4th International Conference on the Use of Space Technology for Water Management

FLASH FLOODS DUE TO URBANIZATION

A CASE STUDY OF MALIR RIVER BASIN (MRB)-KARACHI

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Content

Introduction

- Global climate is causing earth warming and a shift in the weather pattern
- Causing extreme weather events such as heavy rainfall, tropical cyclones, and long dry seasons
- The world is experiencing the largest urban growth in the history and Pakistan is one of the most urbanized country in South Asia
- There is a link between urbanization and climate change
- Rapid urbanization may alter natural hydrology of the area and cause
  - Blockage in drains
  - Flash flooding

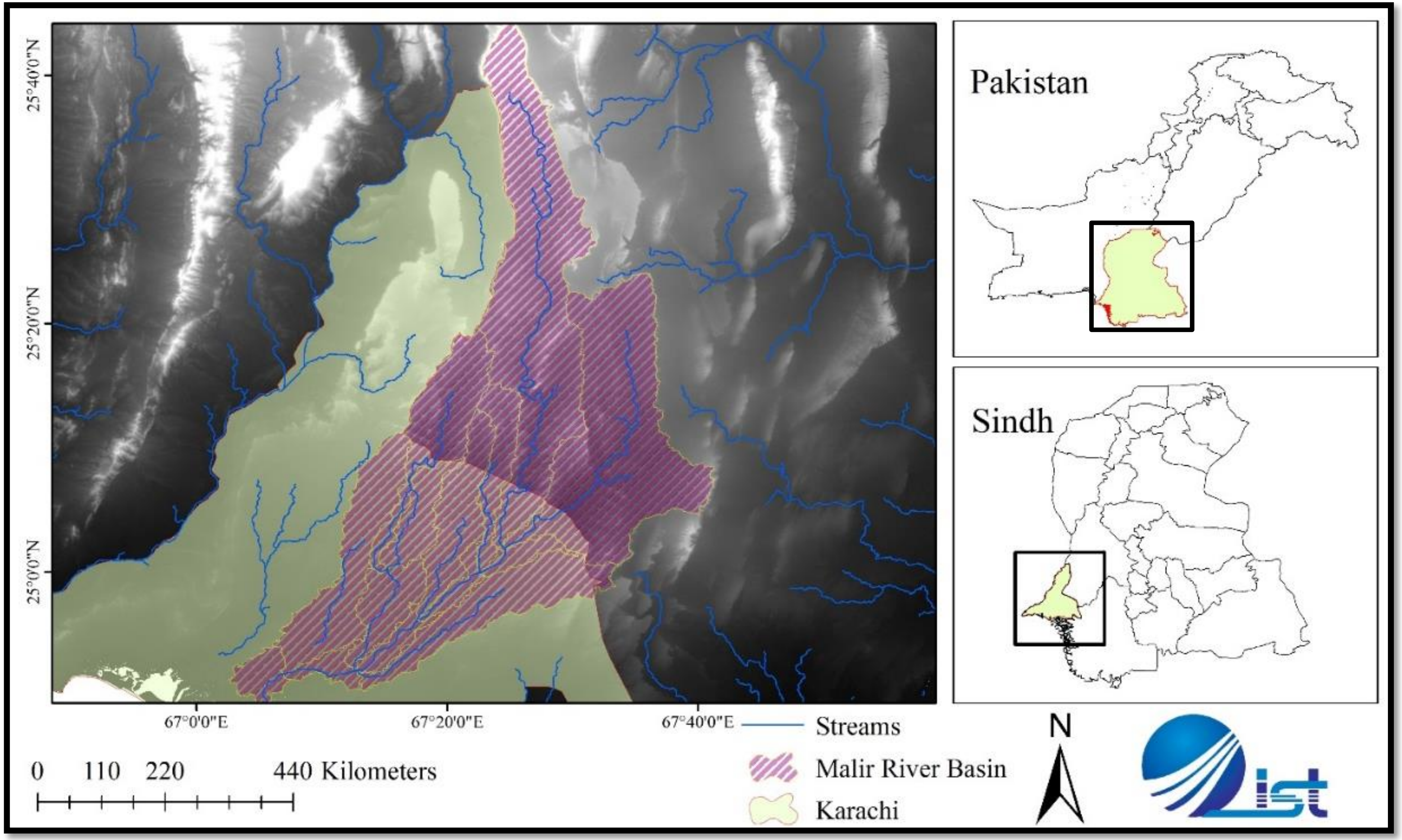
Continue…

- Rainfall-runoff causes flooding if the drainage systems haven’t the sufficient capacity to accommodate these flows
- This type of rainfall-runoff response causes flash floods in urban locality
- Flash flooding occurs when heavy rainfall occurs within a very short time
- According to US National Oceanic and Atmospheric Administration (NOAA), flash floods get their peaks within six hours of heavy rainfalls

Flash flood events of the world

S. No.	Country	City/Region	Year	Rain	Deaths
1	Pakistan	Rawalpindi	2001	335	61
2	China	Shanghai	2015	NA	20
3	China	Beijing	2012	170	79
4	Italy	Eastern Italian Alps	2003	396.2	NA
5	USA	Central Texas	2002	254	12
6	France	South-eastern	2002	300	20
7	India	Chennai	2015	More than 200 mm	189
NA = Not available					

Study Area



25°40'0"N
25°20'0"N
25°0'0"N
67°0'0"E
67°20'0"E
67°40'0"E
Pakistan
Sindh
Streams
Malir River Basin
Karachi
N
0 110 220 440 Kilometers

Impacts of Urbanization

- In past few years floodplains were over exploited to fulfil urban need
- Small streams and *nalas* abandoned due to the development of settlements, industries and agricultural fields
- Some of the streams and nalas have vanished and some are encroached by different landuses
- This encroachments in river beds led to the flash flood in urban areas

Blockages in river bed

IMPACT of URBANIZATION

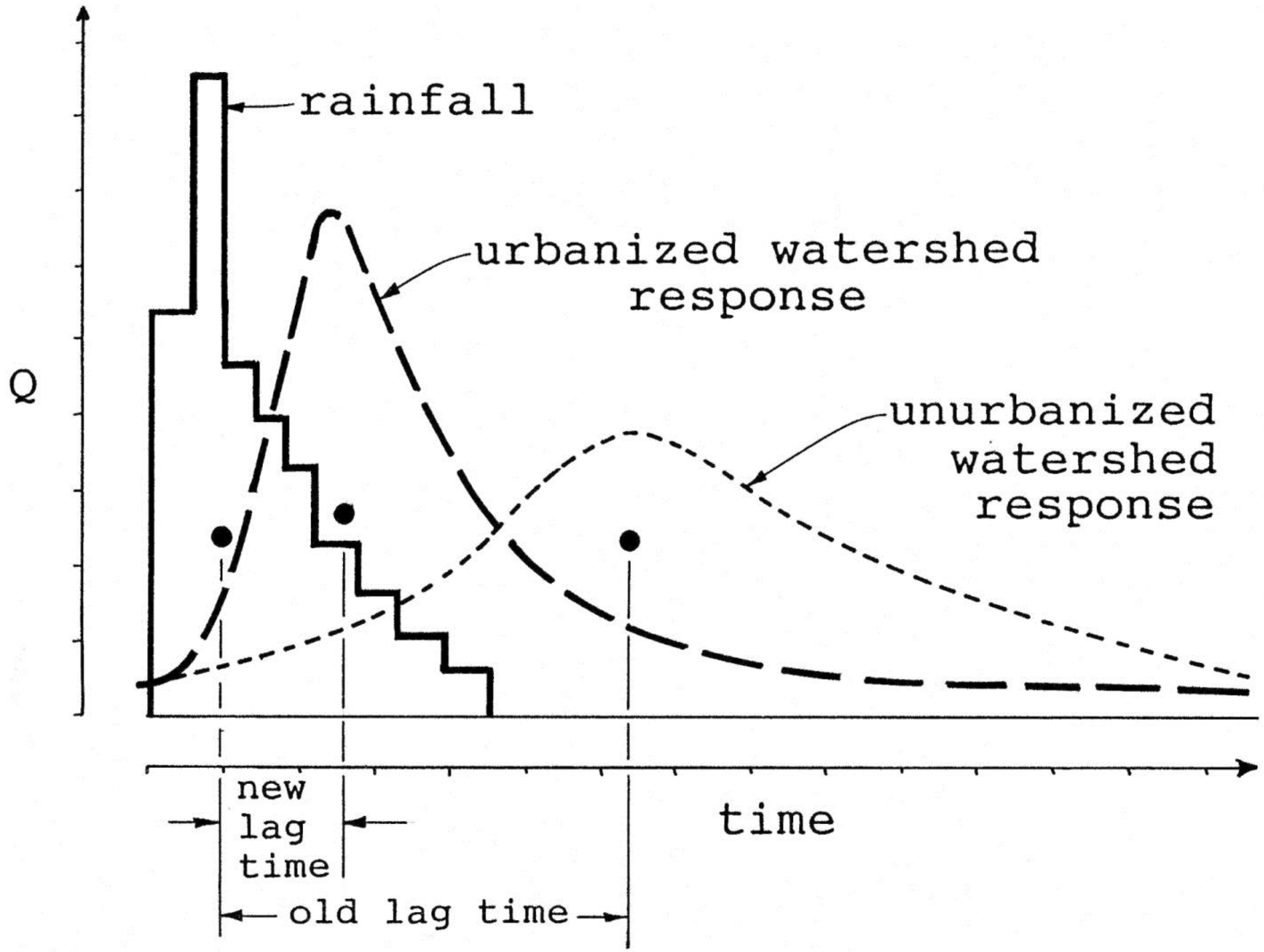
Flash floods

- Due to heavy rainfalls in short time period
- Rainwater convert into runoff without any loss

2013 Flood

Cont…

High rainfall runoff response due to paved surface



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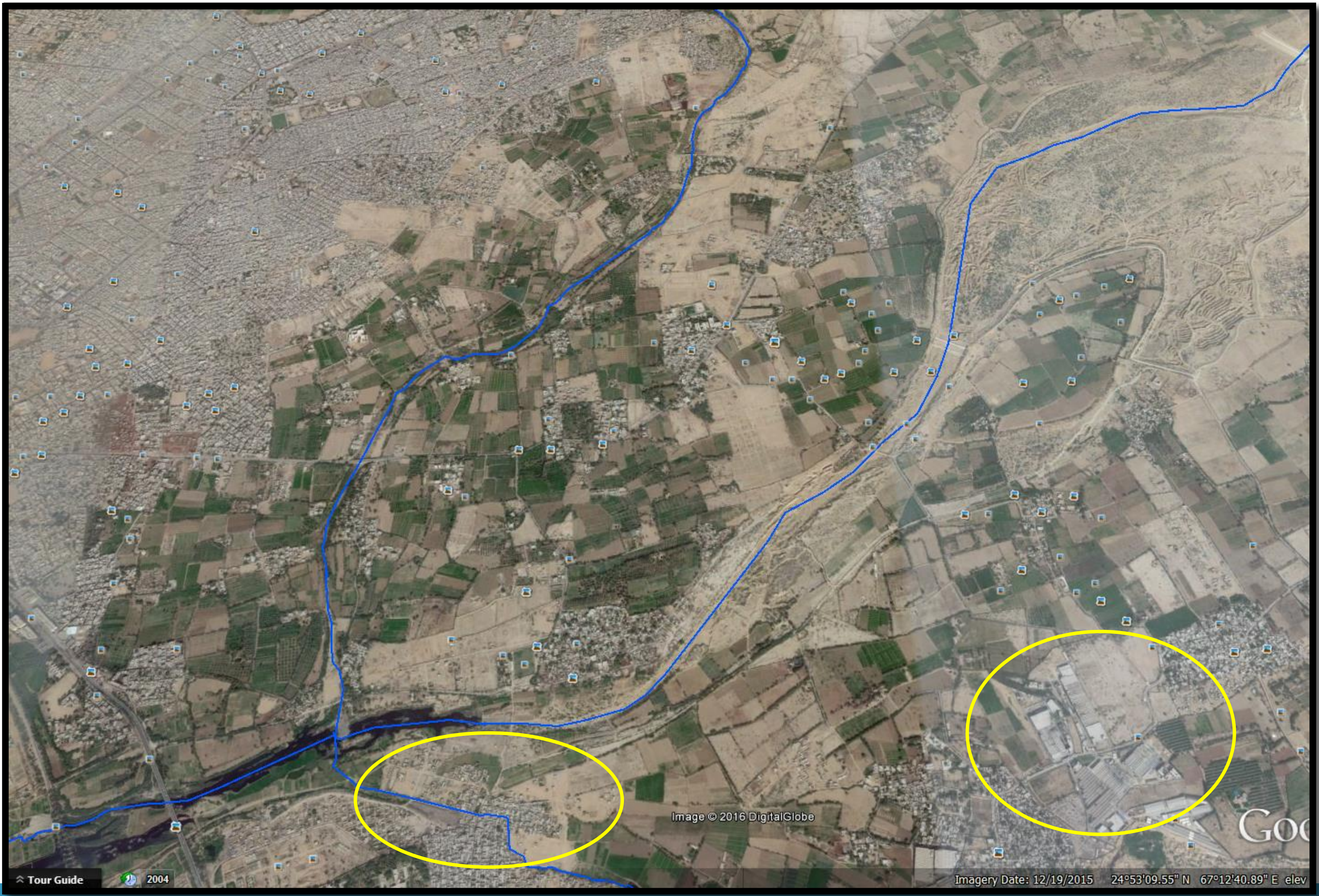
Reduced agricultural production in Malir River Basin

- More land is needed to accommodate the urban population



Characteristics of Study Area

- The climate of Malir River Basin is dominated by sea breezes throughout the year
- May and October causes the highest temperatures up to 41°C and the coldest months are January and February, with the mean minimum temperature of 13°C
- Maximum rainfall occurs during monsoon
- The average annual rainfall of basin ranges from 10 mm to 150 mm (1985 -2014) data provided by Pakistan Meteorological Department
- It is one of the major rivers of Karachi

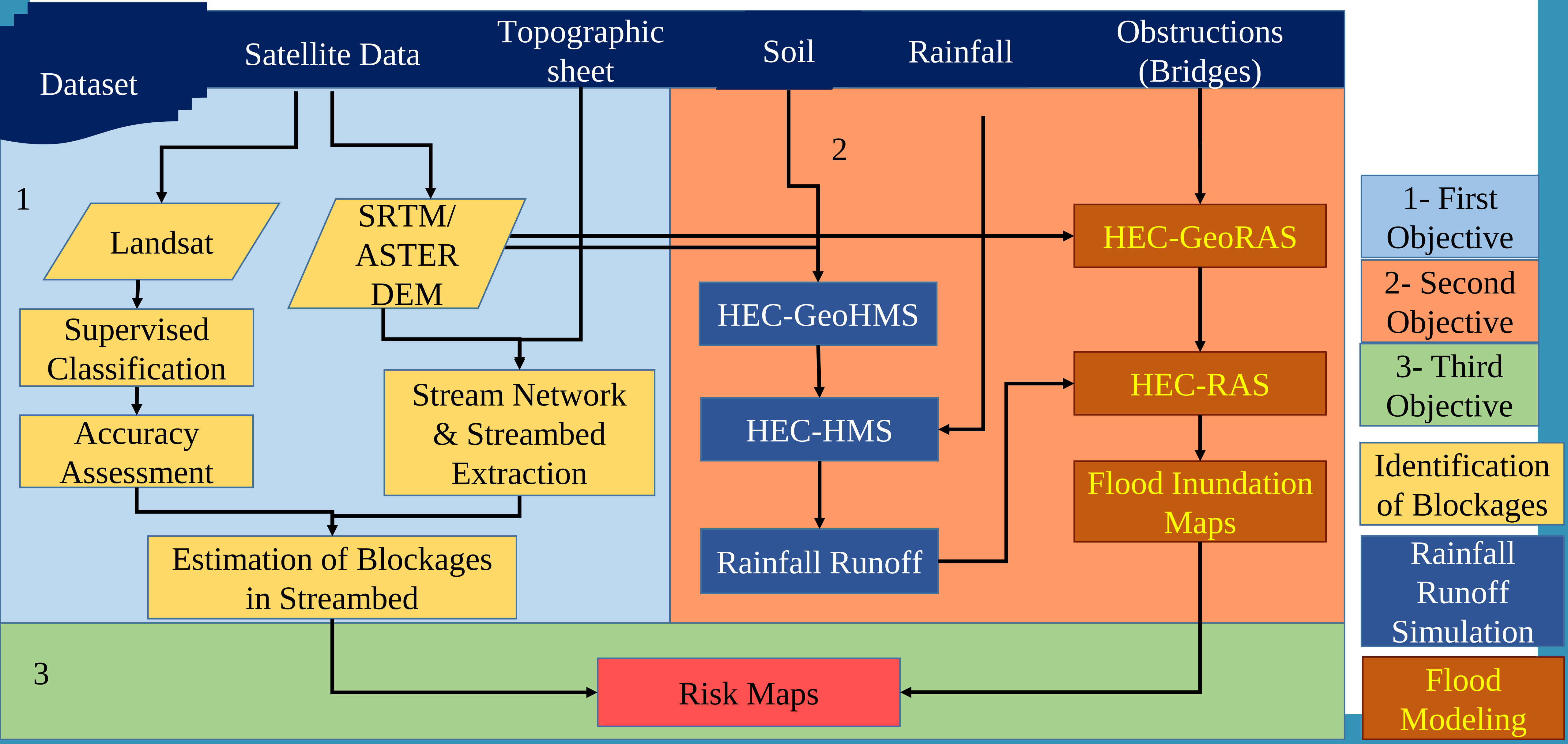
Historical Extreme Rainfall Events in Karachi

Flood Date (day-month-year)	Rainy hours	Rainfall (mm)	People killed
07-8-1953	24	278.1	0
01-7-1977	24	207	248
07-8-955	48	284.5	0
17-8-2006	0	77	13
20-07-2007	0	191	228
22-8-2007	0	80	0
20-07-2009	4	142	20
13-09-2011	0	145	0
13-08-2013	0	150	50

Objective

1. LULCs changes in the MRB
2. Rainfall runoff modeling
3. Development of flood extent map and Damage Assessment

Methodological framework



Study Data

1. Satellite Data

i. **Satellite images**

- Landsat ETM+ (7) of January 2000
- Landsat TM OF January 1993, 2009
- Optical Land Imager (OLI) and Thermal Infrared (TIR) (8) of January 2015

ii. **Digital Elevation Model (DEM)**

- Shuttle Radar Topographic Mission (SRTM)
- Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER)

2. Topographic sheets (1970s)

Continue...

3. In-situ Climate Data

- Rainfall data (1985 to 2014) --- Pakistan Meteorological Department (PMD)

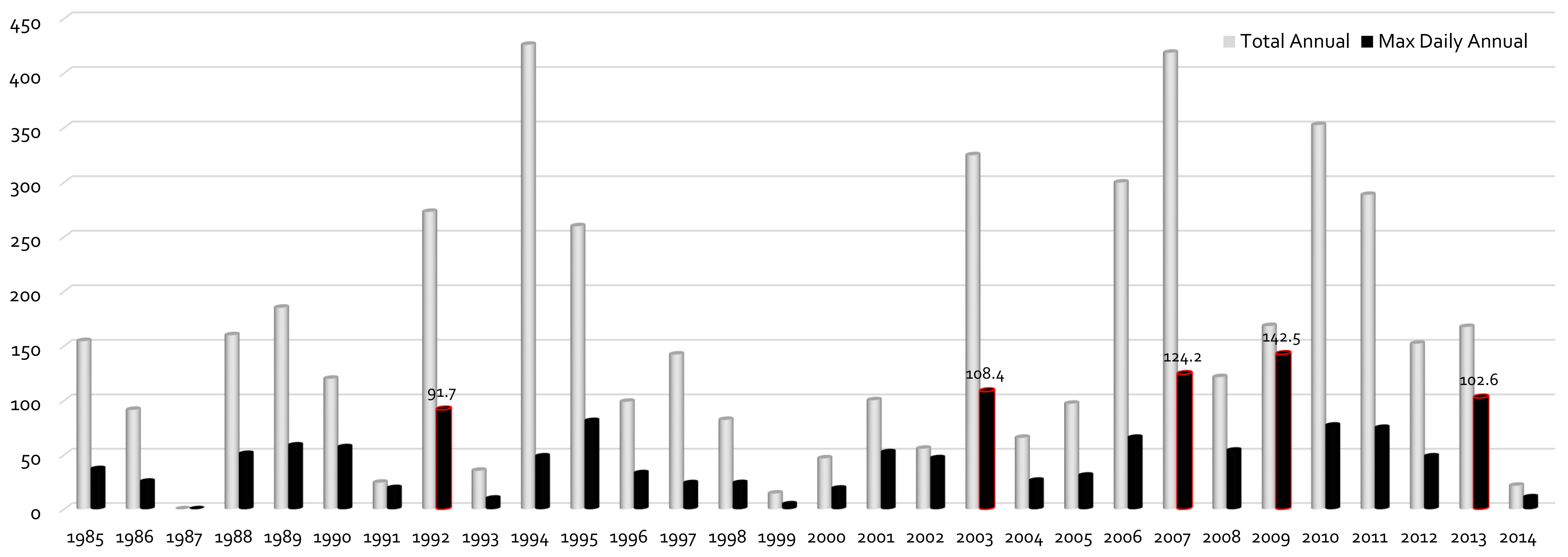
4. Soil Data

- Harmonized World Soil Database (HWSD) - Food and Agriculture Organization (FAO) and International Institute for Applied System Analysis (IIASA)

Landuse/Landcover (LULC) Mapping

- Temporal LULCs changes were identified and mapped for the year of 1993, 2000, 2009 and 2015
- Classification of LULCs was done according to the LULC Atlas developed by Pakistan Space and Upper Atmosphere Research Commission (SUPARCO) and Food and Agricultural Organization (FAO)

Total Annual and Max Daily Annual Rainfall (1985-2014)

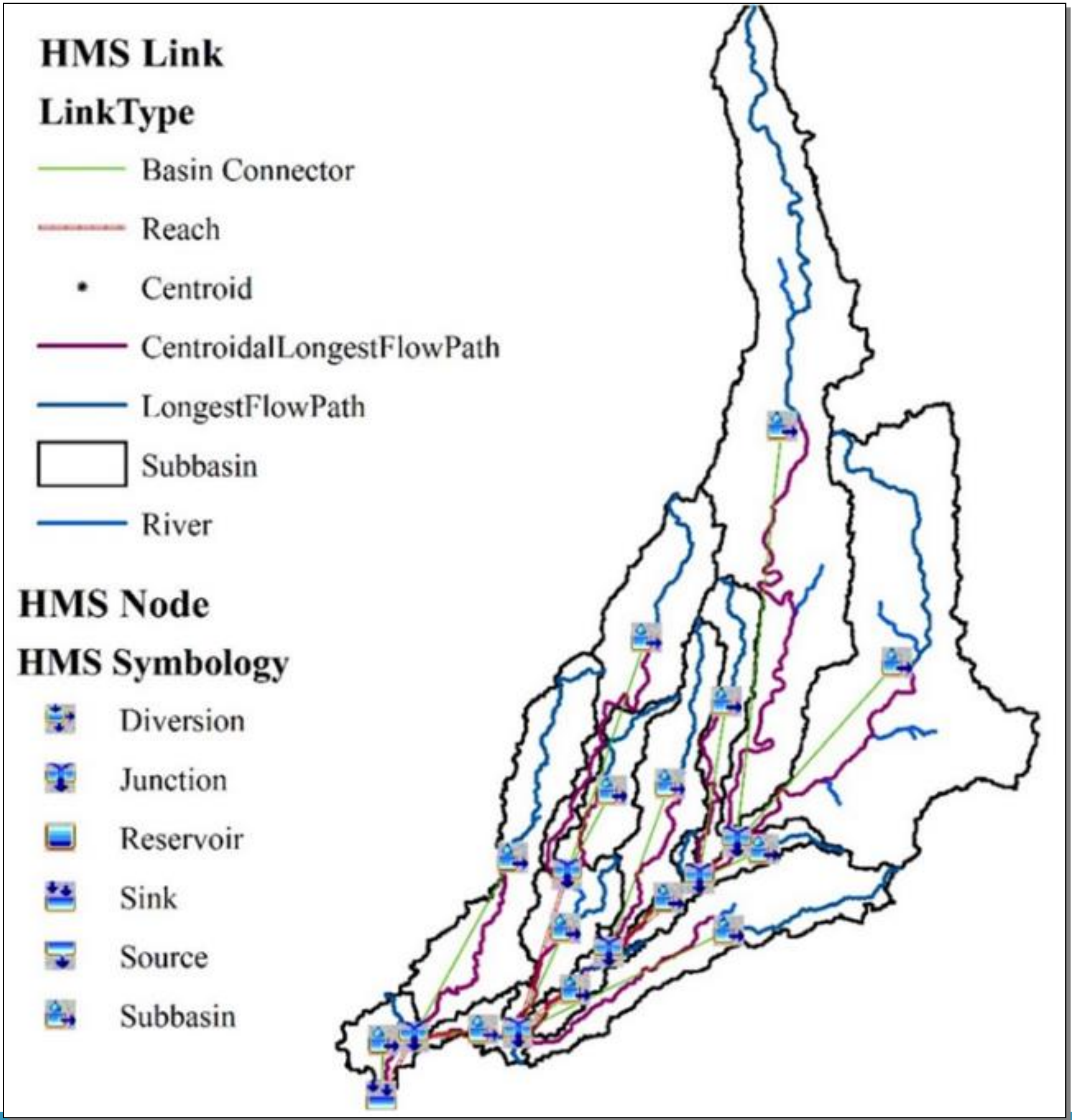


Rainfall-Runoff Modelling

- HEC-GeoHMS and HEC-HMS developed by the Hydrologic Engineering Center of US Army Corps of Engineers
- HEC-GeoHMS is a Geographical Information System (GIS) extension

SCS Curve Number (CN)

- The SCS curve number is a simple and common method used to simulate rainfall runoff
- Developed by the USA Soil Conservation service "SCS" (now called Natural Resources Conservation Service-NRCS) a division of US Department of Agriculture.
- This method is the most popular one to compute peak runoff rates and volumes of small and ungauged streams

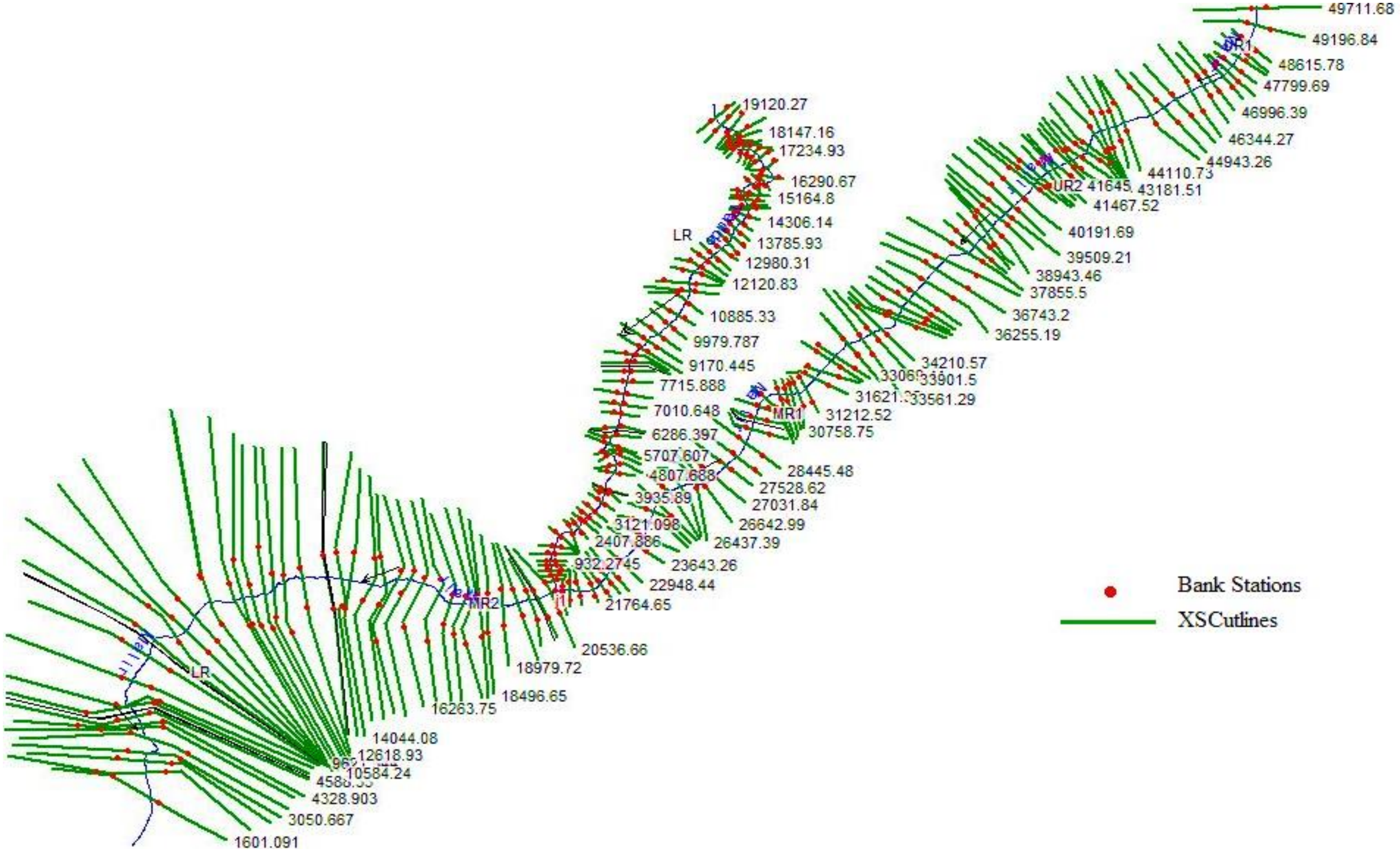


HMS Link
LinkType
Basin Connector
Reach
Centroid
CentroidalLongestFlowPath
LongestFlowPath
Subbasin
River
HMS Node
HMS Symbology
Diversion
Junction
Reservoir
Sink
Source
Subbasin

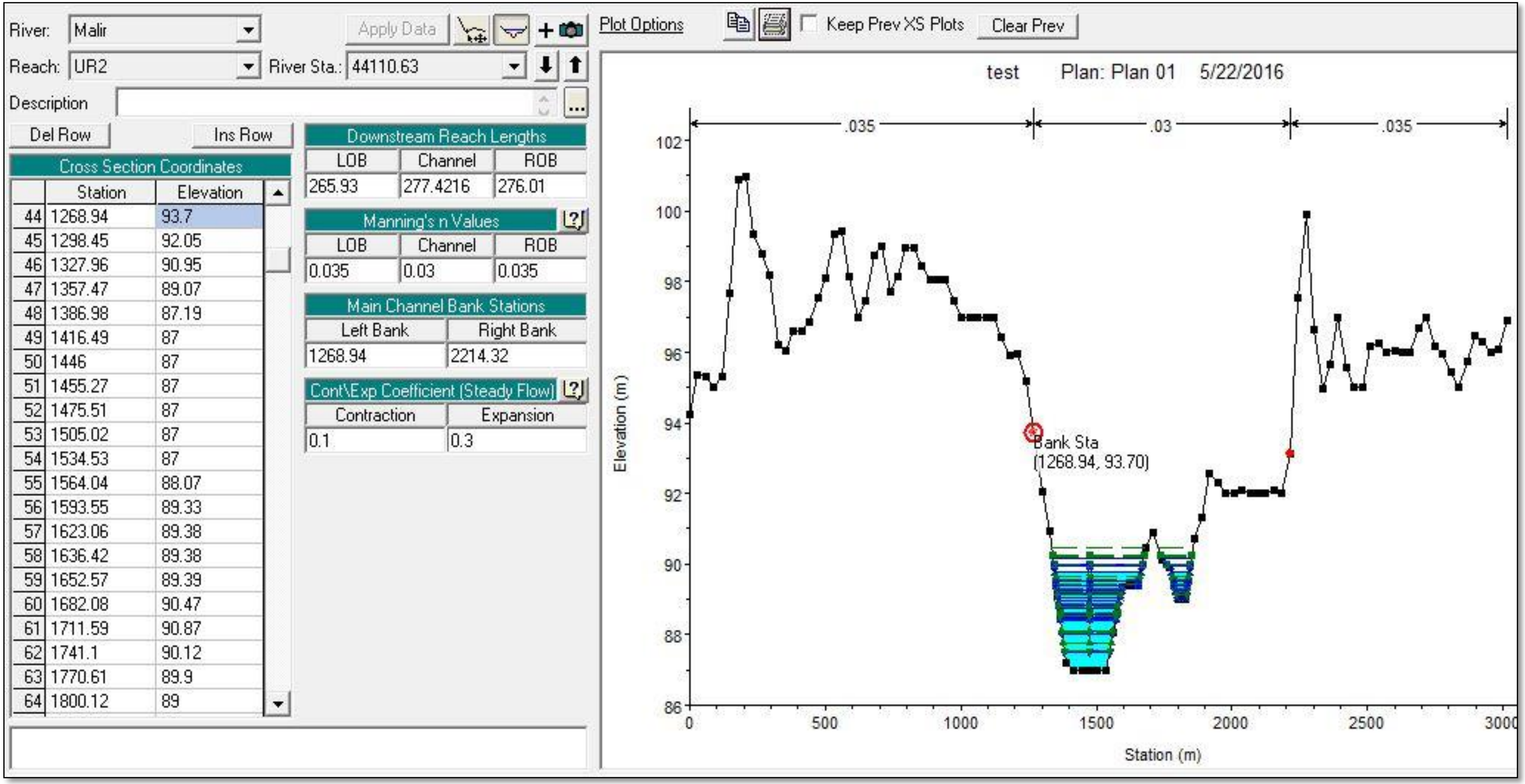
Hydraulic Modeling

Hydrograph obtained from the hydrologic modeling using HEC-HMS inputted into the hydraulic modeling system Hydrologic Engineering Center- River Analysis System (HEC-RAS) and its geospatial extension HEC-GeoRAS

RAS Geometry



2D Plot of XSCutline



Flow Data Preparation

Simulated Flow in Each Reach (m3/sec)

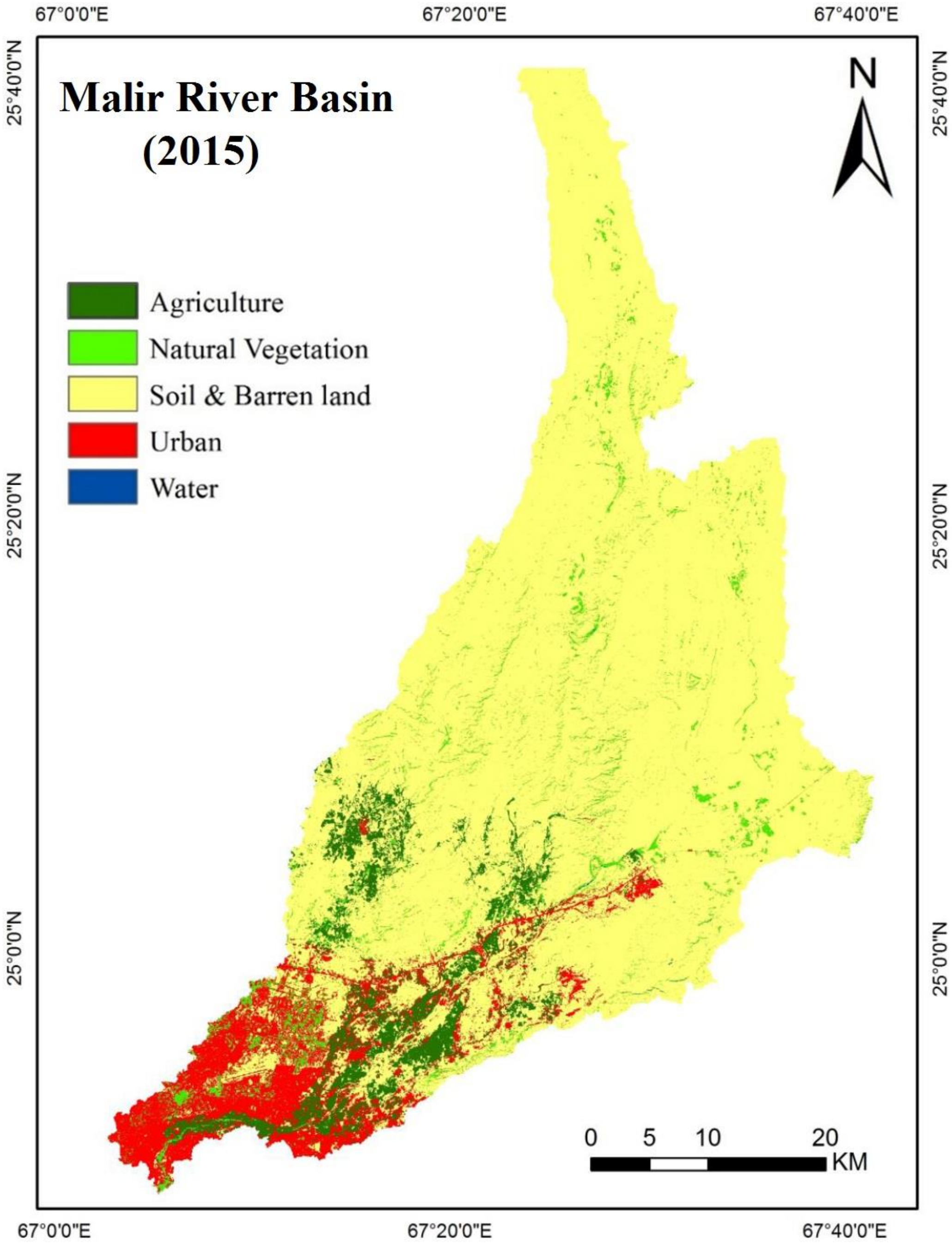
Reach	Flow m^3/sec				
	2013	2009	2007	2003	1992
*UR Malir	954	1502.3	1284.9	1312.4	1102.2
UR2 Malir	1025.1	1623.9	1389.3	1431.2	1202.2
*MR1 Malir	1149.3	1824.6	1557.2	1611	1353.3
MR2 Malir	1613.1	2550.1	2170.4	2236.4	1880.1
*LR Malir	1801.1	2851.2	2431.6	2498.9	2100.7
THADDO	228	351.5	299.1	290.5	244.5

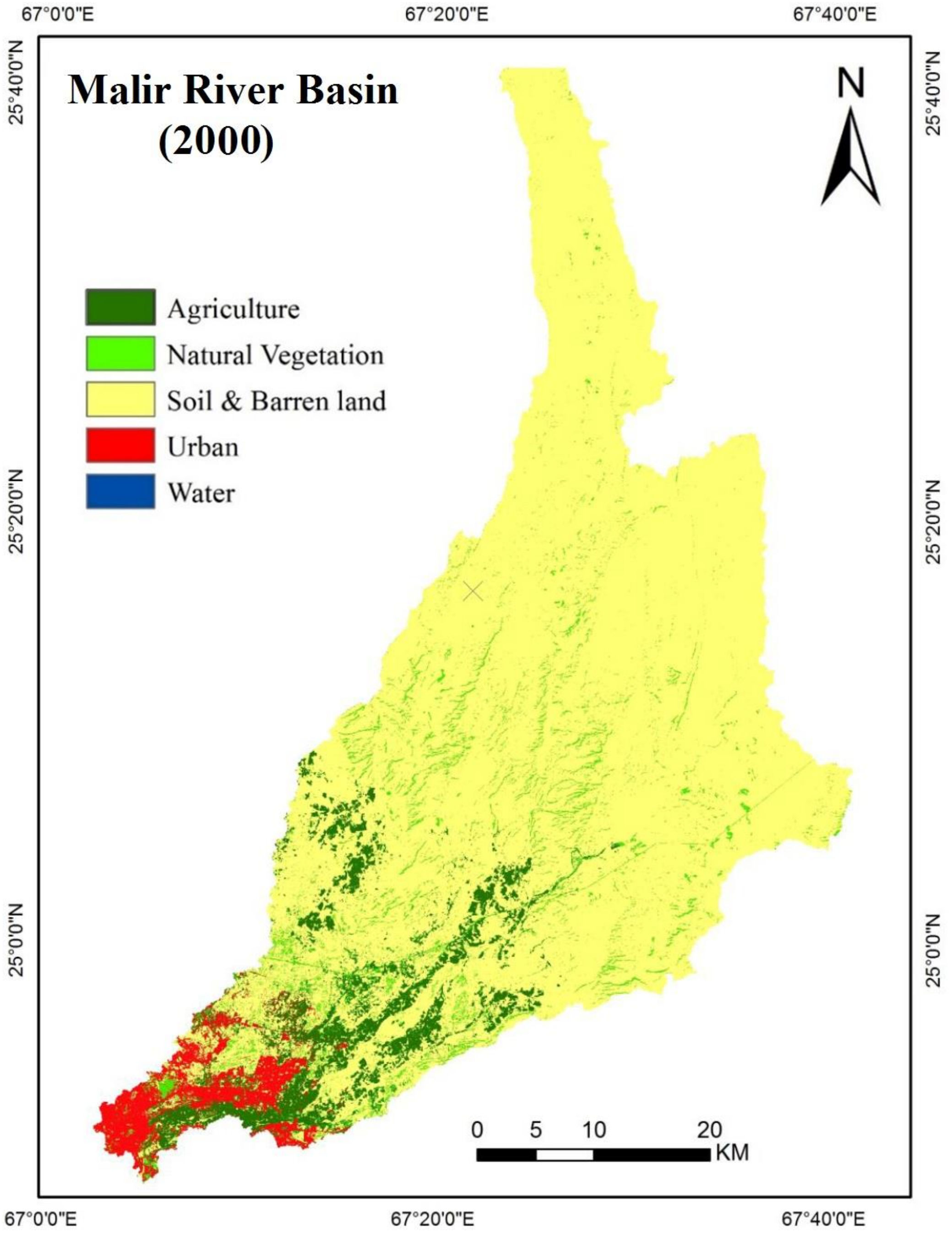
*UR= Upper Reach, MR= Middle Reach, LR= Lower Reach

Flood Modeling and Inundation Mapping

- Steady flow analysis done to model flood inundation extent and depth
- For normal depth computation, the downstream slope of 0.00273 calculated from DEM is used
- Simulated rainfall-runoff data of five (05) historical events of 1992, 2003, 2007, 2009 and 2013 were used to model the flood extent and depth
- Modeled flood data were exported to GIS environment to map flood extent and flood depth
- The flood extent was overlaid with LULC map of the Malir Basin to estimate the elements at risk and to generate the risk maps of the area

RESULTS


Malir River Basin
(2015)
Agriculture
Natural Vegetation
Soil & Barren land
Urban
Water
N
0 5 10 20
KM
67°0'0"E
67°20'0"E
67°40'0"E
25°40'0"N
25°20'0"N
25°0'0"N


Malir River Basin
(2000)
Agriculture
Natural Vegetation
Soil & Barren land
Urban
Water
N
0 5 10 20
KM
67°0'0"E
67°20'0"E
67°40'0"E
25°40'0"N
25°20'0"N
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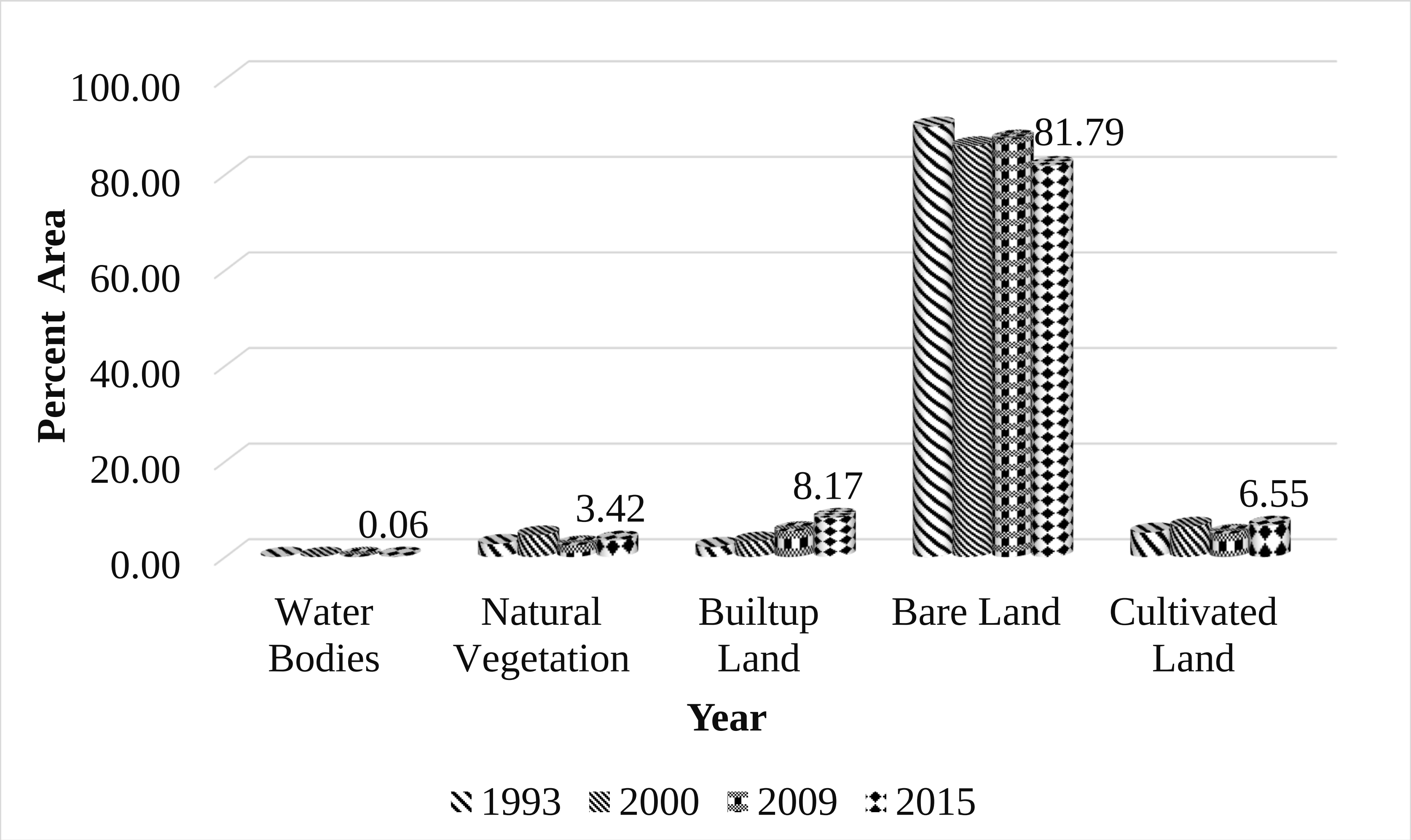
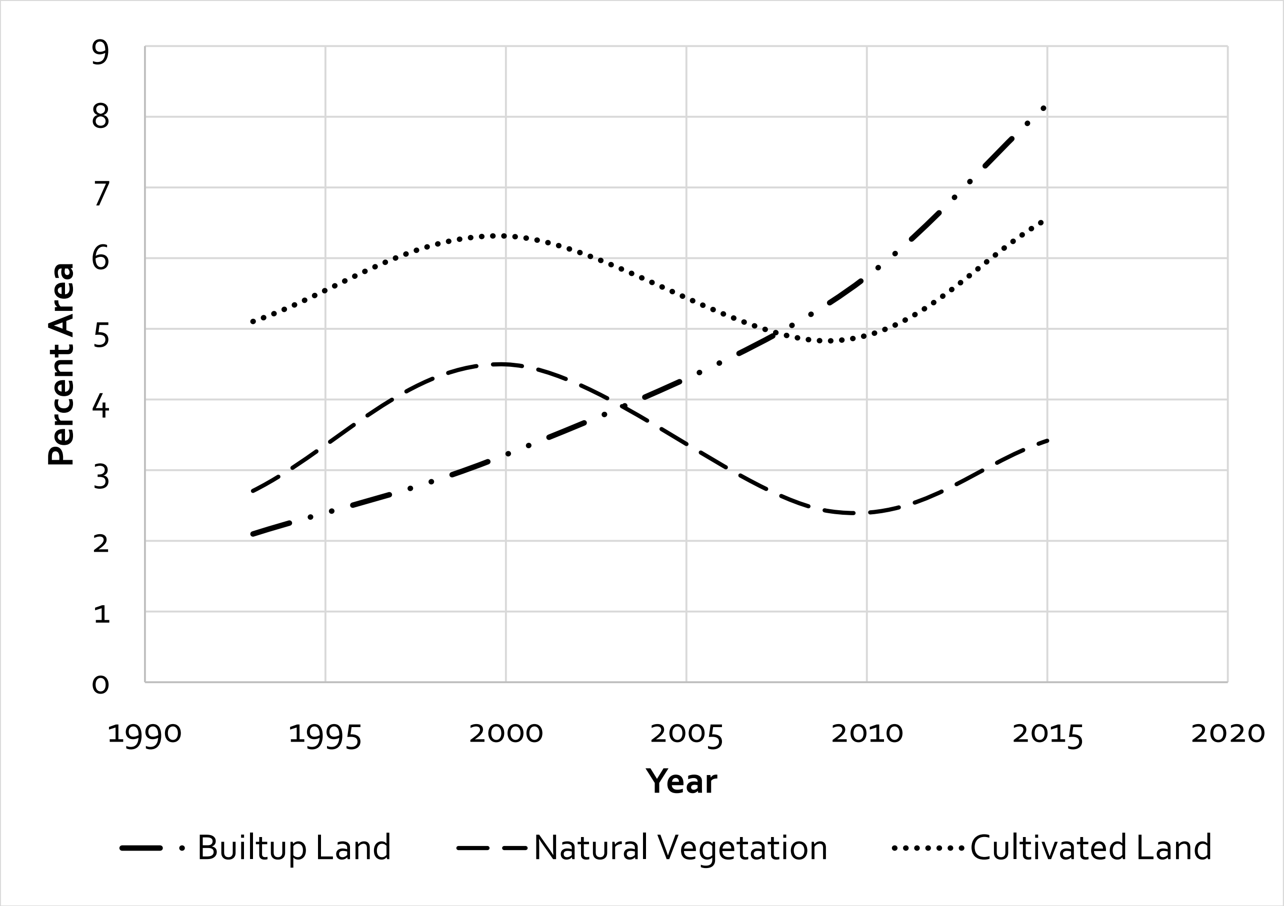
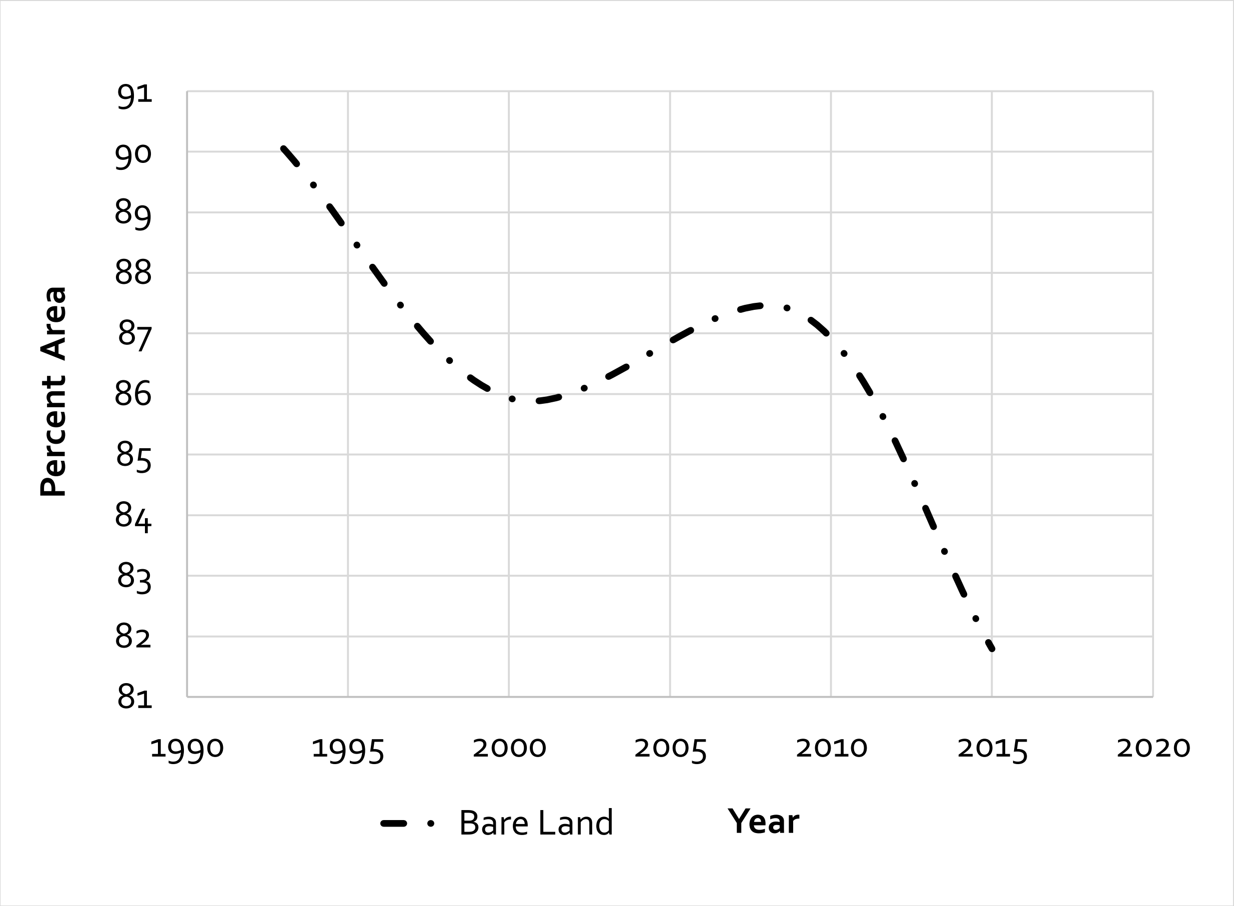
LULC Change



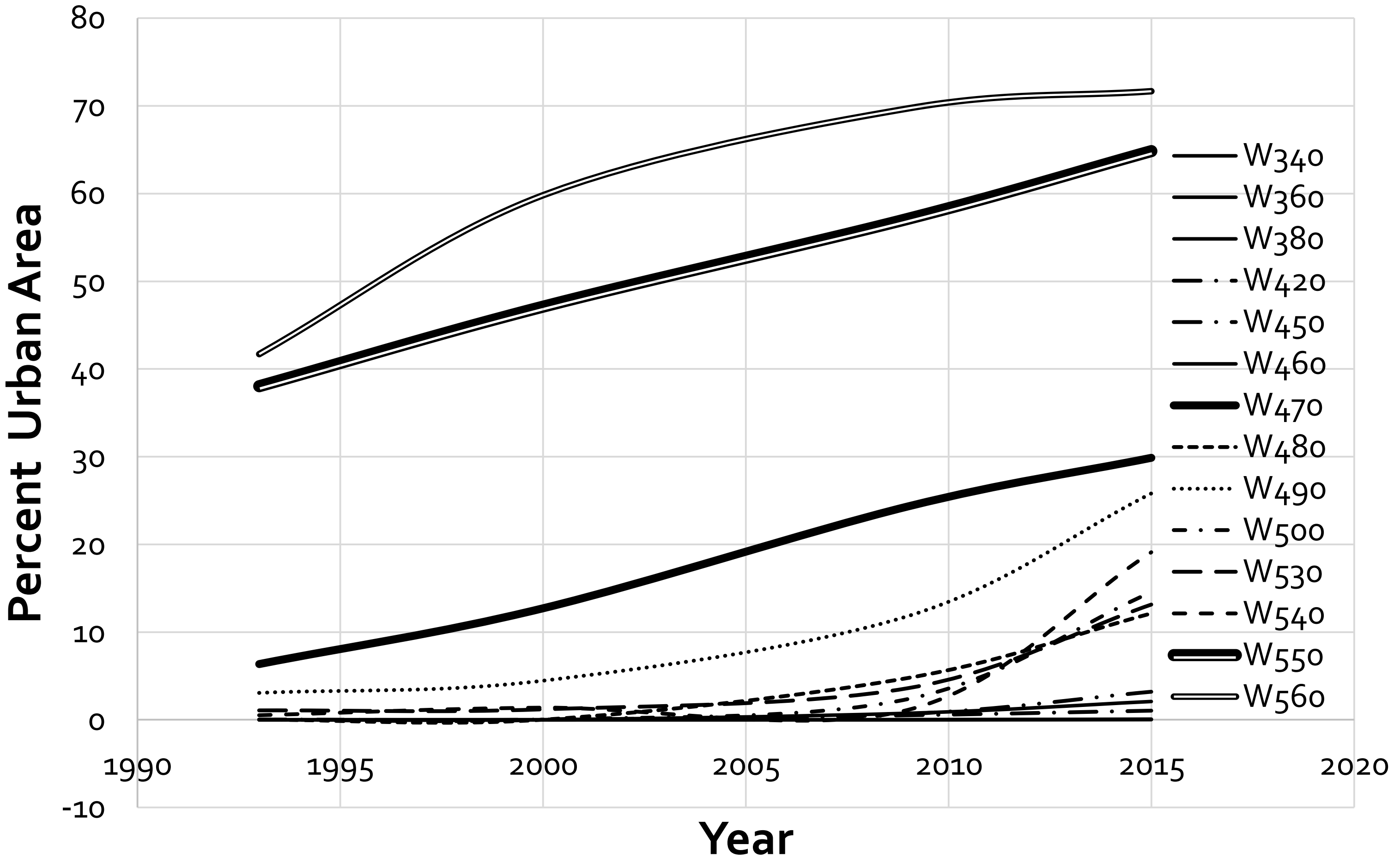
100.00
80.00
60.00
40.00
20.00
0.00
Percent Area
0.06
3.42
8.17
81.79
6.55
Water Bodies
Natural Vegetation
Builtup Land
Bare Land
Cultivated Land
Year
1993
2000
2009
2015

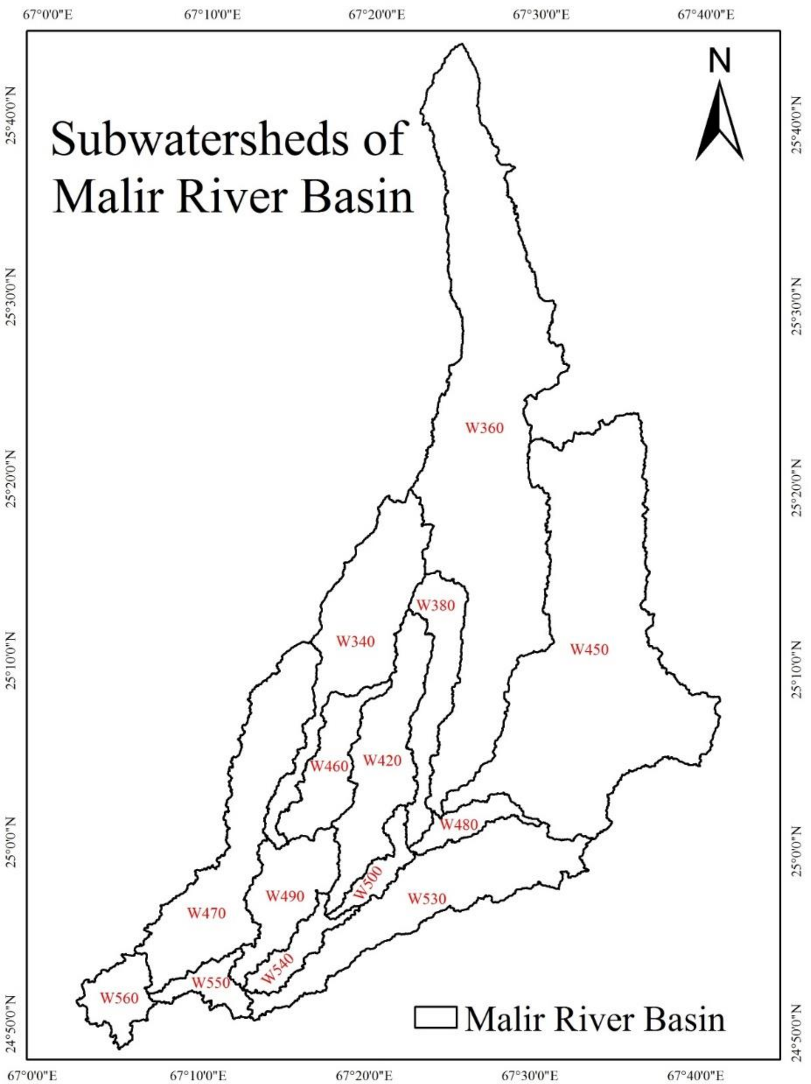
LULC Change (Built-up Land, Natural Vegetation, Cultivated Land bareland)



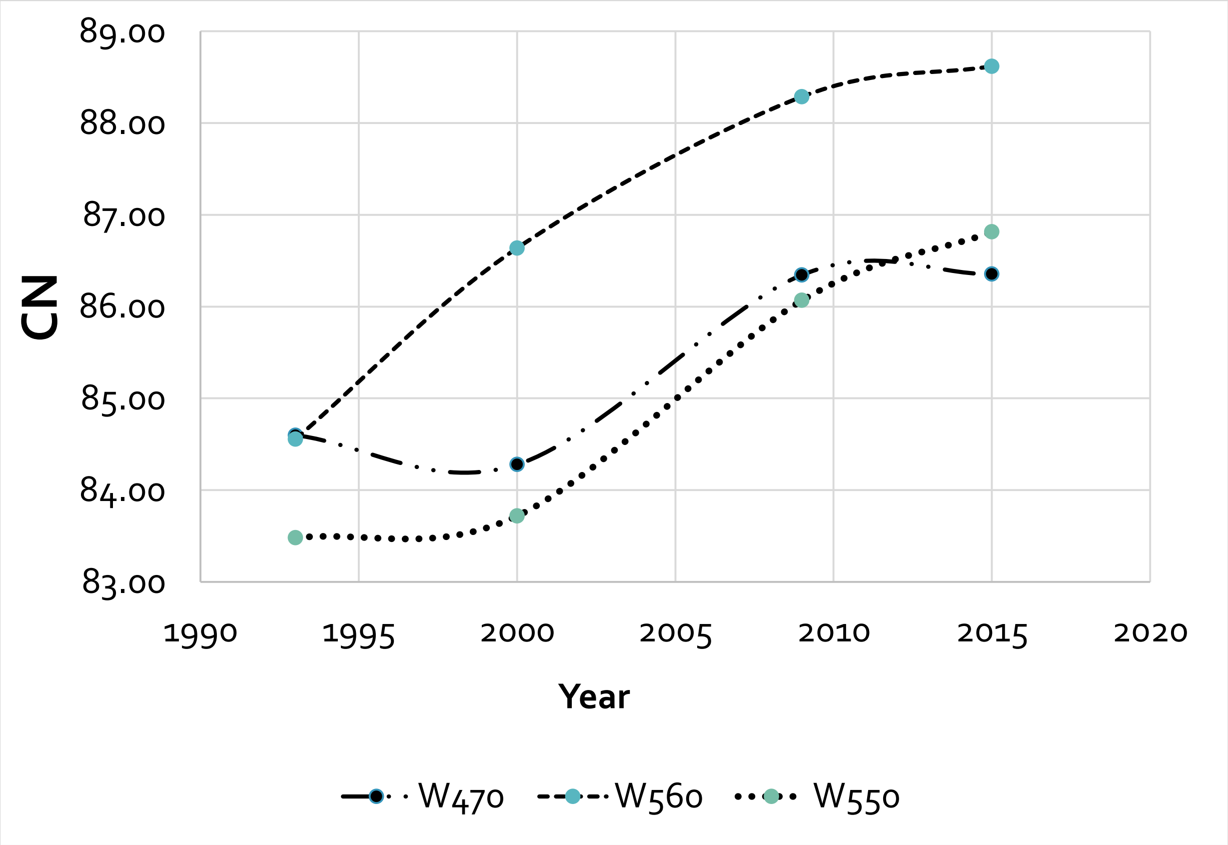


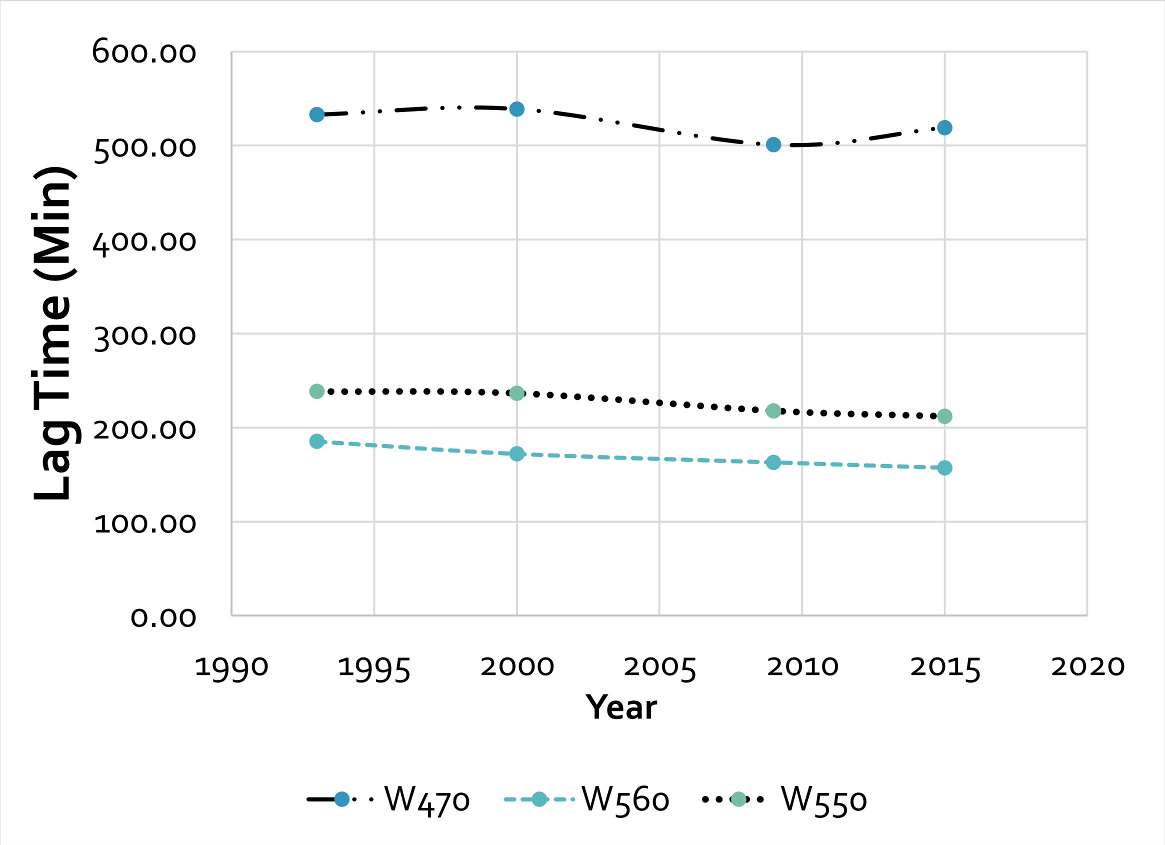
Trend of Urbanization in Each Subwatershed



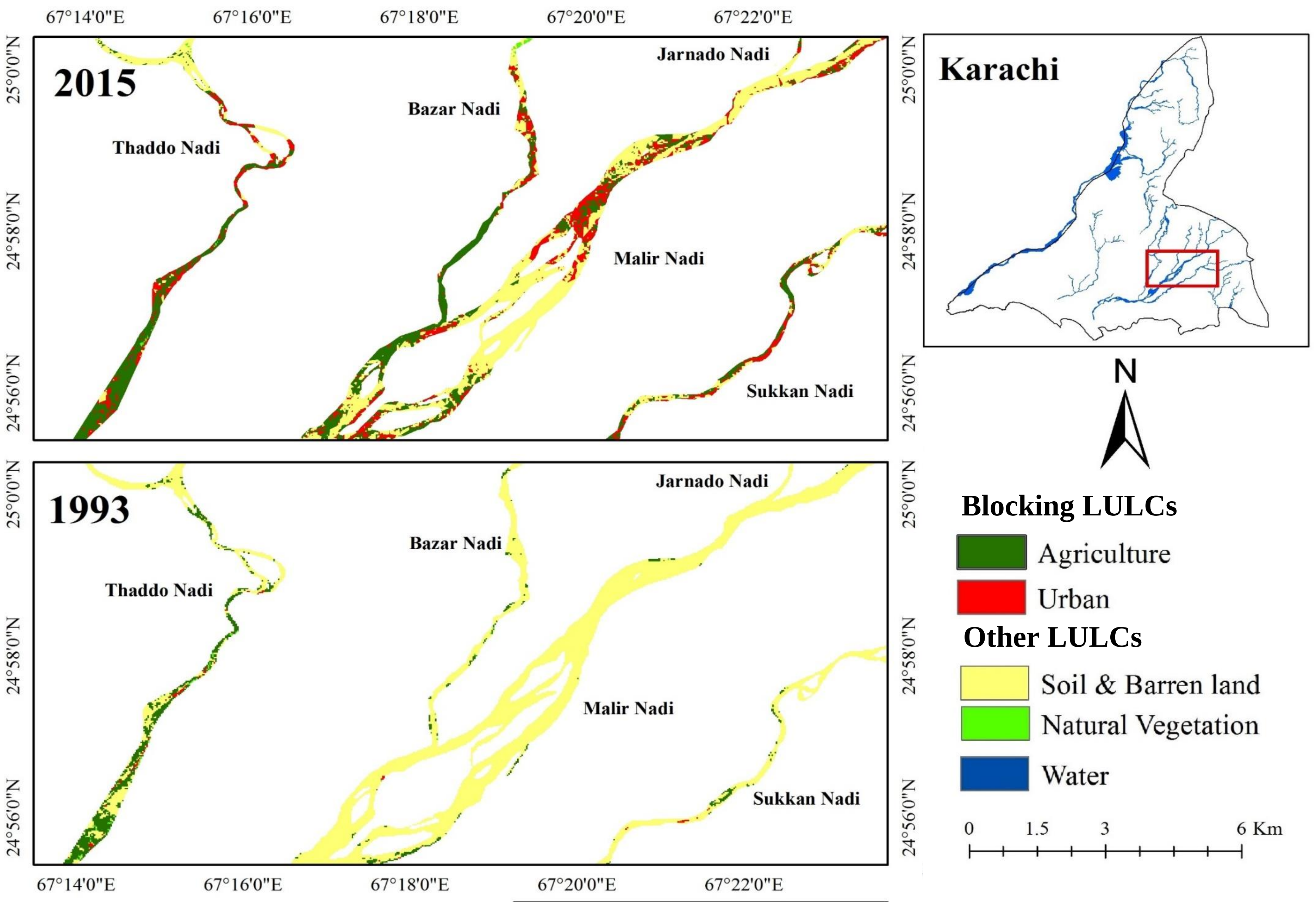


Impact of urbanization on CN and Lag time

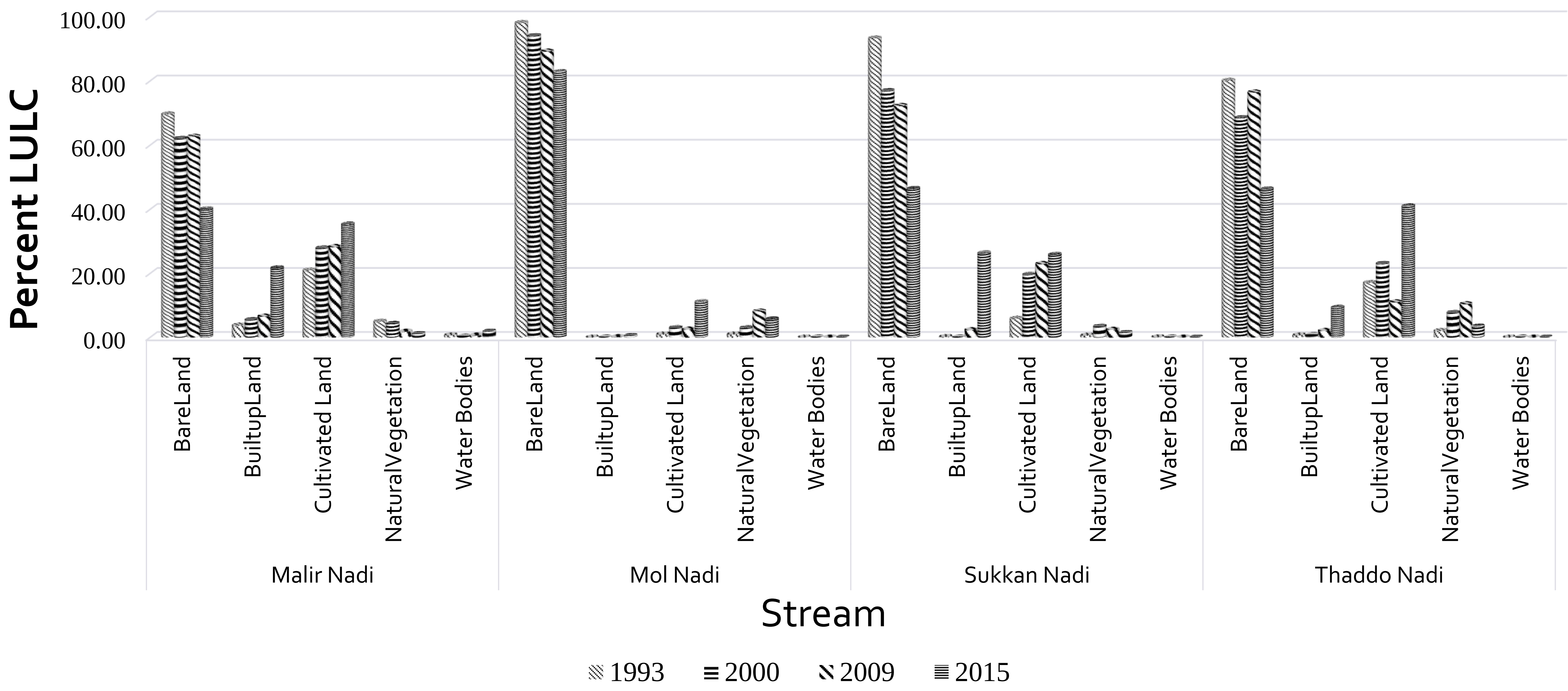




Identification of Stream Blockages



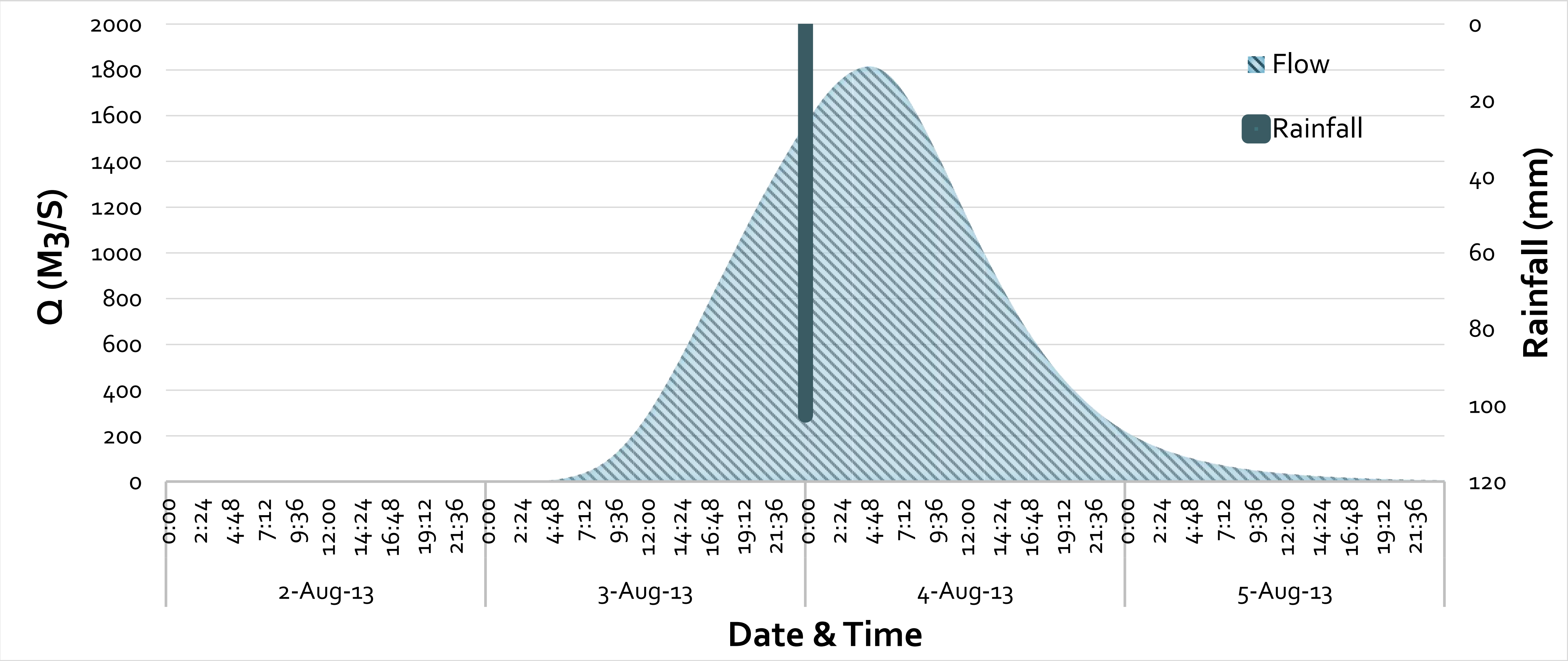
Percent blockages due to LULCs in Malir, Mol, Sukkun Nadi and Thaddo Nadi



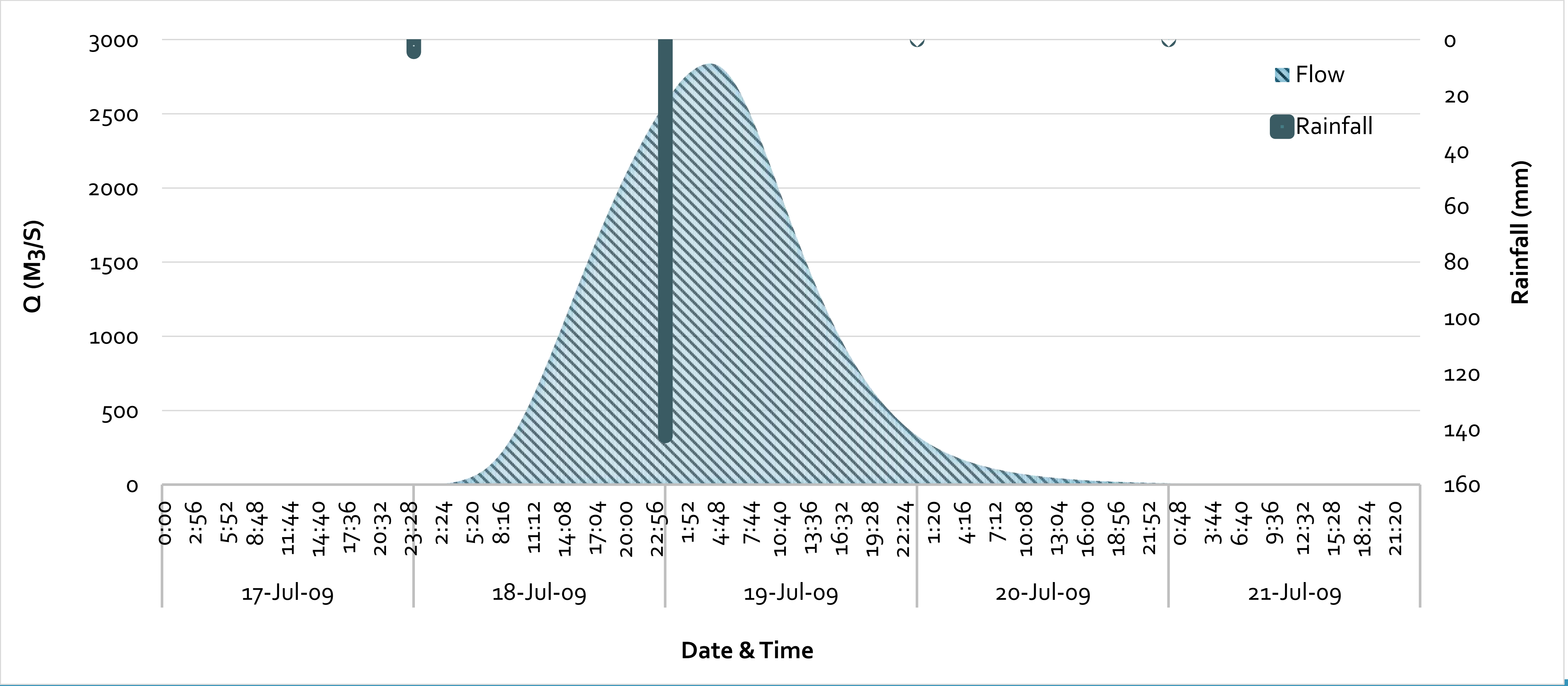
Rainfall Runoff Simulations

S.No.	Year	Date	Highest Rainfall	Max Daily Annual (mm)	Rainy days per year(>2.5)	Month of max	Flow at outlet (m^3/s)
1	2013	02-05 August	102.6	91.7	14	August	1796
2	2009	17-21 July	142.5	108.4	17	July	2838
3	2007	8 -12 August	124.2	124.2	14	August	2393
4	2003	16-02 August	108.4	142.5	6	July	2478
5	1992	11-14 August	91.7	102.6	8	August	1915
6	2052	17-21 July	142.5	-	-	-	3264.1

Time series flow at outlet of Malir River (2013)



Time series flow at outlet of Malir River (2009)



Peak Discharges in each reach of Malir River Basin

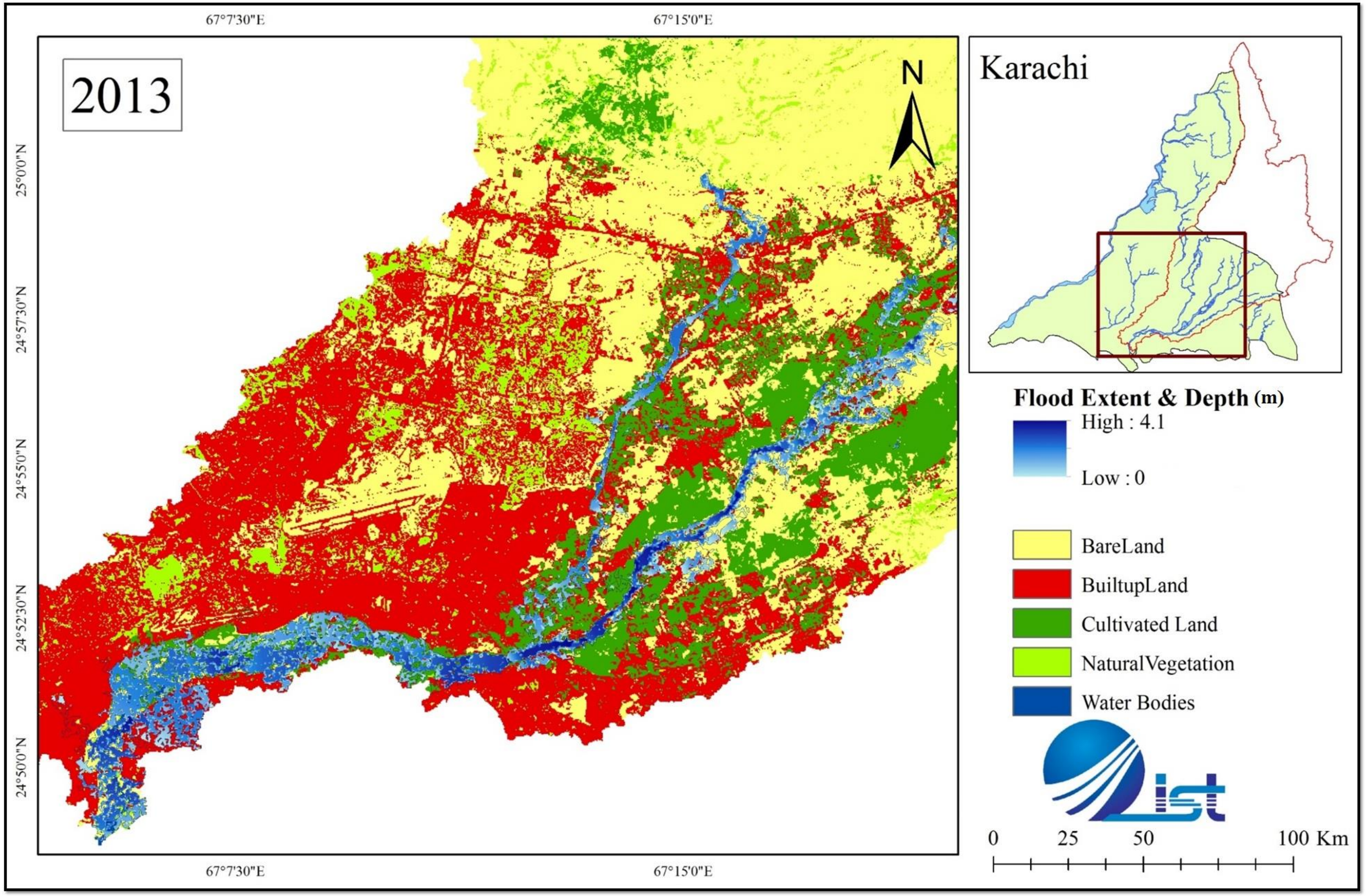
Stream Name	Drainage area	Peak discharge (m^3/s) 2013	Peak discharge (m^3/s) 2009	Peak discharge (m^3/s) 2007	Peak discharge (m^3/s) 2003	Peak discharge (m^3/s) 1992
Malir UR1	1158.96	954	1485.1	1262.6	1293.2	1000.5
Malir UR2	1270.665	1025.1	1604.6	1364.6	1409.6	1087
Malir MR1	1431.28	1149.3	1803.6	1529.4	1586.2	1222.8
Malir MR2	1972.527	1613.1	2523.1	2133.5	2200.8	1700.3
Malir LR	2208.83	1801.1	2822.8	2392.1	2458.4	1897.1
Thaddo	240.149	228	347.5	294.2	286.3	225.8

Flood modeling

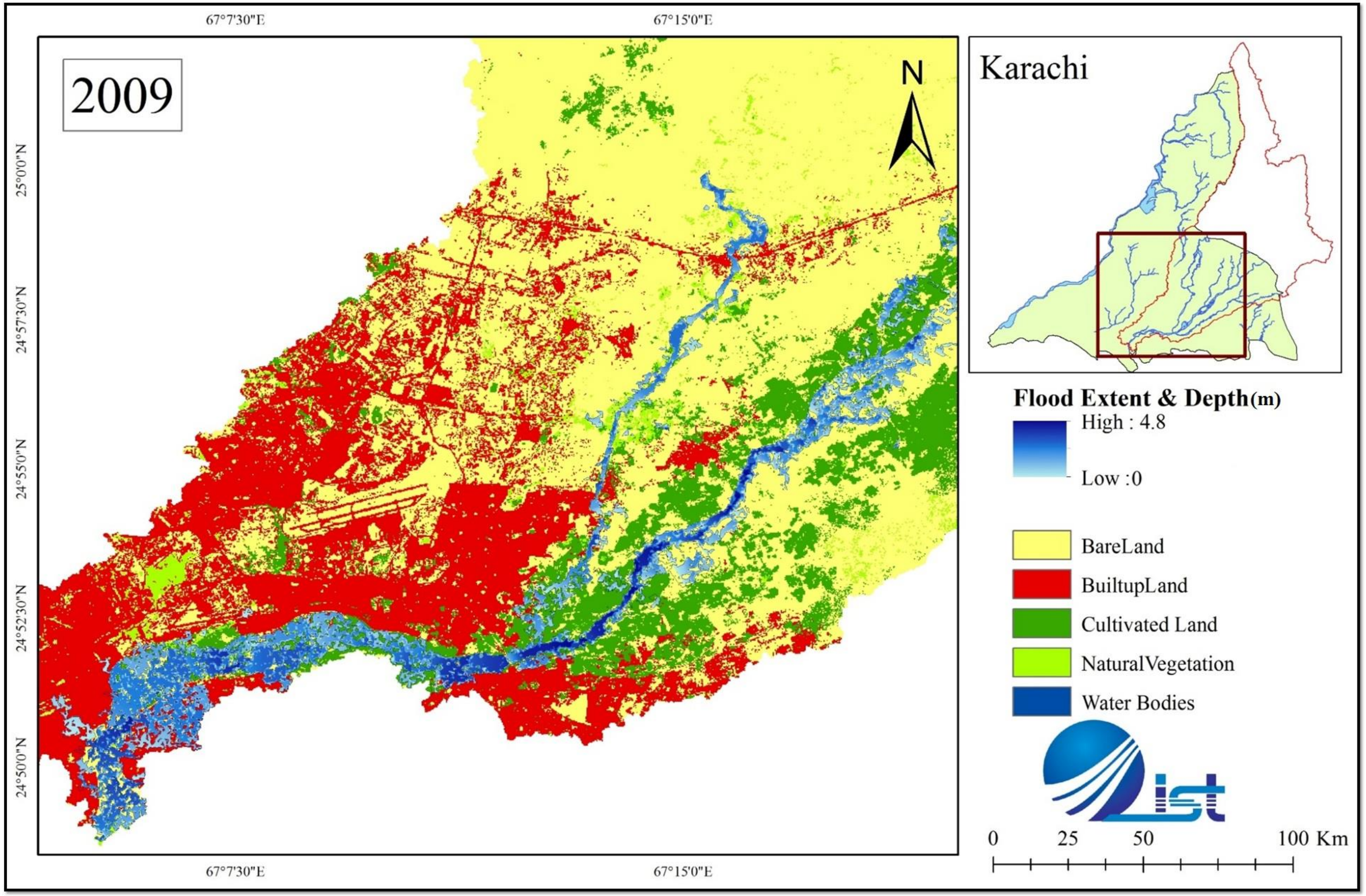
Modeled Flood Extent and Depth

Year	Extent (m)	Depth (m)
2013	33	4.1
2009	38	4.9
2007	36	4.5
2003	36.4	4.6
1992	33.4	4.2

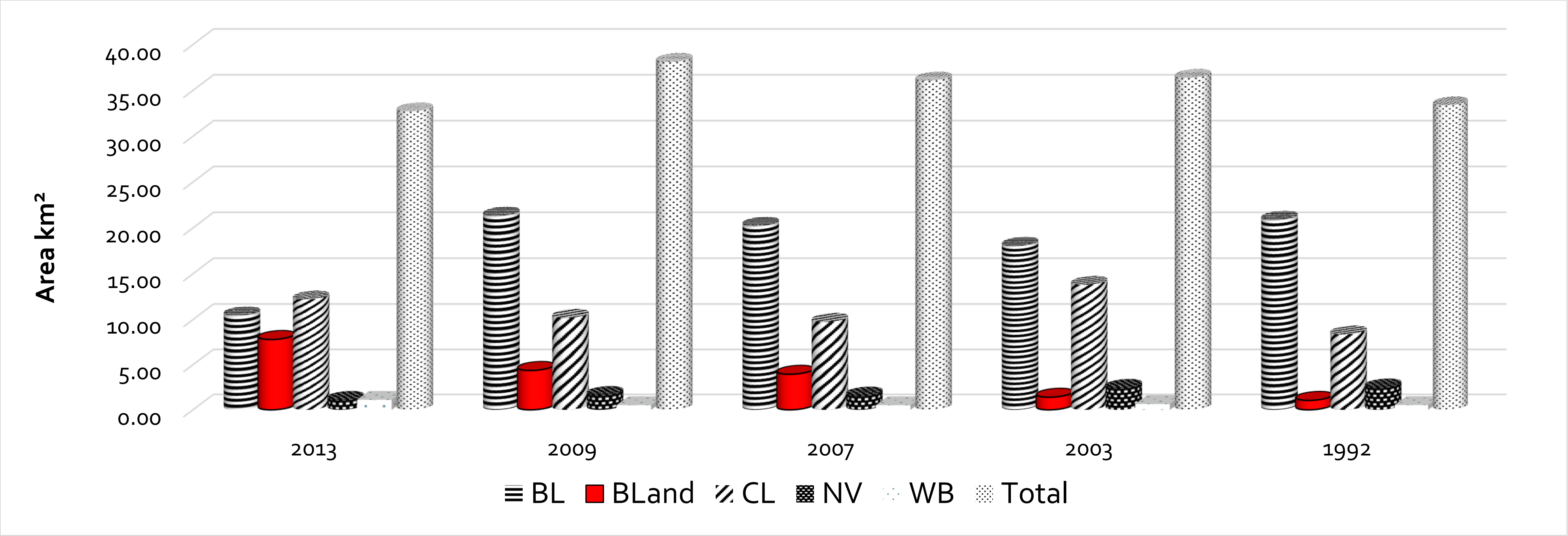
Flood Extent and Depth of 2013 Flood



Flood Extent and Depth of 2009 Flood



Damage Assessment of Each Flood Event



Conclusion

- First objective - LULCs changes in the Malir riverbed from 1993 to 2015.
- Result shows that;
  - 21 % stream bed of Malir River
  - 26% in Sukkun, and
  - 09 % of Jarnado River
- converted into urban or built-up land and the process on.......

Continue….

- Second objective - rainfall runoff modeling
  - In 1992, 2003, 2007, 2009 and 2013 Karachi received maximum rainfall in a day or few hours of the day
  - These five major events of extreme rainfall were used to simulate rainfall-runoff
  - Flood of 2009 was the worst event in last three decades
  - The inundated area due to floodwater (1992-2013) was between 33 km^2 to 38 km^2 and with a varying depth of 4.1 - 4.9 meters
  - Maximum extent (38 km^2) and depth (4.9 meters) were observed during flood in 2009

Continue….

- Third objectives – Develop flood map and estimation of element at risk
  - In 1992 during the flood 01 km^2 of the urban area was at risk
  - In 2013 flood more than (07) km^2 of the urban area was inundated
- Increase urban area increased the element at risks
- The vulnerability of the watershed to the floods has also intensified

Recommendations

1. There is an urgent need to revive the natural drainage system of the city to save it from flood-related calamities.
2. There is a need establish a scientific inventory of water bodies of the city and delineate flood zones within the mega city.
3. Any further increase in agriculture and built-up lands should also be very carefully monitored and should be strictly prohibited wherever it is adversely altering the natural paths of the storm water.
4. Sewerage and drainage responsibilities of Karachi should be assigned to the responsible agencies in a way that storm drains and natural drains (nalas) are under the jurisdiction of the city, town, and union council
5. Allocation of urban zones with watershed management system can reduce flood related risks