increased by 3 times from post-monsoon (141 ha) to 543 ha in pre-monsoon. Wetland type-wise area estimates and seasonal changes in terms of open-water and vegetation are given in Table 43.

Table 43: Salient observations of Rudrasagar Lake from satellite data

Name:	Rudrasagar Lake
Location:	$23^0$29'10" to $23^0$32'52" N Latitude $91^0$17'23" to $91^0$20'04" E Longitude
Wetland Type:	Waterlogged (Natural)
Wetland Area: Perimeter :	688 ha 68 km
<u>Open-water</u> Post-monsoon: Pre-monsoon:	 547 ha 145 ha
<u>Vegetation</u> Post-monsoon: Pre-monsoon:	 141 ha 543 ha
Overall Turbidity:	Moderate-High

The catchment including the 12 km buffer area extends over 69917 ha. There are 74 wetlands with an aerial extent of 2117 ha out of which the Rudrasagar Lake accounts for 688 ha (32 %). Overall, the seasonal change in open-water is almost a 3 times reduction from post-monsoon (1563 ha) to pre-monsoon (582 ha). Vegetation has shown an increasing trend from post-monsoon (451 ha) to 1438 ha in pre-monsoon.

Table 44: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Rudrasagar Lake

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	7	28	21	14	8	15
1102	Ox-bow Lake/Cut-off Meander	18	93	67	40	26	54
1105	Waterlogged	45	1305	983	218	322	1087
1106	River/Stream	1	390	287	292	-	-
1201	Reservoir/Barrage	2	296	201	14	95	282
1202	Tank/Pond	1	4	4	4	-	-
	Total	74	2116	1563	582	451	1438

Wetland map of the Rudrasagar Lake catchment including the 12 km buffer area is given in the Plate 91. The seasonal status of open-water spread and vegetation are given in the Plates 92-95 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

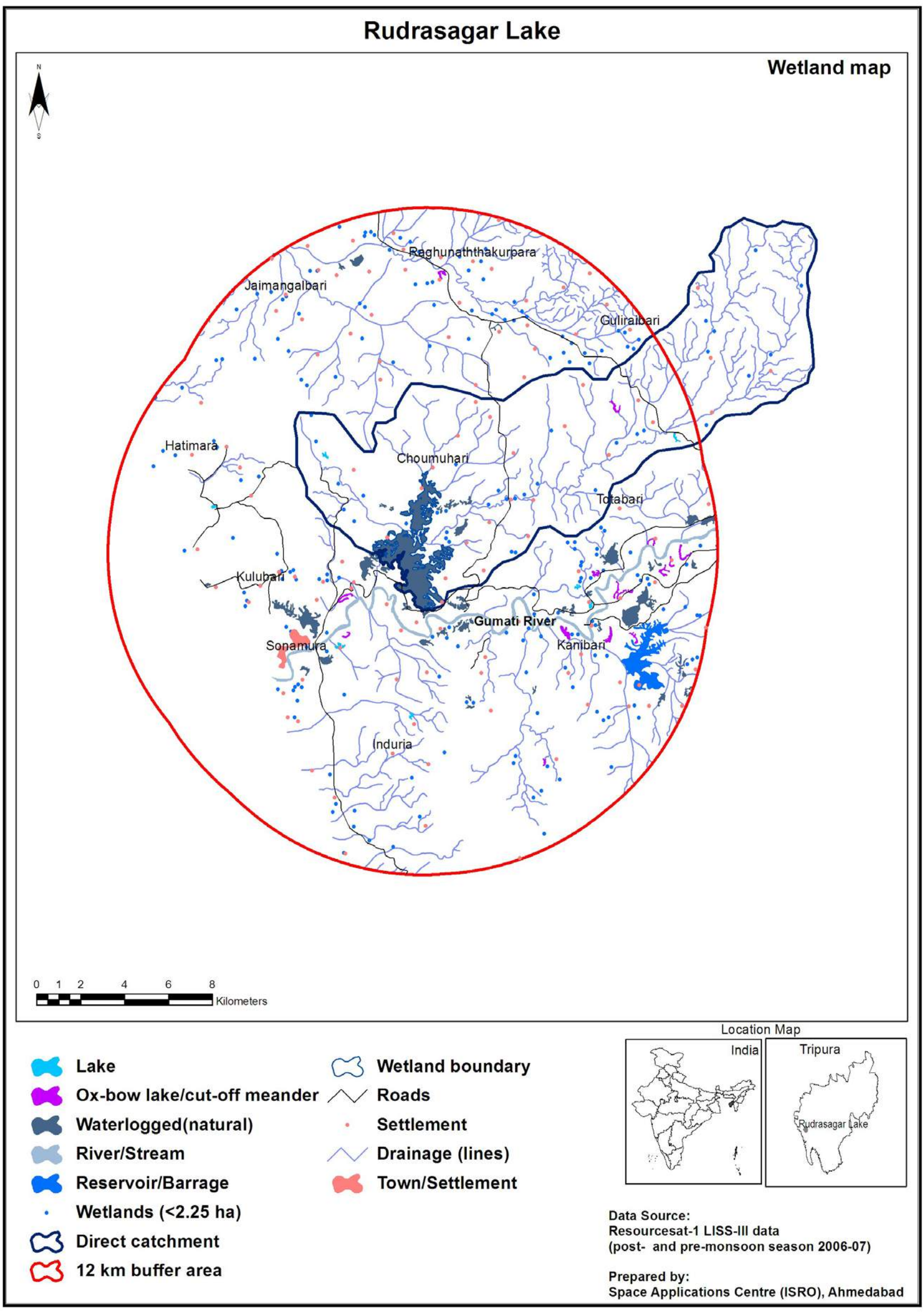

Plate 91: Wetland map of Rudrasagar Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

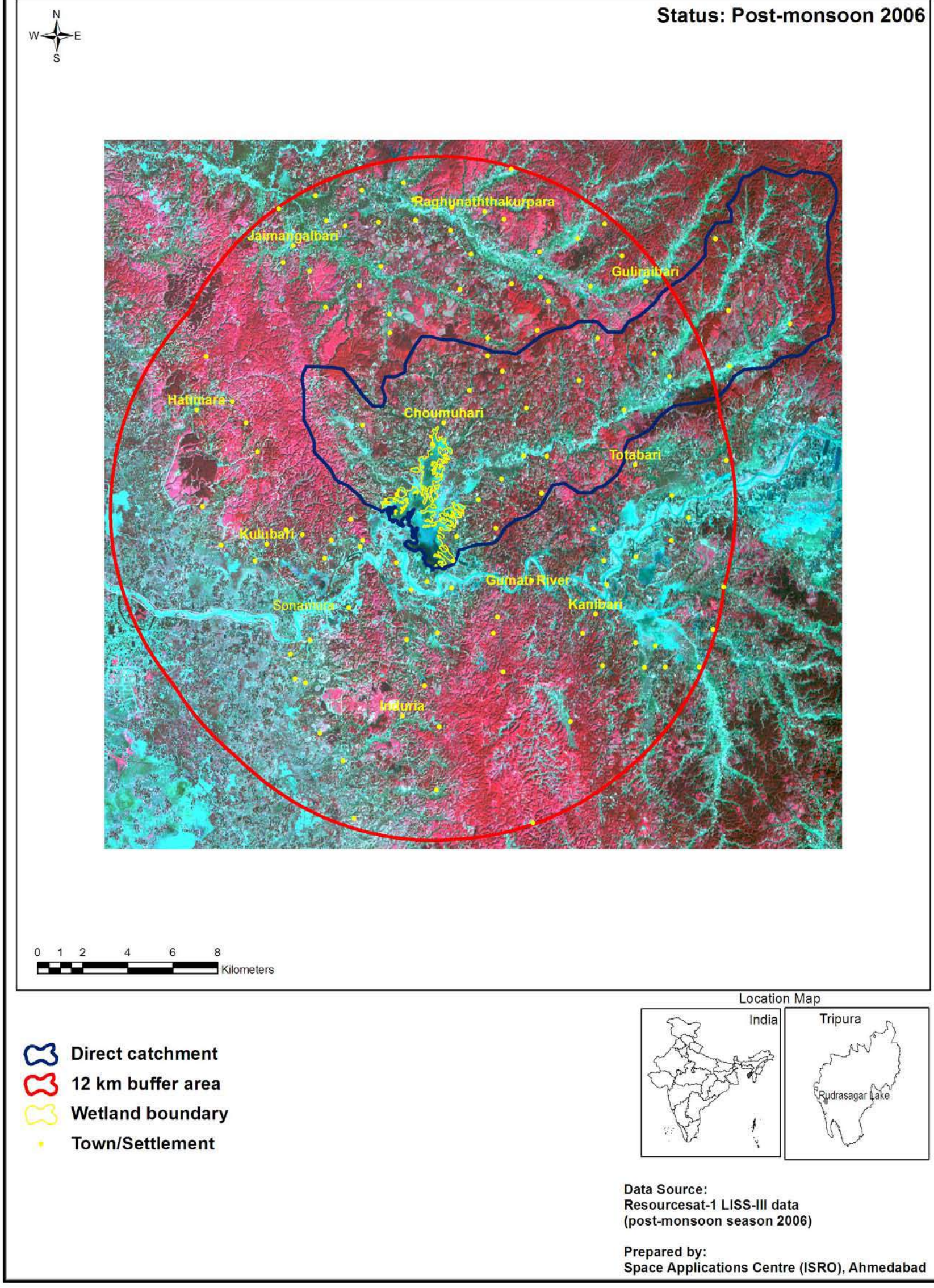

Plate 92: Rudrasagar Lake and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (30-November-2006)

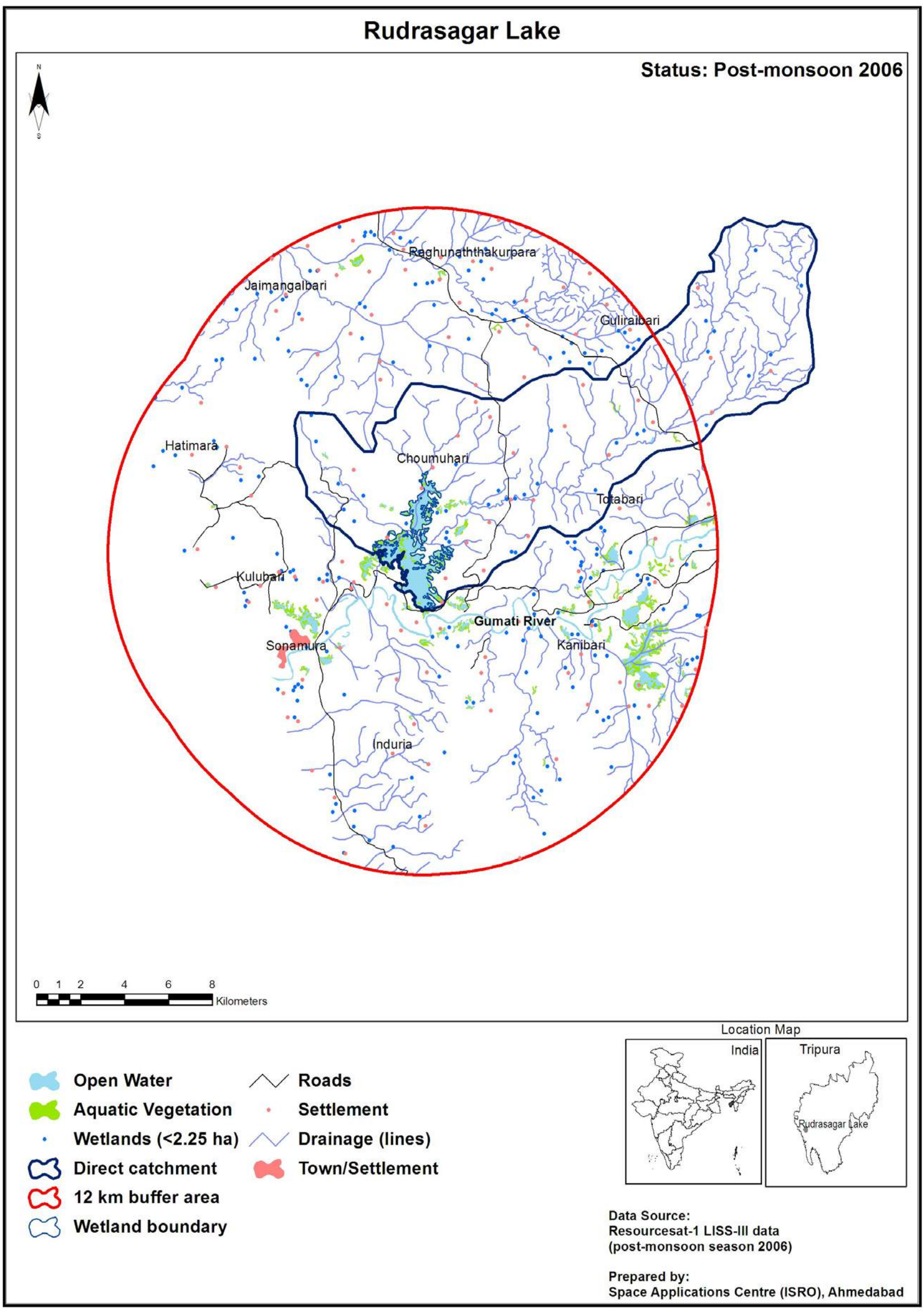

Plate 93: Open-water and vegetation status of Rudrasagar Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

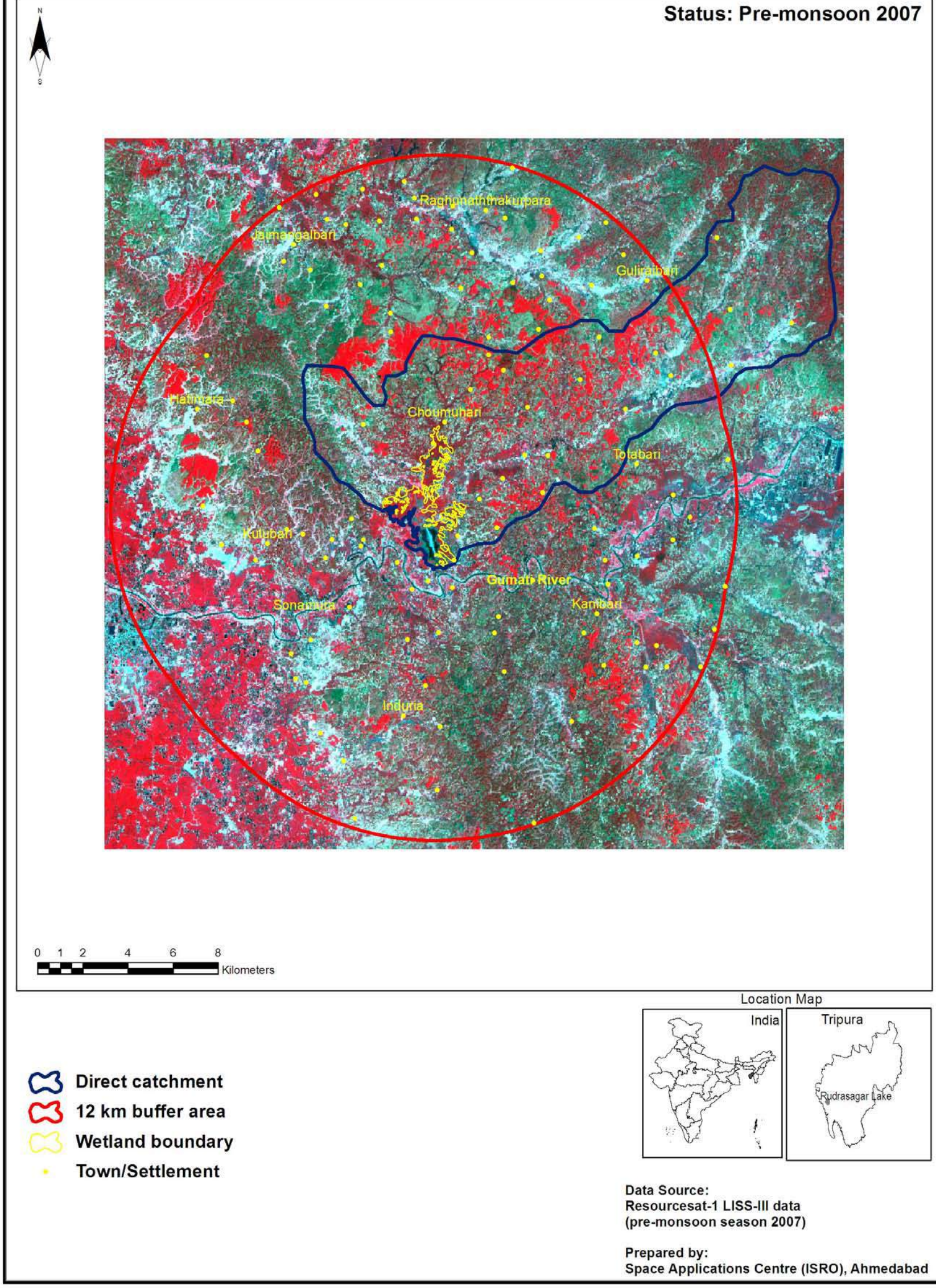

Plate 94: Rudrasagar Lake and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (30-March-2007)

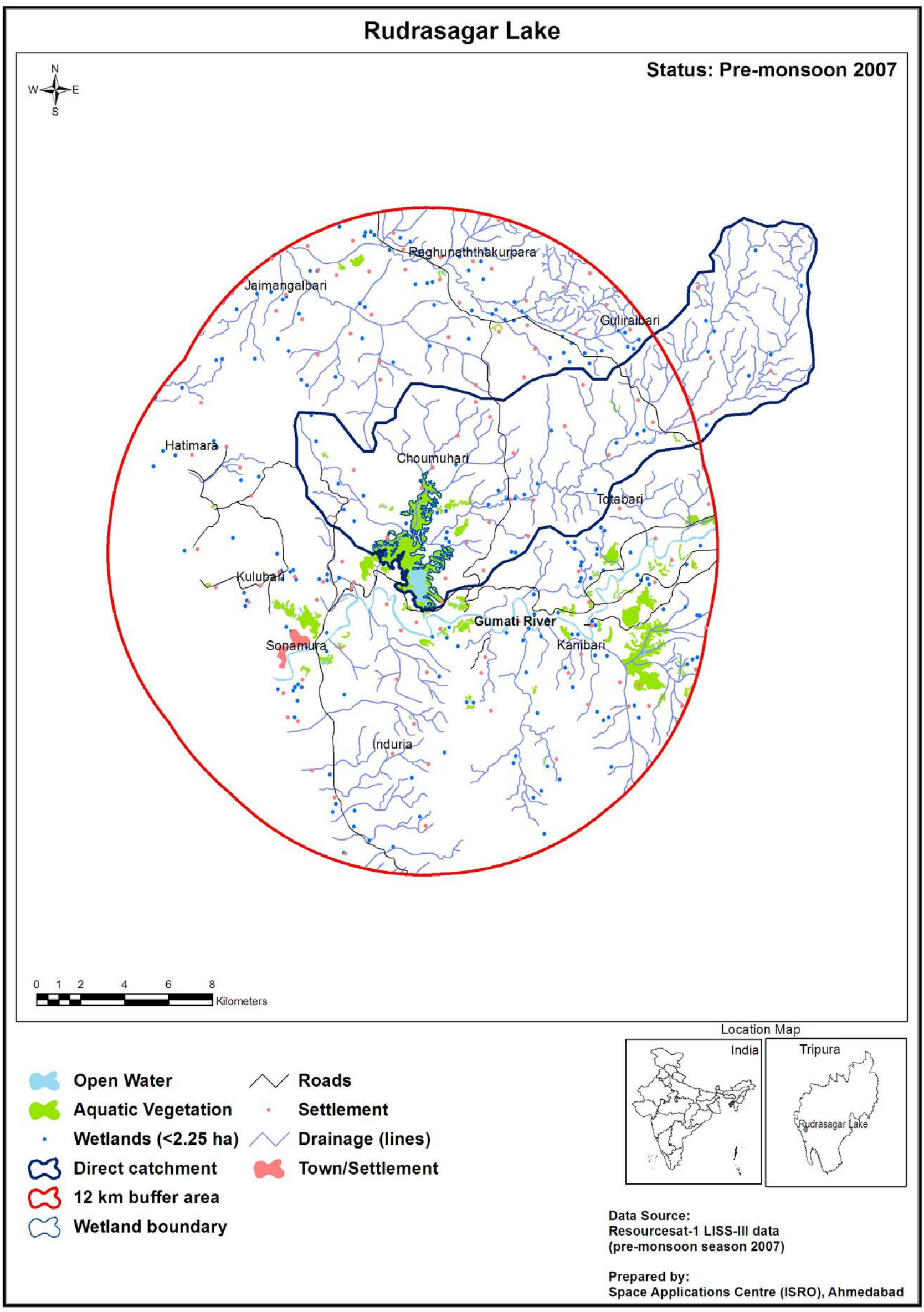

Plate 95: Open-water and vegetation status of Rudrasagar Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.20 Sambhar Lake (Ramsar site no. 464)



Sambhar Lake is the largest saline natural lake located in Rajasthan. The average depth is 3 meters in the monsoon while in pre-monsoon it becomes very shallow (< 1m). During monsoon season it receives rain water from its catchments through mendha river. There are thousands of salt plan constructed at the periphery of the Sambar Lake.

The Lake was designated as a Ramsar site on 23/03/1990 owing to the compliance of criteria 2, 5 & 6 as described below:

- Wetland supports threatened ecological communities.
- Wetland regularly supports 20, 000 or more waterbirds.
- Wetland regularly supports 1 % of the individuals in a population of one species or subspecies.

It is shallow lake with varying depth from 0.5 m to 2 m. About 45 species of birds have been recorded. During winter, it receives tens of thousands of birds some migrating from as far north as Siberia. Some of the common birds recorded are: lesser flamingo, greater flamingo, tufted duck, pochard, white pelican, brown-headed gull, black-headed gull, herring gull, redshank, greenshank, common sandpiper, blackwinged stilt, pintail, shoveler, dabchick, purple moorhen, demoiselle crane, large Indian pratincole, and avocet. The greater and lesser flamingos are regular visitors. Sambhar Lake assumes its importance for harbouring large number of flamingos, next only to Rann of Kuctchch in the country. The vegetation present in the catchment area in mostly *xerophytic* type. Shoreline vegetation includes the halophytes *Suaeda fruticosa, Solsola baryosma* and *Cressa cretica*. The most dominant algae in Sambhar Lake and the salt pans are *Dunaliella salina*, *Chlmydomonas sp., Anabaena sp*. Sambhar Lake as observed on Resourcesat-1 LISS-III image is given in the Figure 29.

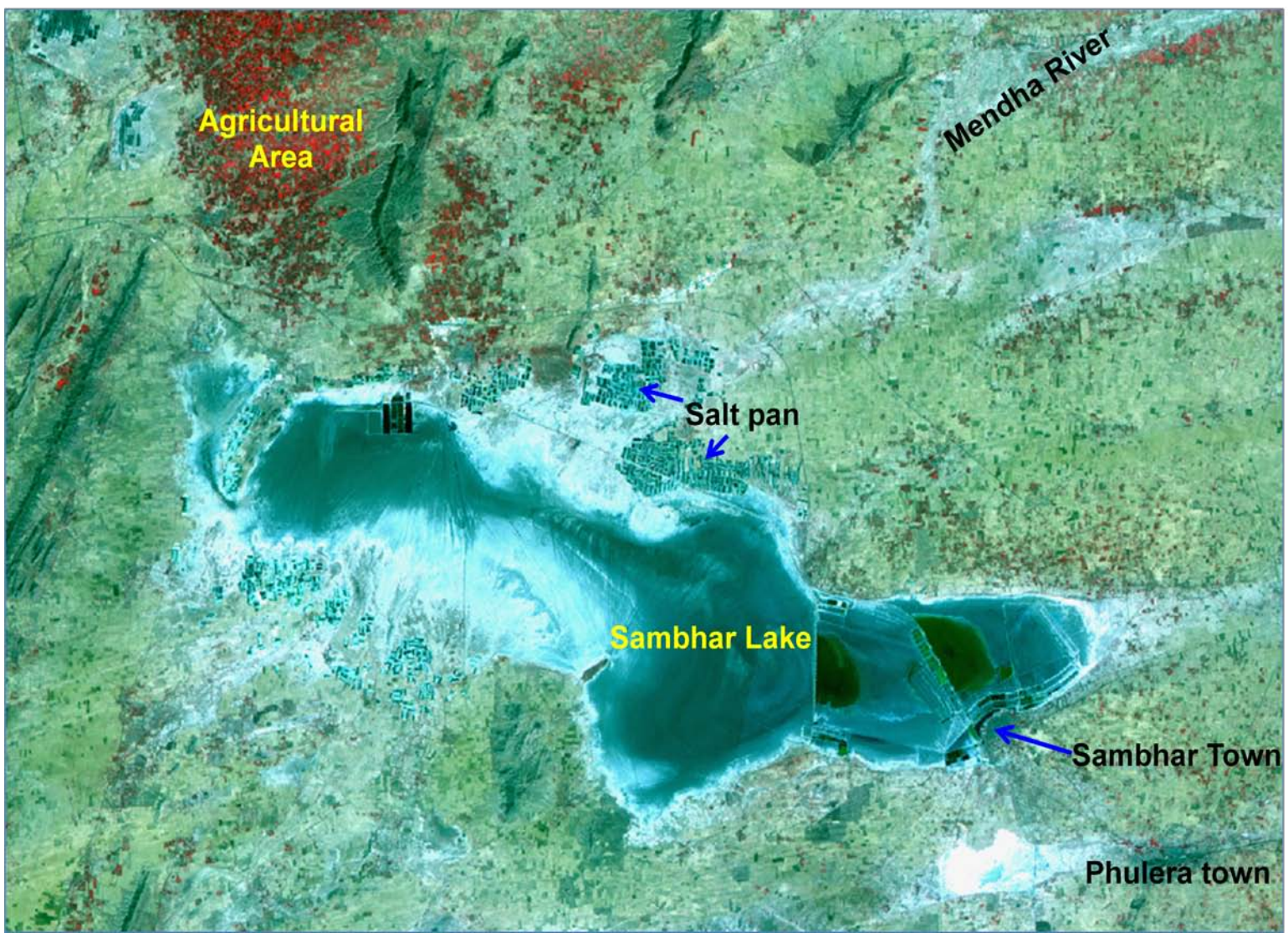

Figure 29: Sambhar Lake and its environ as seen in LISS-III FCC (05-October-2006)

Sambhar Lake has an aerial extent of 24294 ha. Area under open-water in Post-monsoon is 17866 ha had shown a decrease of about 7 % in pre-monsoon (Table 45). The wetland is devoid of vegetation.

Table 45: Salient observations of Sambhar Lake from satellite data

Name:	Sambhar Lake
Location:	26°51'56" to 27°03'19" N Latitude 74°53'30" to 75°14'14" E Longitude
Wetland Type:	Lake/Pond
Wetland Area: Perimeter :	24294 ha 229 km
Open-water Post-monsoon: Pre-monsoon:	 17866 ha 16601 ha
Vegetation Post-monsoon: Pre-monsoon:	 Nil Nil
Overall Turbidity:	High

Sambhar Lake has a large catchment including the 12 km buffer area (468329 ha) and dominated by agriculture and barren land use. The other wetland types are mainly manmade Tank/ponds and salt pans. Vegetation is not observed in the catchment. The details for each of wetland type present in the catchment and buffer area are given in the Table 46.

Table 46: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Sambhar Lake

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	3	24308	16170	14807	-	-
1106	River/Stream	5	7396	-	-	-	-
1201	Reservoir/Barrage	1	83	64	-	-	-
1202	Tank/Pond	23	306	200	49	-	-
1204	Salt Pan	27	4079	2597	2215	-	-
	Total	59	36172	19031	17071	-	-

Wetland map of the Sambhar Lake catchment including the 12 km buffer area is given in the Plate 96. The seasonal status of open-water spread and vegetation are given in the Plates 97-100 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

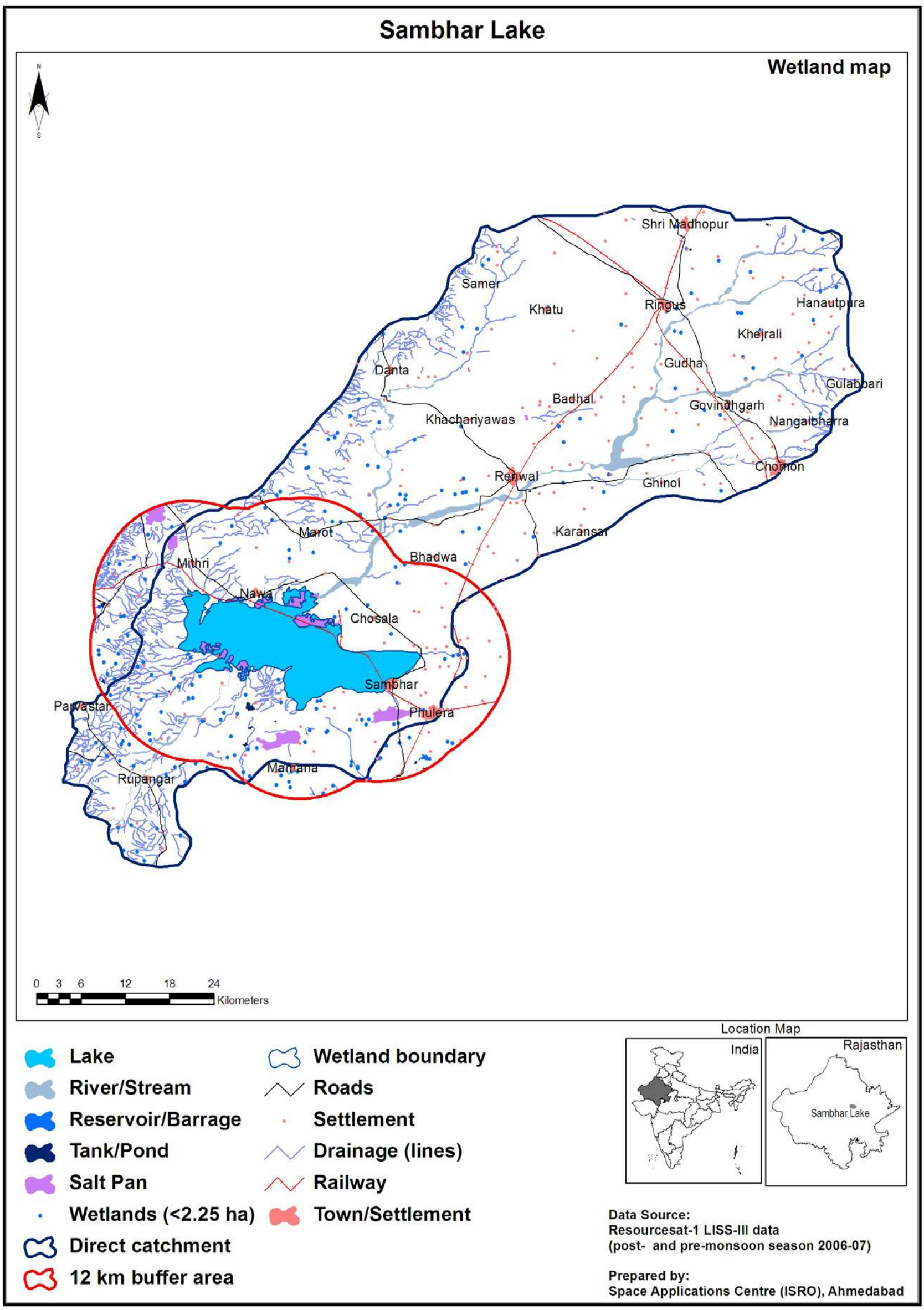

Plate 96: Wetland map of Sambhar Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

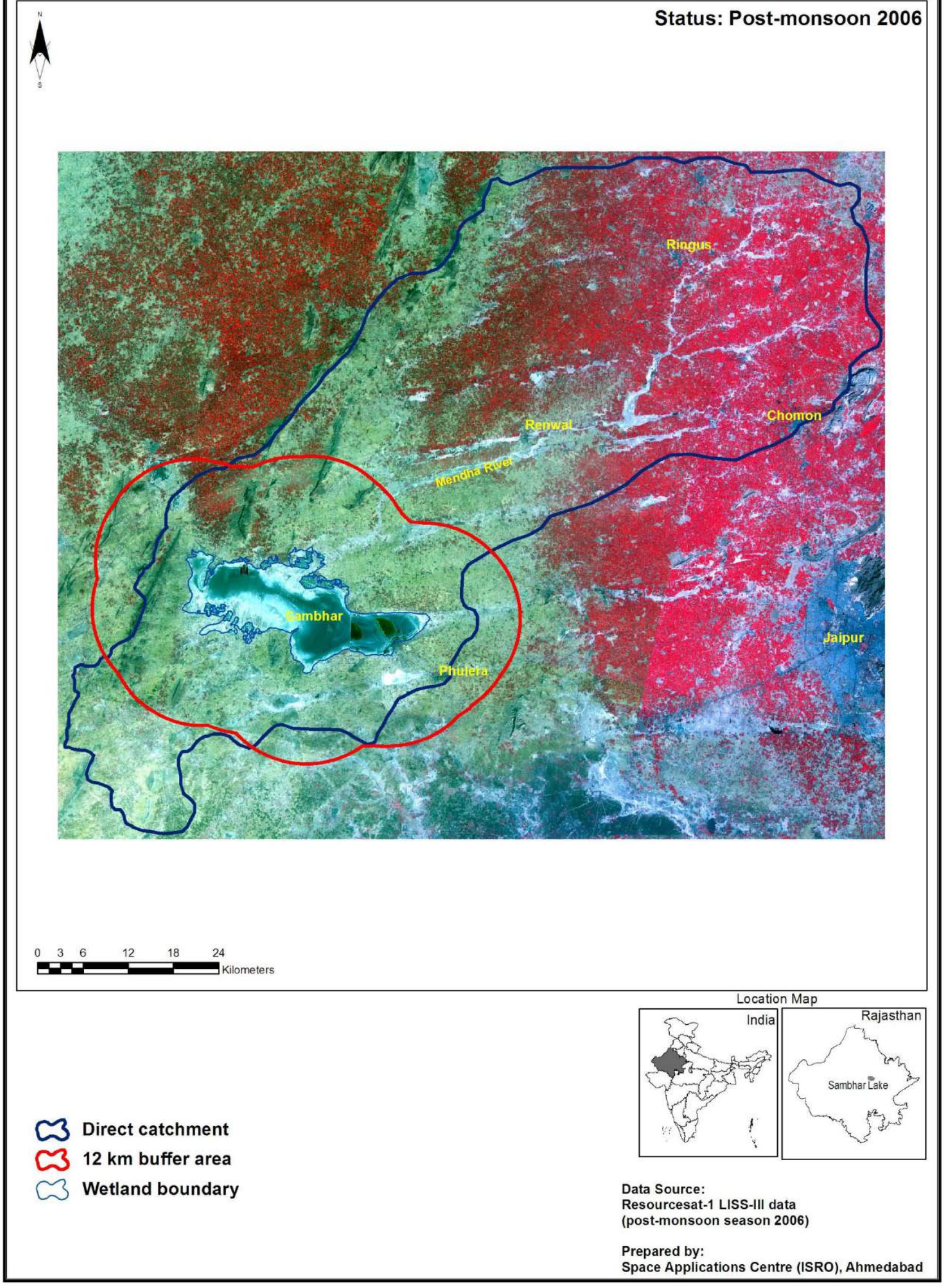

Plate 97: Sambhar Lake and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (05-October-2006)

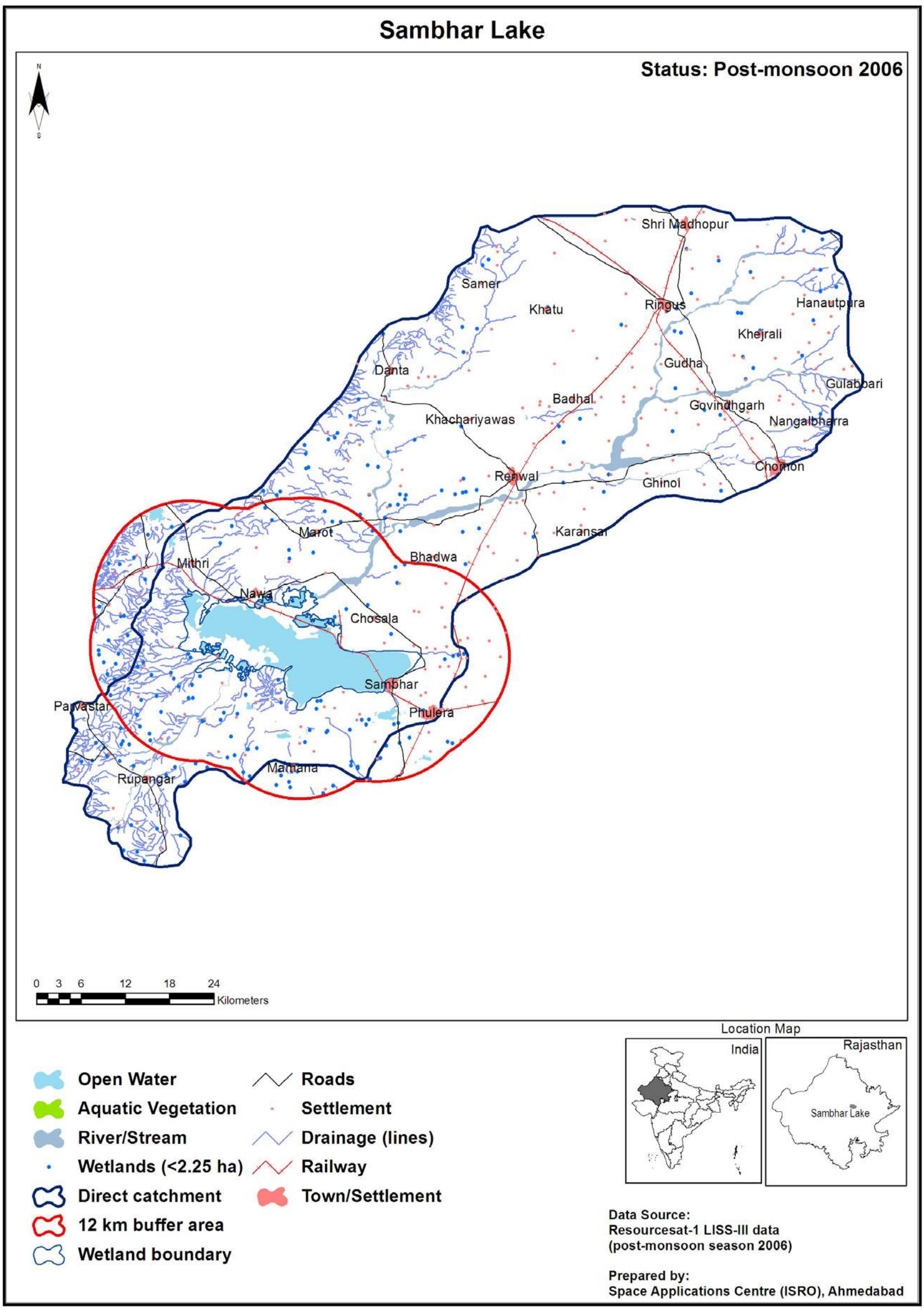

Plate 98: Open-water and vegetation status of Sambhar Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

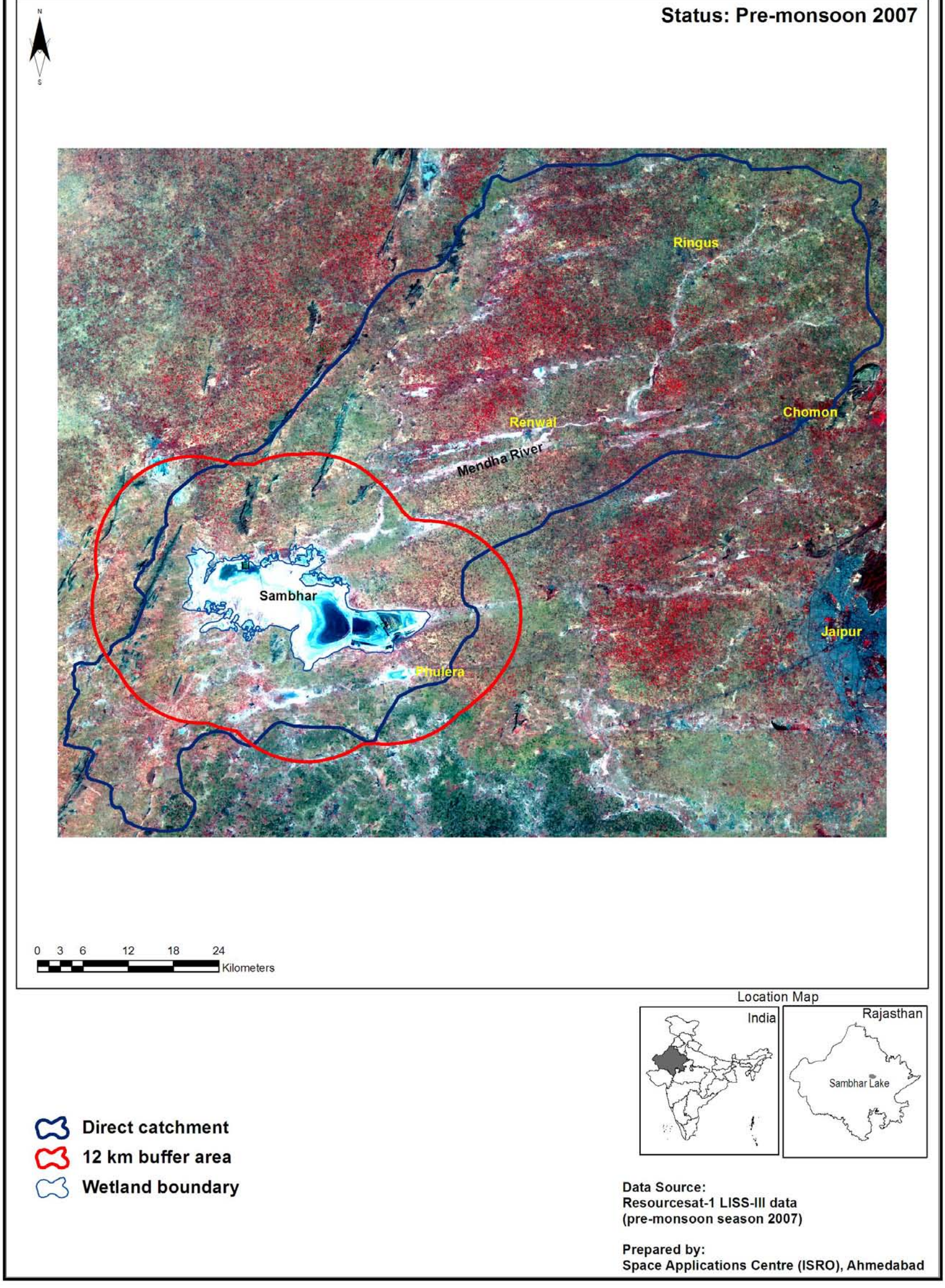

Plate 99: Sambhar Lake and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (08-March-2007)

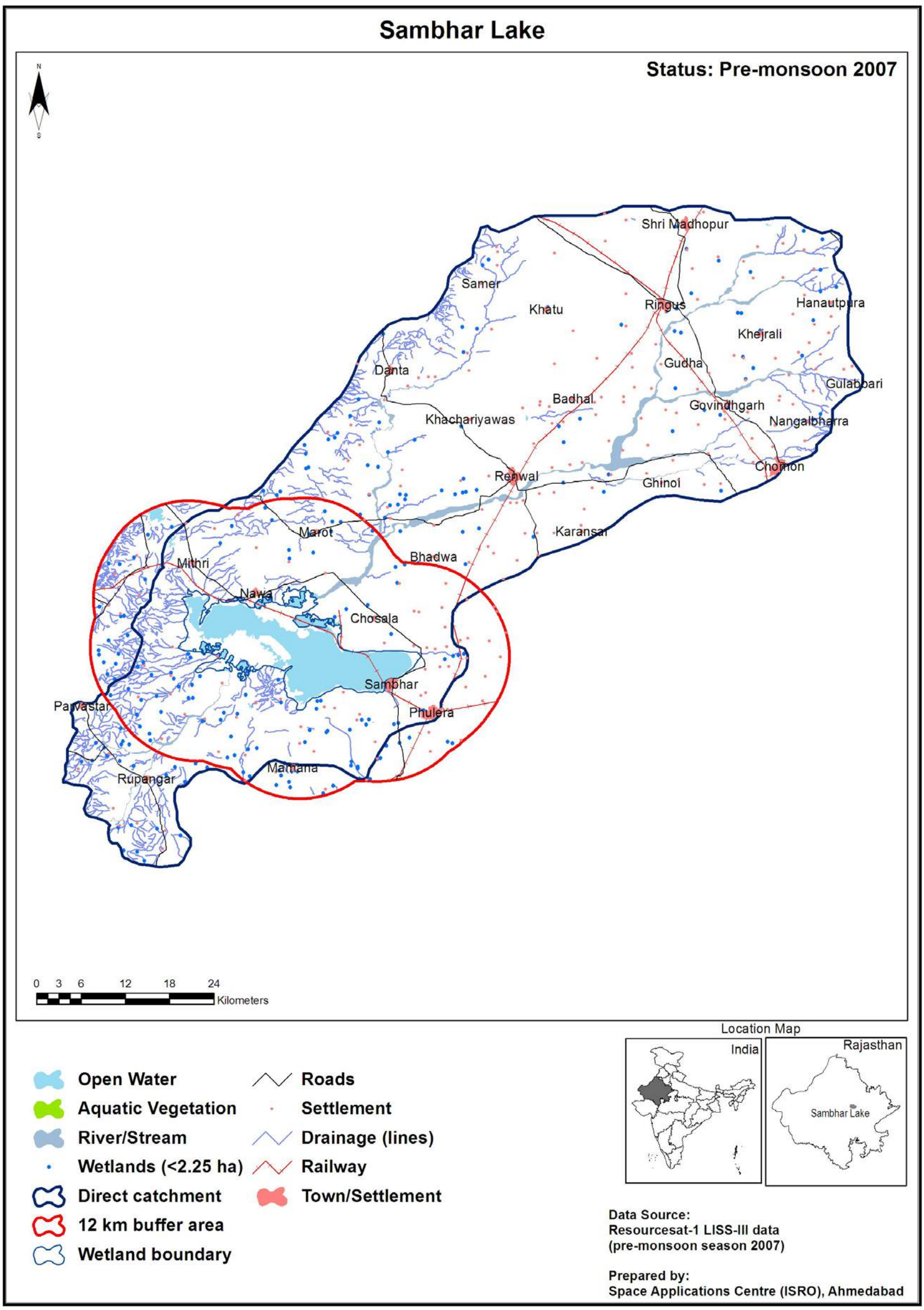

Plate 100: Open-water and vegetation status of Sambhar Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.21 Sasthamkotta Lake (Ramsar site no. 1212)



The Sasthamkotta Lake is a freshwater lake situated on the right bank of Kallad river in Kollam district if Kerala. The source of water is from underground springs. It is the most important source of drinking water to almost half million people of Kollam district.

It was declared as Ramsar site on 19/08/2002 owing to the compliance of criteria 1, 2, 7 & 8 as described below:

- A representative and unique wetland type.
- Wetland supports threatened ecological communities.
- Wetland supports significant proportion of indigenous fish biota
- Wetland supports important source of food for fishes.

It is an unique fresh water lake, fed by underground springs and the water is free from common salt and minerals and metals. It supports critically endangered and vulnerable fish species. It supports 27 species of fish that depend for food, spawning and nursery. The most common fish in the lake is *Callichrous bimaculatus* and *Wallago attu*. Conspicuously, the wetland is devoid of aquatic flora. Phytoplankton is scarce. Bonnet monkeys frequent the banks. Notable migratory birds are teals. Sasthamkotta Lake as observed on satellite image along with field photographs Figure 30.

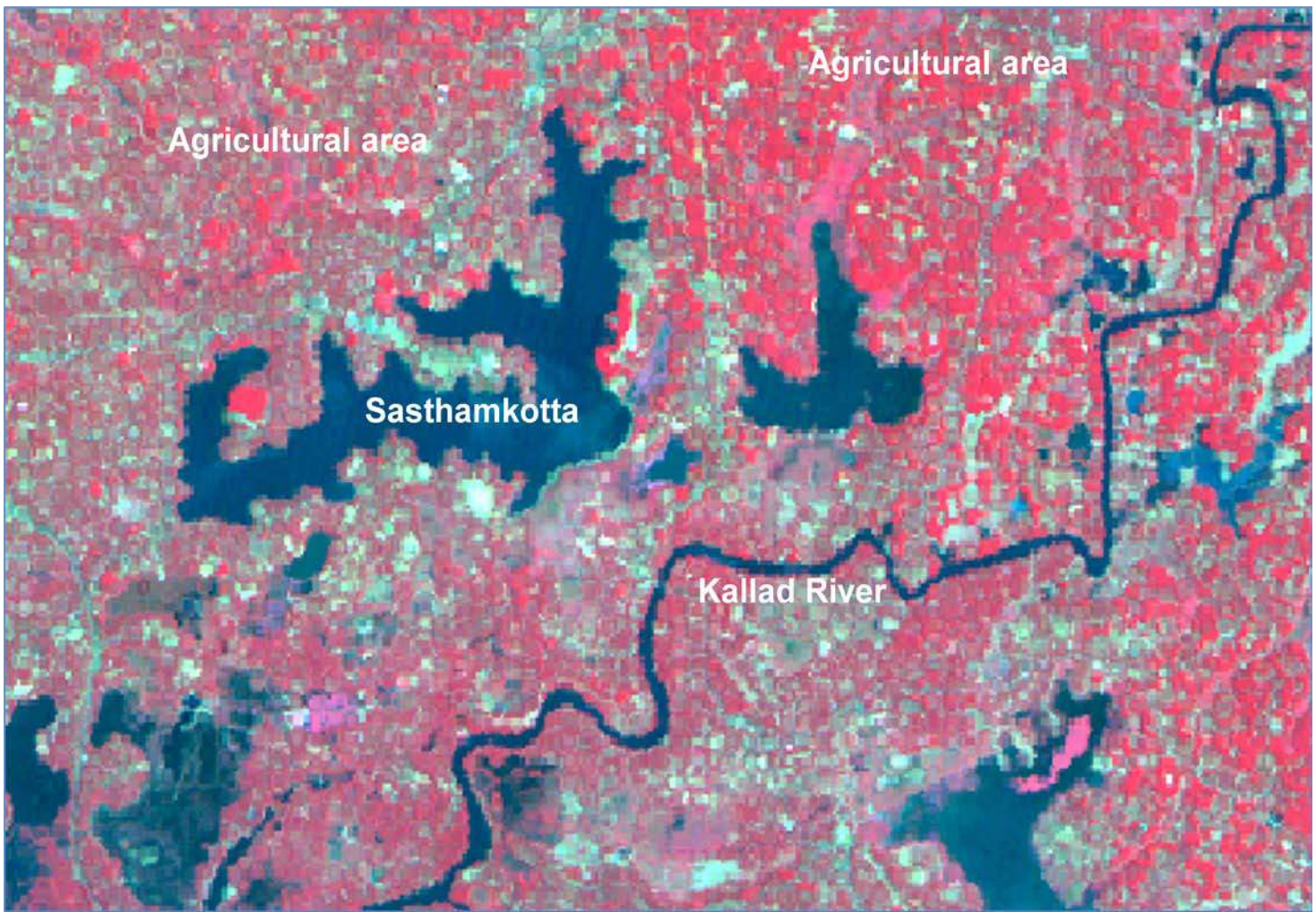

Figure 30: Sasthamkotta Lake and its environ as seen in LISS-III FCC (23-March-2007)

Sasthamkotta Lake has an extent of 354 ha with 22 km of perimeter. The open-water spread remained unchanged for both seasons at 354 ha (Table 47). This site is devoid of vegetation.

Table 47: Salient observations of Sasthamkotta Lake from satellite data

Name:	Sasthamkotta Lake
Location:	09°01'32" to 09°03'23" N Latitude 76°36'38" to 76°38'59" E Longitude
Wetland Type:	Lake/Pond
Wetland Area: Perimeter :	354 ha 22 km
<u>Open-water</u> Post-monsoon: Pre-monsoon:	 354 ha 354 ha
<u>Vegetation</u> Post-monsoon: Pre-monsoon:	 Nil Nil
Overall Turbidity:	Low

Sasthamkotta Lake has a catchment of 58225 ha including the 12 km buffer area with 130 wetlands. These wetlands extended over 7455 ha of area. Lagoon is the largest wetland type with 5116 ha of area under this wetland type. Seasonal variation in open-water spread is very marginal. Wetland type-wise area estimates and seasonal changes in terms of open-water and vegetation are given in Table 48.

Table 48: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Sasthamkotta Lake

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	1	354	354	354	-	-
1105	Waterlogged	93	992	271	202	729	626
1106	River/Stream	9	594	590	573	-	-
1202	Tank/Pond	15	222	141	83	85	130
2101	Lagoon	8	5262	5116	5121	142	136
2103	Sand/Beach	4	31	-	0	-	-
	Total	130	7455	6472	6333	956	892

Wetland map of the Sasthamkotta Lake catchment including the 12 km buffer area is given in the Plate 101. The seasonal status of open-water spread and vegetation are given in the Plates 102-105 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

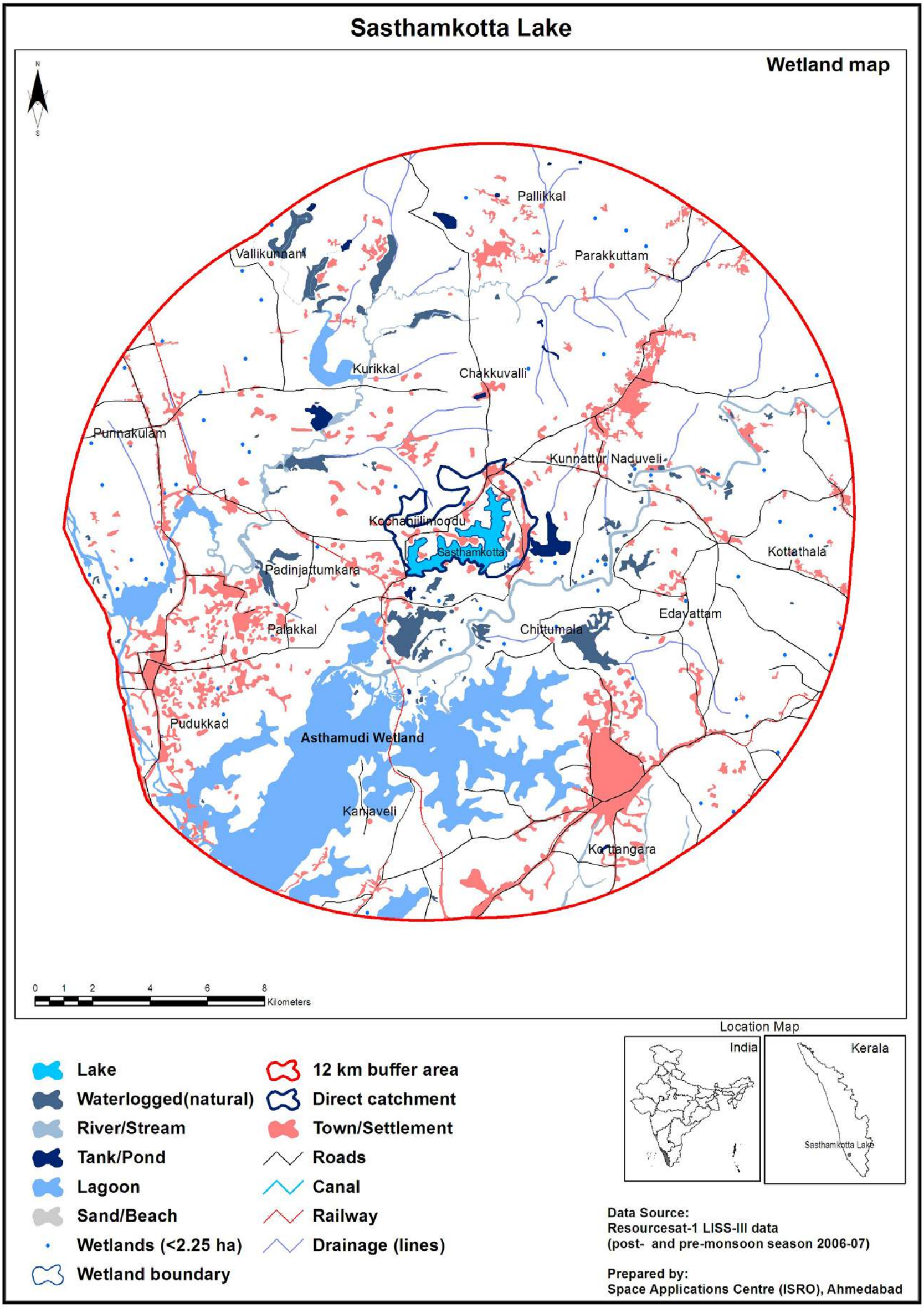

Plate 101: Wetland map of Sasthamkotta Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

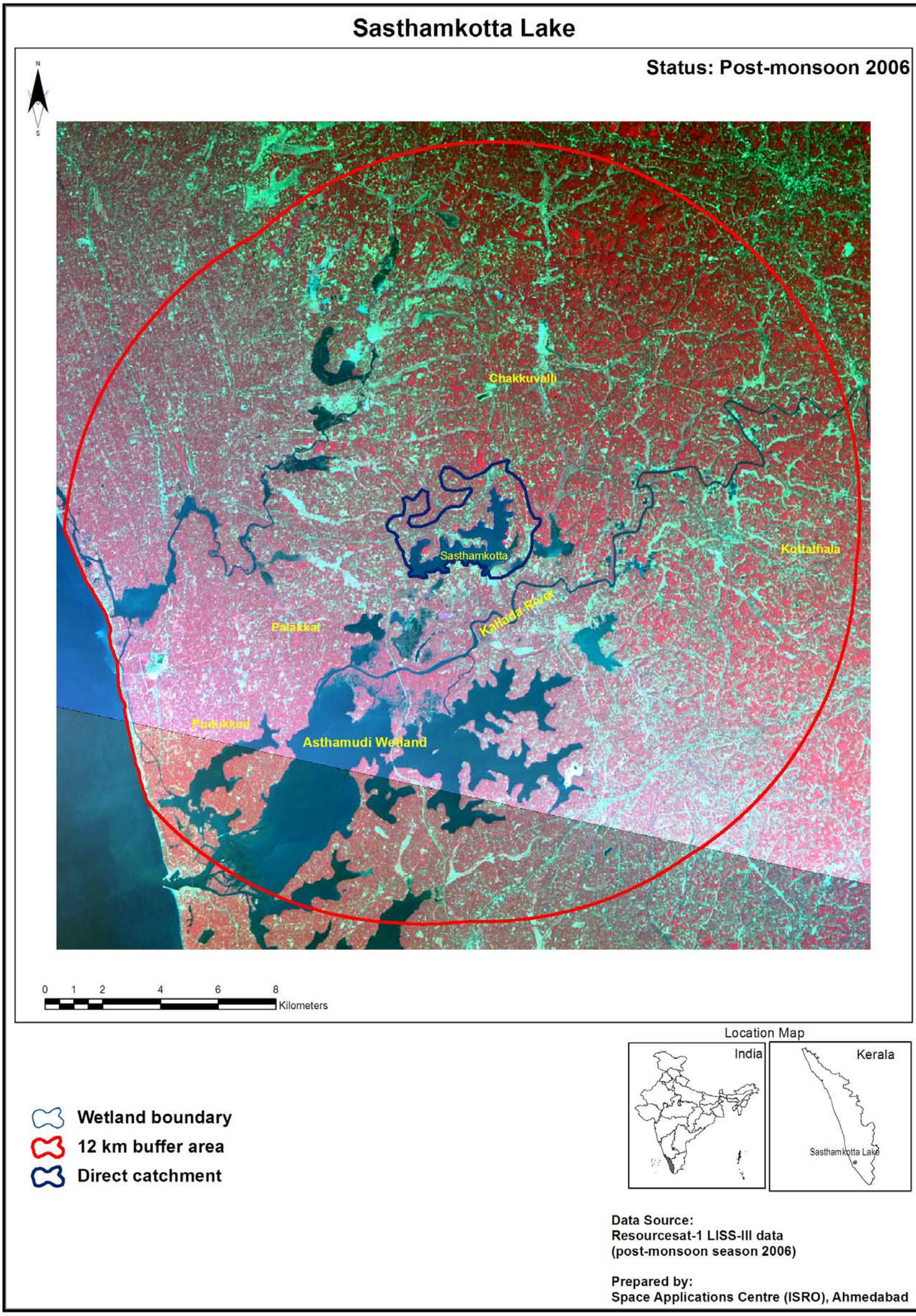

Plate 102: Sasthamkotta Lake and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (28-November-2006)

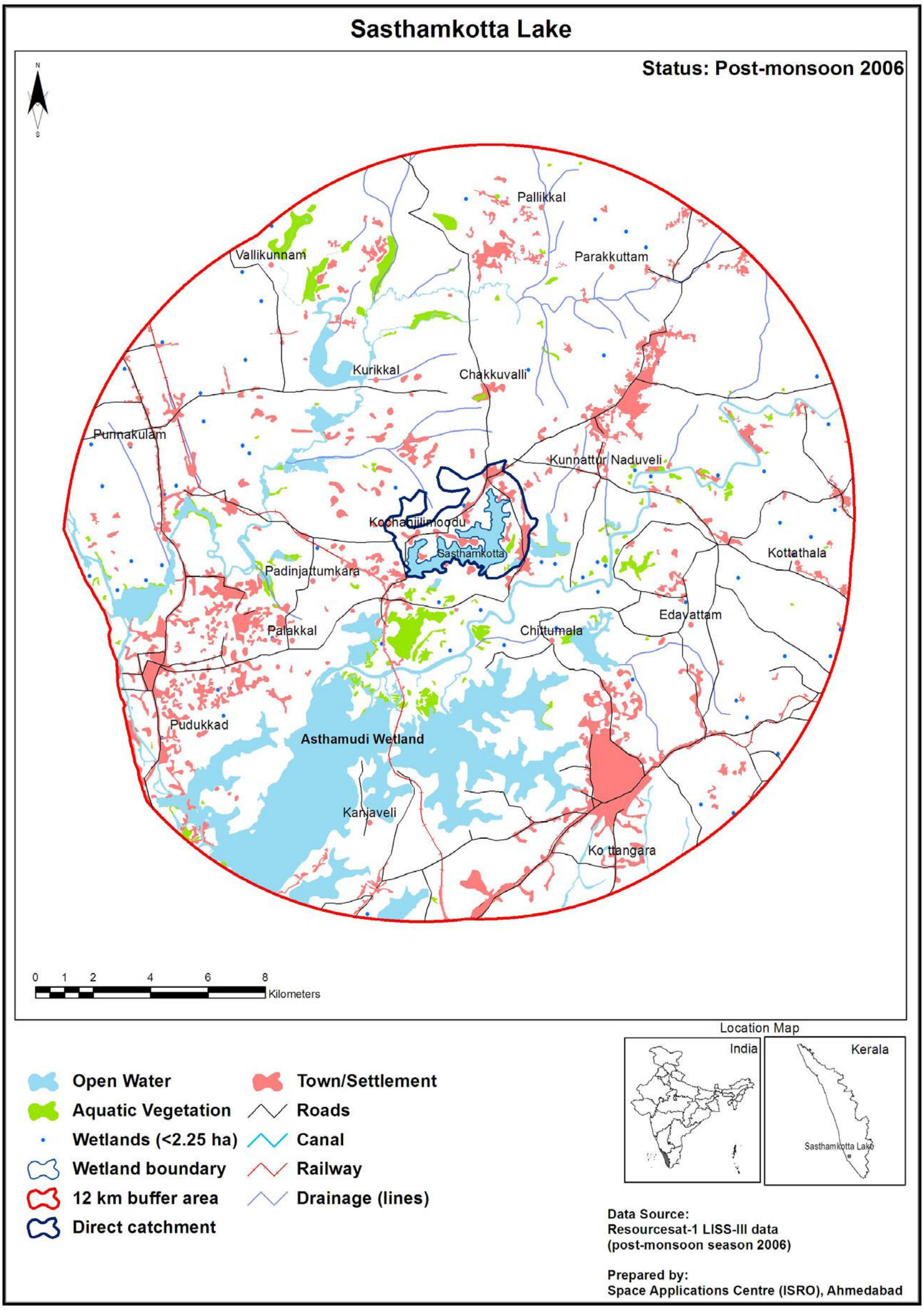

Plate 103: Open-water and vegetation status of Sasthamkotta Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

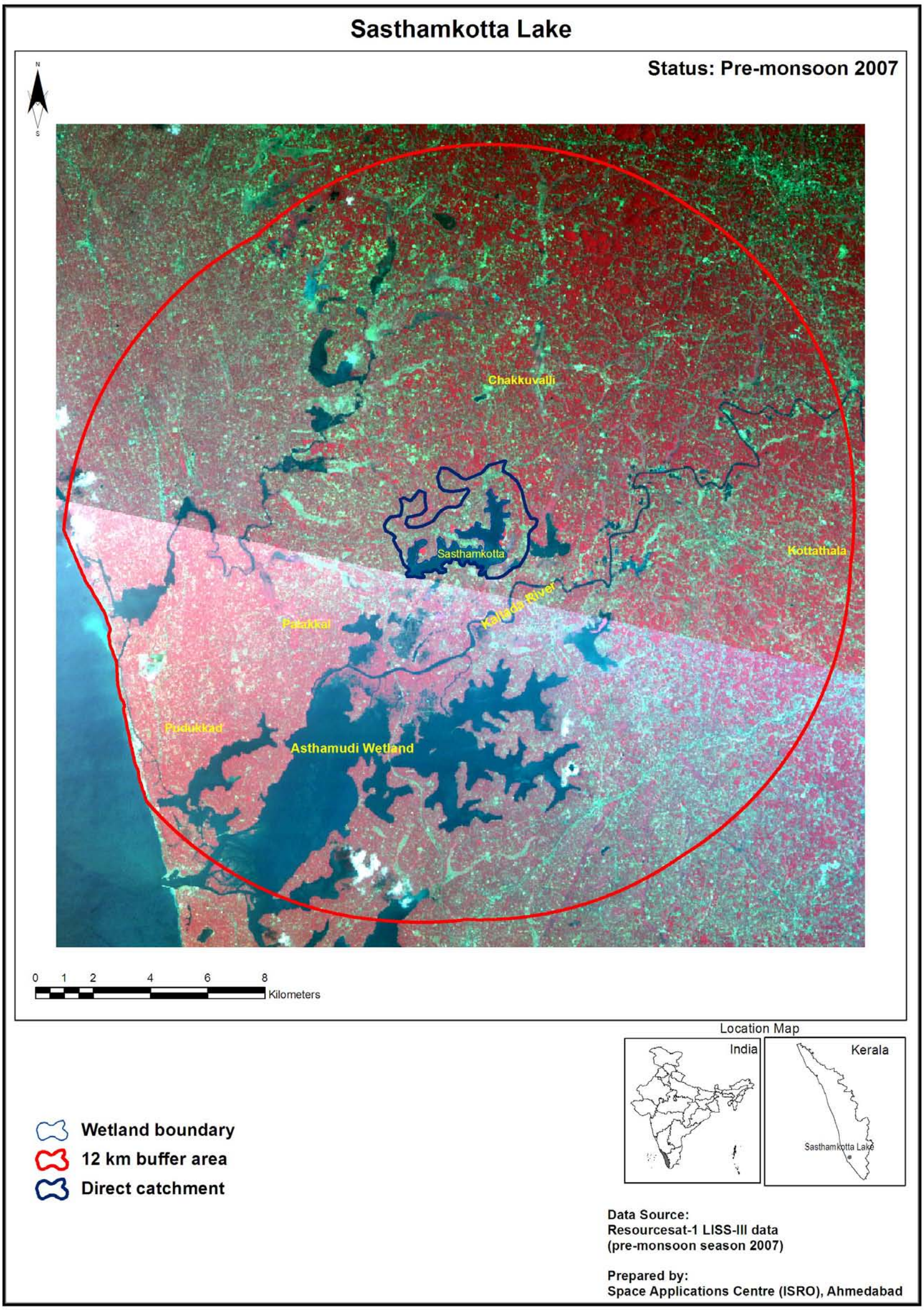

Plate 104: Sasthamkotta Lake and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (23-March-2007)

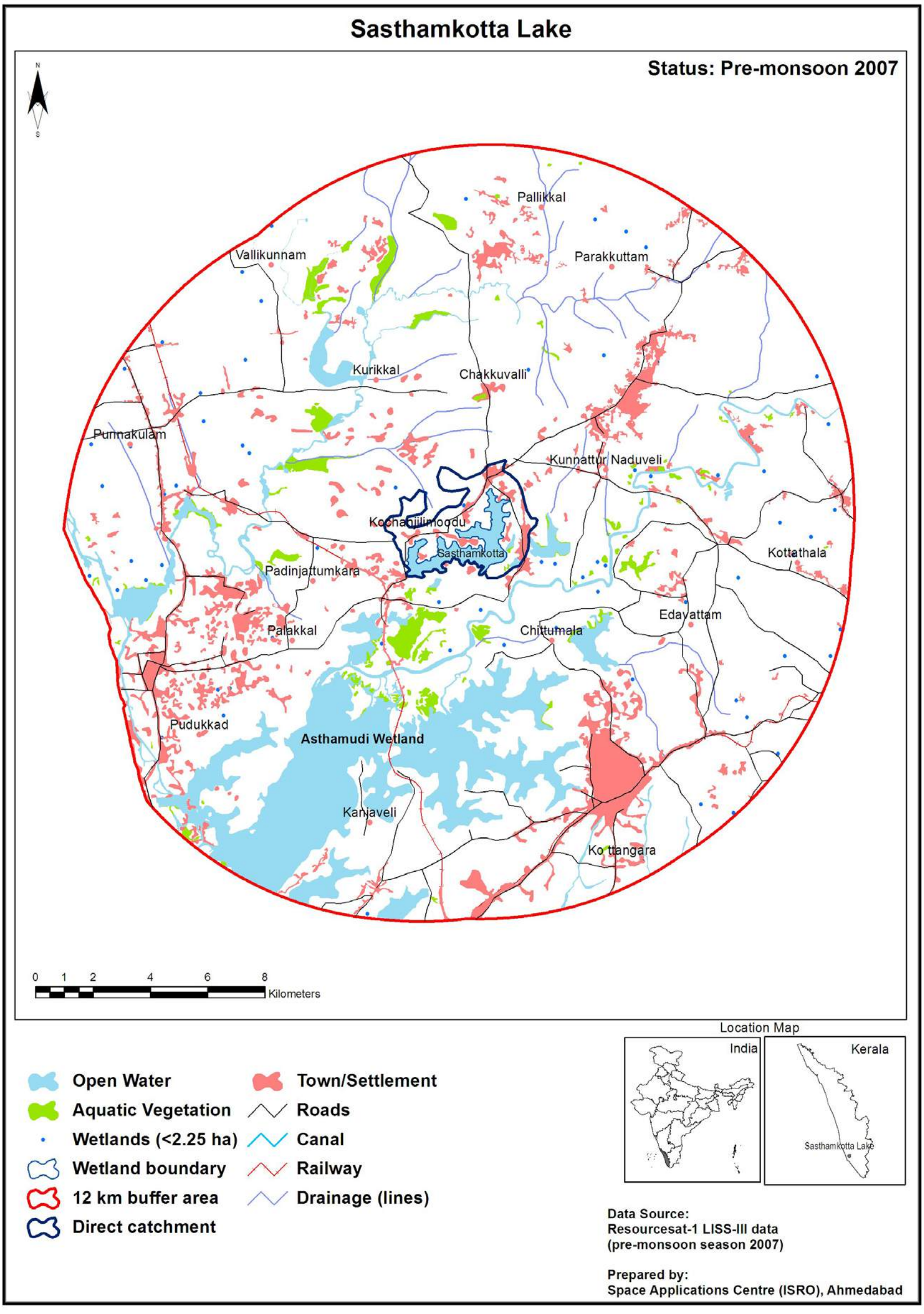

Plate 105: Open-water and vegetation status of Sasthamkotta Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.22 Surinsar-Mansar Lakes (Ramsar site no. 1573)



These are a pair of small fresh water lakes in Udhampur district of Jammu and Kashmir state. Surinsar Lake is oval shaped with a maximum depth of 24 m while the Mansar Lake is a semi-oval wetland with a maximum depth of 37 m. There is no natural inlet or outlet of the lakes. These lakes are part of the declared wild life sanctuary. This pair of lakes was declared as Ramsar sites on 08/11/2005 owing to the compliance of criteria 2, 3 & 4 as described below:

- Wetland supports globally threatened ecological communities.
- Wetland supports populations of animal/plant species important for maintaining biological diversity.
- Wetland provides refuge to wildlife during adverse condition.

The lakes support two important species of turtles, viz: the Indian Flapshell Turtle and the Indian Soft-shell Turtle listed in IUCN Red List category. The Mansar lake also supports a very rare medusa. The lakes are rich in fish diversity.

These lakes show growth of macrophytes in terms of floating, submerged and emergent types. The phytoplankton consists of 207 species while the zooplankton comprises of 54 taxa. These lakes attract a migratory waterfowl e.g. *Fulica atra, Gallinula chloropus, Podiceps nigricollis, P. cristatus, Aythya fuligula* and *A. ferina*. Surinsar and Mansar Lakes as observed on satellite image is shown in Figure 31.

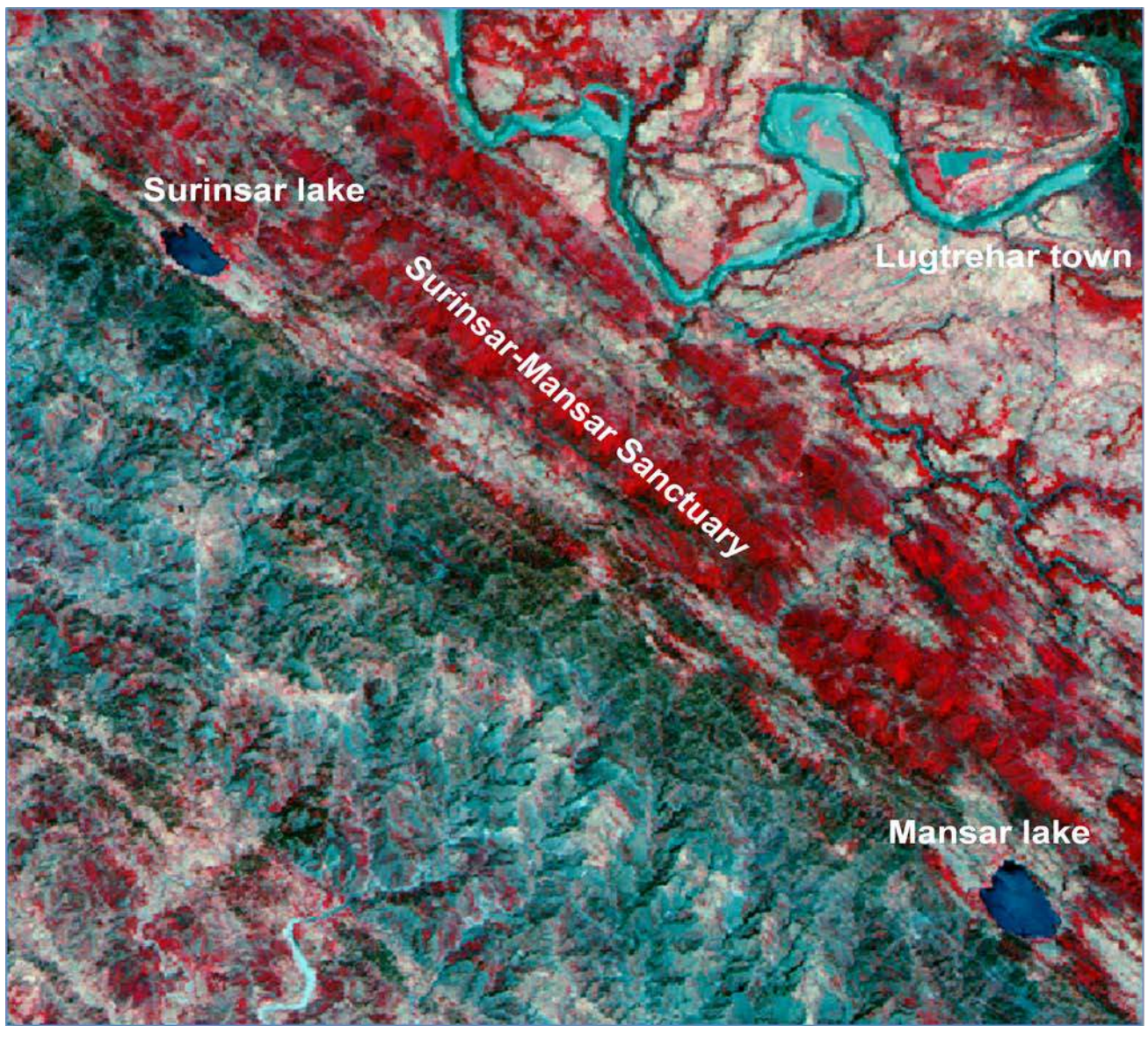

Figure 31: Surinsar and Mansar Lakes and its environ as seen in LISS-III FCC (23-May-2007)

Surinsar and Mansar Lakes have 31 and 58 ha area and perimeters are 2 and 3 km respectively. Both these lakes have not shown any variation in the extent of open-water spread. No aquatic vegetation is detected (Table 49).

Table 49: Salient observations of Surinsar-Mansar Lakes from satellite data

Name:	Surnisar and Mansar Lakes
Location:	$32^0$41'14" to $32^0$46'46" N Latitude $75^0$01'49" to $75^0$09'20" E Longitude
Wetland Type:	Lake/Pond
Wetland Area: Perimeter :	Surinsar : 31 ha and Mansar: 58 ha Surinsar : 2 km and Mansar: 3 km
Open-water Post-monsoon: Pre-monsoon:	 Surinsar : 31 ha and Mansar: 58 ha Surinsar : 31 ha and Mansar: 58 ha
Vegetation Post-monsoon: Pre-monsoon:	 Nil Nil
Overall Turbidity:	Low

The catchment including the 12 km buffer area is predominantly hilly terrain with natural vegetation. Apart from the two lakes, the other wetlands are mainly river/streams. (Table 50).

Table 50: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Surinsar-Mansar Lakes

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	2	89	89	89	-	-
1106	River/Stream	20	3698	863	1049	-	-
	Total	22	3787	952	1138	-	-

Wetland map of the Surinsar-Mansar catchment including the 12 km buffer area is given in the Plate 105. The seasonal status of open-water spread and vegetation are given in the Plates 106-110 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

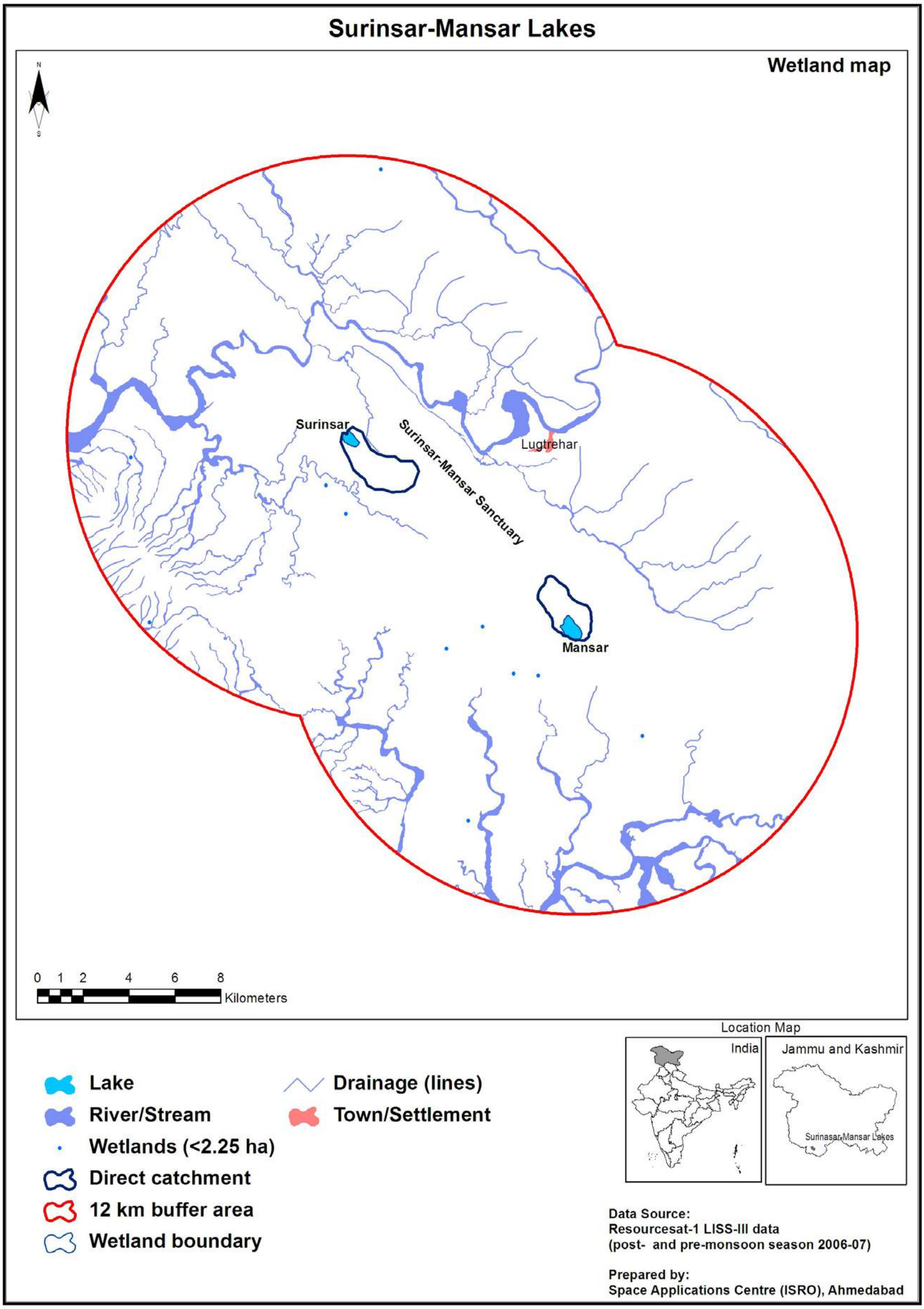

Plate 106: Wetland map of Surinsar and Mansar Lakes (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

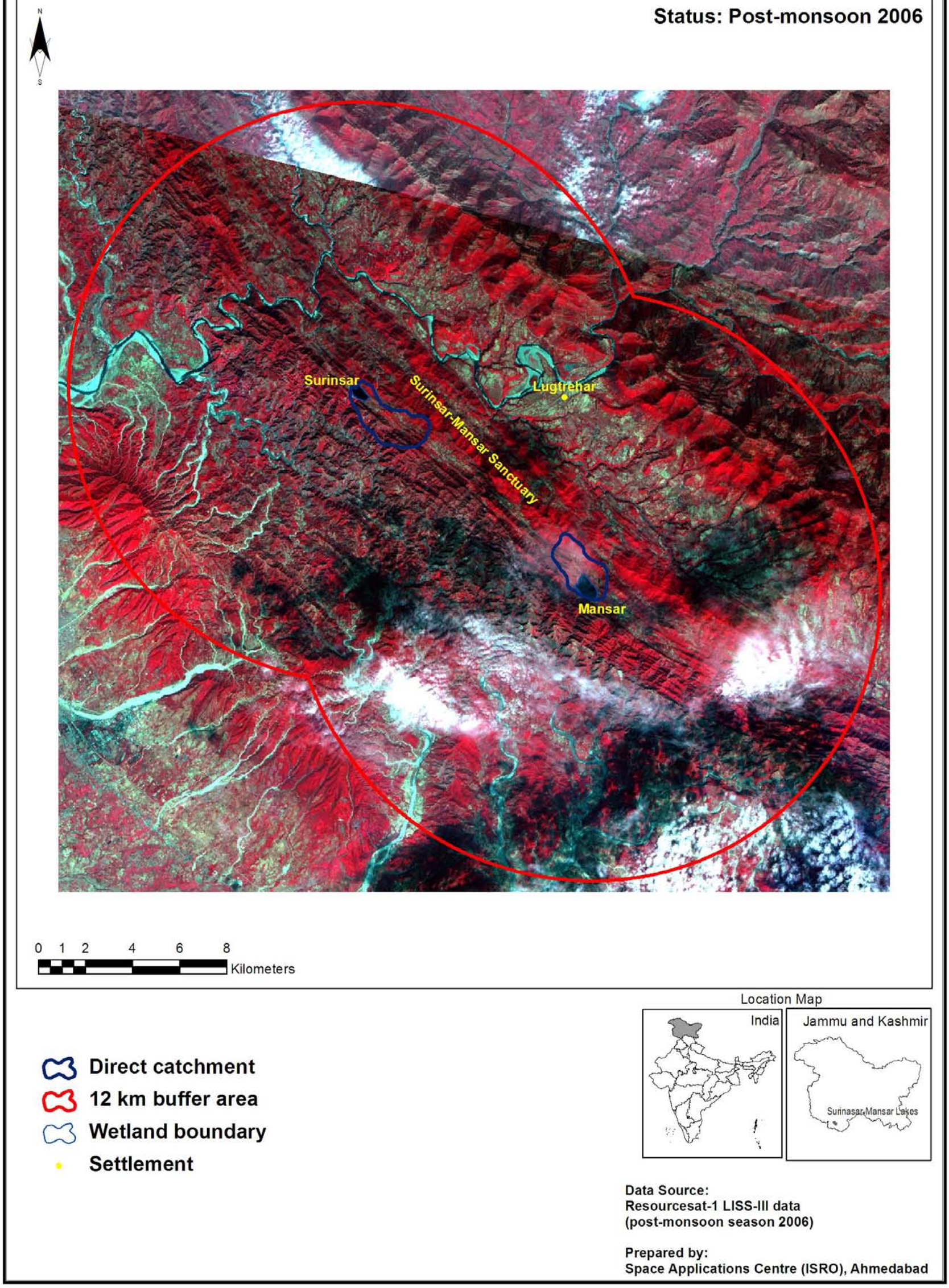

Plate 107: Surinsar and Mansar Lakes and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (28-November-2006)

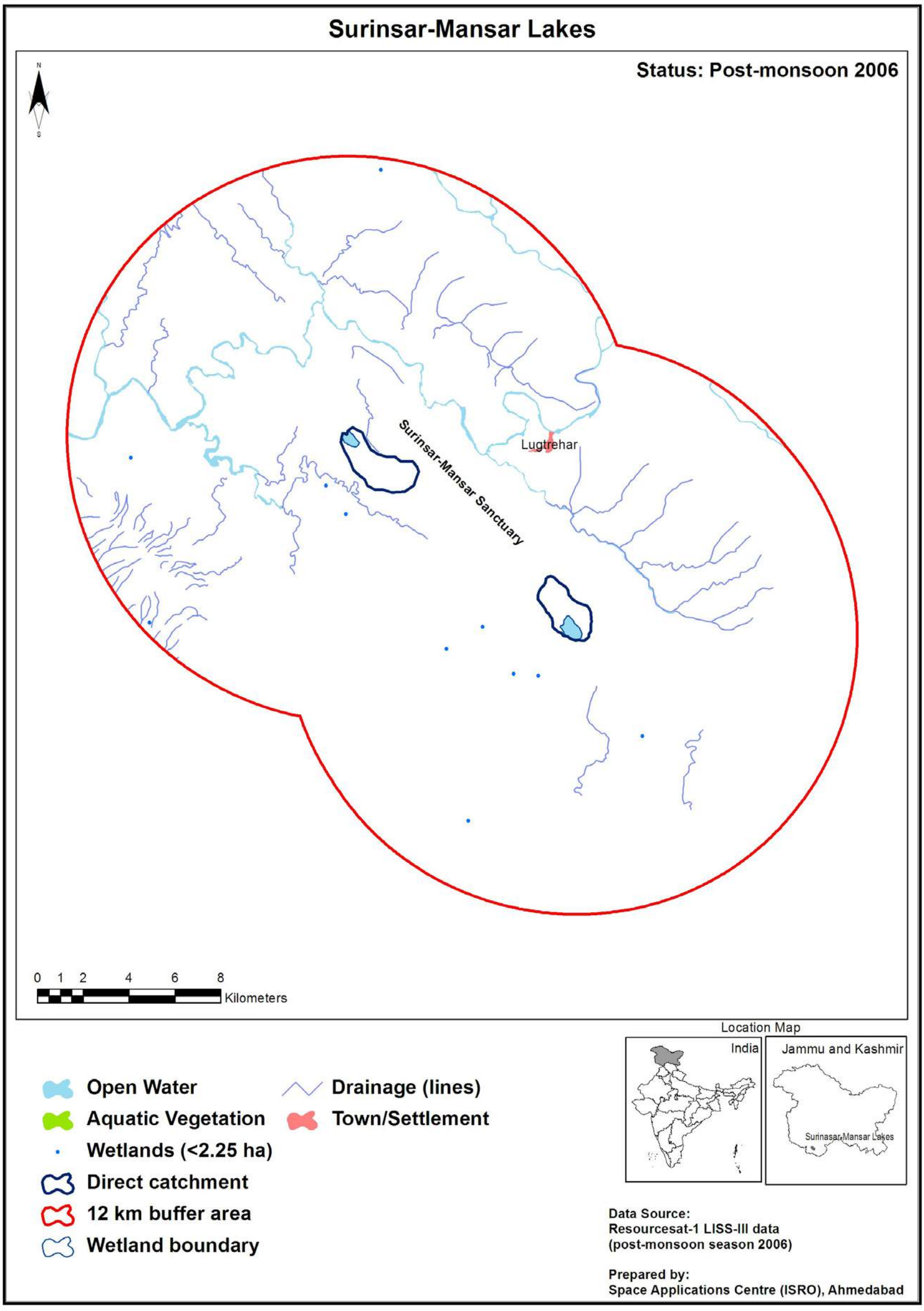

Plate 108: Open-water and vegetation status of Surinsar and Mansar Lakes (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

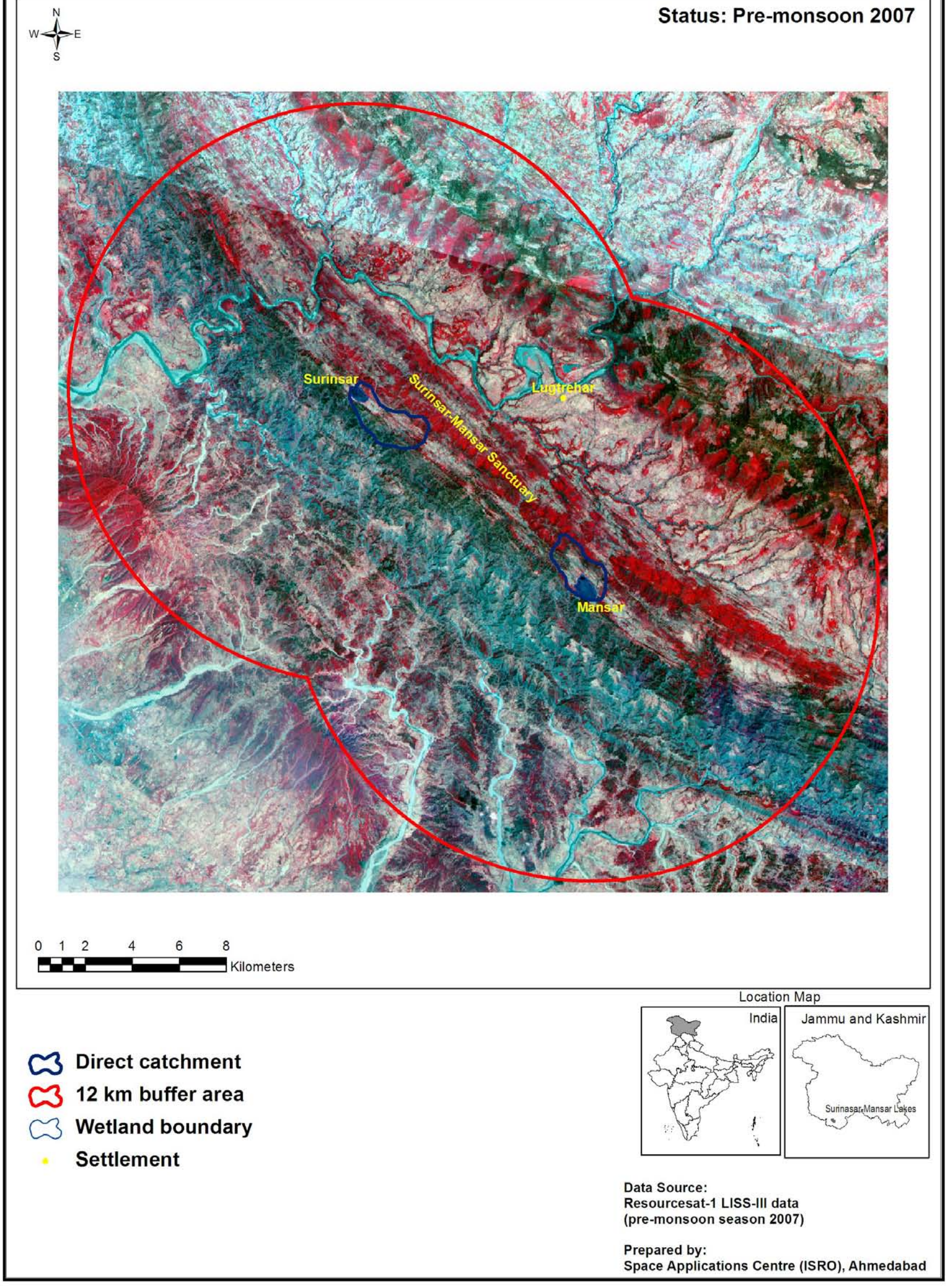

Plate 109: Surinsar and Mansar Lakes and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (23-March-2007)

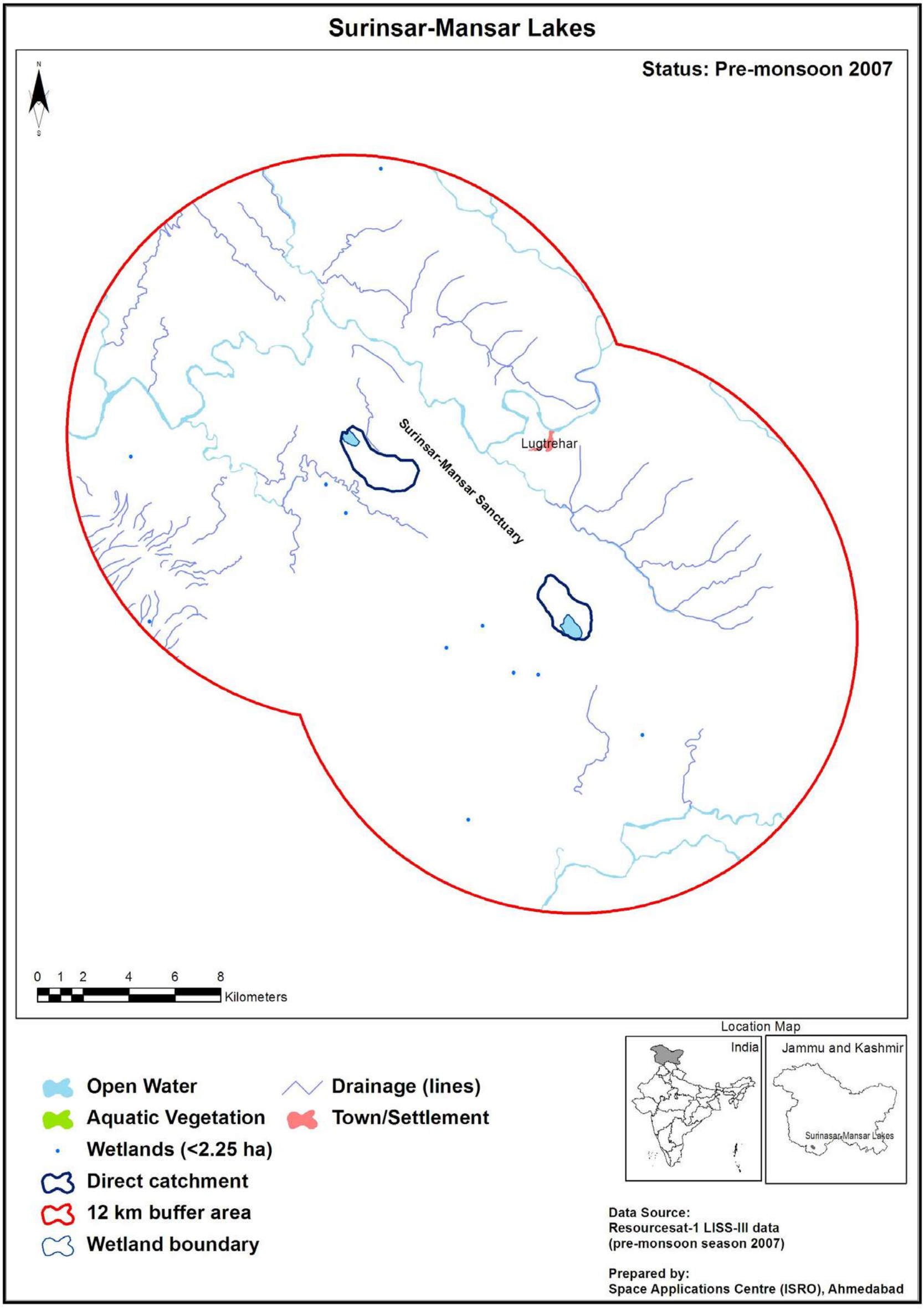

Plate 110: Open-water and vegetation status of Surinsar and Mansar Lakes (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.23 Tsomoriri (Ramsar site no. 1213)



Tsomoriri, is a high altitude lakes in eastern Ladakh. It is the largest high altitude Trans-Himalayan lake situated entirely with in Indian territory. The lake is landlocked with no active outlet, thus the water is brackish. The lake is fed by streams and snowmelt from two major rivers, creating marshes at the inlet position. The lake shows characteristic seasonal freezing and melting cycle. Tsomoriri has been designated as a Ramsar Site on 19/08/2002 owing to the compliance of criteria 2 & 6 as described below:

- Wetland supports threatened ecological communities.
- Wetland regularly supports 1 % of the individuals in a population of one species or subspecies.

The lake plays vital role as breeding and staging posts for over 40 species of water birds belonging to 6 families. The lake has the best known breeding ground of Bar-headed goose in Indian territory. During Autumn migration, the lake serves as an important staging area for variety of water fowl, including the Near Threatened Ferrugunious Pochard.

The catchment supports large ungulates like the great Tibetan sheep (Vulnerable) and Tibetan wild ass - *Equus kiang* (Data Deficient) both endemic to the Tibetan plateau plus possibly a third, the Tibetan gazelle - *Procapra picticaudata* (Threatened). Also included are a number of smaller herbivore species endemic to the region: one species of vole (*Alticola roylei*), three species of mouse hares, *Ochotona macrotis, O.curzoniae, O.ladacensis*, one species of hare (*Lepus oistolus*) and one species of marmot (*Marmota himalayana*). . Tsomoriri wetland as observed on satellite image is shown in Figure 32.



Figure 32: Tsomoriri wetland and its environ as seen in LISS-III FCC (10-October-2006)

Tsomoriri wetland occupies 14530 ha of area with a perimeter of 109 km. The seasonal variation in term of water spread is negligible. Wetland is devoid of vegetation in the post-monsoon. From the pre-monsoon data 6 ha of vegetation was estimated (Table 51).

Table 51: Salient observations of Tsomoriri from satellite data

Name:	Tsomoriri
Location:	$32^0$42’24” to $33^0$01’39” N Latitude $78^0$14’48” to $78^0$23’02” E Longitude
Wetland Type:	High Altitude Wetland
Wetland Area: Perimeter :	14530 ha 109 km
<u>Open-water</u> Post-monsoon: Pre-monsoon:	 14530 ha 14524 ha
<u>Vegetation</u> Post-monsoon: Pre-monsoon:	 Nil 6 ha
Overall Turbidity:	Low

The catchment including the 12 km buffer area of Tsomooriri wetland is 164914 ha. The landscape is devoid of any vegetation and snow-clad in winter. The lake is bound by steep peaks of >5000 m. The Pare Chu river flows along the southern side of the lake. Another wetland Nuro Sumdo lies between Tsomoriri and Pare Chu. Total 32 high altitude wetlands are found in the catchment/buffer area (Table-52).

Table 52: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Tsomoriri

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1103	High Altitude Wetland	32	15173	15173	15167	-	6
	Total	32	15173	15173	15167	-	6

Wetland map of the Tsomoriri wetland catchment including the 12 km buffer area is given in the Plate 111. The seasonal status of open-water spread and vegetation are given in the Plates 112-115 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

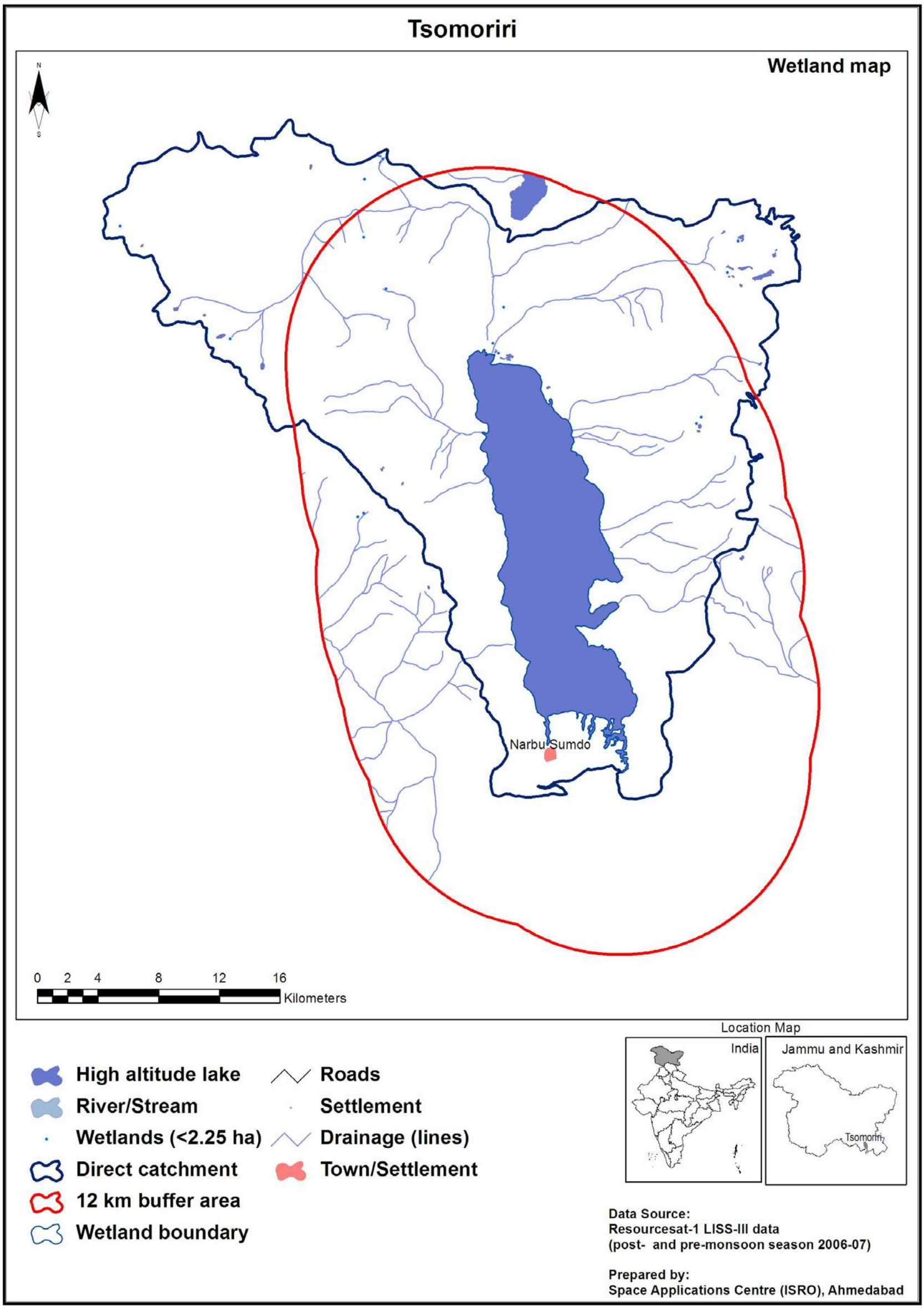

Plate 111: Wetland map of Tsomoriri Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

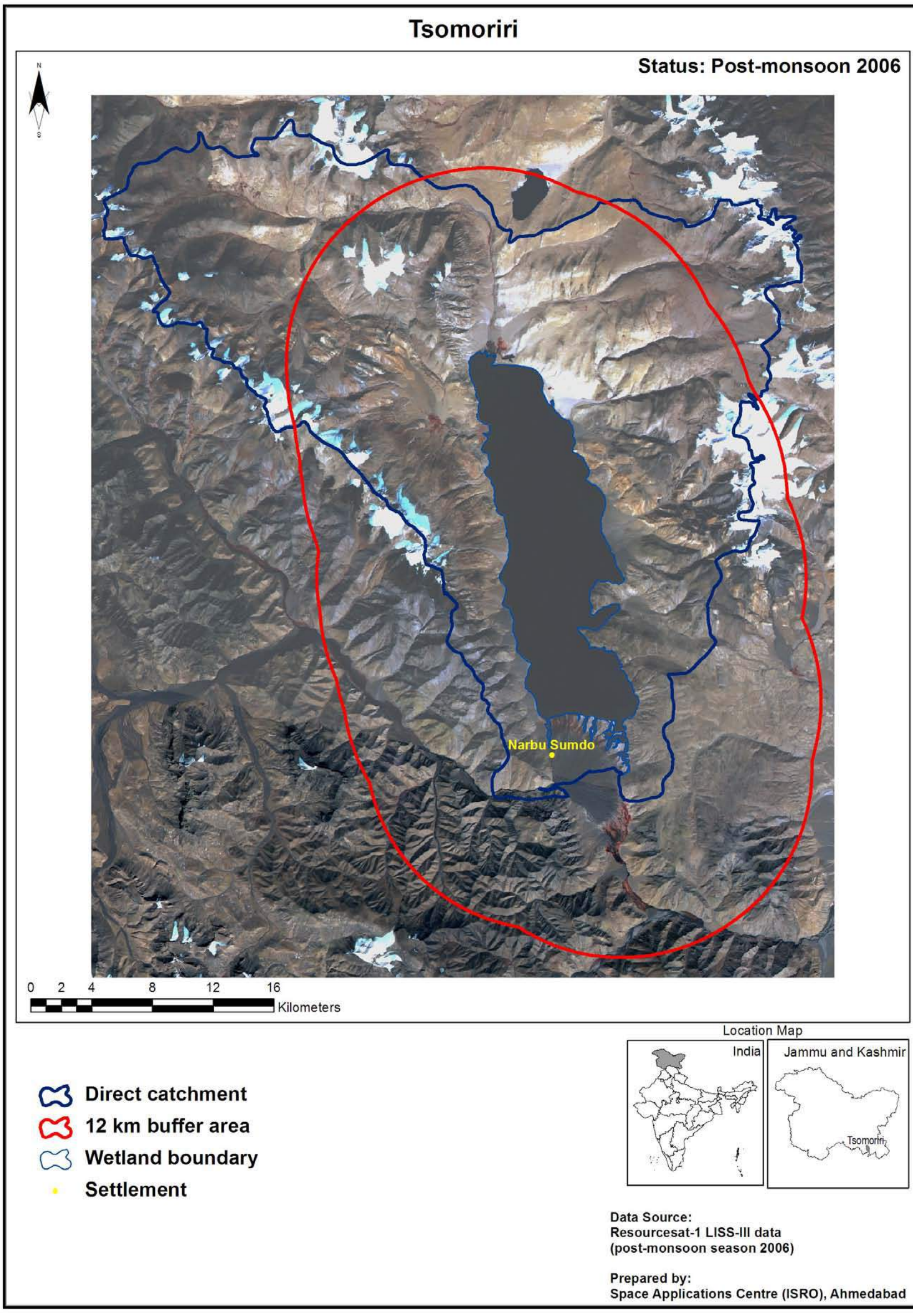

Plate 112: Tsomoriri Wetland and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (10-October-2006)

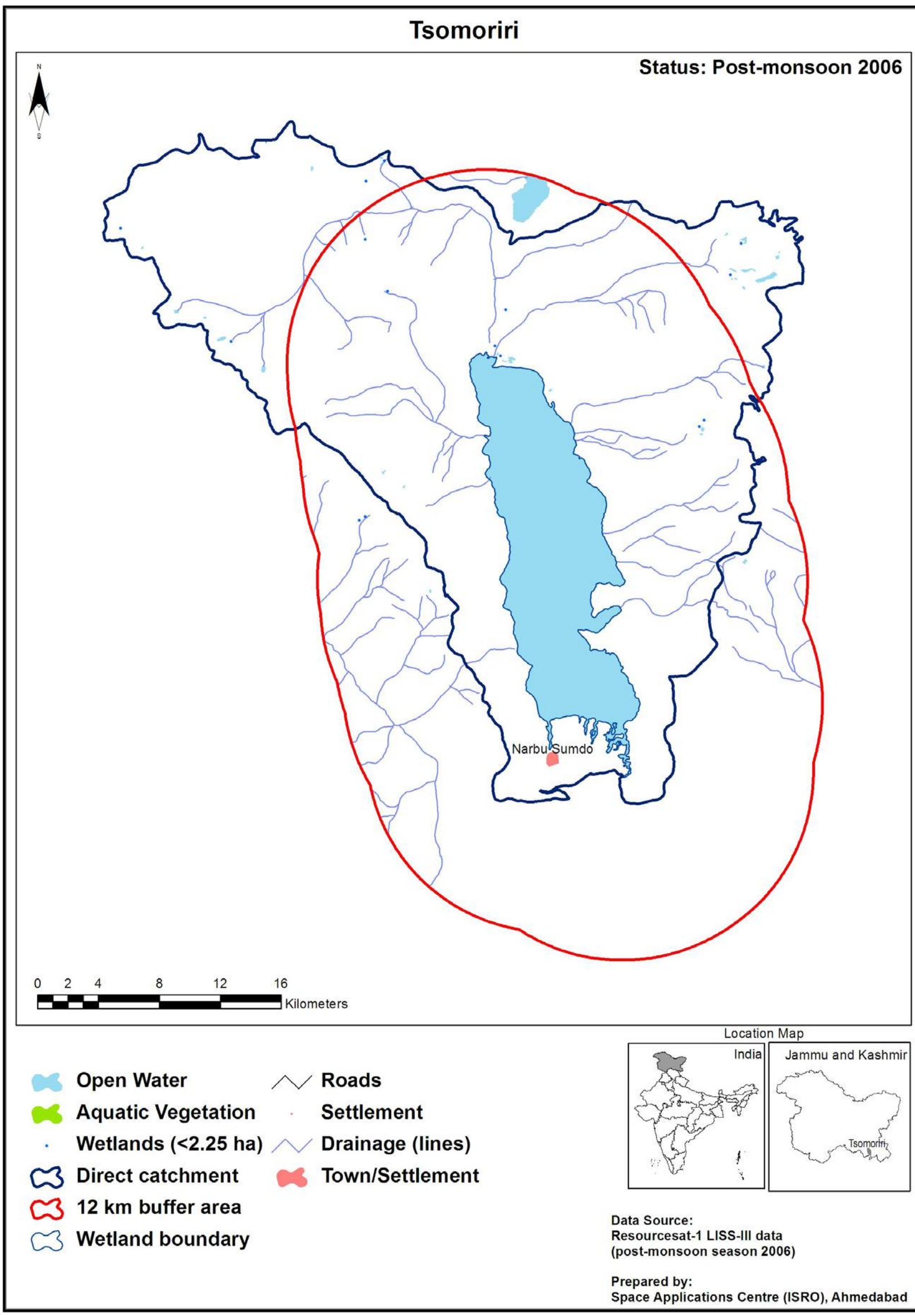

Plate 113: Open-water and vegetation status of Tsomoriri Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

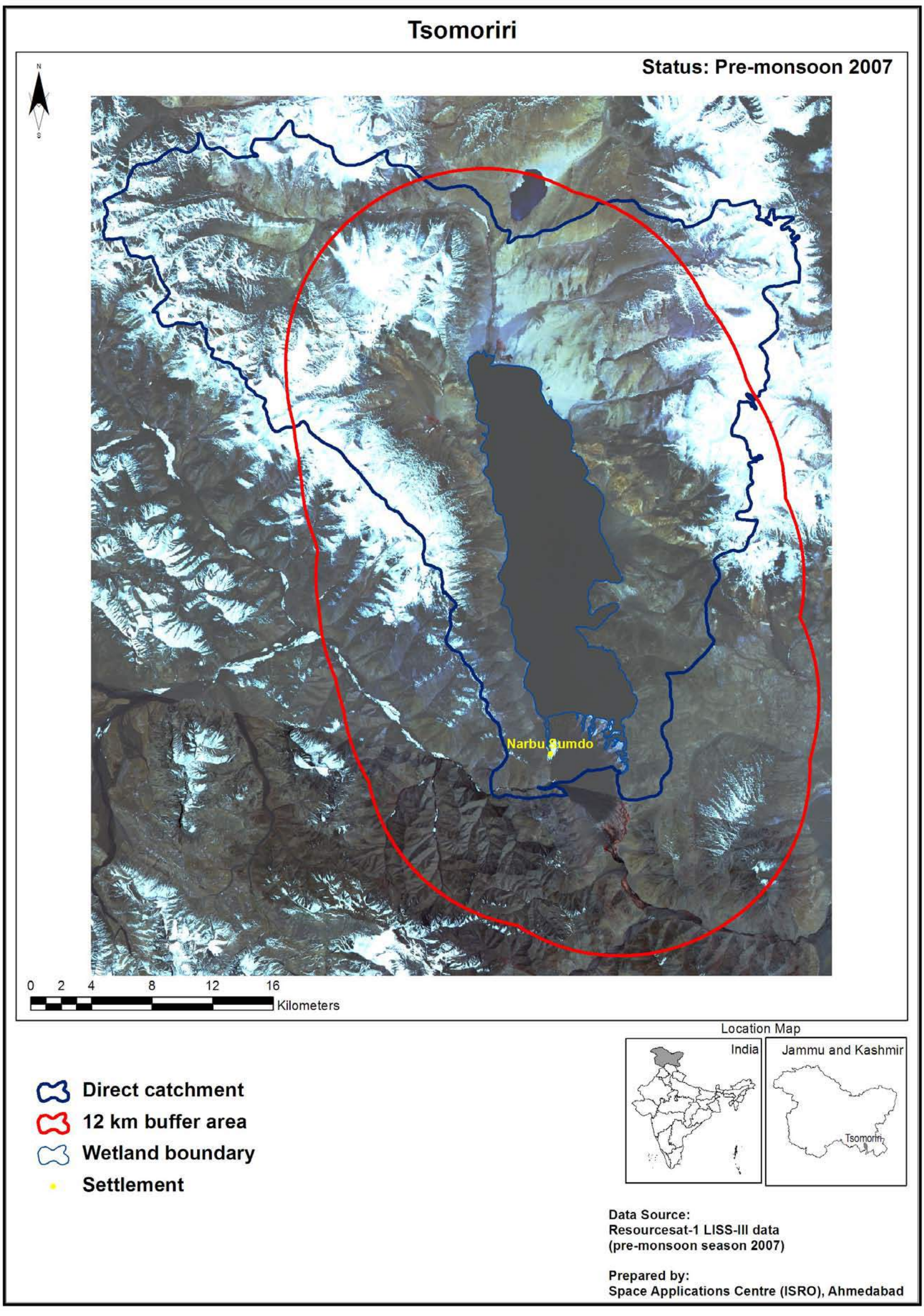

Plate 114: Tsomoriri Wetland and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (14-May-2007)

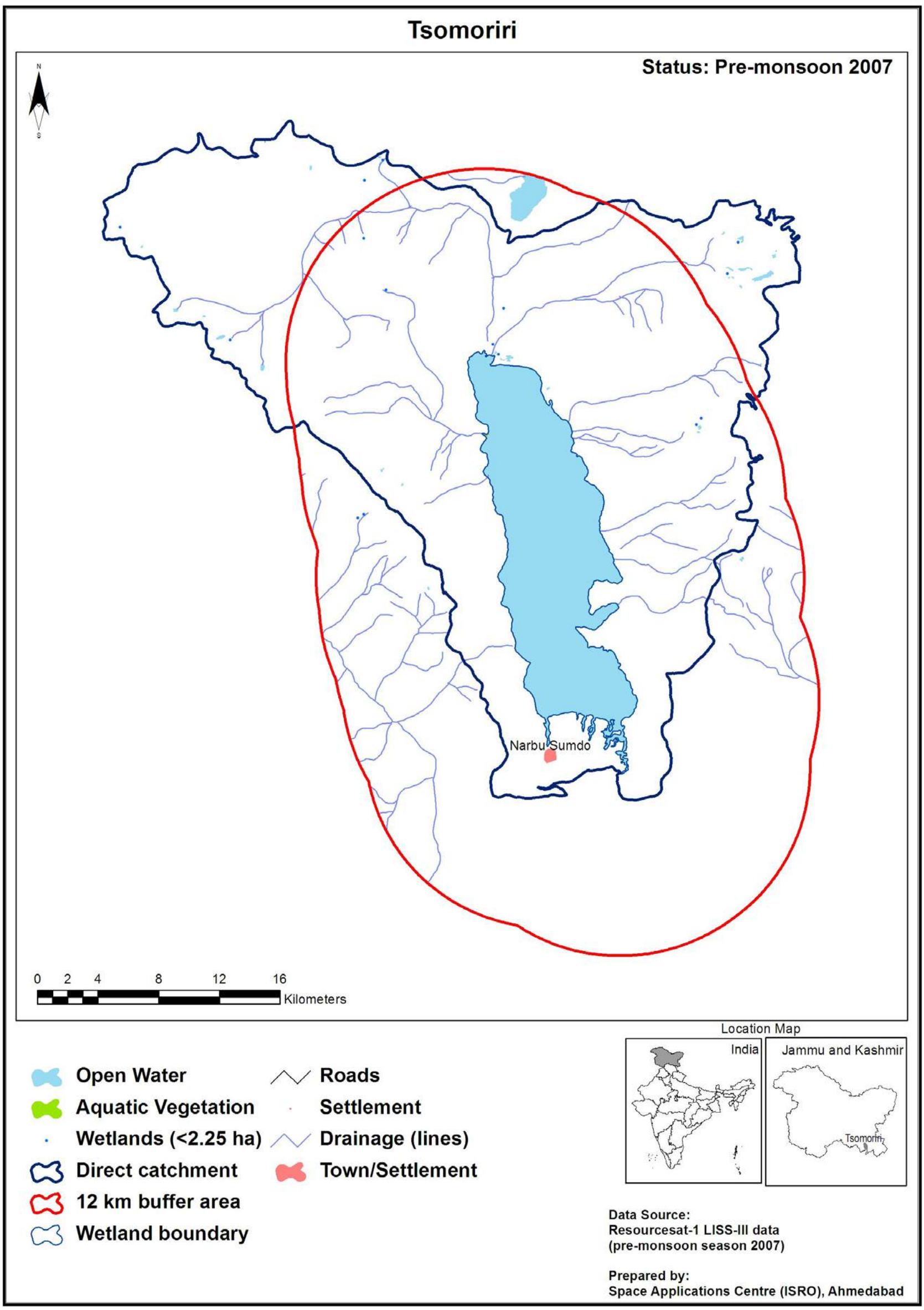

Plate 115: Open-water and vegetation status of Tsomoriri Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.24 Upper Ganga River - Brijghat to Narora Stretch (Ramsar site no. 1574)



The stretch of the river Ganga from Brijghat to Narora, is situated in the state of Uttar Pradesh. This stretch is shallow with intermittent deep-water pools but with significantly religious importance. It is the only Ramsar site falling in River/Stream wetland type in India.

It was declared as Ramsar site on 08/11/2005 owing to the compliance of criteria 2 & 5 as described below:

- Wetland supports threatened ecological communities.
- Wetland regularly supports 20, 000 or more waterbirds.

This stretch of the Ganga supports Ganges river dolphins (*Platanista gangetica*) listed in CITES, IUCN Redbook as endangered, common otters (*Lutra lutra*), two species of crocodiles i.e. endangered *Gavialis gangeticus* and *Crocodylus palustris*. Out of 12 species of turtle indentified from this stretch, 6 are considered as endangered including Indian softshell turtle (*Aspideretes gangeticus*). Avifauna includes more than 100 species. Fish form the largest group of living natural resources of this stretch of the river. Fishes like *Wallago attu, Chela laubuca, Colisa fasciatus, Chandra ranga, Glossogobius giuris, Nangra punctata, Puntius sp.,* and *P. sophore* are common in the river.

Upper Ganga River (Brijghat to Narora stretch) as observed on satellite image is shown in Figure 33.

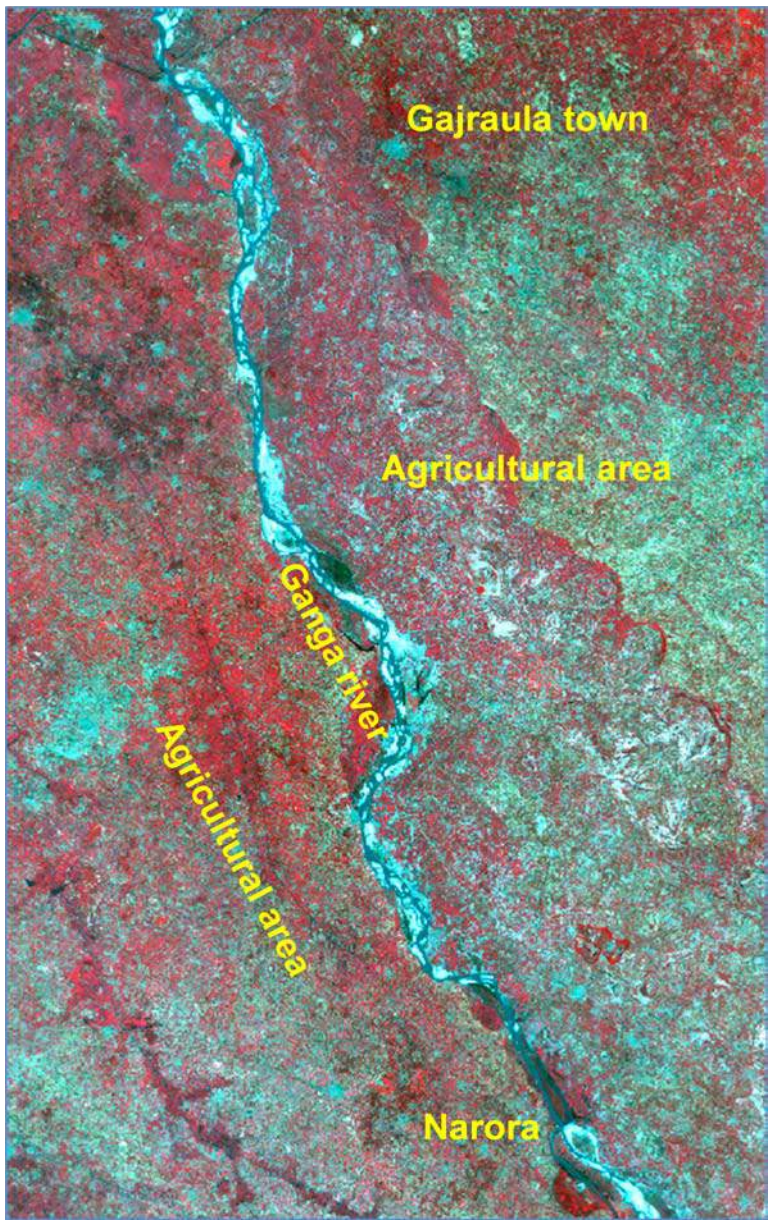

Figure 33: Upper Ganga River (Brijghat to Narora Stretch) and its environ as seen in LISS-III FCC (15-October-2006)

Upper Ganga River (Brijghat to Narora Stretch) has an estimated extent spread over 11364 ha with a perimeter of 167 km. Due to the presence of riverine islands; the open-water spread was about 50 % of the wetland. The open-water is observed a reduction from 5584 ha in post-monsoon to 5373 ha in the pre-monsoon. Wetland vegetation is observed along the stretch of the wetland has shown an increase from 25 ha to 58 ha for the same period (Table 53).

Table 53: Salient observations of Upper Ganga River (Brijghat to Narora Stretch) from satellite data

Name:	Upper Ganga River (Brijghat to Narora Stretch)
Location:	28°10'26" to 28°47'18" N Latitude 77°07'04" to 78°25'57" E Longitude
Wetland Type:	River/Stream
Wetland Area: Perimeter :	11364 ha 167 km
Open-water Post-monsoon: Pre-monsoon:	 5584 ha 5373 ha
Vegetation Post-monsoon: Pre-monsoon:	 25 ha 58 ha
Overall Turbidity:	Moderate – High

The direct catchment including the 12 km buffer area of this Ramsar sites is spread over 254482 ha. Including the site, there are 130 wetlands with an estimated area of 14483 ha. River/Stream wetland type singularly dominate the wetland extend with an area of 12333 ha. The other major wetland types are waterlogged and Ox-bow Lake/Cut-off Meander. In terms of open-water extent, there is about 23% reduction from post-monsoon (8311 ha) to pre-monsoon (6388 ha). A marginal decrease of 8 ha is observed in pre-monsoon from 361 ha estimated in post-monsoon. Wetland type-wise area estimates and seasonal changes in terms of open-water and vegetation are given in Table 54.

Table 54: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Upper Ganga River (Brijghat to Narora Stretch)

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	14	76	72	49	4	-
1102	Ox-bow Lake/Cut-off Meander	22	266	237	86	26	8
1104	Riverine Wetland	8	376	281	128	95	17
1105	Waterlogged	21	503	317	136	180	136
1106	River/Stream	12	12333	6553	5775	-	-
1202	Tank/Pond	27	94	65	38	8	2
1203	Waterlogged	26	835	786	176	48	190
	Total	130	14483	8311	6388	361	353

Wetland map of the Upper Ganga River (Brijghat to Narora Stretch) catchment including the 12 km buffer area is given in the Plate 116. The seasonal status of open-water spread and vegetation are given in the Plates 117-120 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

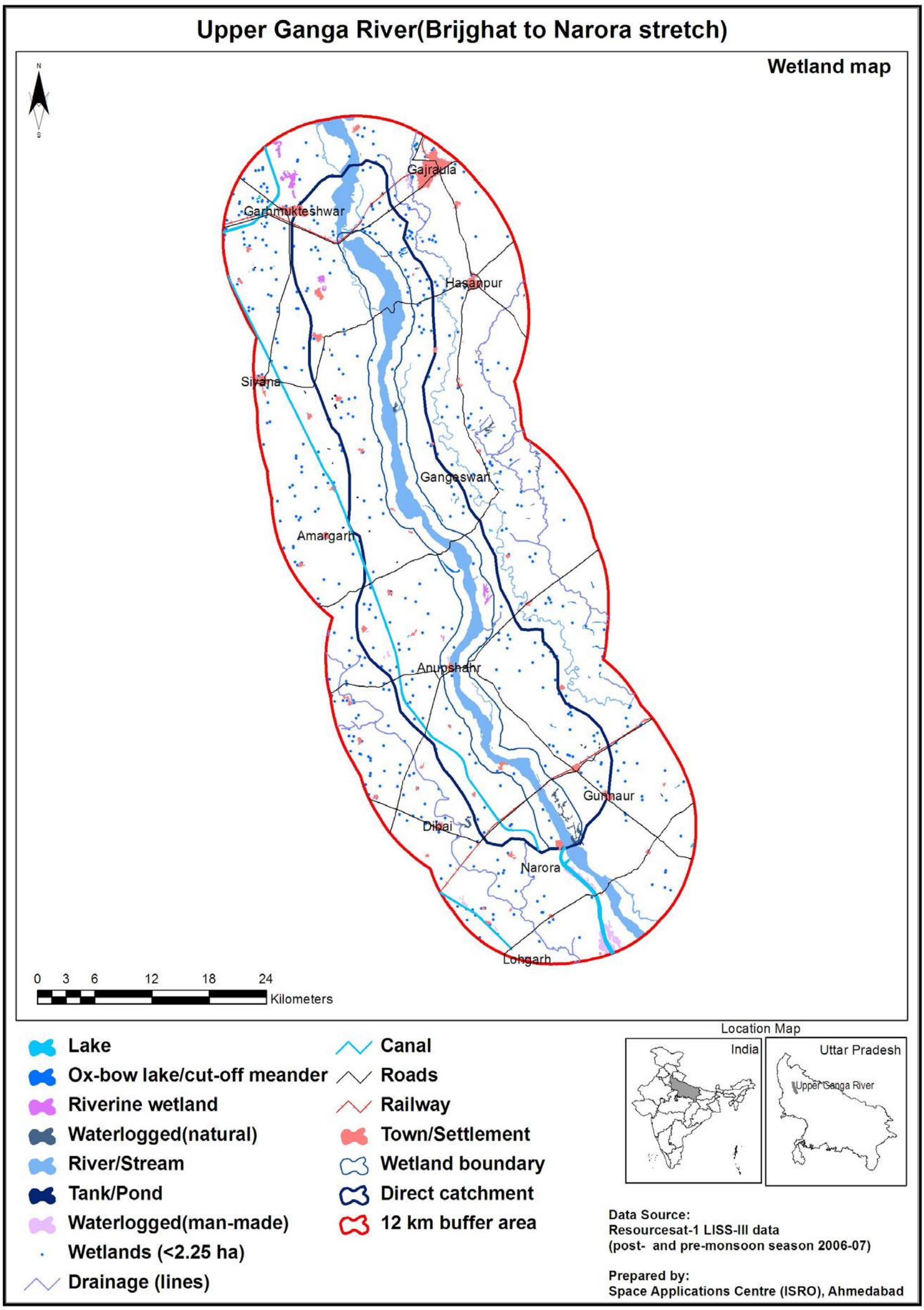

Plate 116: Wetland map of Upper Ganga River - Brijghat to Narora Stretch (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

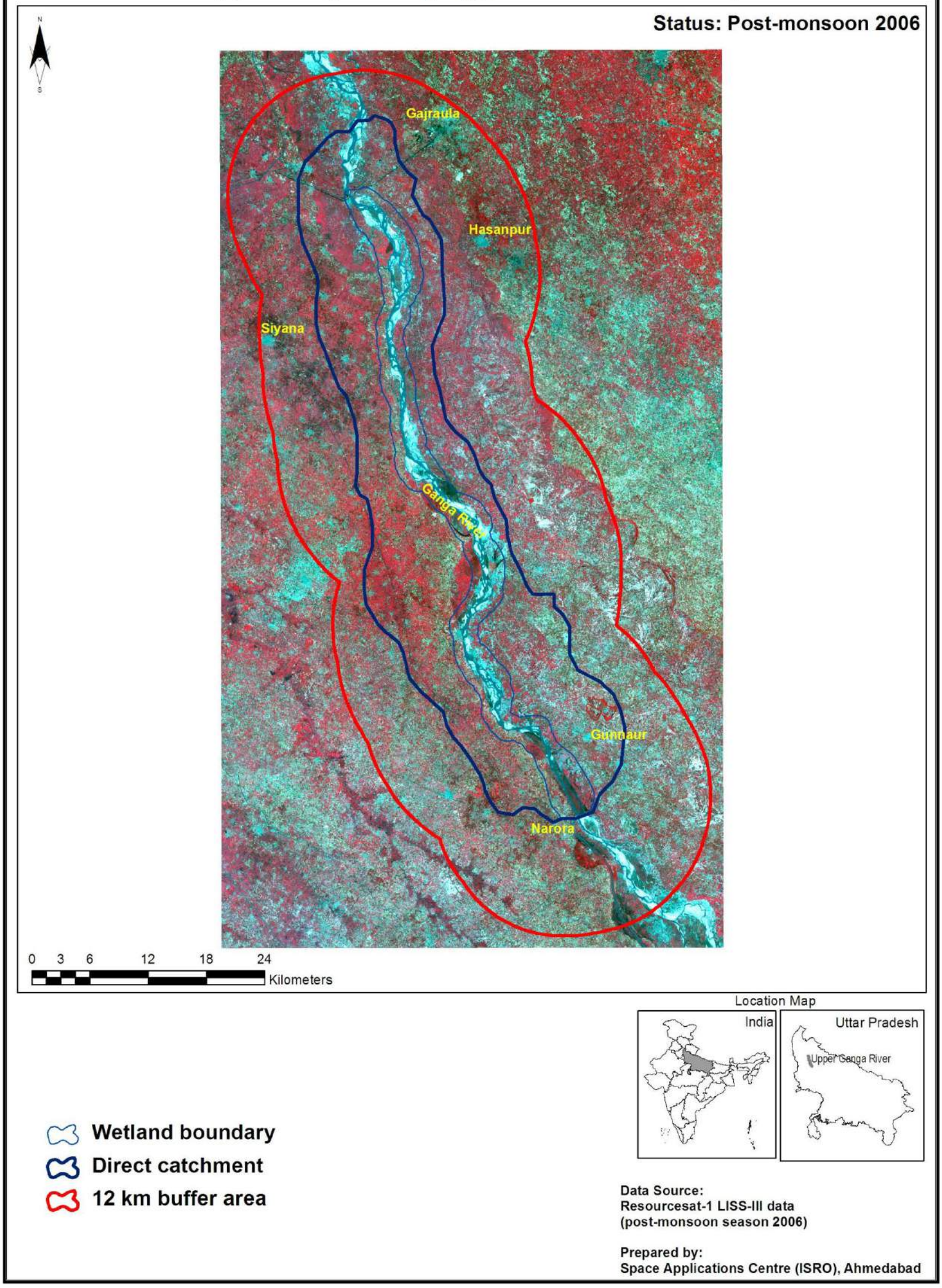

Plate 117: Upper Ganga River - Brijghat to Narora Stretch and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (15-October-2006)

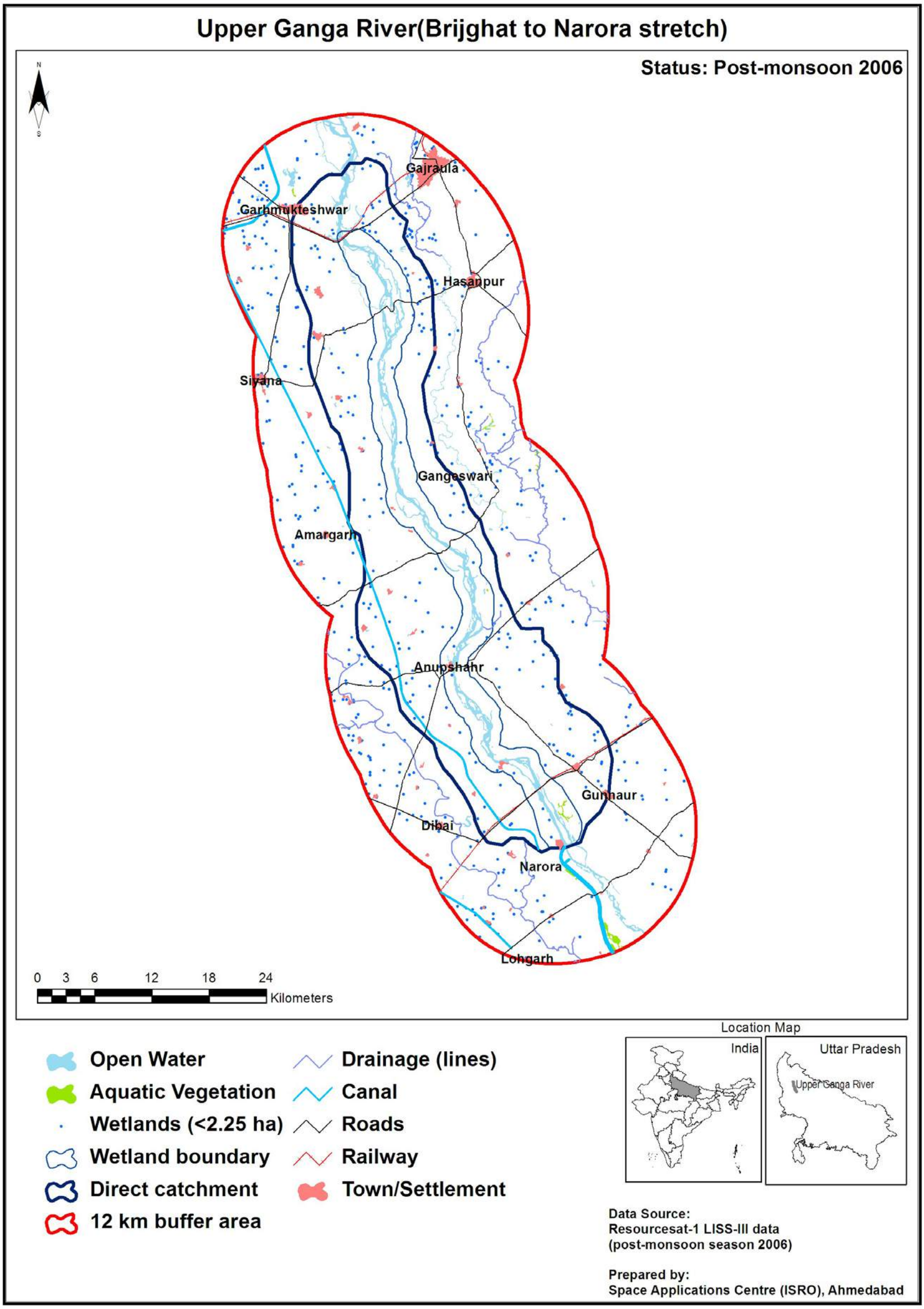

Plate 118: Open-water and vegetation status of Upper Ganga River - Brijghat to Narora Stretch (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

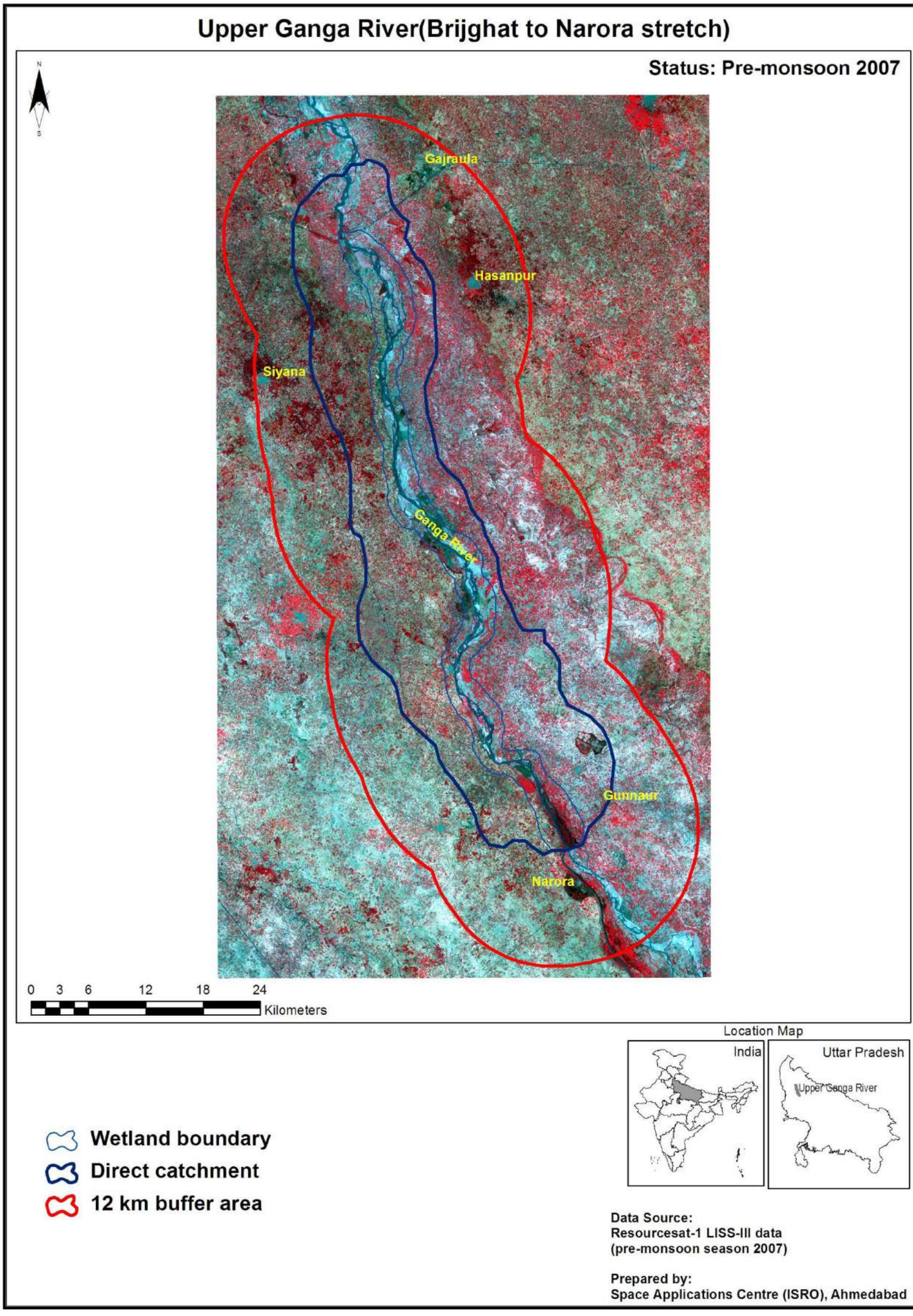

Plate 119: Upper Ganga River - Brijghat to Narora Stretch and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (19-May-2007)

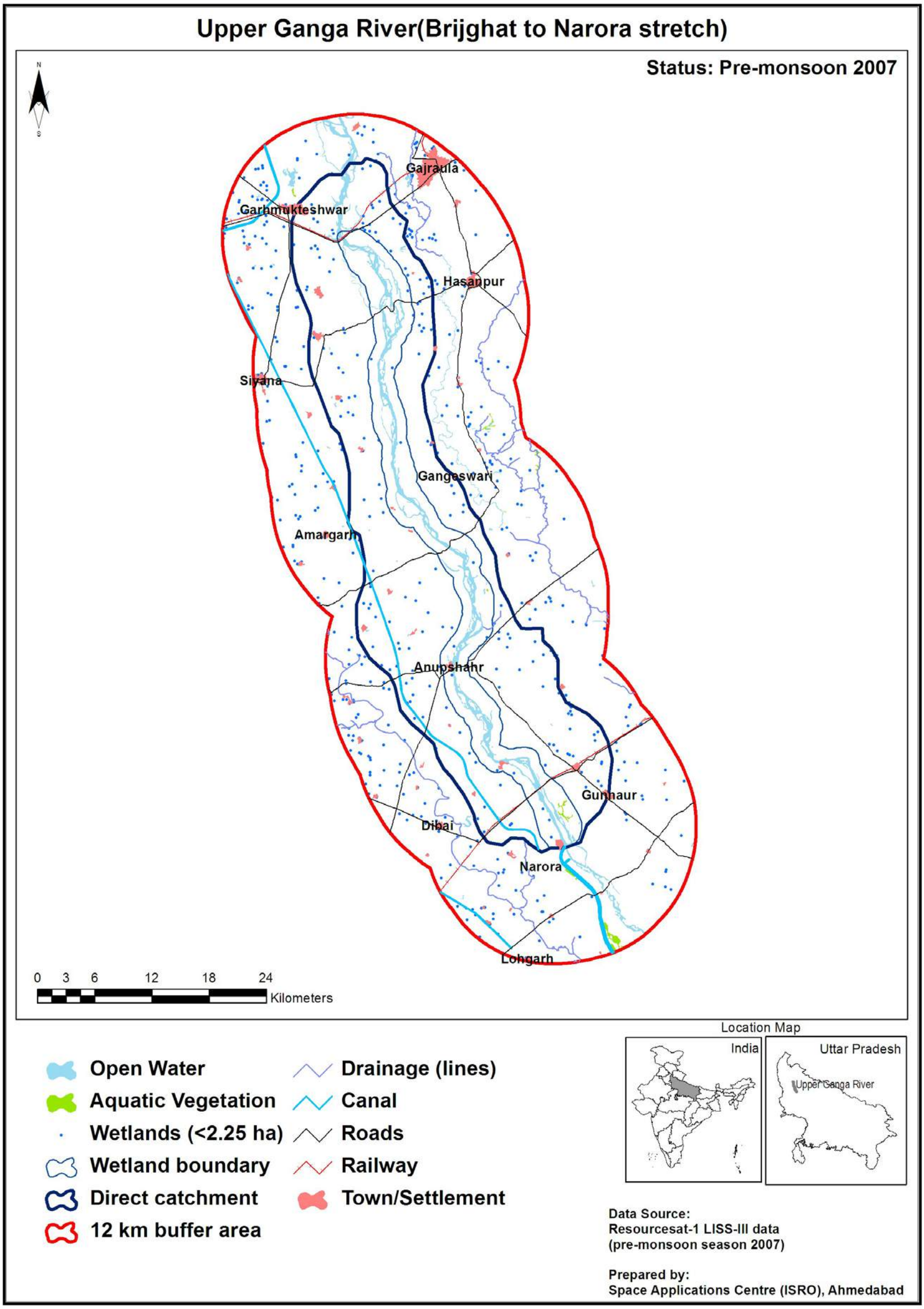

Plate 120: Open-water and vegetation status of Upper Ganga River - Brijghat to Narora Stretch (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.25 Vembanad-Kol Wetland (Ramsar site no. 1214)



The Vembanad-kol wetland is a coastal lagoon in Kerala state. It has a single, narrow opening to the Arabian sea near Kohi. It is aligned north-south, parallel to the shoreline and widest at the southern side.

Vembanad - Kol Wetland has been designated as a Ramsar Site on 19/08/2002 owing to the compliance of criteria 4, 5 & 6 as described below:

- Wetland provides refuge during adverse conditions to threatened species.
- Wetland regularly supports 20, 000 or more waterbirds.
- Wetland regularly supports 1 % of the individuals in a population of one species or subspecies.

Avifauna includes 149 species. More than 36,000 birds mainly waterbirds and raptors have been recorded. Many species of birds are much above their 1% of Bio-geographic population threshold viz: Little Coromorants, Garganeys, the Indian Wishkered Tern. The lake is also famous for its fish fauna. Around 58 species of fish including many commercial fish are reported from the lake. Vembanad-Kol wetland as observed on satellite image is shown in Figure 34.

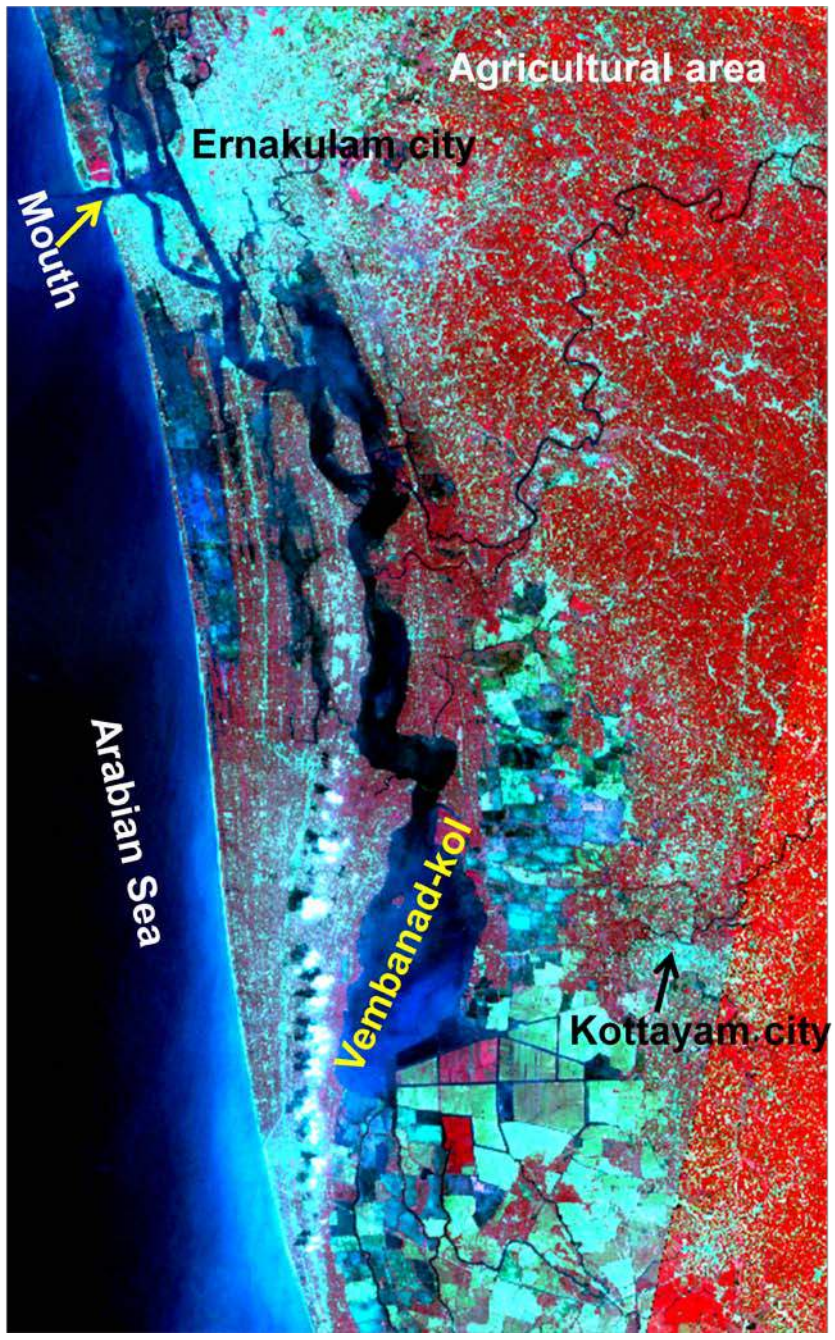

Figure 34: Vembanad-Kol wetland and its environ as seen in LISS-III FCC (27-February-2006)

Vemband-kol wetland is spread over an area of 17589 ha with a perimeter of 186 km. The seasonal variation (17442 ha to 117503 ha) in terms of open-water spread is negligible. The vegetation was observed to be 147 ha in post-monsoon which got reduced to 86 ha in pre-monsoon season (Table 55).

Table 55: Salient observations of Vemband-kol wetland from satellite data

Name:	Vembanod-Kol Wetland
Location:	$09^0$29’43” to $09^0$59’25” N Latitude $76^0$13’49” to $76^0$27’34” E Longitude
Wetland Type:	Lagoon
Wetland Area: Perimeter :	17589 ha 186 km
<u>Open-water</u> Post-monsoon: Pre-monsoon:	 17442 ha 17503 ha
<u>Vegetation</u> Post-monsoon: Pre-monsoon:	 147 ha 86 ha
Overall Turbidity:	Low-Moderate

The catchment including the 12 km buffer area is estimated to be 416113 ha. Including the Ramsar site, there are 287 wetlands with an estimated area of 41702 ha (Table 56). The open-water spread has a marginal variation from post-monsoon (37906 ha) to pre-monsoon (37168 ha) season. The variation in the extent of vegetation has shown decrease from 3673 ha to 2747 ha (Table 56). Wetland type-wise area estimates and seasonal changes in terms of open-water and vegetation are given in Table 56.

Table 56: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Vemband-kol wetland

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1105	Waterlogged	191	7417	4565	4298	2943	1788
1106	River/Stream	33	9629	9624	9489	-	-
1201	Reservoir/Barrage	1	381	356	381	22	-
1202	Tank/Pond	26	67	26	-	48	40
2101	Lagoon	17	24033	23276	22941	660	919
2102	Creek	14	62	59	59	-	-
2103	Sand/Beach	5	113	-	-	-	-
	Total	287	41702	37906	37168	3673	2747

Wetland map of the Vembanad-kol catchment including the 12 km buffer area is given in the Plate 121. The seasonal status of open-water spread and vegetation are given in the Plates 122-125 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

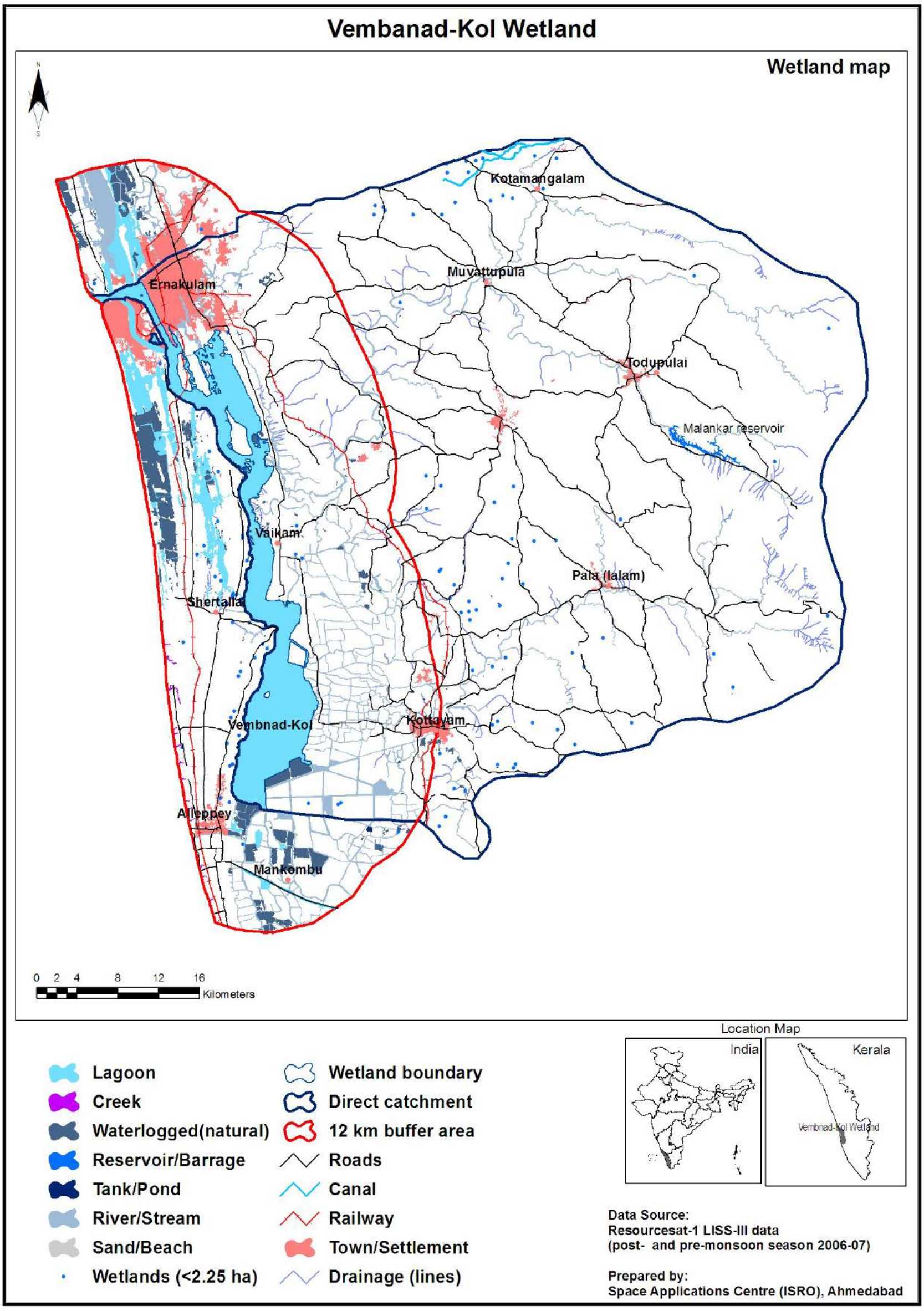

Plate 121: Wetland map of Vembanad-Kol Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

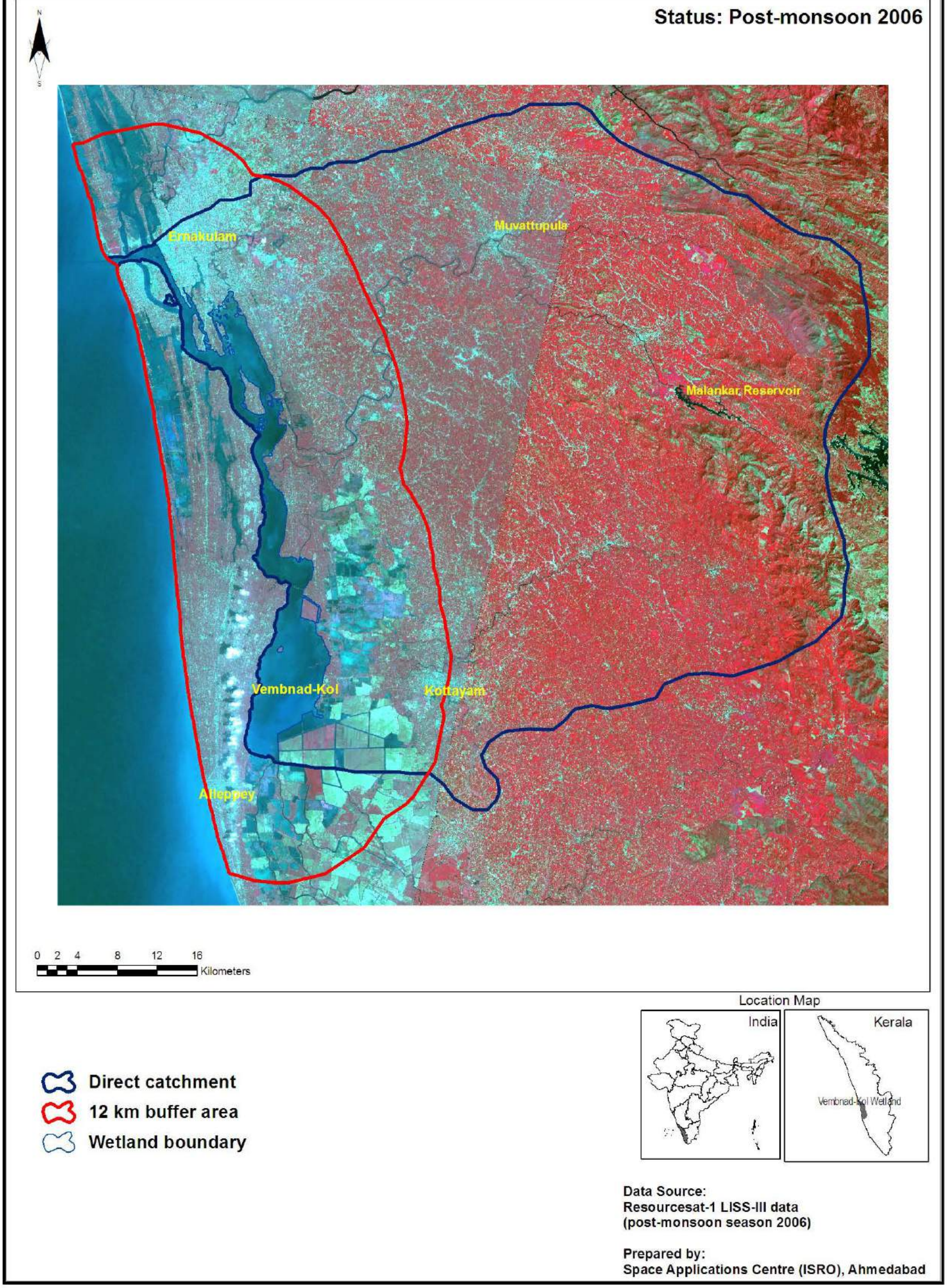

Plate 122: Vembanad-Kol Wetland and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (22-February-2006)

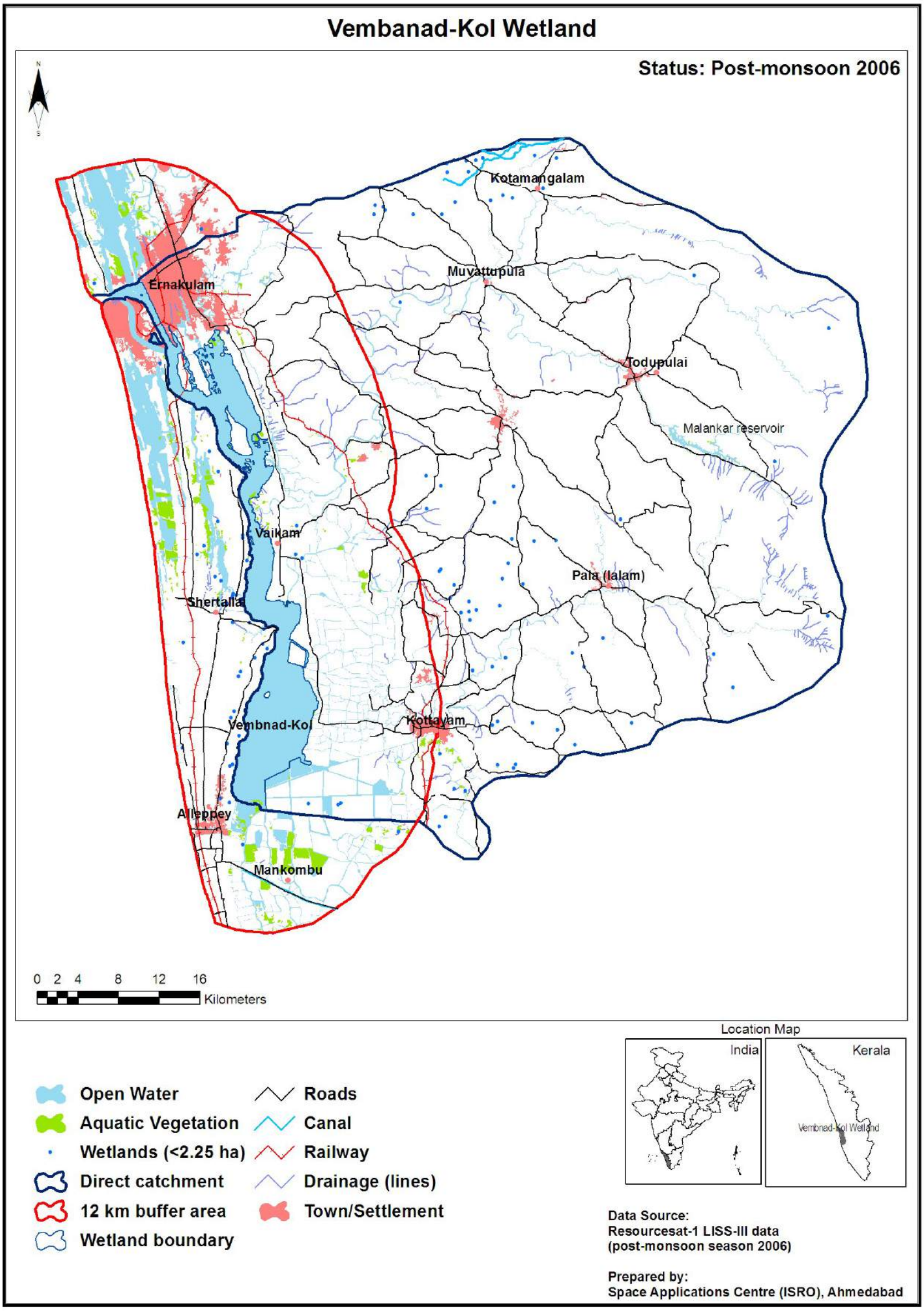

Plate 123: Open-water and vegetation status of Vembanad-Kol Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

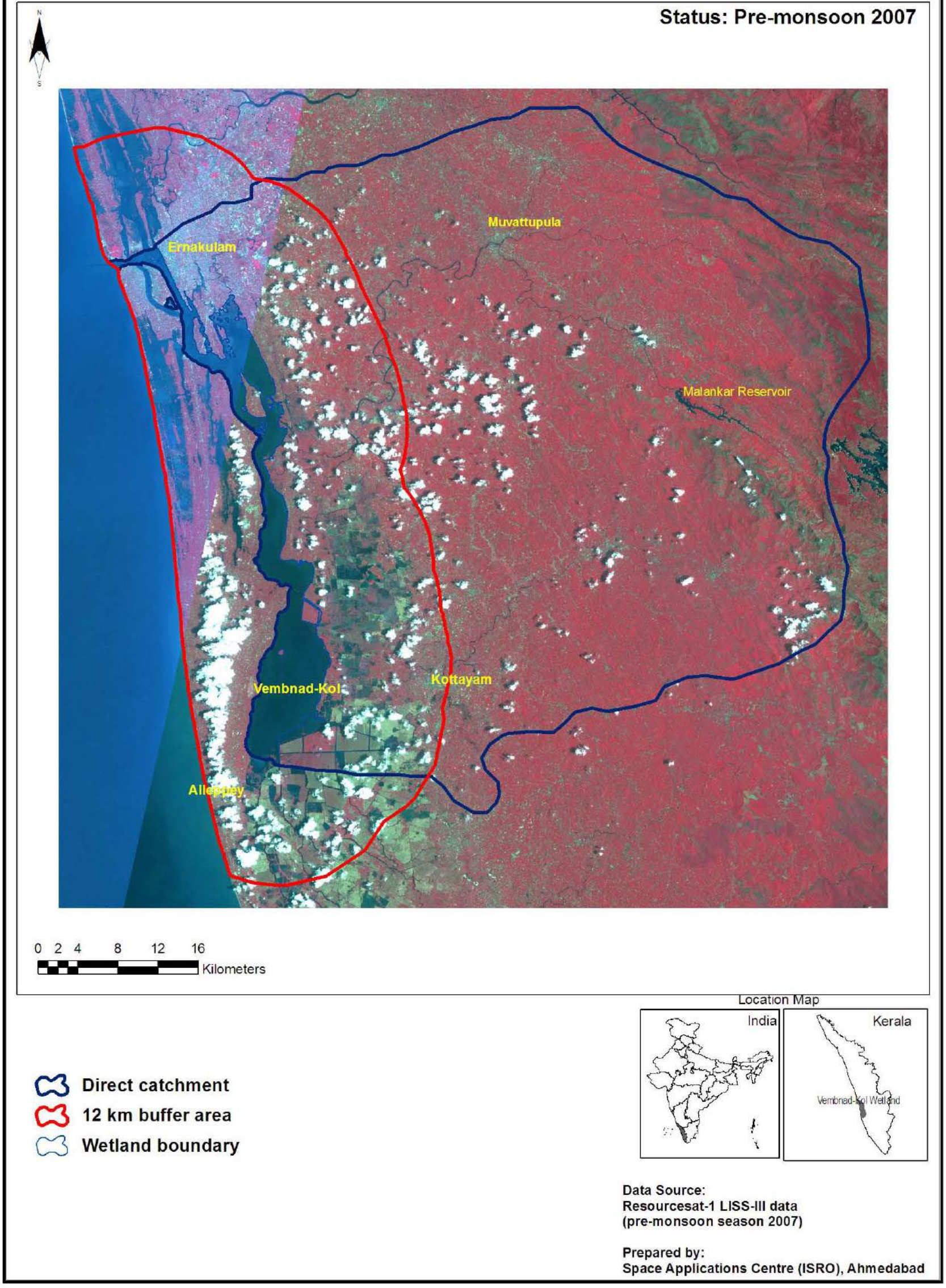

Plate 124: Vembanad-Kol Wetland and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (23-March-2007)

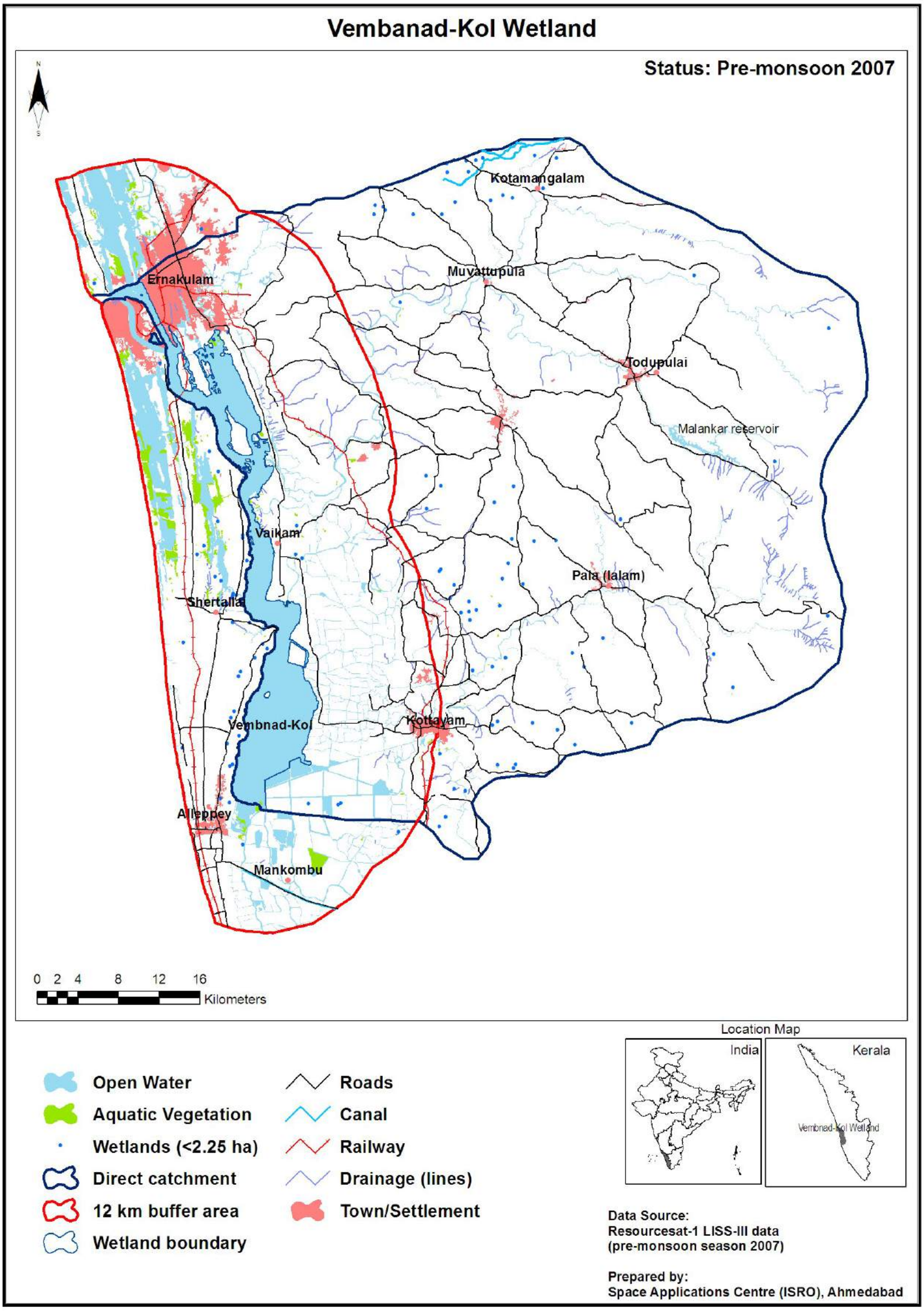

Plate 125: Open-water and vegetation status of Vembanad-Kol Wetland (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

4.2.26 Wular Lake (Ramsar site no. 461)



The Wular lake lies on the flood plains of the River Jhelum in the Kashmir valley. It is one of the largest freshwater lakes in Asia. The lake is surrounded by high mountain ranges on the north east and north-west sides. Due to the topography, the lake encounters strong wind. The name of the lake originates from the word meaning turbulence caused by wind. The lake, along with the extensive marshes surrounding it, is an important natural habitat for wildlife. The catchment area of the lake supports magnificent coniferous forests, alpine pastures and orchards, adding to the natural beauty and biodiversity of the wetland area. In recognition of its biological, hydrological and socio-economic values, the lake was included in 1986 as a Wetland of National Importance under the Wetlands Programme of the Ministry of Environment and Forests, Government of India for intensive conservation and management purposes.

Subsequently on 23/03/1990, it was designated as a Wetland of International Importance under the Ramsar Convention owing to the compliance of criteria 2, 5 & 6 as described below:

- Wetland supports threatened ecological communities.
- Wetland regularly supports 20, 000 or more waterbirds.
- Wetland regularly supports 1 % of the individuals in population of a species or subspecies.

The lake is a suitable wintering site for a number of migratory waterfowl species such as the common teal, pintail, shoveller, common pochard, mallard and others. It is also an important habitat for fish, accounting for 60 per cent of the total fish production within the State of Jammu and Kashmir. The lake is a source of livelihood for a large human population living along its fringes. The lake sustains a number of endangered and endemic species of flora and fauna.. Wular Lake as observed on satellite image is given the Figure 35.

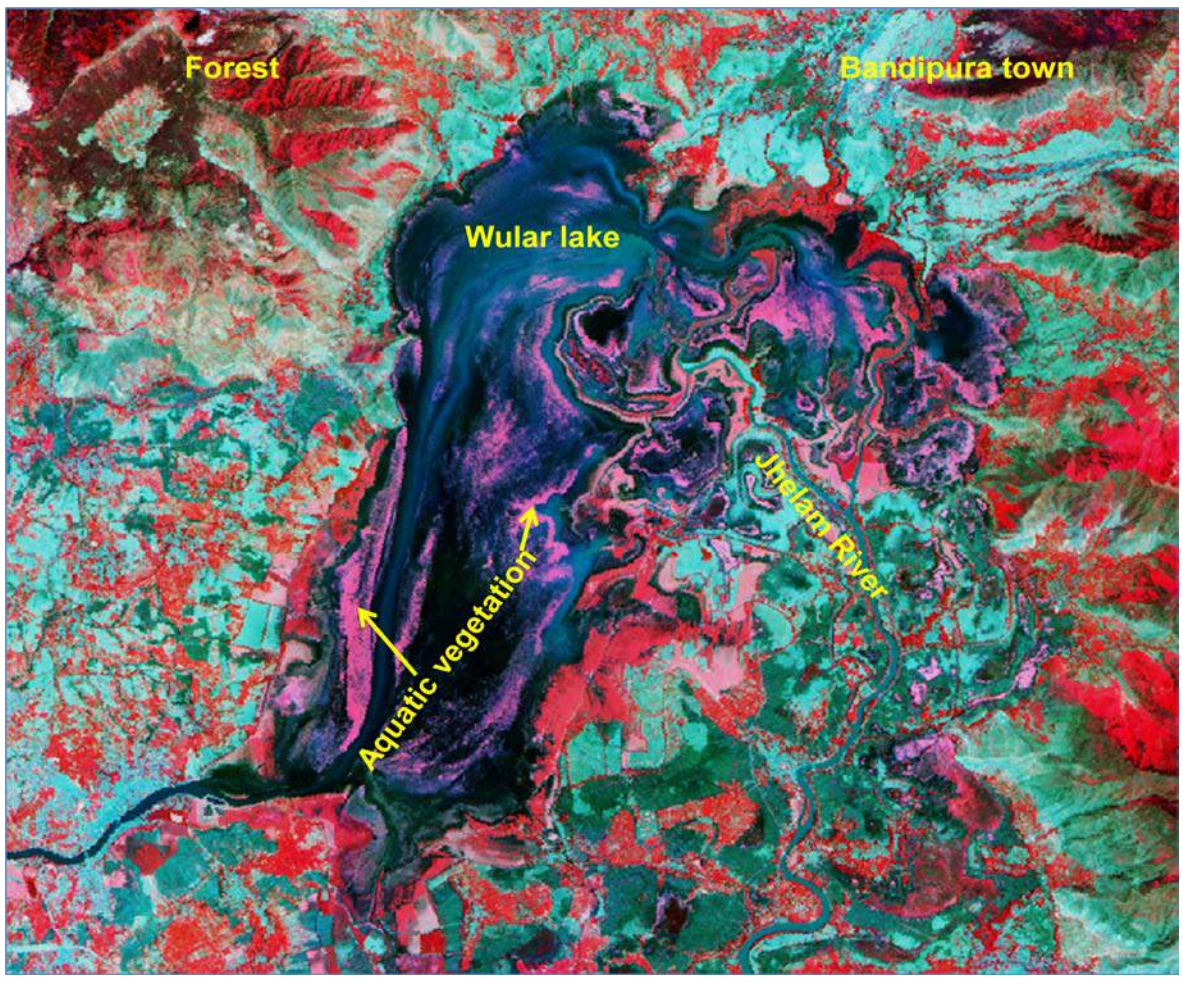

Figure 35: Wular Lake and its environ as seen in LISS-III FCC (18-May-2007)

Wular Lake is spread over an area of 11277 ha with a perimeter of 129 km. There was 3 fold increase in open-water spread form 1764 ha in post monsoon to 4935 ha in pre-monsoon season (Table 57). On the other hand there was a 1.5 times decrease in the vegetation from 9481 ha to 6304 ha (Table 57).

Table 57: Salient observations of Wular Lake from satellite data

Name:	Wular Lake
Location:	34^0 17' N and 34^0 25' N Latitude 74^0 30' E and 74^0 40' E Longitude
Wetland Type:	Lake/Pond
Wetland Area: Perimeter :	11277 ha 129 km
<u>Open-water</u> Post-monsoon: Pre-monsoon:	 1764 ha 4935 ha
<u>Vegetation</u> Post-monsoon: Pre-monsoon:	 9481 ha 6304 ha
Overall Turbidity:	Moderate-High

The catchment including the 12 km buffer area is estimated to be spread over 287357 ha. Including the Wular Lake, there are 76 wetlands with an estimated area of 22682 ha (Table 58). The Wular Lake itself accounts for about 50 % of the area. The other major wetland type is Riverine wetlands with an estimated of 8300 ha followed by River/Stream (2727 ha). A two-fold increase was observed in open-water spread from post-monsoon (4745 ha) to 9176 ha in pre-monsoon season). In case of vegetation, about 25 % decrease was observed from post-monsoon (17810 ha) to 13445 ha in pre-monsoon (Table 58). Wetland type-wise area estimates and seasonal changes in terms of open-water and vegetation are given in Table 58.

Table 58: Type-wise aerial estimates of wetlands in the catchment and 12 km buffer area of the Wular Lake

Wetland type code	Wetland type	Number of wetlands	Area (ha)				
			Wetland	Open-water		Aquatic Vegetation	
				Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon
1101	Lake/Pond	8	11571	1932	5196	9557	6454
1103	High Altitude Wetlands	7	84	84	84	-	-
1104	Riverine Wetland	52	8300	42	1381	8253	6991
1106	River/Stream	9	2727	2687	2515	-	-
	Total	76	22682	4745	9176	17810	13445

Wetland map of the Wular Lake catchment including the 12 km buffer area is given in the Plate 126. The seasonal status of open-water spread and vegetation are given in the Plates 127-130 in the form of images and corresponding spatial layers based on the post-monsoon (2006) and pre-monsoon (2007) data of Resourcesat-1 LISS-III.

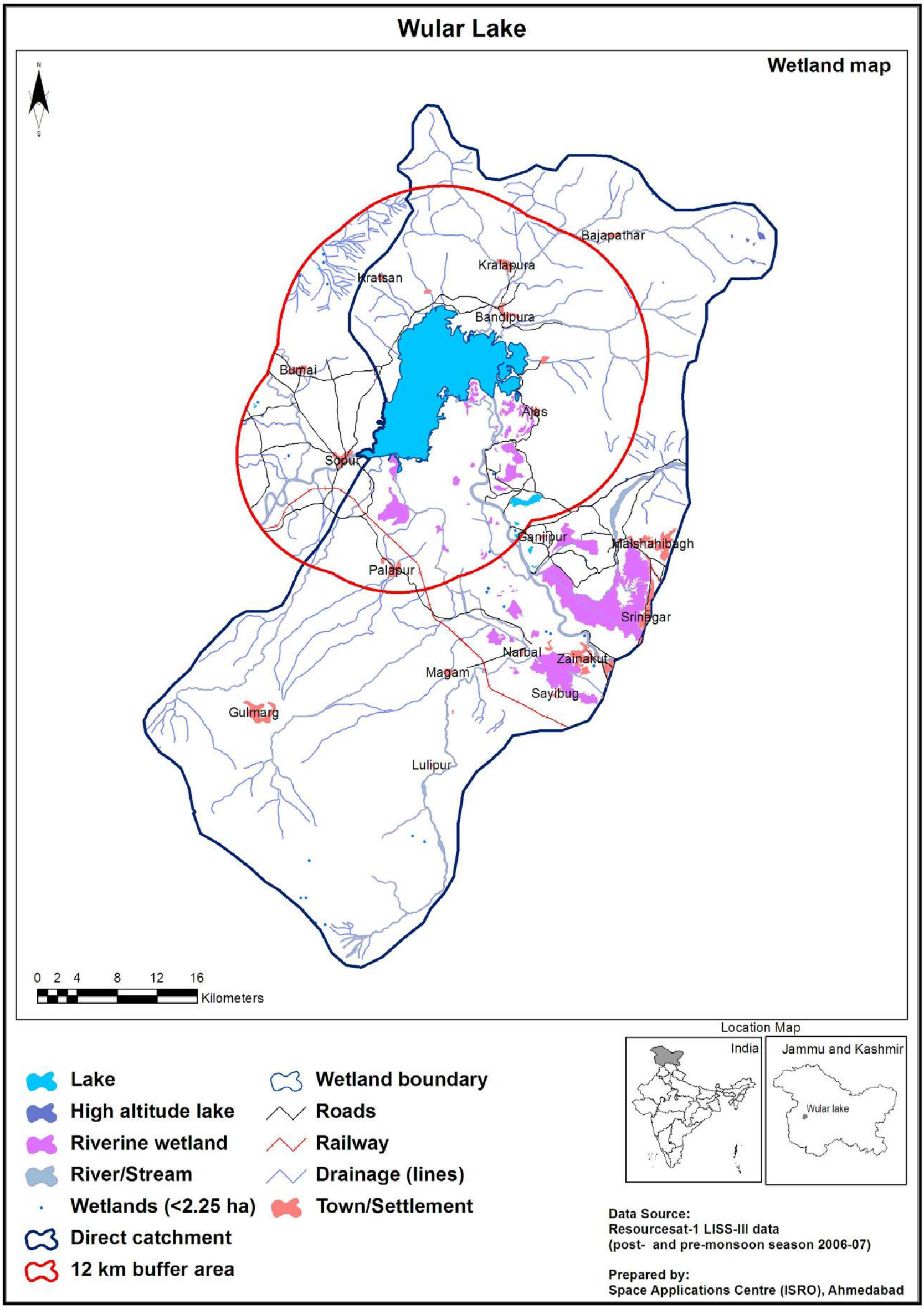

Plate 126: Wetland map of Wular Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III data of post-monsoon (2006) and pre-monsoon (2007)

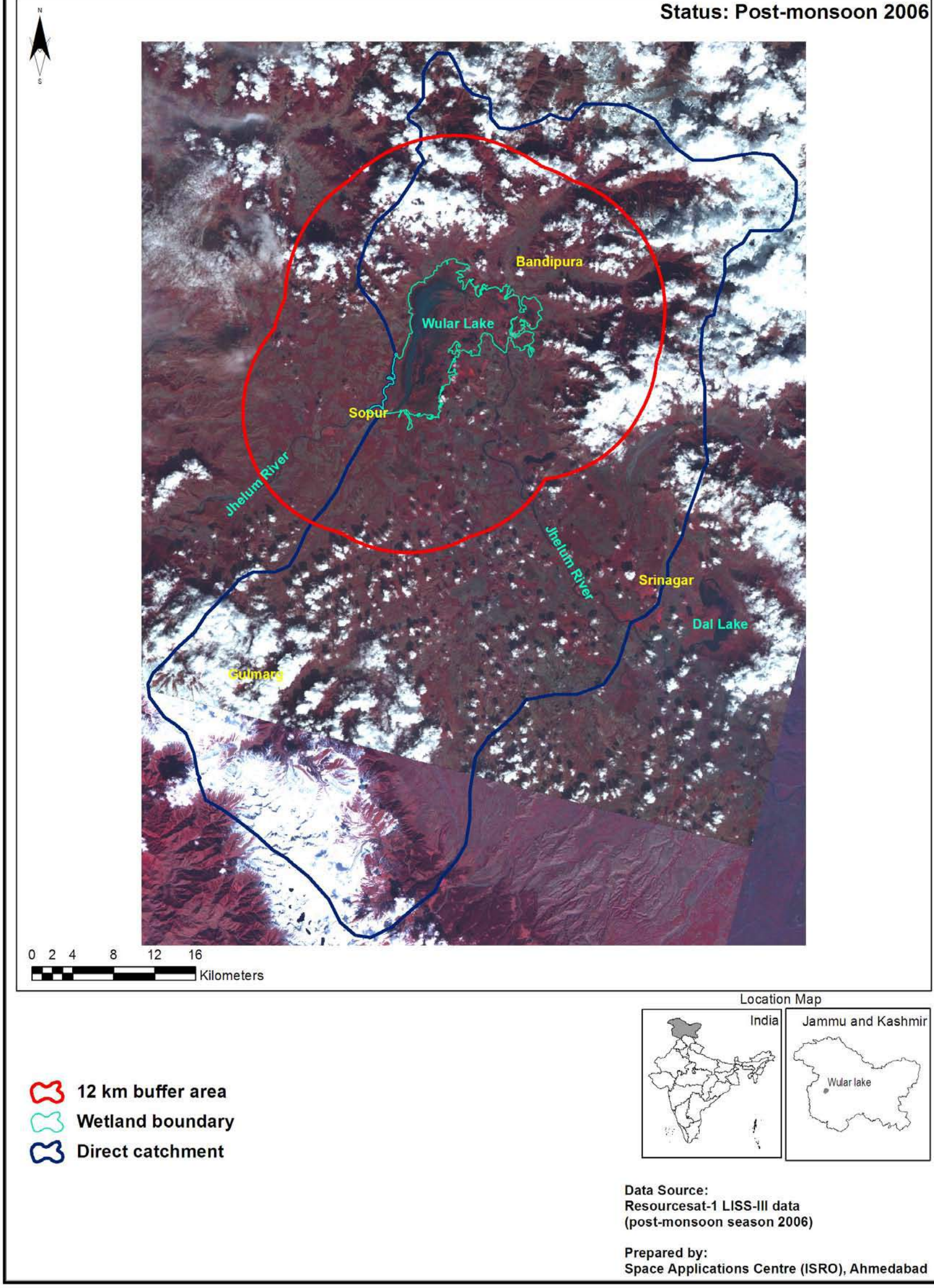

Plate 127: Wular Lake and its environs as seen on Resourcesat-1 LISS-III image of post-monsoon season (14-October-2006)

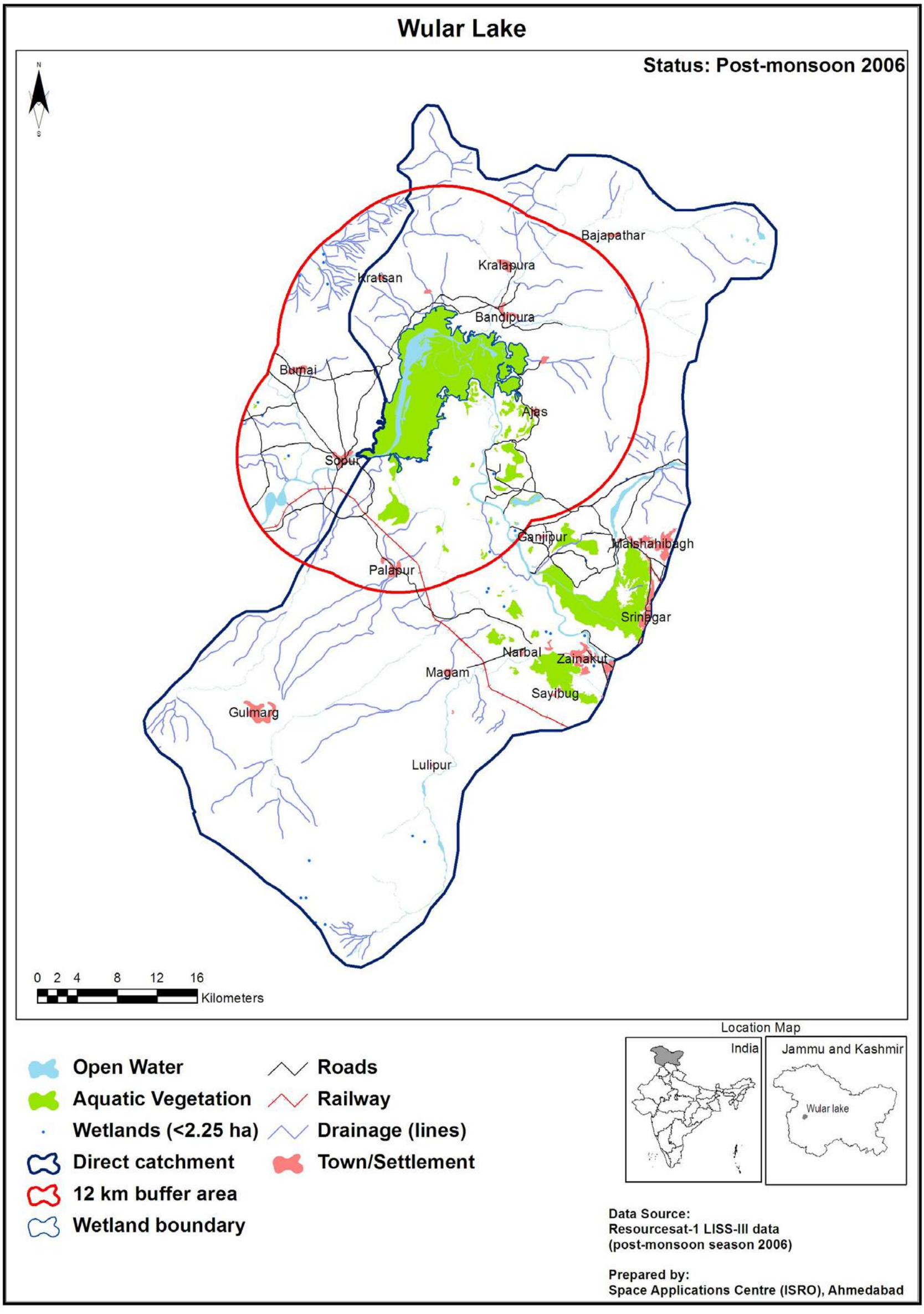

Plate 128: Open-water and vegetation status of Wular Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of post-monsoon-2006

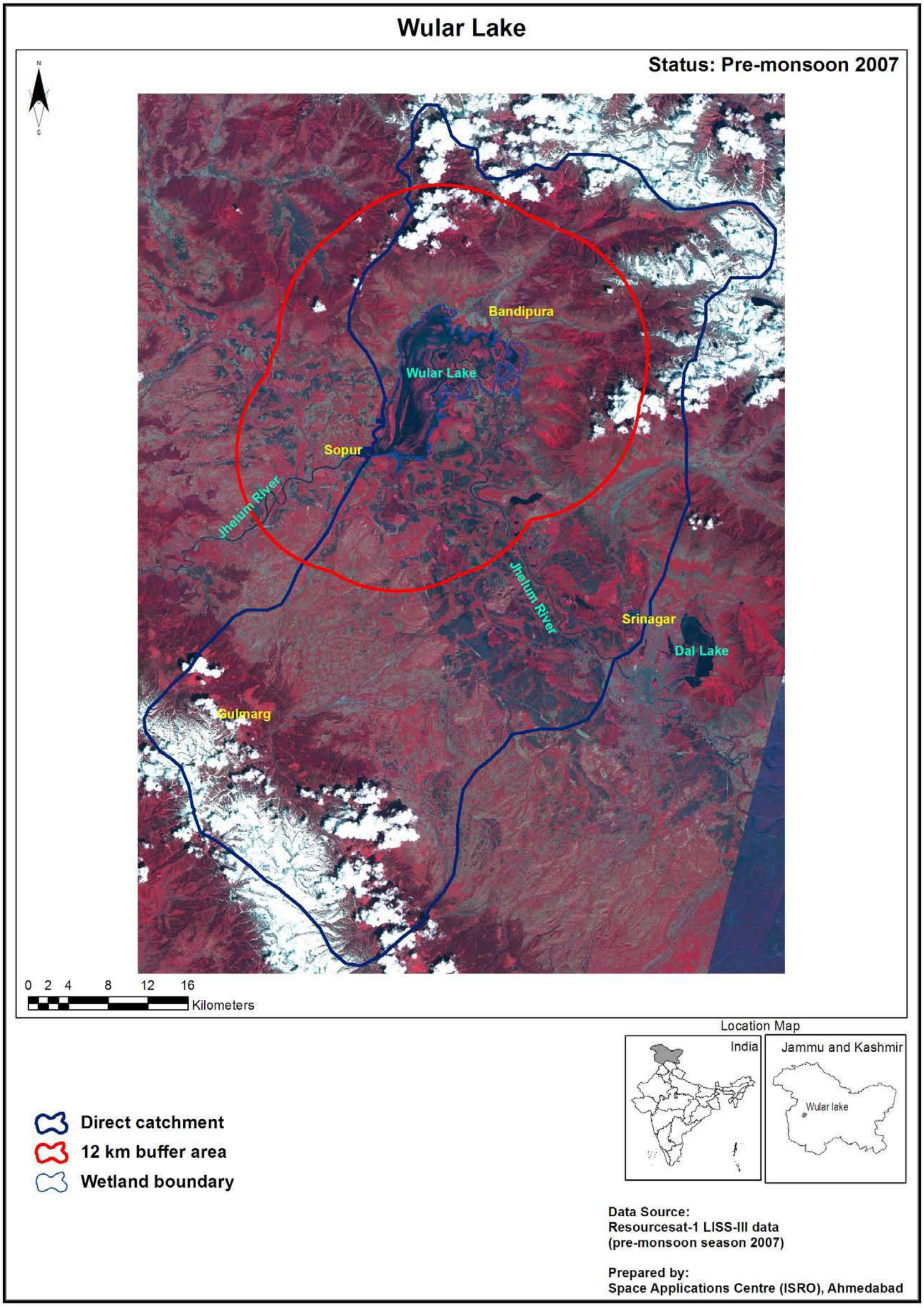

Plate 129: Wular Lake and its environs as seen on Resourcesat-1 LISS-III image of pre-monsoon season (18-May-2007)

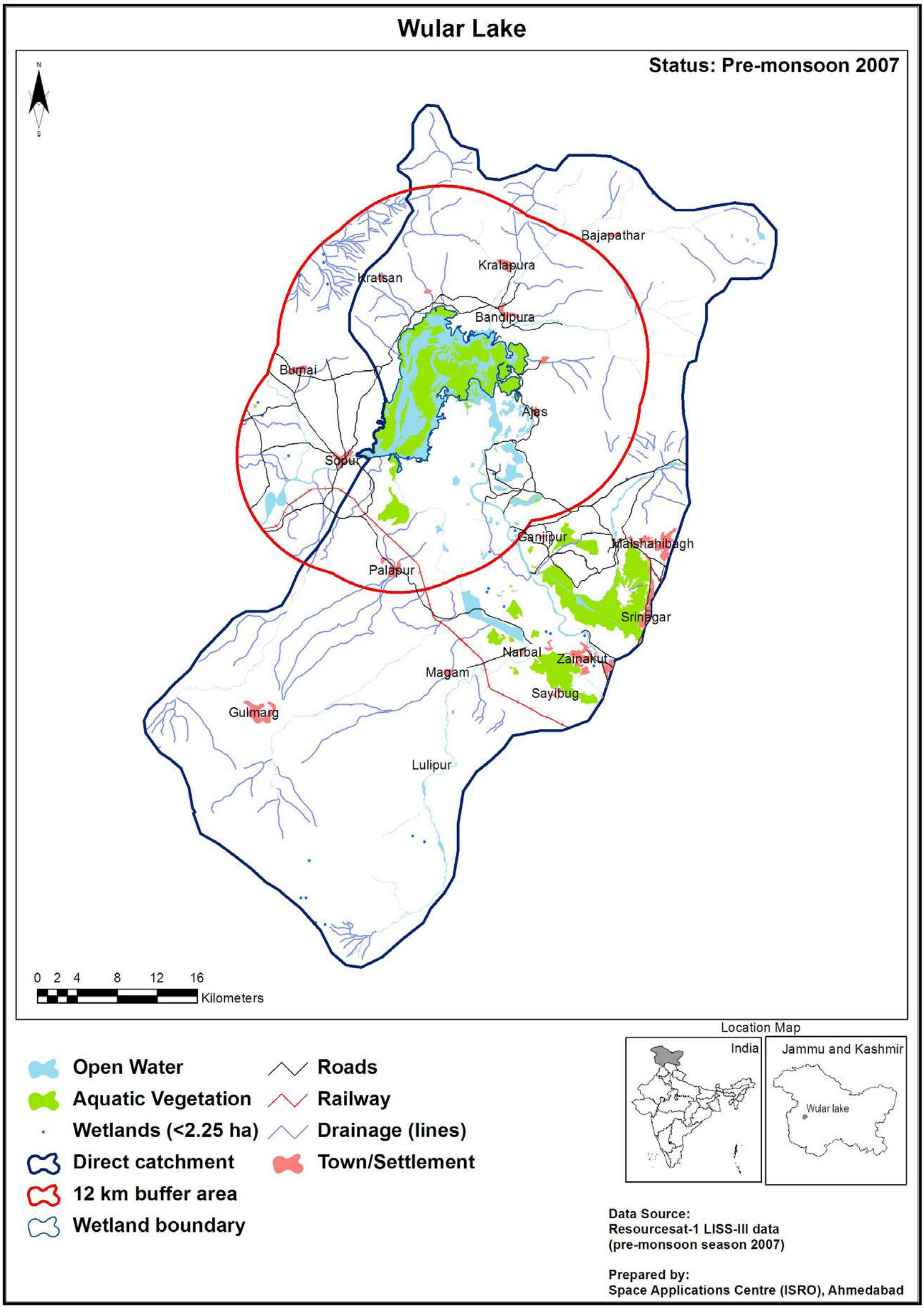

Plate 130: Open-water and vegetation status of Wular Lake (catchment including 12 km buffer area) based on Resourcesat-1 LISS-III image of pre-monsoon-2007

5. Conclusions

This is the first atlas of Ramsar wetlands in India prepared at 1:50, 000 scale using advanced space technology. Since, this information has been derived as a part of the National Wetland Inventory; one gets an overall idea about the Ramsar wetlands in relation to the total wetland diversity in India. The total area under Ramsar Sites in India is 402505 ha, which is around 2.64 per cent of the estimated total area of the wetlands in India. The GIS data base enables to analyse the distribution pattern of Ramsar sites in relation to bio-geographic zone or agro-climatic region to assess the overall scope of further identification of new areas. The data base created under the NWIA project will facilitate integrated analysis for decision making based on various criteria like size, type, location, water and vegetation status etc, for such planning.

Monsoon plays the most important role in the hydrology of wetlands in India. Use of two season remote sensing data has enhanced the seasonality of various structural components of the Ramsar wetlands like the water spread, turbidity of water and vegetation status. The status of aquatic plants mainly the floating, emergent and shore vegetation get enhanced during the pre monsoon due to receding water. Also, use of wetland water resources for irrigation of agriculture crops is well deciphered during the summer season. Thus, the maps and statistics generated will be of use to assess the ecosystem service as well as to identify the critical issues pertaining to management of each site.

The atlas has also highlighted the status of catchment of each site, including a 12 km buffer area. It is in general observed that eutrophication is common problem in all the sites, particularly those in the plain areas. This is mainly due to the runoff bringing nutrient and silt from the agriculture and degraded forest areas in the catchment. Encroachment of the lake for agriculture, particularly during the summer as the water recedes is another observation. Monitoring of the wetlands during summer season is thus crtical for management planning.

This work further strengthens the utility of satellite remote sensing data in providing accurate and timely information to assess the ecological status of wetlands. This is of particular significance to a large country like India, with a diverse type of wetlands spread in not so accessible high attitudes of Himalayan terrain to the mangrove swamps in the coasts. The synoptic view of satellite image is ideal to assess the lake and surrounding area which are highly interlinked. This atlas on Ramsar sites may be considered as the base information to design further work to facilitate management of these complex ecosystems that have multi prong use by local communities. The availability of satellite remote sensing data at various spatial resolutions from indigenous Indian Remote Sensing satellites provides ample scope of various scale mapping**.**

Combined with the Geographic Information System, a powerful tool is now available for scientific planning for wise- use of wetlands.

A detailed atlas of Ramsar wetlands at finer scale of at least 10,000 highlighting the concern areas that require intervention to check further degradation of quality of wetlands and addressing the ecosystem service of each site in the context of local communities is the need of the hour, which may be taken up by concerned authorities, Such atlases are also useful for general public awareness regarding wetland issues.

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