

MAPPING OF SURFACE WATER BODIES IN PUNJAB USING HIGH RESOLUTION REMOTE SENSING DATA

Project submitted to the Central University of Punjab

For the award of

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In

Department of Geography and Geology

By

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DECLARATION

I hereby declare that the project work entitled, as “Mapping of Surface Water Bodies of Punjab Using High Resolution Remote Sensing Data” has been prepared by me under the guidance of Dr. Kiran K. Singh (Assistant Professor), Department of Geography and Geology, School of Environment and Earth Sciences, Central University of Punjab. No part of this project work has formed the basis for the award of any degree or fellowship previously

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CERTIFICATE

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ABSTRACT
Mapping of Surface Water Bodies in Punjab and High Resolution of Remote Sensing Data

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This study is an attempt to create boundary of Punjab state and surface water bodies map from NATMO atlas map, SOI map, Landsat-8 data and Google Earth image using GIS software. It has also compared the variation in status which is extracted from the data or image of various scale or resolution. According to NATMO data, the water bodies in Punjab are 1476. 109km² (excluding canals), according to Landsat-8 are 2844.55 km² (including canals), according to SOI are 764.93 km² and according to Google earth are 141.06 km². Variation in the status of the area and length of surface water bodies is due to the scale and resolution of images. High resolution image is capable of creating precise boundaries. The purpose of this study was to create precise boundaries of the state and water bodies. Management of water bodies calls for generation of multiple inventories and demarcation of precise boundary is one of the inventories. This study also suggests the Map making organisations to revise their maps by using recent geospatial technologies.

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List of Abbreviations

Sr. no.	Full Form	Abbreviations
1	MISSION AVIATION FELLOWSHIP	MAF
2	WATER RESOURCE INFORMATION SYSTEM	WRIS
3	NATIONAL ACTION PLAN ON CLIMATE CHANGE	NAPCC
4	PATIALA AND EAST PUNJAB STATES UNION	PEPSU
5	SUTLEJ– YAMUNA LINK	SYL
6	NATIONAL ATLAS AND THEMATIC MAPPING ORGANISATION (NATMO)	NATMO
7	SURVEY OF INDIA	SOI,
8	GEOGRAPHIC INFORMATION SYSTEM	GIS
9	INDIAN SPACE RESEARCH ORGANISATION	ISRO
10	GENERATION OF DATABASE AND IMPLEMENTATION OF WEB	GDIW
11	WORLD GEODETIC SYSTEM	WGS
12	FEDERAL COMMUNICATIONS COMMISSION	FCC.
13	MASTERS IN COMPUTER MANAGEMENT	MCM.
14	UPPER BARI DOAB CANAL	UBDC
15	RESIDUES SODIUM CARBONATE	RSC

Chapter 1: Introduction

The main source of water on earth is rainfall, a part of rainfall penetrates into the earth become ground water, a part is evaporate to form humidity and some part of it runs off into ocean, seas and lakes in the form of surface water. India is a vast country and many rivers flow, lakes, ponds and wetlands exist on the land of country to avail surface water to the nation. India is divided into three major regions according to its topography- Himalayan region, Ganga-Brahmaputra Plains region, Peninsular region. The state of Punjab is situated in the Sutlej plains which are western part of Sindhu-Ganga-Brahmaputra Plains. These alluvial plains constitute a vast underground water reservoir, which is most productive in India. But, the scene has changed, while Punjab is much productive but in that state which was called land of five rivers with plenty of water, nowadays water is growing scarce. Underground water is depleting at very fast rate. Underground water is getting depleted in all districts of the state, mainly in Central and North-Eastern Punjab.

1.1 Water Resources of Punjab State: Punjab, one of the smallest (area) states of India, is rich in natural resources and biodiversity. Punjab, formally known as Land of five rivers, has water resources in the form of three rivers flowing on the land of this state. The water is an important element for the human culture, living organisms, and natural habitat. It is used for drinking, cleaning, agriculture, transportation, industry, recreation, and animal husbandry, producing electricity for house, industrial and money-making use. The major rivers of the state Punjab are Sutlej, Ravi, Beas and Ghaggar. Sutlej River enters Punjab near Nangal & moves down to plain area at Ropar, passes through Ludhiana and joins Beas River at Harike. The lower Sutlej basin is irrigated by Bist-Doab and Sir hind irrigation system. The Punjab state has been a very large network of canal system. Canal as well as tube well irrigation play an important role for the agricultural in the state. A small part of Punjab state mainly the North and North east part of Punjab has been experienced some kandi or sub-Siwalik region such as areas of Rupnagar, Hoshiarpur, parts of Gurdaspur and Pathankot districts (WRIS, 2016). Canals are the prevailing means of irrigation in the western half of the state. In the central region of Punjab Tube well play an important role in irrigation facilities than the canal irrigation. Canal irrigation is very close to it in

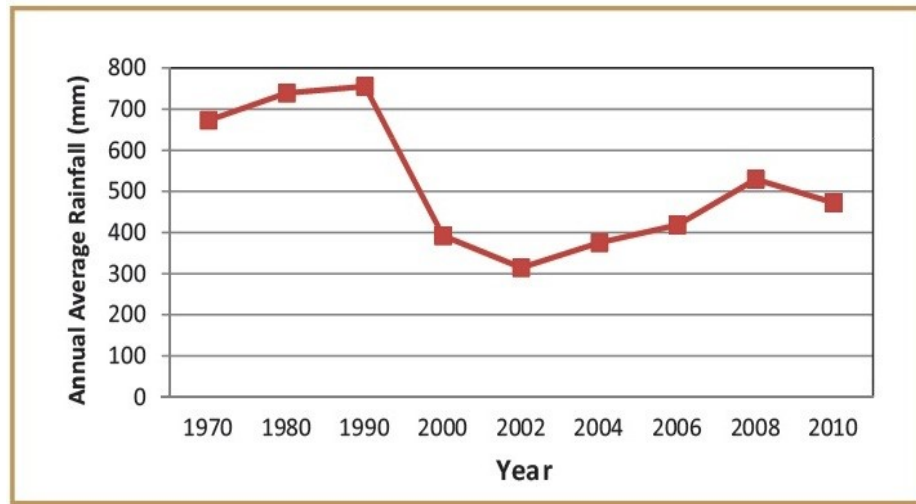
the foothill districts of the state parquet of higher level and wave's nature of the land surface (WRIS, 2016).

1.2 Use of Water in agriculture sector in Punjab: The north and central part of the Sutlej basin is an area of increased ground water over-exploitation. The South-Western part of the state is water logged and affected by salinity. Besides this, problems of high levels of fluoride, selenium and arsenic in the ground water have been reported in the lower Sutlej basin. Major part of the basin experiences ground water over exploitation condition, thereby indicating a negative balance when withdrawal exceeds the replenish able ground water recharge (NAPCC, 2011).

After Green Revolution, the diversified agriculture cropping pattern has changed to wheat-paddy cycle. Traditionally, the farmers had followed the Maize-Wheat or Sugarcane-Maize-Wheat cropping pattern but during about last four decades, they have shifted to Wheat-Rice cropping pattern thereby leading to increased demand on irrigation water. Because of intense agricultural practices, use of High Yield Variety Seeds, large quantity of fertilizers and pesticides for better yields crops has adopted in order to achieve national food security. Dependency on groundwater for irrigation, urban and rural Population consumption, industry and power generation has increased greatly due to limited availability of surface water in the state. The area under paddy in Punjab increased from 2.27 lakh hectares in 1960-61 to 11.83 lakh hectares in 1980-81 and further to 29.70 lakh hectares in 2015-16 (Ghuman, 2018).

Since mid-90 s there has been decrease in annual rainfall experiencing in the state. The annual average rainfall has been decreased from 739.1mm in 1980 – 565.9 mm in 2005 (Kumar et al, 2007). Fig 1.1 also shows the change in average annual rainfall in Punjab State during 1990s. As far as surface water resources are concerned there are limited and are fully utilized which meet the ever growing demand for agricultural, urban and rural population and industry, dependency on groundwater has been increasing.

Fig 1.1: Average Annual rainfall in Punjab (1970-2010)



Source:<http://punenvis.nic.in/index3.aspx?ssid=5959&subsublinkid=5067&langid=1&mid=1>

The agriculture in the state is therefore, mainly dependent upon large requirement of water. In 2005-06, 84 percent of the total cropped area was under wheat and paddy crops. Whereas for wheat crops, this increase on the Marginal (from 80-91 percent) during this period (2008) (Kumar et al, 2007). Out of the total irrigated area, through the groundwater and the tube wells has been increasing from 55-72 percent during this period. The method of irrigation like flooding method as well as overuse of water (both in terms of quantity and number of irrigations) has further increased the water consumption. The needs could not meet by surface water provided by rivers and canals. So, the number of tube wells has increased, shed light on the enhanced consumption of groundwater as well. There were only 1.92 lakh shallow tube wells in the State, during the year 1970, which has increased to 6.00 lakh in 1980, and presently there are more than 10 lac tube wells in the state (Department of Agriculture, Punjab, 2012). The total average water availability from river is 34.34 MAF and 14.54 MAF of water has been allotted to Punjab (Singh & Mann, 2017).

Approximately 82 per cent of the rainfall in Punjab (411.8mm out of the annual 501.4mm) took place between May and September in the years 2010-2014 (Singh & Mann, 2017). As per the Food and Agriculture Organization estimates, 9.35 MAF for 2009-10, 9.45 MAF for 2010-11, 9.40 MAF for 2011-12, 9.49 MAF for 2012-13 and

9.51 MAF for 2013-14 water available from rainfall. While estimating data of total requirement of water in Punjab, rainfall and river water availability, it has been observed that on an average 24 MAF of water is needed which is supplied by groundwater. About 50 per cent (i.e. 24 MAF of total 48 MAF) of water which is required to grow paddy has been extracted from groundwater (Singh & Mann, 2017).

1.3 Historical Background of Surface Water distribution among Punjab and neighboring states/nation: The 1947 partition of India and Pakistan left Punjab state with unresolved issue of surface water share of Indus River system. According to Indus Waters Treaty, 1960 the water of tributaries of Indus system has been allotted to between India and Pakistan which gave exclusive rights of waters of the Ravi, Beas and Sutlej to India mainly Punjab, and Chenab, Jhelum and Ravi to Pakistan. In the meeting of 1955 which was chaired by the then union irrigation minister of PEPSU, Rajasthan, and Jammu and Kashmir to resolve the water of these rivers. Among the total estimated 15.85 million acre-feet (MAF) has been distributed to PEPSU, Rajasthan and Jammu and Kashmir in the proportion of 5.9 MAF, 1.3 MAF, 8 MAF and 0.6 MAF, respectively. The merger of PEPSU to Punjab state in 1956, the Punjab's share became 7.2 MAF. The division of Punjab and Haryana in 1966, raise the issue of water shares again. This division has resulted in actual Punjab having access to only 25% of its surface water resources. The surface water share with Haryana along with Green Revolution in those times forced Punjab to extract water from its aquifers. Increase in number of Tube wells and Electric pumps has resulted in an overexploitation of about 150% of renewable groundwater resources of Punjab State. Punjab has Intensely-irrigated agriculture which covers approximately 80% of the land, and only of agriculture depends upon rain (Vatta et al, 2016). In Actual sense, the share of waters has neglected the scientific aspect but become the political agenda lead to exploitation of river water (Dhillon 1988). Haryana demanded 4.8 MAF water out of Punjab's share but Punjab being riparian state as well as agriculturally developed state shows its need of water and the issue of sharing has emerged. To address this issue, on 24 March 1976, under the Emergency regime, under Section 78 of Punjab Reorganization Act, 1966 to divide the water between two states, the Government of India passed this executive order. As per the study about

history of surface water sharing of Punjab by Ghuman, 2017, while in 1977, the Shiromani Akali Dal, then government of Punjab has challenged the validity of Sections 78–80 of water sharing under Punjab Reorganization Act, 1966 with the help of law and order in the Supreme Court. But, in 1978, the Government of Punjab accepted the idea of Sutlej– Yamuna Link (SYL) canal from the Haryana government to acquire land. In 1981 agreement, out of the total available waters (assessed on the basis of 1920–21 to 1960–61) of 17.17 MAF, Punjab, Haryana and Rajasthan were respectively allocated 4.22 MAF, 3.50 MAF and 8.60 MAF. Jammu and Kashmir and Delhi were given 0.65 MAF and 0.20 MAF. During, this era, Congress was the ruling party at Centre and in Punjab State also, this could be the possible cause of withdrawing the case pending at Supreme Court regarding water sharing. On 8 April 1982, Indira Gandhi laid the foundation stone of SYL canal at a village Kapuri in Patiala district of Punjab. But, the opposition party Shiromani Akali Dal along with Communist Party of India (Marxist) launched the Dharm Yudh Morcha from Kapuri to protest against the SYL canal. The Rajiv–Longowal Punjab Accord (between Rajiv Gandhi and Santharchand Singh Longowal) on 24 July 1985 specified the construction of the SYL. The central government constituted the Eradi Tribunal in 1986 to resolve the issues of Ravi and Beas river water sharing between Punjab and Haryana. In view of the Punjab Accord that The tribunal on 30 January 1987 upheld the legality of 1955, 1976 and 1981 agreements and also increased the share of Punjab and Haryana to 5 MAF and 3.83 MAF respectively. Sikh militants have killed the chief engineer of the construction of SYL canal in July 1990 so the construction has stopped. In 2002, Supreme court directed the government of Punjab to complete the construction of SYL canal and in 2004 again giver directions. In 2016, the Government of Punjab claimed by an advertisement in various newspapers on 22 November 2016 that 4,261 acres of fertile land belonging to 14,308 landowners in 202 villages of Punjab have remained unutilized. The SYL is unresolved issues between Punjab and Haryana. Various dams and Hydro Power Projects are constructed on these rivers which shares the power between various states.

Table 1.1: Major Hydro Power Projects of Punjab

S. No.	Name	Region	Basin	River
1	AnandpurSahib Hydroelectric Project	Ropar	Indus up to International Border	Satluj
2	Ganguwal&Kotla Hydroelectric Project	Rupnagar, Ropar	Indus up to International Border	Satluj
3	Mukerian Hydroelectric Project	Hazipur	Indus up to International Border	Beas
4	RanjitSagar Dam Hydroelectric Project	SHAHPUR KANDI	Indus up to International Border	Ravi
5	Shanan Hydroelectric Project		Indus up to International Border	Uhl
6	UBDC Hydroelectric Project	Gurdaspur	Indus up to International Border	Ravi

Source:http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=Hydro_Electric_Projects_in_Punjab

1.4 Objectives:

1. To Map area under surface Water for the State of Punjab using (NATMO, SOI, Landsat-8 data and Google earth Data).
2. To study the water resources Available and Utilization in Punjab.

Chapter 2: Review of Literature

The studies related to water availability, consumption, pollution and solutions to issues are available. There are some studies related to present study are reviewed.

Vashisht (2008) studied the status of water resources in Punjab and its management strategies: In this period, the entirely development of groundwater resources on Punjab will continue to be utilization to improve the agriculture production, and to gather agreement food demand and ensure the food security. Punjab is an important fertile, grain growing state of India. Moreover, thoughtless exploitation of these water resources has created hydrological imbalance, which is an important concern for the agriculture sustainability in the state.

Gupta, (2009) Ground Water Management in Alluvial Areas: Alluvial formations are important sources of abundant and dependable of groundwater supply. These formations have been widely exploitation for large-scale supply of water for industrial, irrigation and urban use. Punjab is occupied by quaternary alluvial deposits of Indus river basin. . The long term water level undulation data discover that water levels in major parts of the state have declined drastically.

Tsihrintzis, V. A., et al (1996). Water resources is the key to economic development, conservatory the nature as well as the quality. Water resources management needed of multidisciplinary approach that combines a procure of technical tools and expertise the paper highlight the project India- WRIS Web GIS jointly executed by ISRO and central water commission and aims as 'single window' solution of all water resources and related data and information in standardization of GIS format all concerned requirements, organizations and stakeholders scale of information and level of access of the apartment as well as download of different GIS maps, Data and Value added products along with tool kit for further analysis and value addition. India-WRIS Wiki is a collaboration knowledge sharing web interconnection for sharing updated information respecting the various aspects of the water resources of the nation. Apart from the spatial layers, information is also available in textual harassment and image format. India – (WRIS) water resource information system provides a platform to link non-spatial information with spatial layers countrywide and nationwide water

Resources information system, Generation of Database and Implementation of Web Enabled Water, Resources Information System (India-WRIS) in the country.

Central Water Commission, (2005 quality m): the Ministry of Environment and forest established a water quality Assessment authority (2001) in order to preserves the diversity and in the performance for water monitor system by all the operating agencies, different departments, pollution control boards and other agencies so that the water relevant action plan may be drawn.

Chapter 3: Data Sources, Methodology and Area of Study

3.1 Data Sources: The secondary data and mapping have been used for the study.

3.1.1 Secondary Sources: For the secondary sources data has been collected from the journals, newspapers, articles, and government reports.

3.1.2 Remote Sensing: To study the mapping of surface water body of Punjab areas, remote sensing data of Landsat_8 has been used. The four scenes of satellite data has been downloaded from USGS .i.e. (1) 13/10/2017 (2) 14/10/2017 (3) 24/10/2017 and (4) 25/8/2017.

3.2 Methodology: The following methods have been used for creating maps of surface water bodies and state boundary of Punjab State.

3.2.1 Layer Stacking: Layer stacking of data was done using layer stack tool of ERDAS Imagine software for generating of true and false colour composite of Landsat_8 imageries of USGS. For the false colour composite 4, 3, 2 bands have been used for detecting of water bodies in the study areas. The mosaicing of data has been done by using remote sensing and GIS software. In addition Atlas map of NATMO also has been used and map was scanned and rectified on UTM projection with WGS 84 datum.

3.2.2 Image Rectification: The data of surface water bodies and state boundary of Punjab has been created through the mapping of Landsat_8, SOI map and NATMO database in GIS software. After making the water bodies and state boundary on both data base, image rectification tools of ERDAS Imagine used for rectification purposes or comparing of each database. After completing these three maps has been prepared and one another map of Punjab state boundary has been created by using Google earth database. The map related to Surface water bodies has also prepared by using the database of Google earth. The length and areas of surface water bodies and boundary has been compared with each other data base of Landsat_8, SOI maps, NATMO map and Google earth map. Therefore, four different map of Punjab state boundary has been prepared by using four different datasets namely; (a) NATMO (b) SOI (c) Google Earth and (D) Landsat-8.

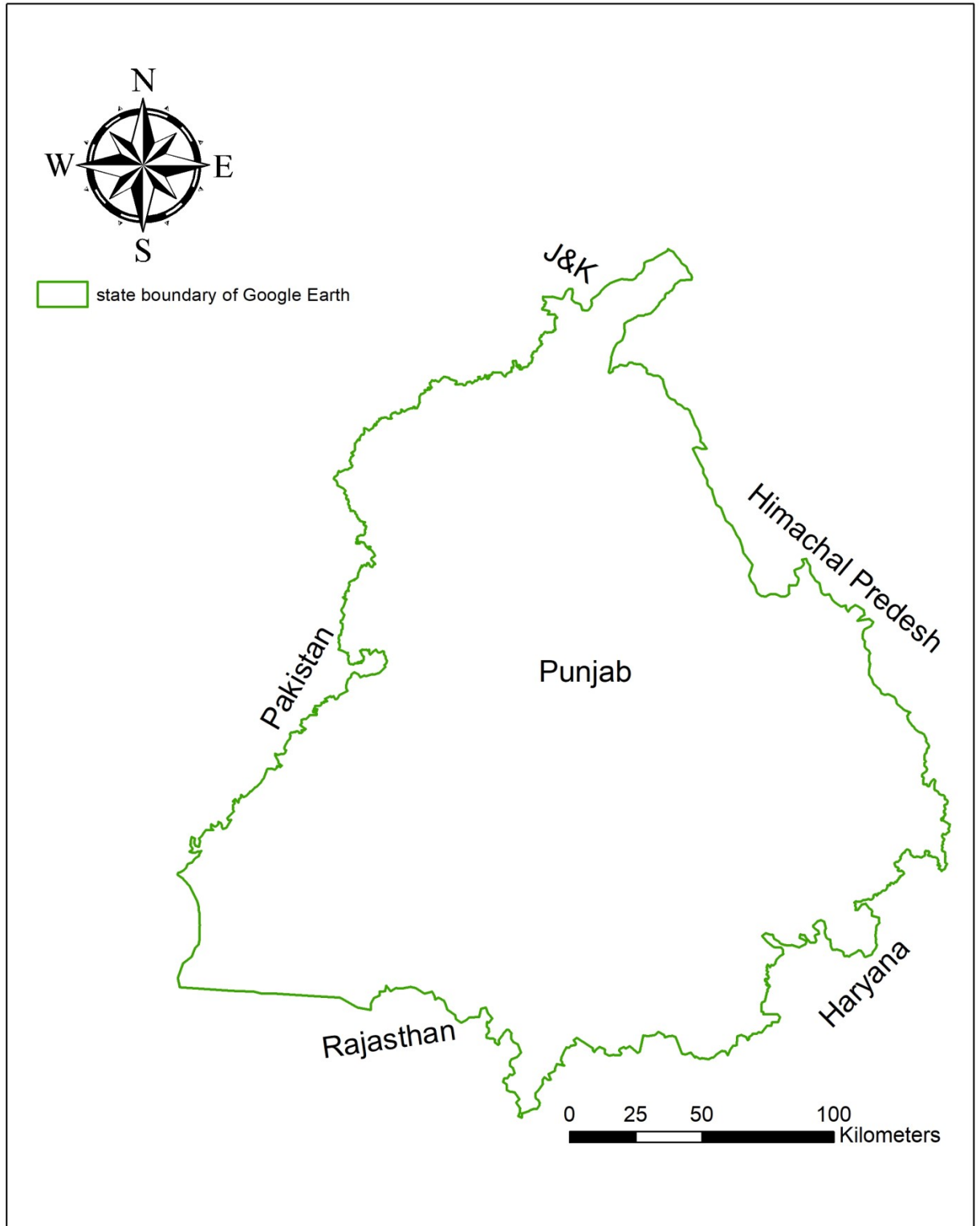
3.3 Area of Study: Punjab State of India has been selected to meet the objectives of the present study. Punjab state is situated in the north-west region of Punjab and shares the international boundary with Pakistan (Map 1). Punjab is located in the northwestern part of the country. The state is bounded on north side by Jammu and Kashmir, on northeast by Himachal Pradesh, on south by Haryana and Rajasthan and on west by Pakistan. The state has been divided into two major parts-sub-shivalik parts and Satluj- Ghagghar plain. Sub-shivalik parts cover the upper portion of the state includes districts like Ropar, Hoshiarpur, Gurudaspur districts. On the other side Satluj and Ghagghar plain consists of the remaining distt. The land of this region is much fertile. This state enjoys a semi-arid monsoon type of climate it is because of long distance from the ocean. The temperature in summers is very high especially in the southern parts winters are very cold in the state. Major rivers of the state include Ravi, Satluj, beas, Indus, Chenab and Ghagghar.

3.3.1 Location of Punjab state in India: The State of Punjab is located on the northwest side of India. The north side of bordered by the state is Jammu and Kashmir, Haryana to the south and southeast side, Rajasthan to the southwest and Himachal Pradesh to the northeast side. It is also international border share with a Pakistan country. The state of Punjab has been total area is about 50,362km² and extends from 29.30° north to 32.32° North latitudes a 73.55° east to 76.50° East longitudes. The Chandigarh is capital of Punjab, and which is also the capital of Haryana and a Union Territory. The map of Google Earth shows the length of the state boundary is higher is about (50358.56 km²) as compared to WRIS Diva-GIS, SOI, and others Sources. The geographical area of Punjab is about 50362 km²(1.54 percent of the country geographical area) is has been divided into 22 districts with 141 blocks. About 80 percent of the state's geographical are cultivated with cropping.

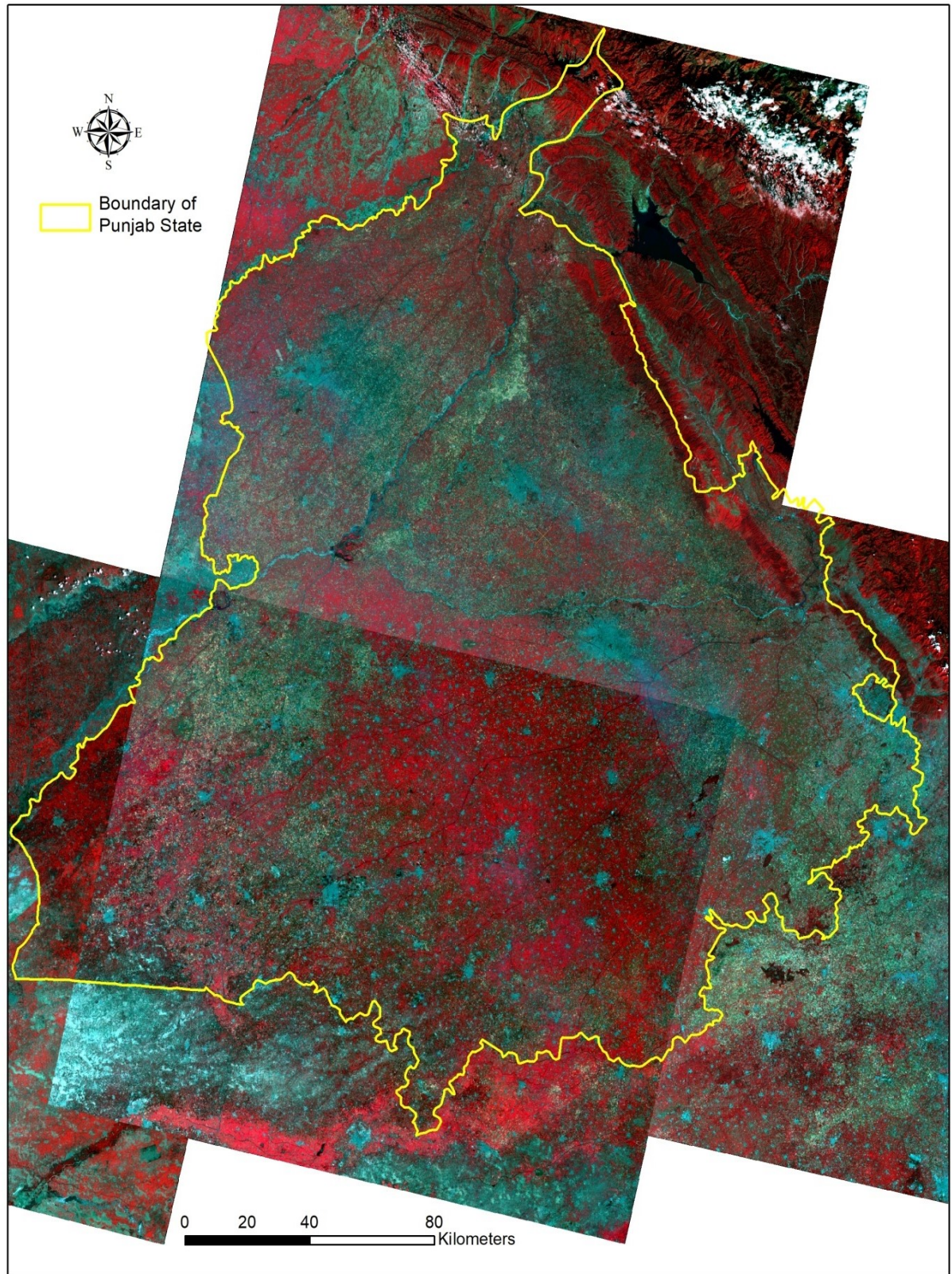
3.3.2 Climate: The region continent locating of Punjab reflects in it climate that vary from extremely hot and moisture during the summer season to clearly cold and dry during the winter season. The lowest temperature during the cold months of December and January is 5 degree, and in the summer months of May and June is temperature the extreme limits 44 degree. Much of the state is summer are high

Temperature and moisture. The state of Punjab Receive much of the rainfall from southwest monsoon, in the months of June to October. Average Rainfall modify from 100 to 800 mm in separate parts of state in 2016-17 as surface water resources. And average annual rainfall for is 435.6 mm. The state of Punjab is about more than 70percent of the rainfall happen in the months of July and August. The important characteristic of the rainfall in Punjab is that it is a highly changeable in time and space.

3.3.3 Economy of Punjab State: The economy of the state is mainly based on agriculture. The net sown area was 4.20 m ha, total irrigated area 4.06 m ha(97.4%), canal irrigated area 1.10 m ha(27.4%), tube well irrigated area 2.93 m ha(70%), total cropped area 7.90 m ha, cropping intensity 189.4% in 2011(Department of Agriculture, Punjab, 2012). In the Punjab state 85% of geographical area is under agriculture. It has a cropping intensity of 184%.



Map: 3.1. Location map of Punjab State in India shown above the state boundary prepared from Google earth.



Map: 3.2. Boundary of Punjab state overlaid on Landsat-8 image of year 2017 (image is shown in FCC).

Chapter 4: Results and Discussions

4.1 Availability of water resources in Punjab: Because any partial region, available water sources in the state of Punjab consists of: (i) rainfall (ii) surface water from canal networks and since is a whole regions of the hydrological cycle, this is the three water sources are privileges to each other. The present status of all the three water resources in Punjab state is discussed below.

4.1.1 Rainfall: The state of Punjab annual average rainfall is a 580 mm, which is the greatly eccentric in process in time and space. The state of Punjab (1994) effort away the total annual rainfall concluded cropped area of Punjab equal to 1.57 million hectare-meter (Mha-m). About 80 percent of total rainfall of Punjab region has occurred in the short span of three months mainly in monsoon seasons. The state of Punjab is the highest temperature (between 44.2 degree and 44.7 degree) as 2015-16 (ENVIS, 2011). The mean annual rainfall is about 705 mm, which varies from 1200 mm at Pathankot to less than 300 mm at Abhor, representing wettest and driest stations, as 2015-16 the state of major part of the rainfall happen between the months of July and September. This seasons growing Kharif crops and Rabi crops and soil is moist. The state of Punjab can be divided into three zone, viz. Central zone, North-Eastern Shivalik Foothill (Kandi) zone, Central zone, and South-western zone;

Shivalik Foothill Zone: This zone composed areas accurately 9600-km² which is around 19 percent of total geographical area of the state. The districts such as Gurdaspur, Hoshiarpur, Nawanshehar, Pathankot and Ropar come underneath in this zone. The average annual rainfall in the zone is 936 mm. This zone affected by soil and water erosion is about of 4500km² area in this zone (36percent) and high rainfall (average annual rainfall is about 1100 mm) (ENVIS, 2011).

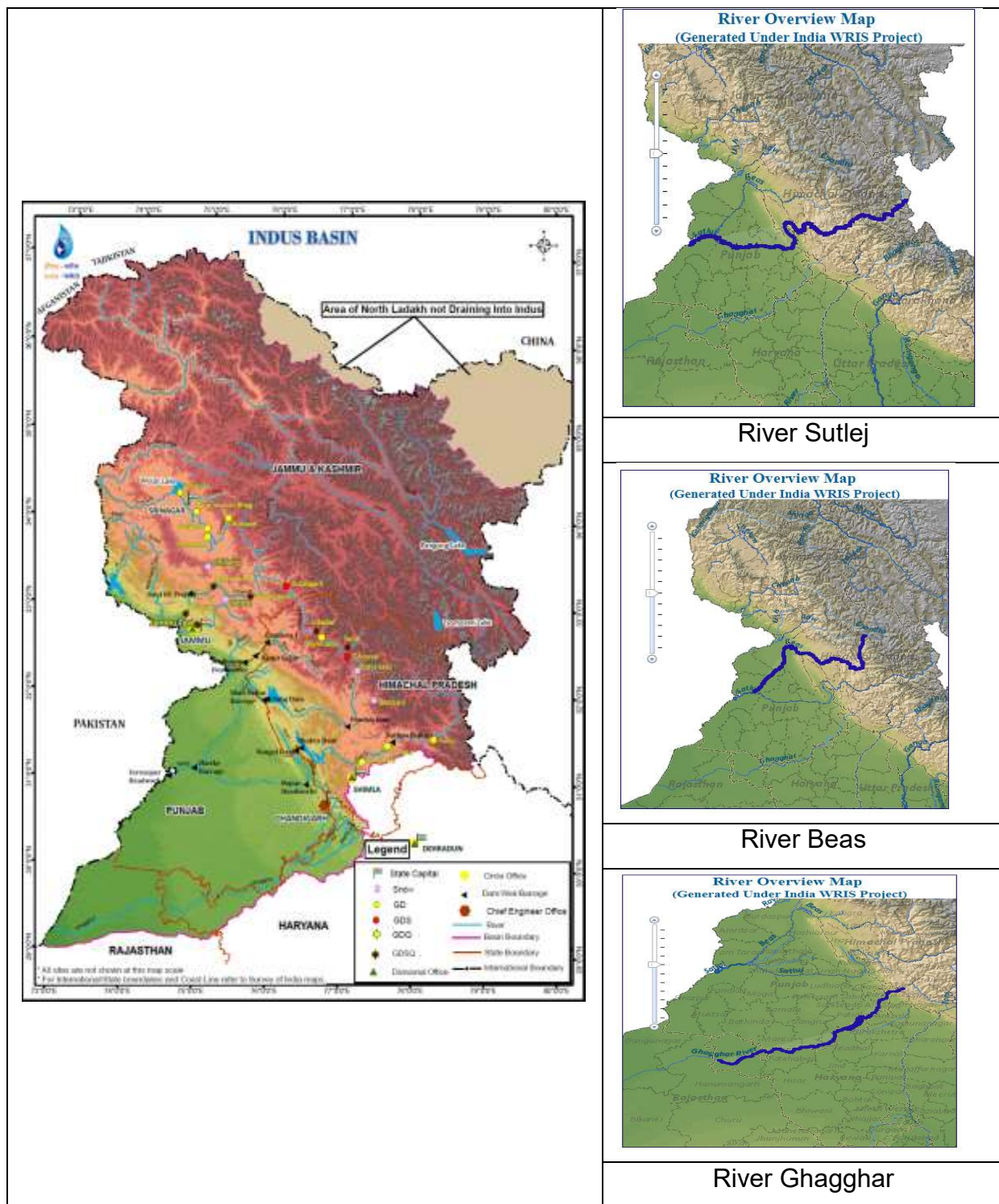
Central zone: In this zone, Amritsar, Kapurthala, Jalandhar, Ludhiana, Fatehgarh, Sangrur and Patiala lies and covered by 47 percent of the total geographical area of the state. The central zone average annual Rainfall is about 709 mm.

South western zone: This zone covered about 34 percent areas, out of total geographical areas of the state. The district likes Ferozepur, FaridKot, Mukatsar,

Mansa, Moga, and Bathindalies under this zone. The amount of rainfall in these districts declined to 342 mm.

4.1.2 Surface water Resource: The state of Punjab director of water resources, Punjab estimate the availability of the surface water in the state, the total surface water resources available, Punjab state share is approximately 1.80 Mha-m. (2005-08). The total surface water available annually is about 1.45 Mha-m, which is farmland is 1.54 Mha-cultivation areas. The utilization of surface water through canal network every year depends upon the water free from the supply, which are the division on the river in flows.

4.1.2.1 Rivers: Indus River System: The Indus basin extend over China (Tibet), India, Afghanistan and Pakistan draining an area of 11, 65,500 km². In India, the basin spreads over states of Jammu & Kashmir, Himachal Pradesh, Punjab, Rajasthan, Haryana and Union Territory of Chandigarh having an area of 3,21,289 km² which is nearly 9.8 percent of the total geographical area. The geographical extent of the basin is between 72°28' to 79°39' east longitudes and 29°8' to 36°59' north latitudes of the country with a maximum length and width of 756 km and 560 km. The basin is bounded by the Himalayas on the east, by the Karakoram and Haramosh ranges on the north side, the Sulaiman and Kirthar ranges on the west side, and the Arabian Sea on the south side (Map 4.1). The Indus River rises from the extremely mountains of Himalayas around Mansarovar Lake in Tibet at an elevation of 5,182 m. The total length of Indus from origin to its outfall in Arabian Sea is 2,880 km, out of which 1,114 km flows through India. Its principal tributaries in India are Jhelum, Chenab, Ravi, Beas and the Sutlej, all joining from left. The major part of this basin is covering with agricultural land recorded is approximately 35.8 percent of the total area and 1.85 percent of the basin is covering by the water bodies. The water resource development on the Indus basin is governed by the various supplies of the Indus water contract 1960. According to this agreeable to the water Bodies of Ravi, Beas and Sutlej shall be available for the unconfined use by India.



Map: 4.1 three major rivers of Punjab as listed on the website of Water Resource Information system of India (WRIS)

Beas River: The Beas River is one of the major rivers under the Indus basin. It originates in the upper Himalayas from Beas Kund near Rohtang Pass in Himachal Pradesh and flows in the east-west direction in Himachal Pradesh till it emerges in the plains near village Talwara in Hoshiarpur District of the Punjab state. The total length of its course upto Beas Dam at Pong is approximately 230 km. The catchment area of Beas River is about 12,560 km² out of which only 777 km is under permanent snow. The rest of the catchment area contributes water on account of rainfall especially from the high rainfall zone of Dharamsala, Palampur and Kangra. The bulk of the discharge of river is received between the months of June and October due to concentration of rainfall in these months. The average annual inflow of Beas River is about 14,800 MCM.

Ravi River: Ravi comes out from the Himalaya's range of Chambal district of Himachal Pradesh which flows on the nearly 725 km distance. The second largest city of Pakistan after Karachi and Capital of Pakistani Punjab, Lahore, is located near to Ravi River. This river is also border river of India and Pakistan and flows in the northern side of Lahore city. The fruitful water of Ravi River is used both for irrigation and drinking purposes.

Sutlej River: The Sutlej River rises near Rakastal which is fed by the lake Mansrover in the Tibetan Plateau at an elevation level of about 4,572 M. The river Sutlej is known as LanggenZigbo inside Tibet/China. The River Sutlej travels about 322 Km inside the Tibetan Province and then enters India near Shipkilla (Tashigang-village) and further Sutlej River travels about 300 km up to Bhakra Dam. This large river has varying climatic and topographic conditions. The total catchment area is about 56,860 km² of which only about 20,000 km² lie in India. The Indian Region an area of about 9,000 km² gets only snowfall, an area of about 5,500 km² gets both snow and rain and an area of about 5,500 km² only rainfall. The above catchment as described indicates that perennial supplies in the river Sutlej are due to large areas of catchment contributing snowmelt. It is estimated that more than 50 percent of the run-off in the Sutlej River is from the snowmelt. The average annual total run-off of river Sutlej is about 16,000 MCM.

Ghagghar River: The river Ghagghar has its origin in the feet of Shiwalik hills and flows towards the North-East of Kalka. The Ghagghar River enters in Punjab from Dera Bass block near the village Kakrali and passes the Patiala, Sangrur and Mansa districts of Punjab State. The Ghagghar River available in Punjab near the village is Monk after covers an areas measure of approximately 180 km in the Punjab Union territory.

4.1.2.2 Canal System in Punjab: Before 1947, headwork at Roper was constructed in the year 1874-82 for utilizing water of river Sutlej in the old Sirhind Canal system and this system was developed on run off the river basis. At present total canal areas in Punjab 2567.45 km². Upper Bari Doab Canal (UBDC), one of the oldest canals in India was first built by Emperor Shah Jehan in the year 1693, for carrying water of River Ravi from Madhopur to Lahore. Improving in the canals is made by Maharaja Ranjit Singh in the 19th century. The type headwork with the proper design distributaries system was construction by the British in 1879. At the time of partition, full supply discharge of UBDC during Kharif crops was 6900 Cs. The utilization of water of rivers Sutlej, Beas and Ravi in the areas of present Punjab forming part of the Indian Union, was 4.55 MAF, 0.50 MAF and 1.48 MAF respectively.

4.1.3 Groundwater resources: Punjab has been a sweetening groundwater with a electricity resistivity quality less than 2000 micro-mhos per centimeter at 25 degree centimeter and residues sodium carbonate (RSC) less than 2.5 meq/liter (me/lit) in nearly 80 percent of its gross geographical area. Replenish of groundwater in the state is a vigorously procreate from the following sources. Rainfall and porous soil from canal networks provide 1.65 Mha-m of water to groundwater (Aulakh, 2004). The area having a water table depth below 10 m has been increased from 3 percent in 1973 and to 53 percent in 2000 (Hira, and Khera, 2000) and additional swells to 76 percent in 2002. Therefore the water table is a decline at an frightening rate in the fresh water zone of the state. Distributing of blocks depending upon the stage of groundwater development is out of total 141 blocks, 103 are 'over exploited' where as the groundwater exploited is more than 85 percent of annual recharge. The depth of water level declined at a high rate that about bore

depth for pumping water increased. Such as increase in the water level are about 65percent of the wells and fall in approximately 34 percent of the wells. Pre-monsoon 2013 discover that there is rising in the water level almost much of the state approximately 74 percent of the wells analyzed. During the water resources available in January 2014, in Punjab, Water level record of 2014 was a comparison that of 2013 (ENVIS, 2011). The available surface water resources in Punjab are being fully utilized through a well organized canal irrigation system. During the already four Periods the net sown area in the state has increased by about 12 percent from 3.8 million ha in 1960-61 to 4.2 million ha during 2004-05. At present, 68percent if the irrigation requirements of agriculture are met through tube wells sunk in superficial confined undergrounds. The available surface water resources of the state are unable to meet the demand of agriculture. The state has witnessed an increase of 83.5percent in the number of tube wells in the last three decades to meet the irrigation requirements. The number of tube wells has increased from 1.92 lakhs in 1970-71 to 11.8 lakhs in 2004-5 (WRIS, 2016). Today presented 79 percent of tube wells in state of Punjab water supply in khandi area, centre zone and southern zone area. The state of groundwater can be divided into three zone viz. Shivalik foothill zone, Central zone, South-western zone.

Shivalik foothill zone: Ground quality of this zone is fabulous but not comfortable to examine and pump, as water table is clearly deep in much portion of the zone. Additionally this zone is a now showing unimportant rise in water table due to the constructing of series of insignificant and examination parts.

Central zone: The over exploited of good quality groundwater due to intensity cropping, this zone is experiencing the maximum reduction in water table.

South-western zone: The long-term rise of water studied by Tasha and Chopra (2004) for 1984-2002 revelation that water table is rebellion in about 20% of the state's geographical area, out of which record rebellion of water table is more than 20percent year in about 50percent of the rising water table area.

4.2 Land utilization of water resources in Punjab: The State Punjab has a larger parts of alluvial land while the Shivalik hills on the North side has fluvial land carvers and deposit of the three rivers (Ravi, Beas, and Sutlej) which flows toward the central Punjab. It includes some parts of forests, water and fertile resources. Thus agriculture is the main scenario of the state, it is the major issue that has been specific that both the land and water resources have over utilized while, their conservation has been slow and adequate so it may lead the frighten that both the land and water may become the major problems in the feature. The curtailing of the natural resources such as the land and water due to the activities created by human is in alarming proportions therefore, many strategies have been evolved for sustainable development and natural resource management. It has also observed that changes taking place in general and in the agriculture sector. The major land uses are, agriculture, water resources, forests, infrastructure, urbanization industrial activities etc. The Land use pattern has undergone a significant transformation in the state owing to changes in different types of agriculture cross, urbanization and industrialization. In recent years there is witness of increasing in the area in non-agricultural uses. It is due to increase in the developmental activities, mostly the land is used for industrial site, housing, transportation systems etc. The changing of land use patter in the state has been responsible for ecological changes in the state.

4.2.1 Agriculture land: About 82.77 percent total land area of Punjab is under agricultural activities. This is double than the nation average land use under agricultural activities. The semi hilly Districts of Punjab such as Gurdaspur, Hoshiarpur, Nawanshahar and Ropar have comparatively less percentage of net sown areas, which is 56 percent and it is 82 percent in southern Punjab. Whereas western districts like Mansa, Bathinda, Faridkot, Muktsar and Ferozepur have higher % of net, sown areas (82 %) this is average for Punjab. It is between 85 percent and 90 percent in Kapurthala, because of sand dunes and sand bars area has also an excessive (81 percent area) net sown areas.

4.2.2 Forests: A very less space lies under the forest areas in the Punjab state i.e. approximately 5.88 percent of the total area of the state. The percentage ratio of forest

cover is very less than the standard average 33.33 percent. Even, an area under forest in Punjab state is only one fourth of the in comparison to 20.8 percent areas of Country.

4.2.3 Irrigation Facilities: Punjab has a high network of irrigation facilities. Both the surfaces and ground water sources are used for irrigation. The surface water's share is limited to 14.54 MAF and the rest of the area is fulfilled with the groundwater. Additionally, data pertaining to Ravi-Beas water during 1981-200 shows that the mean flow has decreased to 14.37 MAF from 17.17 MAF. The snow covers and glacier on the catchment areas of the state is decreasing owing to the global warming and climate change. The net, sown area irrigation has been increased from 71percent during 1970-71 to 97.4 MAF during 2008-9. About 94percent net sown areas in Punjab have irrigation facilities as compare 40.55 national Average.

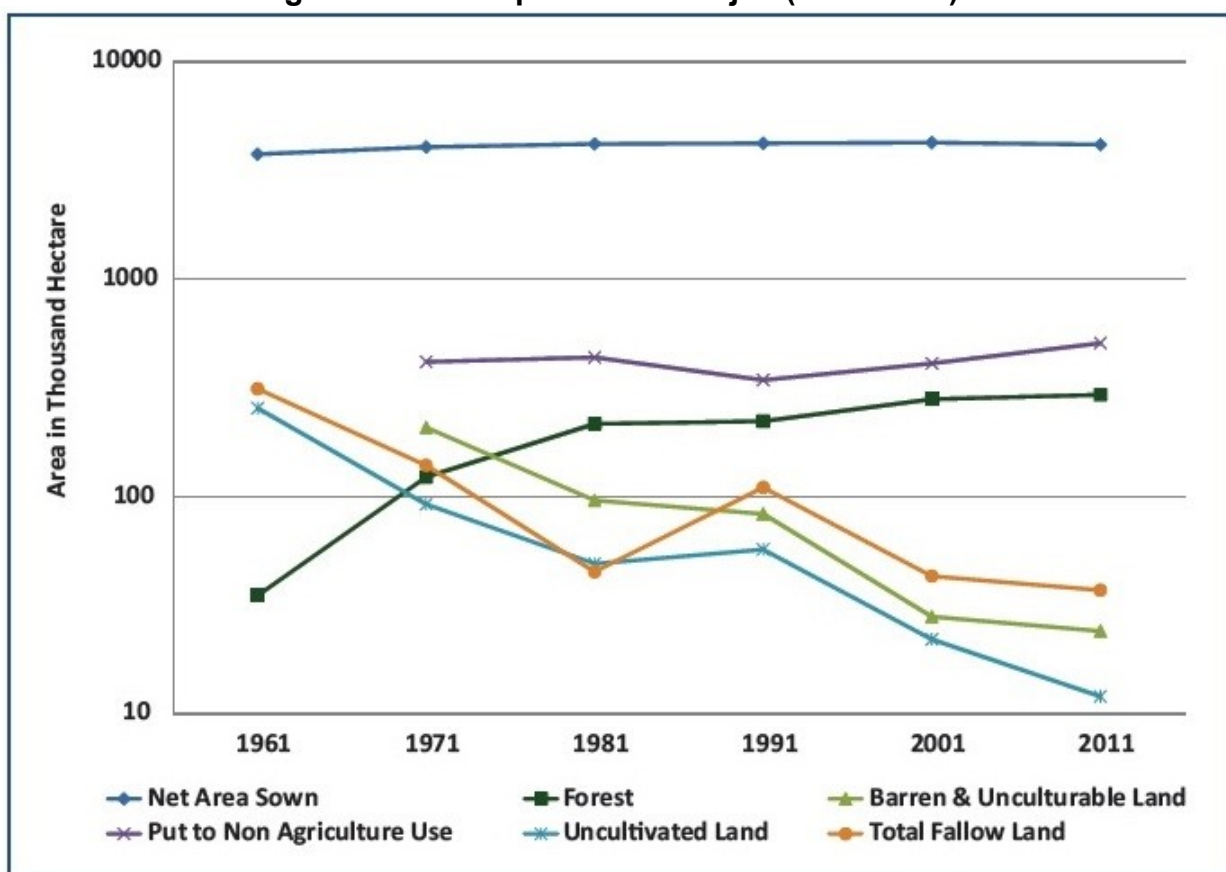
Table 4.1 General information about four rivers of Punjab

Rivers	Total Length in India	Characteristics	Origin
Sutlej	657.04 km	Perennial	Rakastal which is fed by the lake Mansrover in the Tibetan Plateau at an elevation level (EL) of about 4,572 M
Beas	493.08 km	Perennial	Upper Himalayas from Beas Kund near Rohtang Pass in Himachal Pradesh
Ghagghar	468.82 km	Intermittent, endorheic river, inland	Dagshai in the Shivalik Hills of Himachal Pradesh at an elevation of 1,927 metres
Ravi	725 km	Perennial	Multhan tehsil of Kangra district of Himachal Pradesh

Source: WRIS, 2016

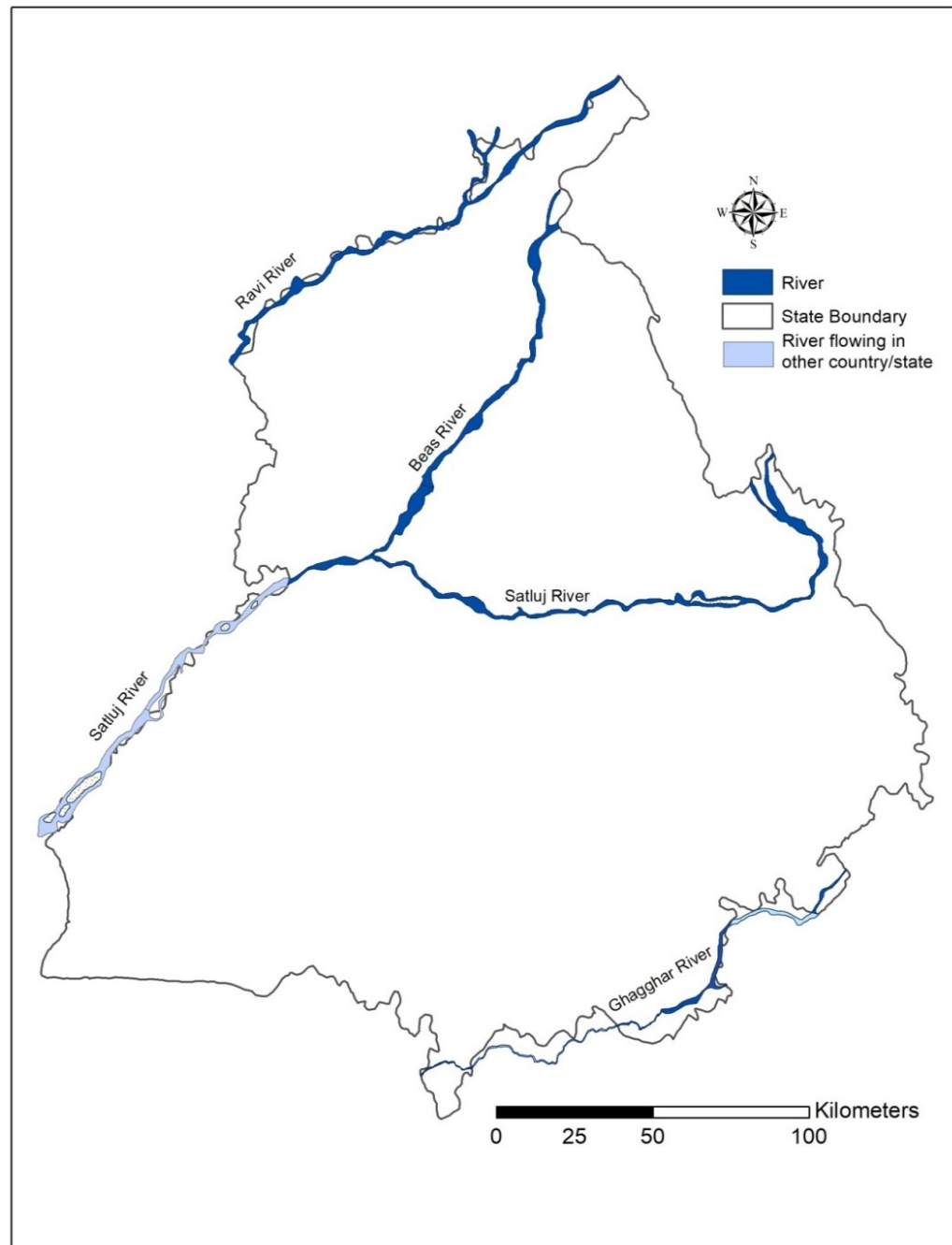
4.3 Changing Land use Pattern in Punjab: According to Punjab Statistical Abstract 2012-13, a major or slight change under various land use has occurred in Punjab region. From the following figure it has depicted that areas under Net Area Sown and non-agricultural uses remain same or little modification from 1961 to 2011. The major land use changes has been noticed in forest, barren and uncultivated land, uncultivated land and total fallow land. The area under forest has been increased in Punjab region from 1961 to 2011. The area under uncultivated land, barren land and uncultivated land and total fallow land decreased from 1961 to 2011. These major changes occurred due to increasing the pressure of population, introduction of green revolution and changes of substitution to cash economy in agricultural sector.

Fig 4.1 Land use pattern in Punjab (1961-2011)



Source: ESOPB, 2014

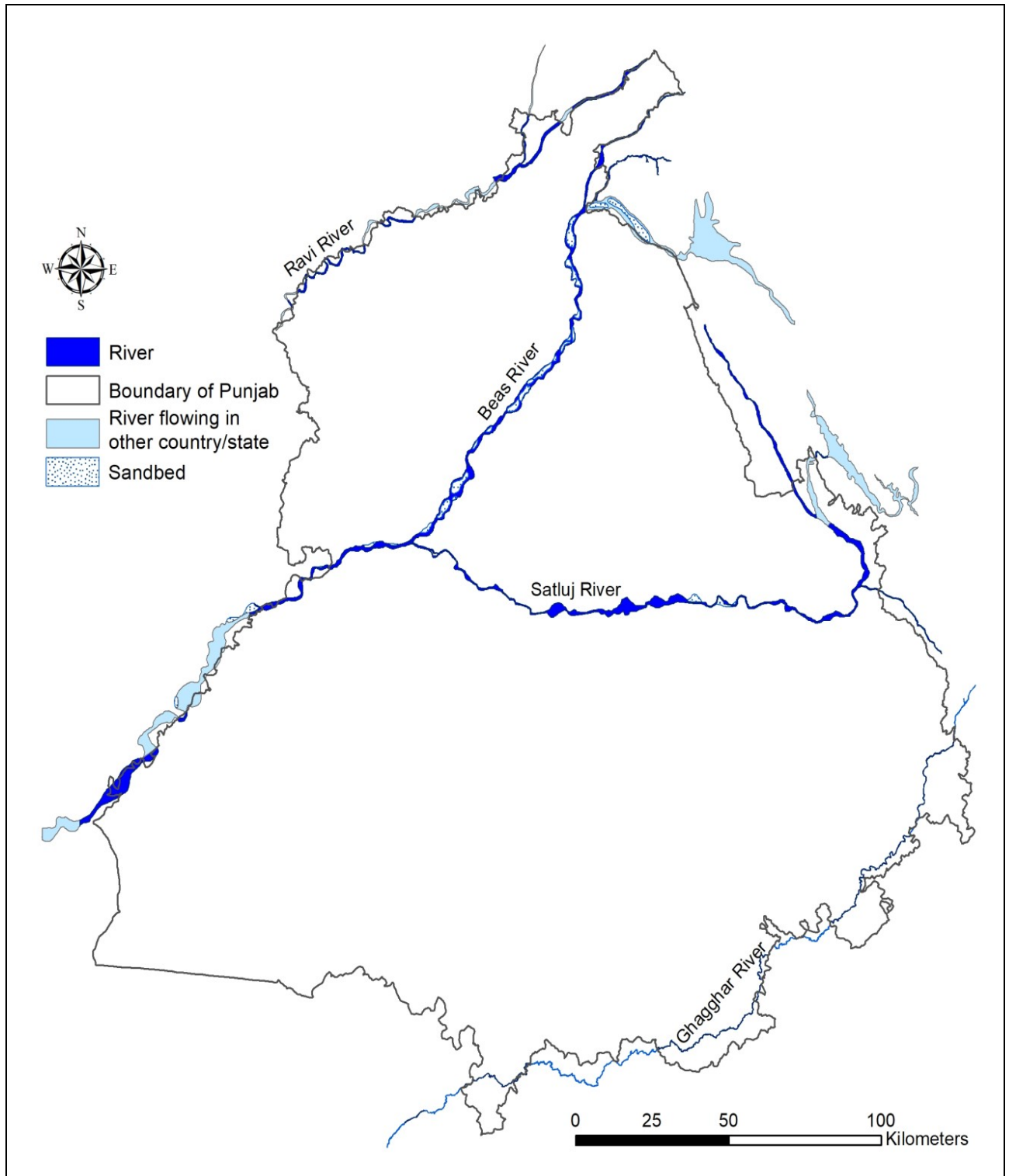
4.4. Digitizing from “NATMO” map: While preparing the map, there are many problems faced. Major problem faced in drawing of maps related to rivers flows and area coverage, as international boundary lies on western side of Punjab State.



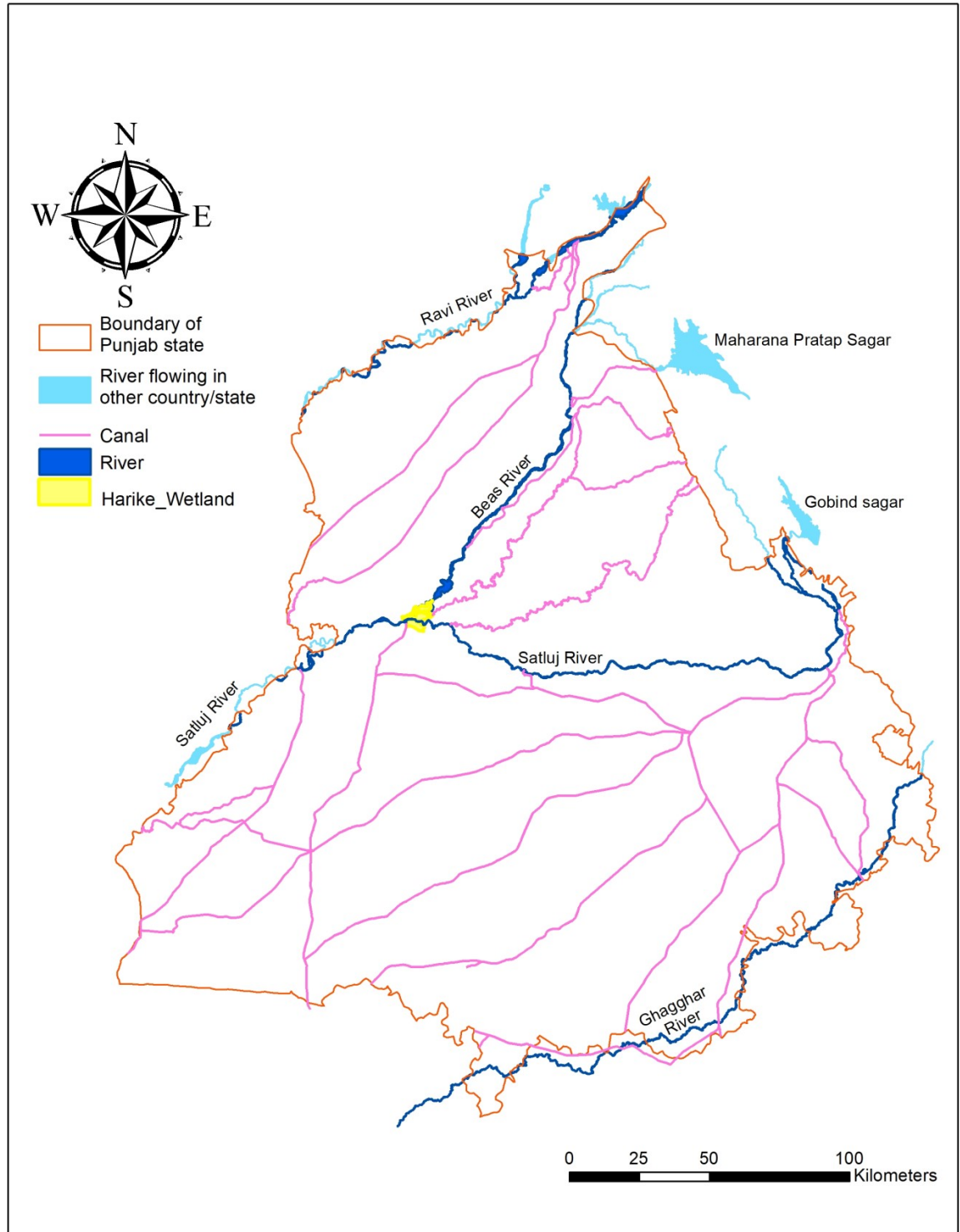
Map: 4.2. Rivers flowing in Punjab as shown in map prepared by National Atlas and Thematic Mapping Organisation (NATMO) on 1: 1000,000 Scale in 2006). (River Sutlej can be seen making boundary of Punjab and Pakistan).

Because, NATMO map shows two rivers through this international border of Punjab and Pakistan which create a lots of flows Problem. They “NATMO” don’t have taken only river channel. But they also included river bed on that the scale of the map is 1:1,000,000 this map being ready on 2006. However, state boundary creates problem because of that the area of all the rivers fluctuates. The image accuracy of Atlas Map of NATMO is a very fine but only the problems faced is state boundary & the rivers bed have taken simultaneously because of that the area of these rivers was getting increased. The Satluj River actually lies in border of Punjab & Pakistan but it actually lies in western part of Pakistan. The boundary is not fine/correct that’s why the area is fluctuating some other reasons is also that rivers contain sand bed area included in rivers areas (Map 4.2).

4.5. Problem faced while digitizing from Survey of India (SOI): While making state river boundary of Punjab state faced lots of problems. Actually, the river bed is also included in these rivers. The image accuracy of this map (Survey of India) is absolutely correct because while making to see rivers correctly. The scale of the map (Survey of India) is 1: 500,00cms. Administrative boundaries, names communications were being updated in 2011. Some part of these rivers (The Ghagghar, the Satluj& the Ravi) Lies on the country & State border. The problem faced is: while river covering area under Punjab, the problem faced while making rivers at the border was of state boundary problem (Map 4.3).



Map: 4.3 Rivers flowing in Punjab as shown in map prepared by Survey of India (SOI) on 1: 500,000 scale, updated on 2011). (Parts of river Sutlej can be seen flowing in Pakistan).

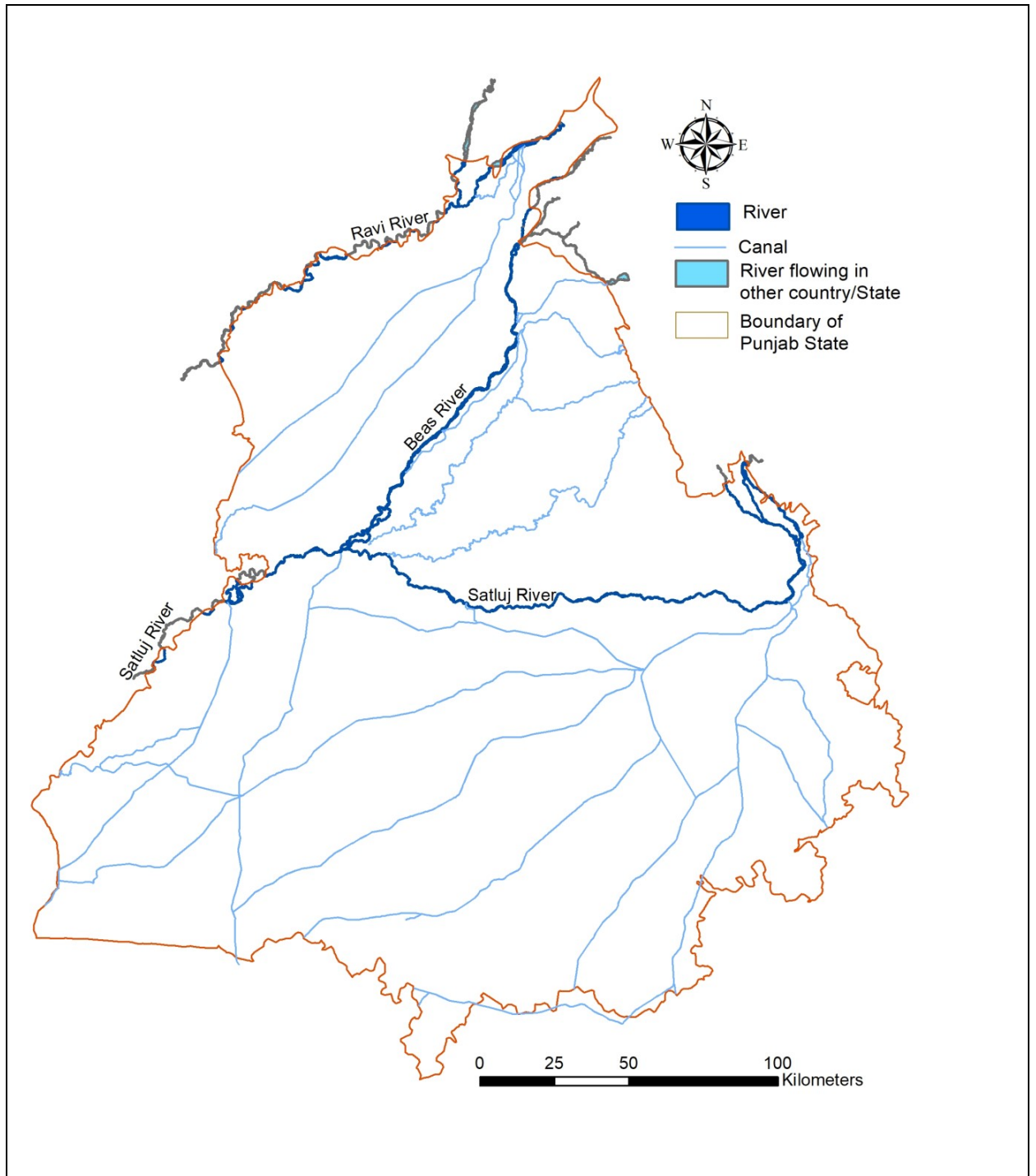


Map: 4.4 Rivers flowing in Punjab as shown in map prepared from Landsat-8 image on 23 meter resolution of 2017

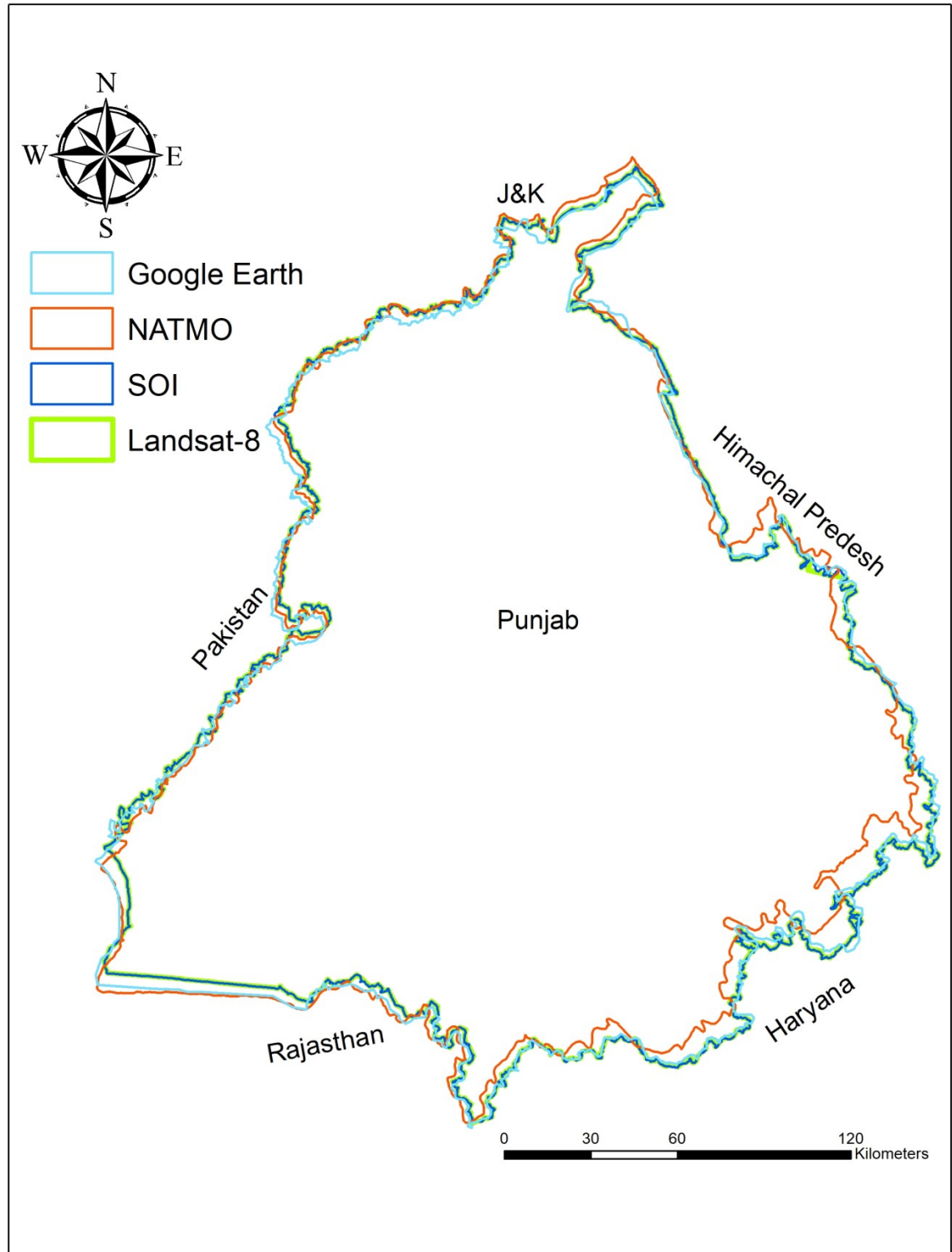
4.6 Problem faced while digitizing from Landsat-8 image: Same problem (state boundary problem) has been faced in the process of the map. Image is of high resolution (23) in this map. The data download is for 2017 year. The problem facing during the making of map related to canal networks, because pixels was not fully cleared after zooming also (due to low resolution image). Only map of river active channels prepared, because sand bed & river bed wasn't fully cleared. The Satluj river flows in the western side found actually in Pakistan (most of the area included on the state boundary) (Map 4.4). The problem of boundary has been faced that show out of line. Linear unit of this image is 1,000000 & the scale of the images is 0.9996.

4.7. Problem faced while digitizing from Google Earth map: While, drawing the map in Google earth faced serious of problem. The state boundary problem on the North western side, Map related to Satluj River and Ravi River and North Eastern & south Eastern side Beas, Satluj, and Ghagghar River. Map 4.5 has been prepared on March-April 2018.

4.8. Differences among the four boundaries of Punjab state: The catchment area of the state boundary of the Google earth is higher(50358.56km²) as compared to others state boundaries whereas the catchment area of the state boundary of the NATMO is 49041.40km² which is smaller as compared to others state boundaries. Much of the variation is seen in South-East side of Punjab as shown in Map 4.6. The difference (variation) is small in the North West side (International border of Punjab and Pakistan).



Map: 4.5. Rivers flowing in Punjab as shown in map prepared from 'Google Earth' 2018

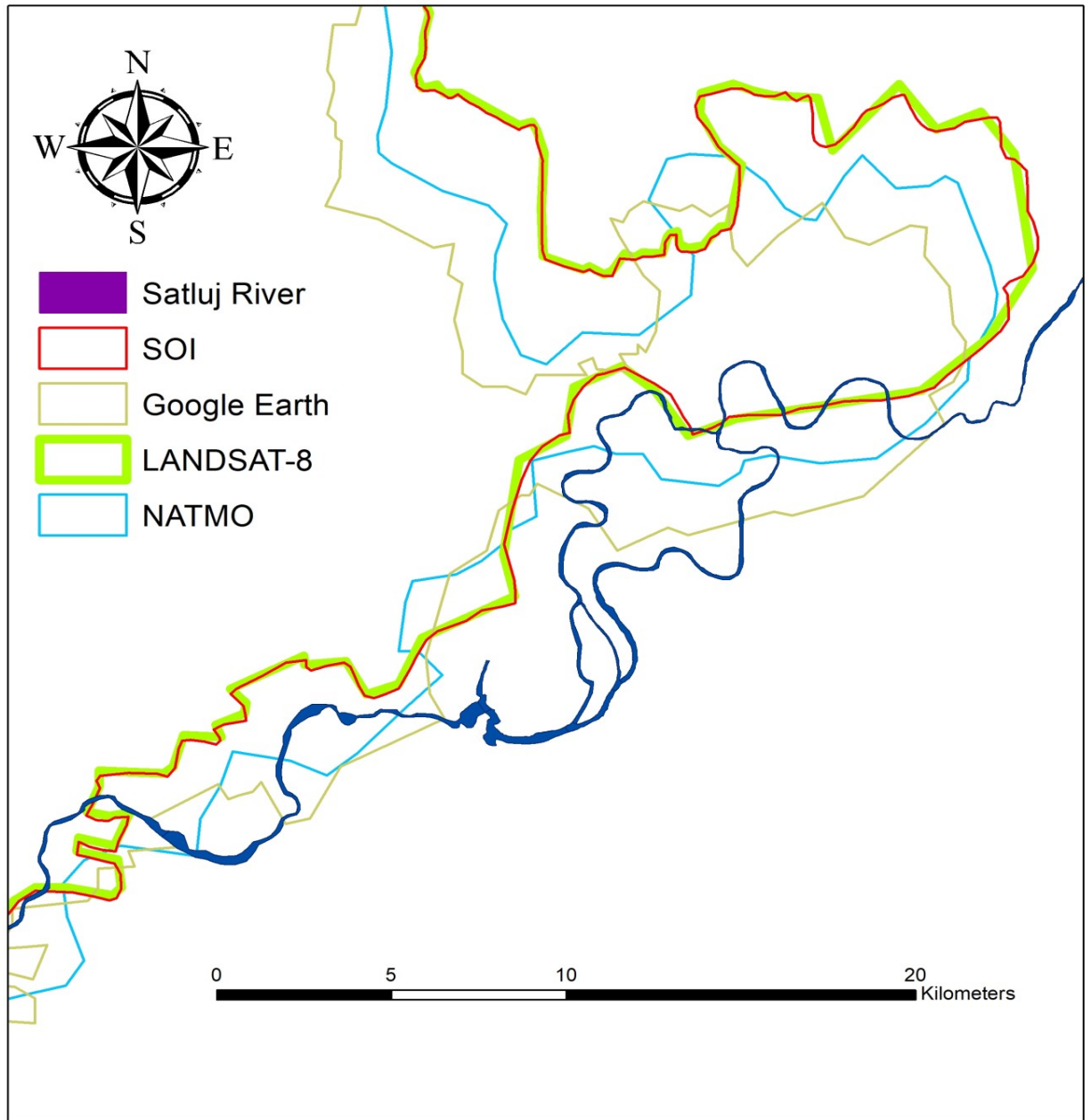


Map: 4.6. Variation map of state boundaries of Punjab state shown in map prepared by: Google Earth, Landsat-8, SOI and NATMO

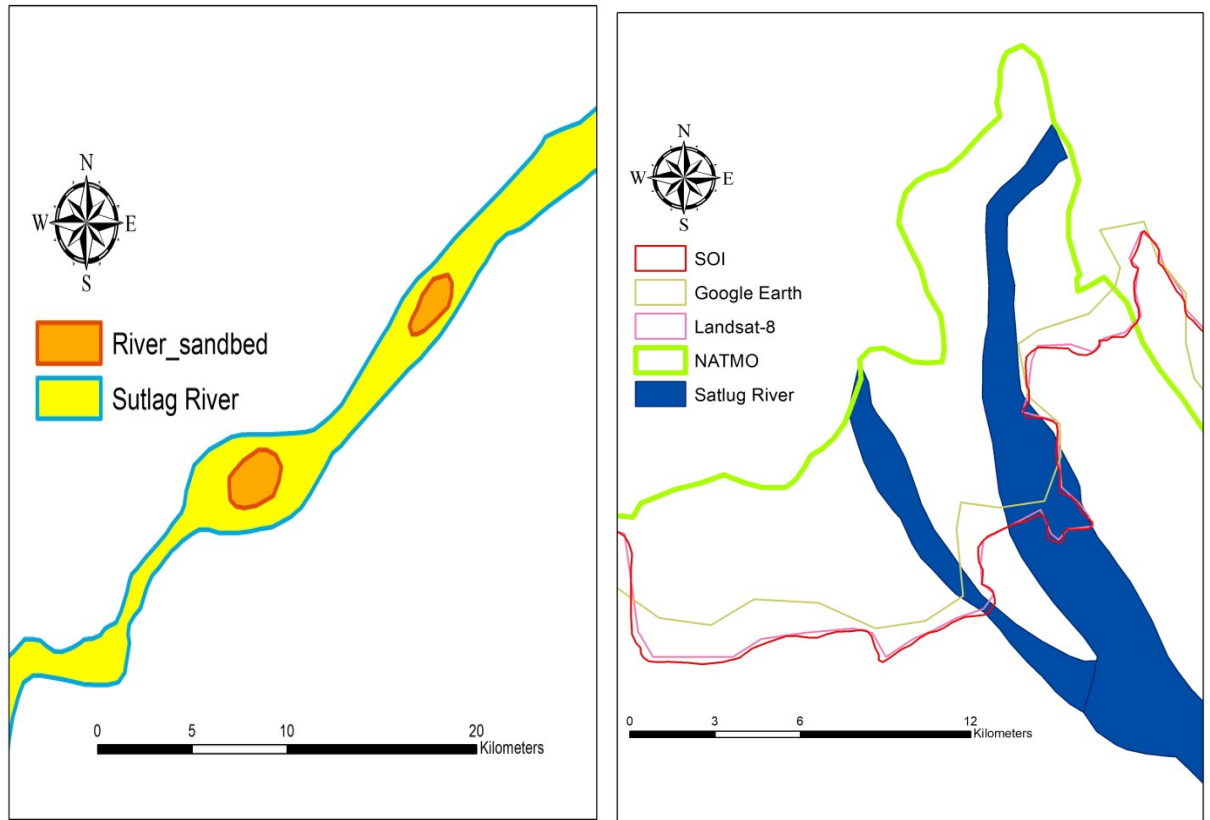
Table 4.2: Area of water bodies/ rivers in Punjab

S. No	Rivers	NATMO		SOI		Landsat_8		Google Earth	
		Length	Area (km ²)	Length	Area (km ²)	Length	Area (km ²)	Length	Area (km ²)
1.	Satluj	265.7664	601.9	361.48	368.95	468.11	50.58	257.5	51.59
2.	Beas	156.7949	299.83	242.10	270.10	167.61	96.21	254.06	50.81
3.	Ravi	215.4521	517.96	141.82	90.25	159.76	93.31	161.5	32.39
4.	Canal					25.15	2567.45		
5.	Ghagghar	90.21684	56.419	213.89	35.63	178.5	17.766		
	Total	728.2302	1476.109	959.29	764.93	958.54	2844.55	701.44	141.06
6	State boundary	4901.40		49906.60		49860.09		50358.56	

4.9 Discussions: Map 4.7 presents the total length and area covered by the Sutlej River in Punjab State. The length measured by Landsat-8 is comparatively higher (468.11 km²) as compared to all the others sources. As for as area is concerned; its area is very small (50.58km²) as compared to other sources. The length of the river drawn by the Landsat-8 represents the maximum state boundary along the western side. So its length is much high. And then small length on a map is from the Google Earth (257.5km²) compared to other maps.

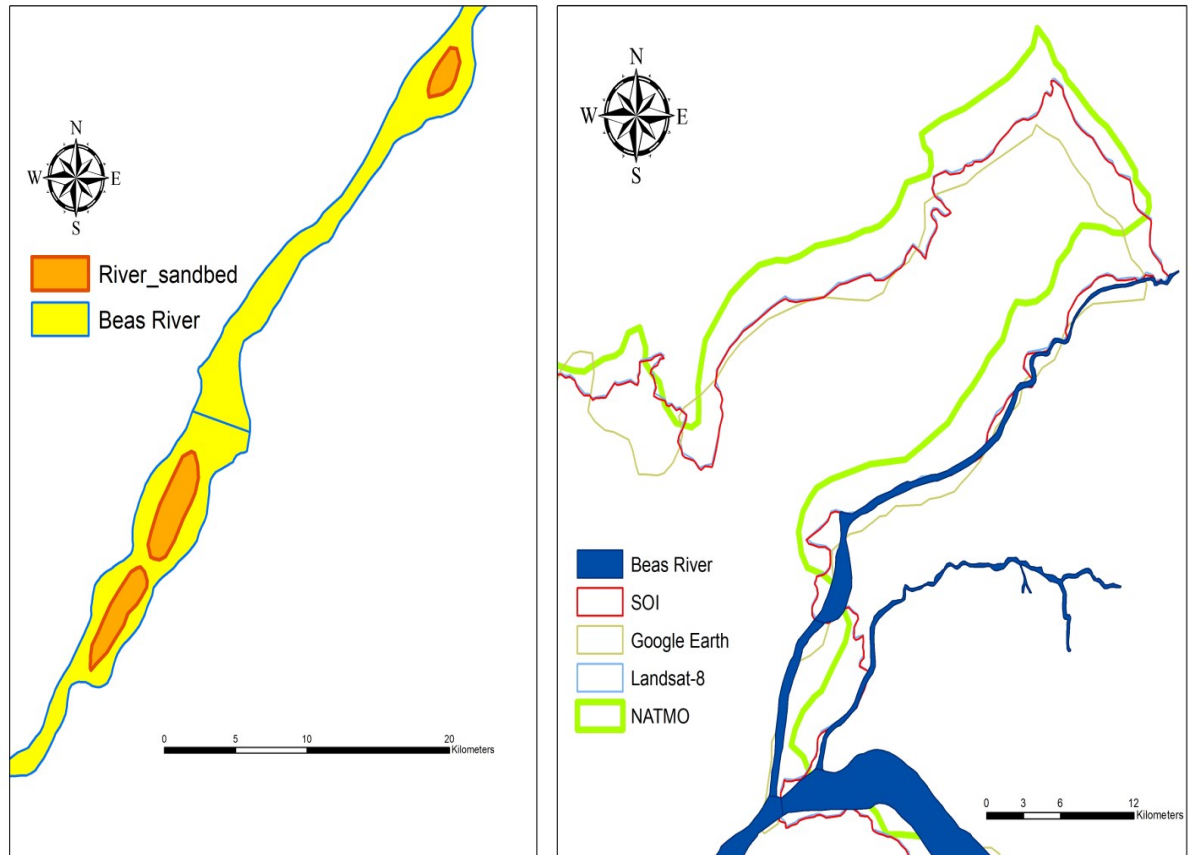


Map: 4.7: Variation map of state boundaries of Punjab state and Satlu River shown in map prepared by: Google Earth, Landsat-8, SOI and NATMO



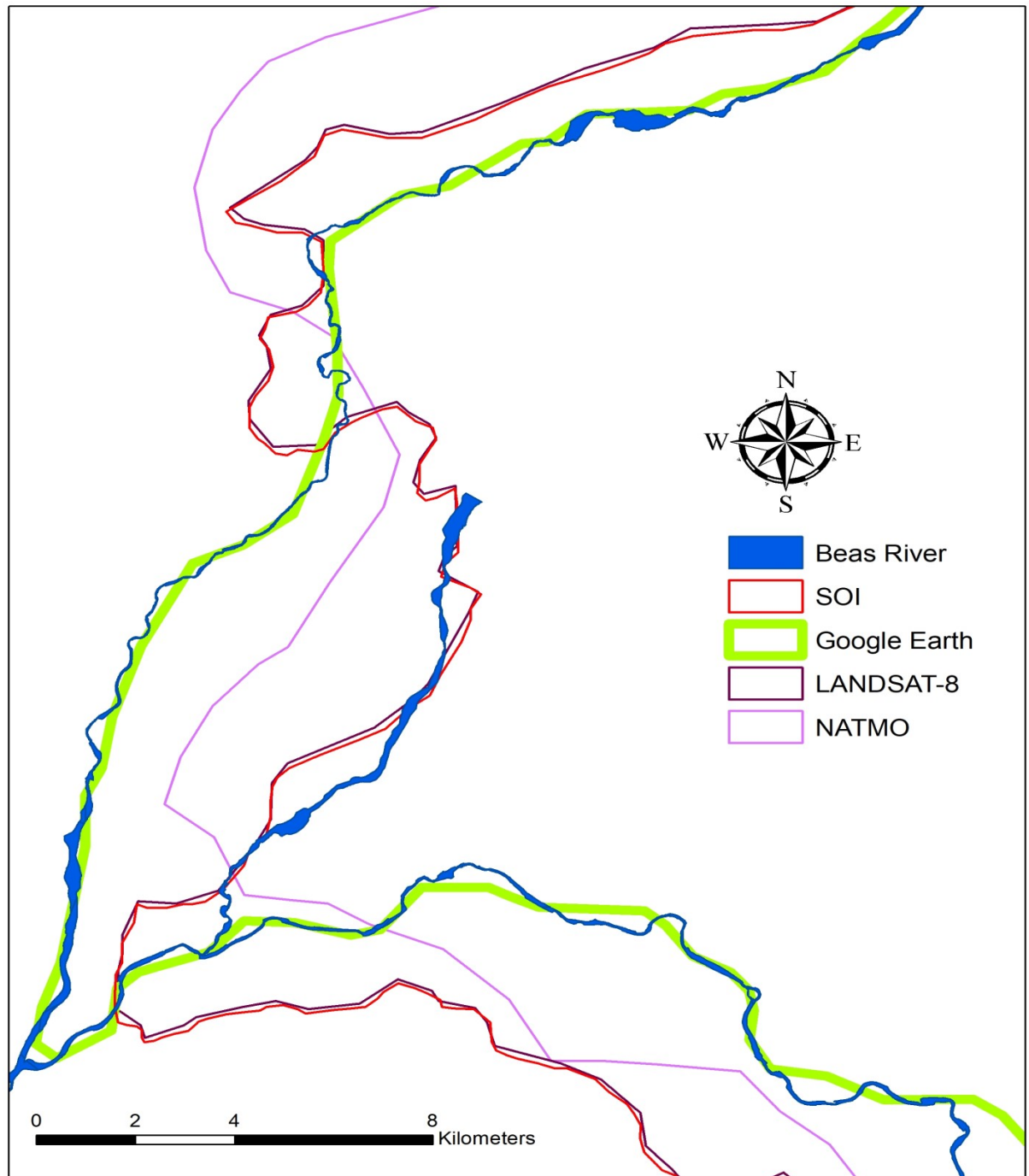
Map: 4.8. Variation map of state boundaries of Punjab state and Areas of Satluj River shown in map prepared by: Google Earth, Landsat-8, SOI and NATMO

Map 4.8 shows the river covered by Sutlej River in the state of Punjab. This map shows that the some part of river in Sutlej lies totally outside the boundary of Punjab.it means that it lies in the border that is in the Pakistan region. The map shows that the area of river in Sutlej is comparatively large (601.9 km^2). The state boundary which is toward North-east side is more in Punjab (Sutlej river) compared to other sources and mostly compared to SOI and Landsat-8 and then the main reason is the inclusion of sand bed and the river bed. And small area of maps is Landsat-8 (50.58 km^2) as compared to other maps



Map: 4.9. Variation map of state boundaries of Punjab state and Areas and length of Beas River shown in map prepared by: Google Earth, Landsat-8, SOI and NATMO

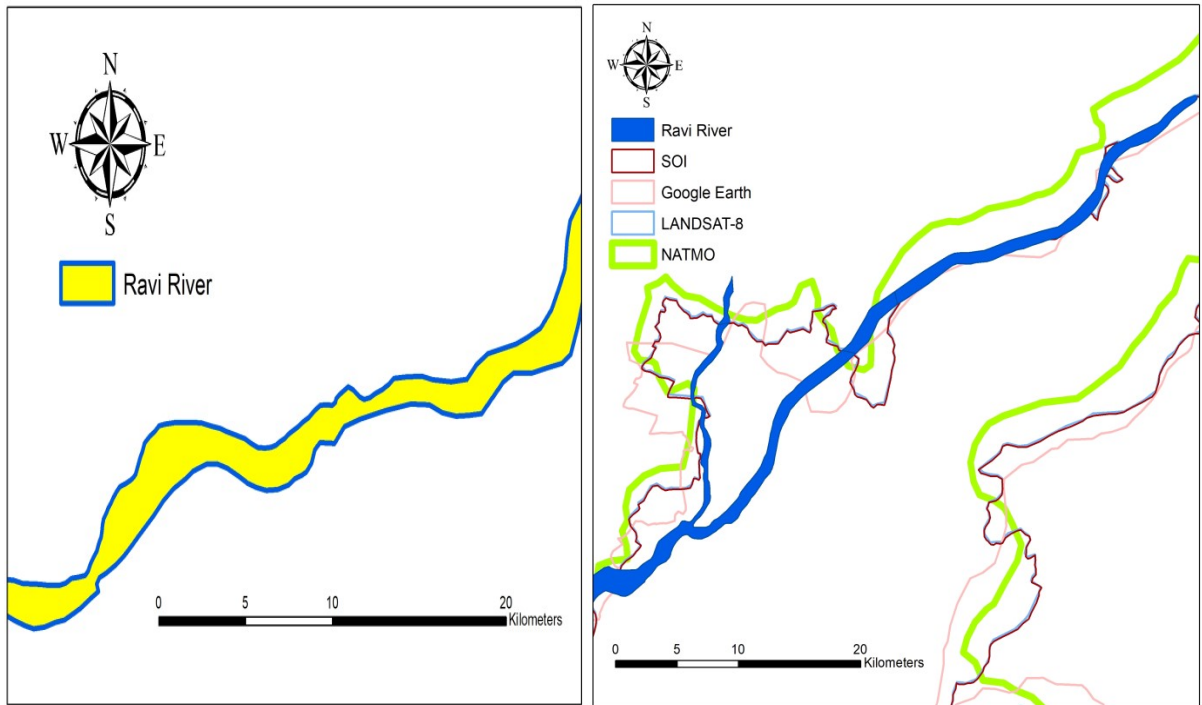
Map 4.9 shows the length and area covered by Beas River in Punjab state. The source of “NATMO” shows that the area cover by River Beas is high (299.83 km^2) as compared to other maps because river bed and sand bed are area included in it. On the river channel as for as its length is concerned it is (156.79 km^2) as compared to other sources the reason for this is that some part of the river flows the North-eastern side of Himachal & Punjab the state boundary of “NATMO” map shows that some part of it flows Himachal & then, to the Punjab. This is the problem associated with the wrong information of state boundary. As per the Google earth the total area covered by Beas is (50.81 km^2).



Map: 4.10. Variation map of state boundaries of Punjab state and length of Beas River shown in map prepared by: Google Earth, Landsat-8, SOI and NATMO

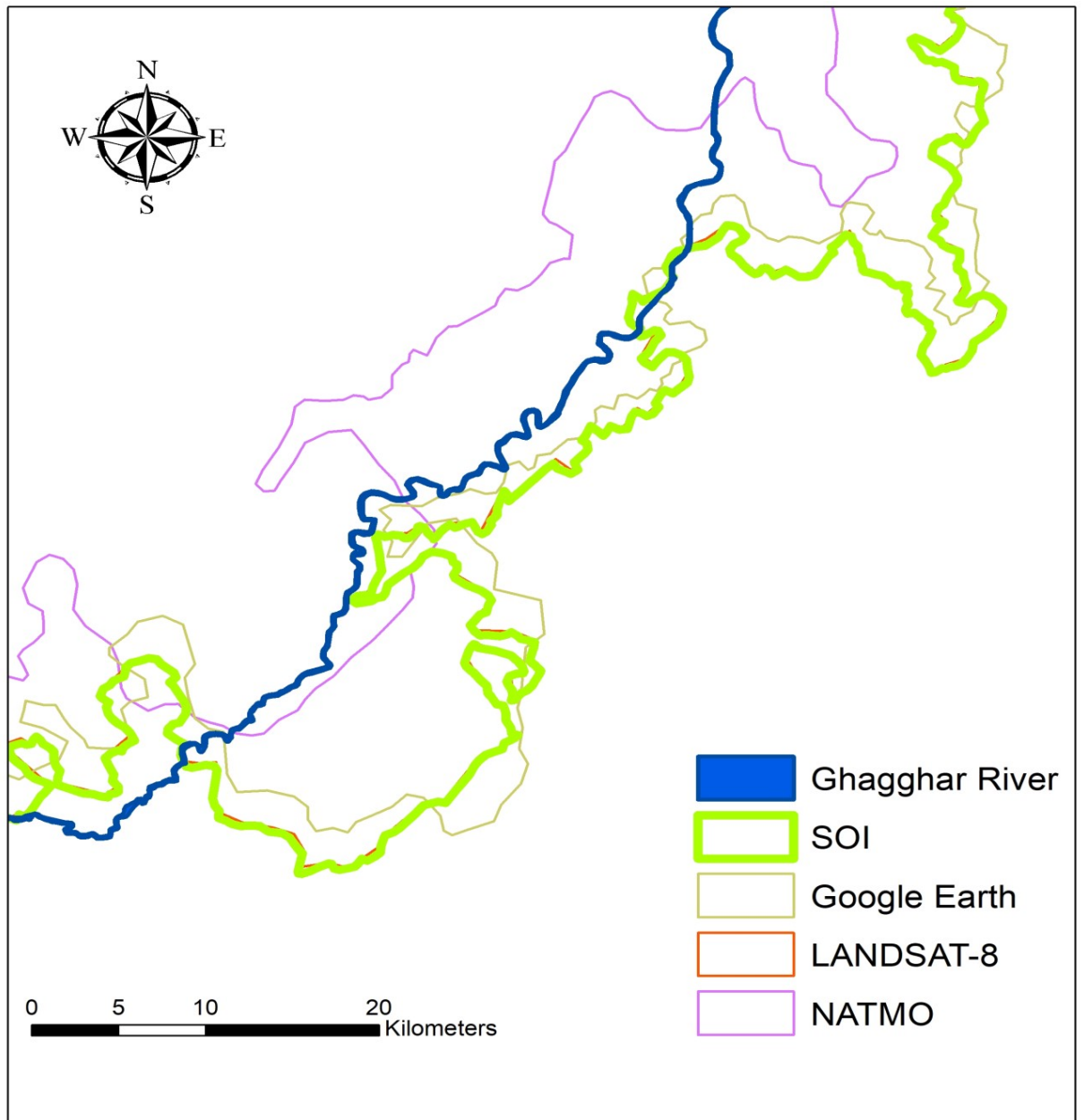
Map 4.10 represents the total length of Beas River in Punjab state. The Google earth shows the River Beas length is comparatively higher (254.6km) as compared to other sources. The reason behind this is the state boundary in the Google earth shows the

river which is flows from the some parts of North side actually shows in Punjab area. Its area is comparatively small (50.81 km²) as compared to other maps because the reasons is that I didn't included river bed and sand bed in the rivers boundary. Here the main focused is on active river channel.



Map: 4.11 Variation maps of state boundaries of Punjab state and Areas and length of Ravi River shown in map prepared by: Google Earth, Landsat-8, SOI and NATMO

Map 4.11 shows the length and area of the Ravi River in Punjab state. The NATMO line shows the Ravi River's both the length & area is comparatively higher as compared to all other sources. The length is higher as compared to others because of the reason that the river flows through North West state border of Punjab & Pakistan region. The area coverage is high as compared to others. The reason is same as the sand bed & river bed are included in blue the river boundary. As compared to the SOI length it is high because of the reason that the state boundary of this river lies in North-western part of Punjab & Pakistan region. The boundary shows that most part of the rivers flows in the Pakistan region (North-Western side). The Google Earth is comparatively lesser as compared to others maps because I have focused only on the river, the sand bed & the river bed are not included in the same.



Map: 4.12. Variation map of state boundaries of Punjab state and Areas and length of Ghagghar River shown in map prepared by: Google Earth, Landsat-8, SOI and NATMO

Map 4.12 represents the length and area of the Ghagghar River in Punjab state. The SOI line shows that the length of the river Ghagghar is higher as compared to others sources. The total length of this river is 213.89km. The boundary of the SOI maps indicates that the river flows along the South-east side of Punjab and represent the border between Punjab and Haryana state. The “NATMO” map shows that the area is

higher (56.41km^2) as compared to others three sources because in this map sand bed & and river bed are included comparatively to others lines and also small area of map might also be the reason.

Note: It is important to note that the total length of SOI is higher (959.29km^2) as compared to others sources (NATMO, GE, & Landsat-8). The total length of Google earth is comparatively low (701.44). The total area of Landsat-8 is higher (2844.55km^2) as compared to rest of three sources. Whereas the total area of Google earth is (141.06 km^2) comparatively low to other sources.

Chapter 5: Conclusion

The existing literature and government reports show the length and area cover by the water bodies in the country as a whole. State wise data about length and area is not available. All the previous studies dealt with the length of the river and area covered by water bodies the country as a whole. In the present work I measured the length and area cover by the water body in the state of Punjab. So major rivers cross the Punjab state are Satluj, Beas, Ravi, and Ghagghar. The present work has been done by using four different sources namely NATMO, SOI, Landsat-8, and Google Earth. The total length of the river in the state of Punjab is 728.23, 959.29, 958.54, 701.44km as per the NATMO, SOI, Landsat-8, and Google Earth respectively. And the total area covered by the water bodies is 1476.10, 764.93, 2844.55 (including canal), and 141.06 km² as per NATMO, SOI, Landsat-8, and Google Earth respectively. While, the total length of rivers in India is 2343.94 Km. There is no significant difference between the total lengths of the river drawn by SOI and Landsat-8 (including canal). There is a little difference between the total length drawn by NAMTO and Google Earth.

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