ANALYSIS OF THE EFFECT OF RAPID URBANIZATION ON FLOODING IN CAGAYAN DE ORO CITY USING LANDSAT IMAGE ANALYSIS AND FLOOD MODELING

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Recovery
from disaster

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Diamond Partner Land Information New Zealand
Toitū te whenua

- **Located in the Pacific Ring of Fire**
- **Visited by an average of 20 storms annually**
- **18 Critical river basins and more than 300 major river systems**

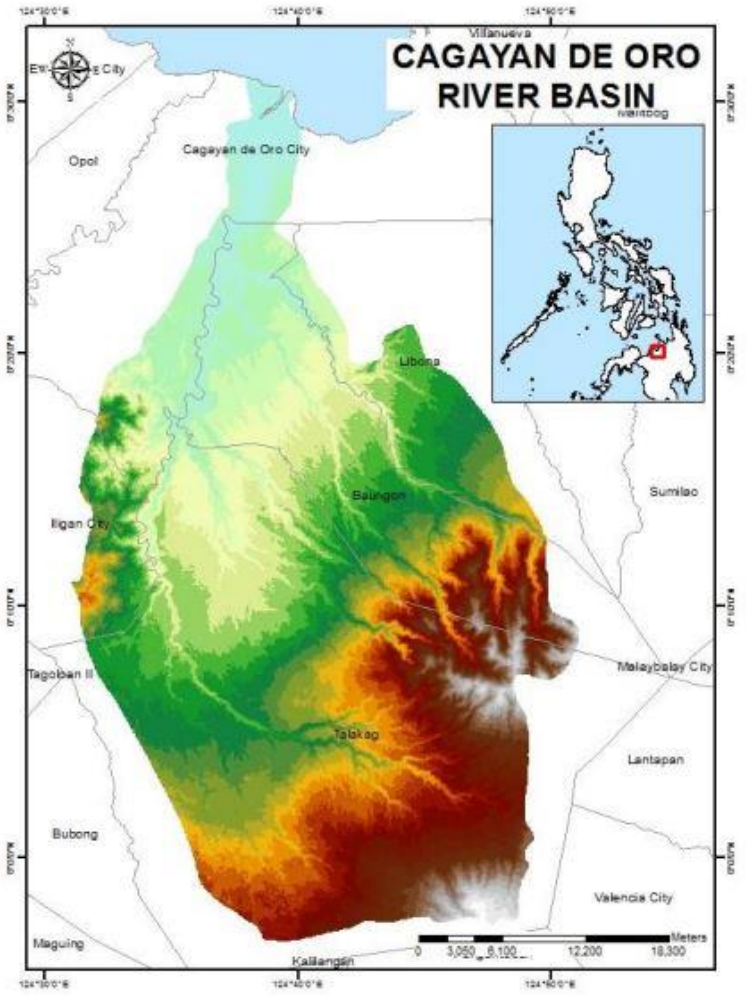
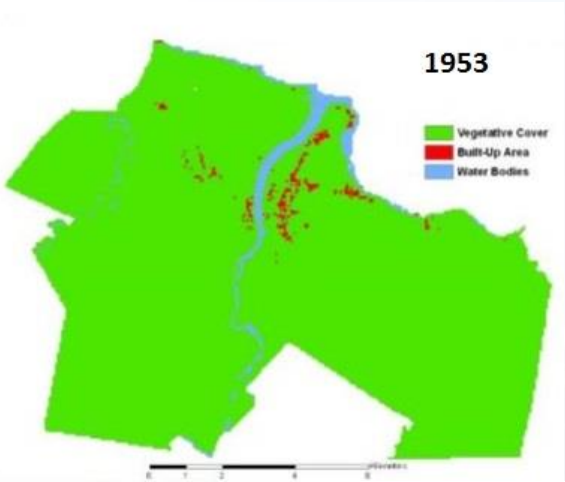


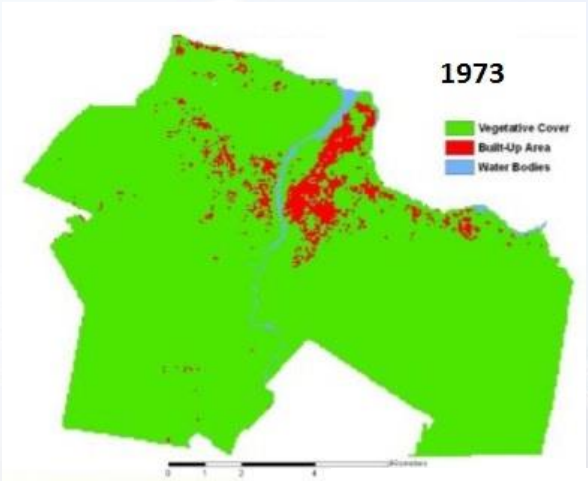
Figure 1 Cagayan de Oro River Basin

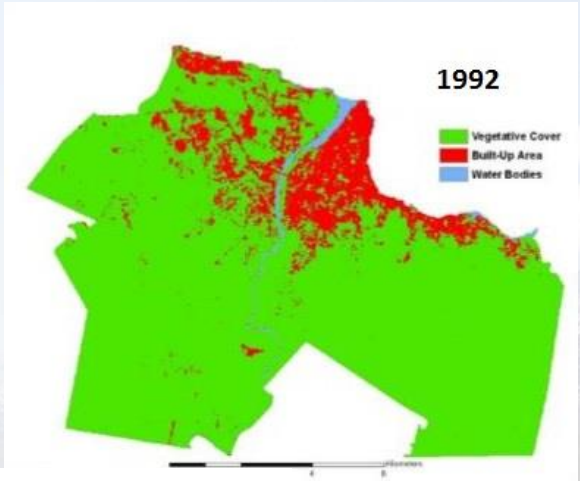
Cagayan de Oro (CDO) City

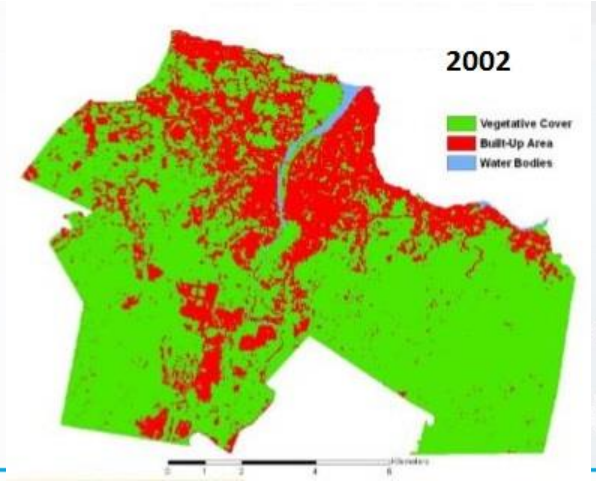
- Highly urbanized
- Total area of 462 sq.km
- Coastal and riverine city, bounded by mountain ranges in the southwest and Macalajar Bay in the north
- 1 of the 18 critical riverbasins
- Dubbed as the gateway to Northern Mindanao and considered the socioeconomic and political center of the region
- 602,088 total population as of May 2010 (latest available census)

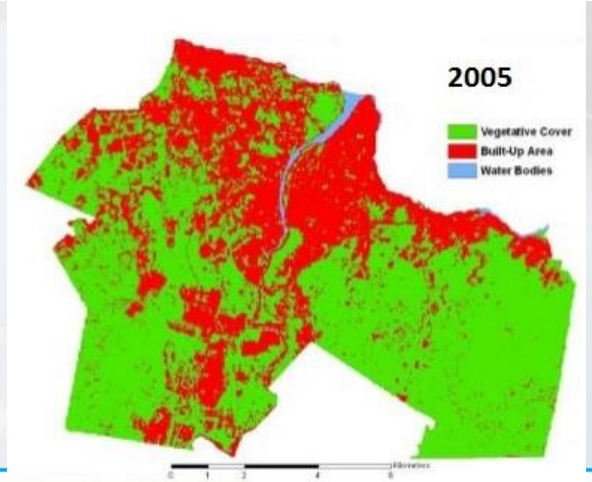
Urbanization of Cagayan de Oro City









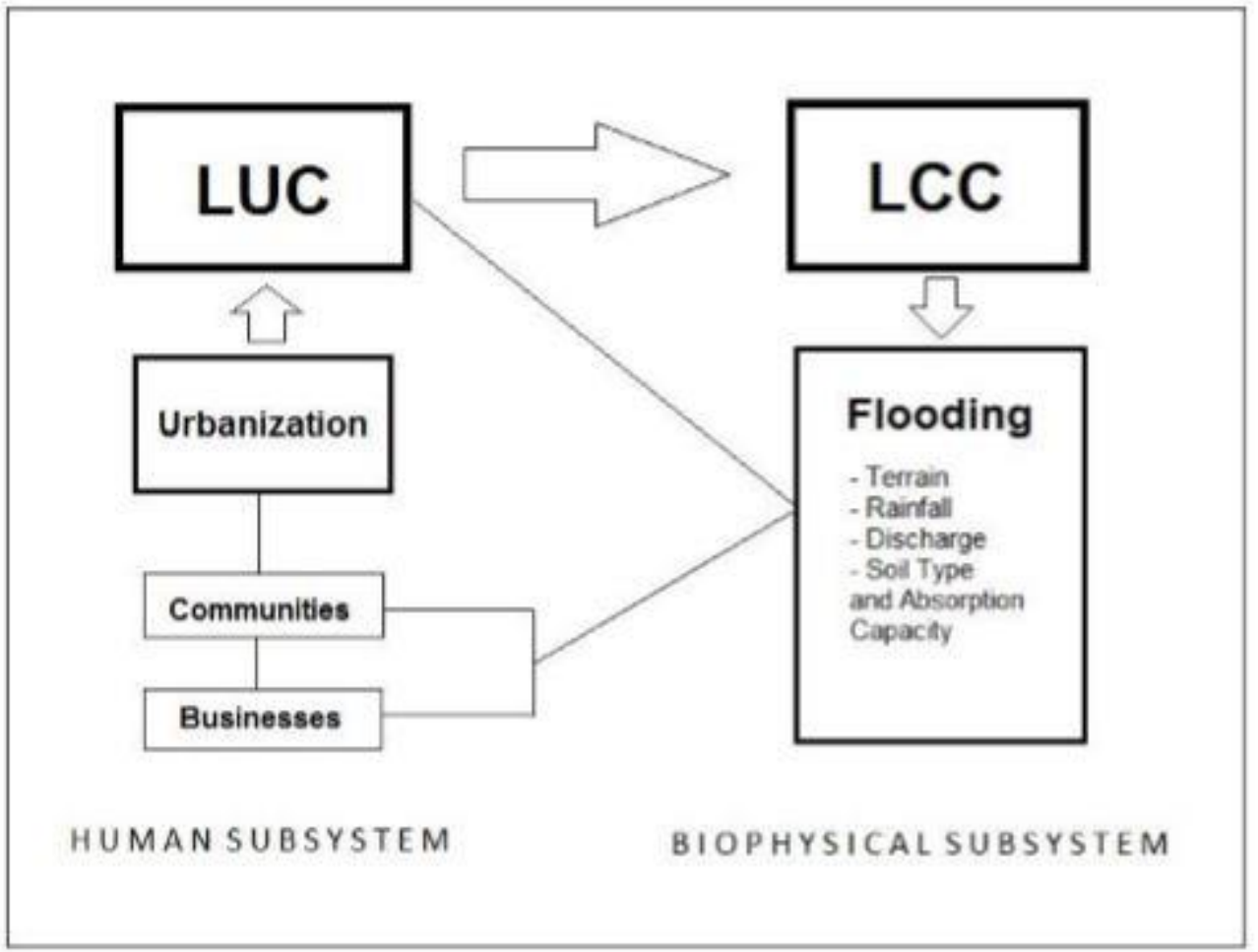


Source: Xavier University Engineering Resource Center

QUICK FACTS: SENDONG

- International Name: Washi
- Landfall in Mindanao: December 16, 2011
- 21st typhoon to hit PAR in 2011
- World's deadliest storm for 2011
- >1200 deaths, 182 missing
- Php 2 billion (USD 43 million) in damages

Urbanization and Flooding



Methodology

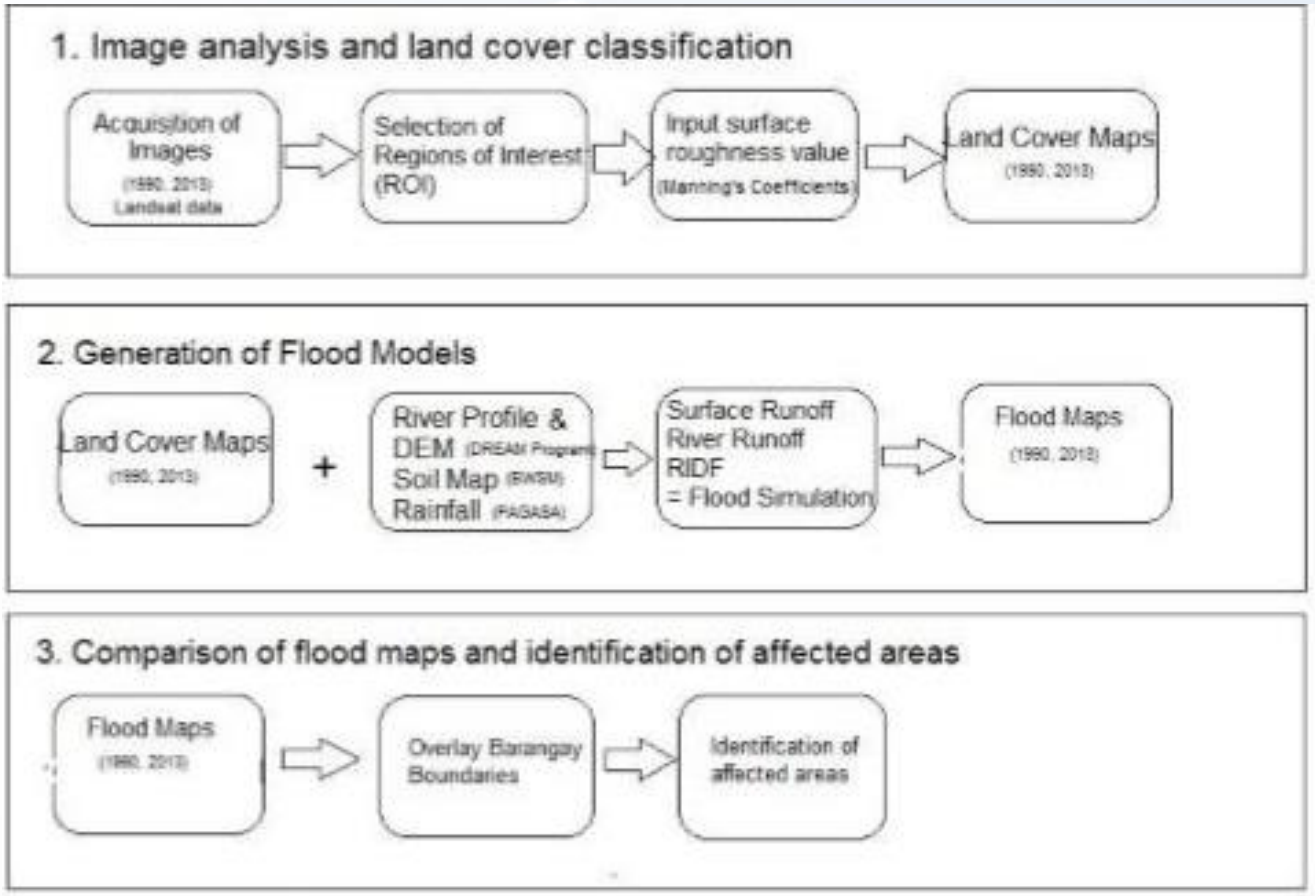
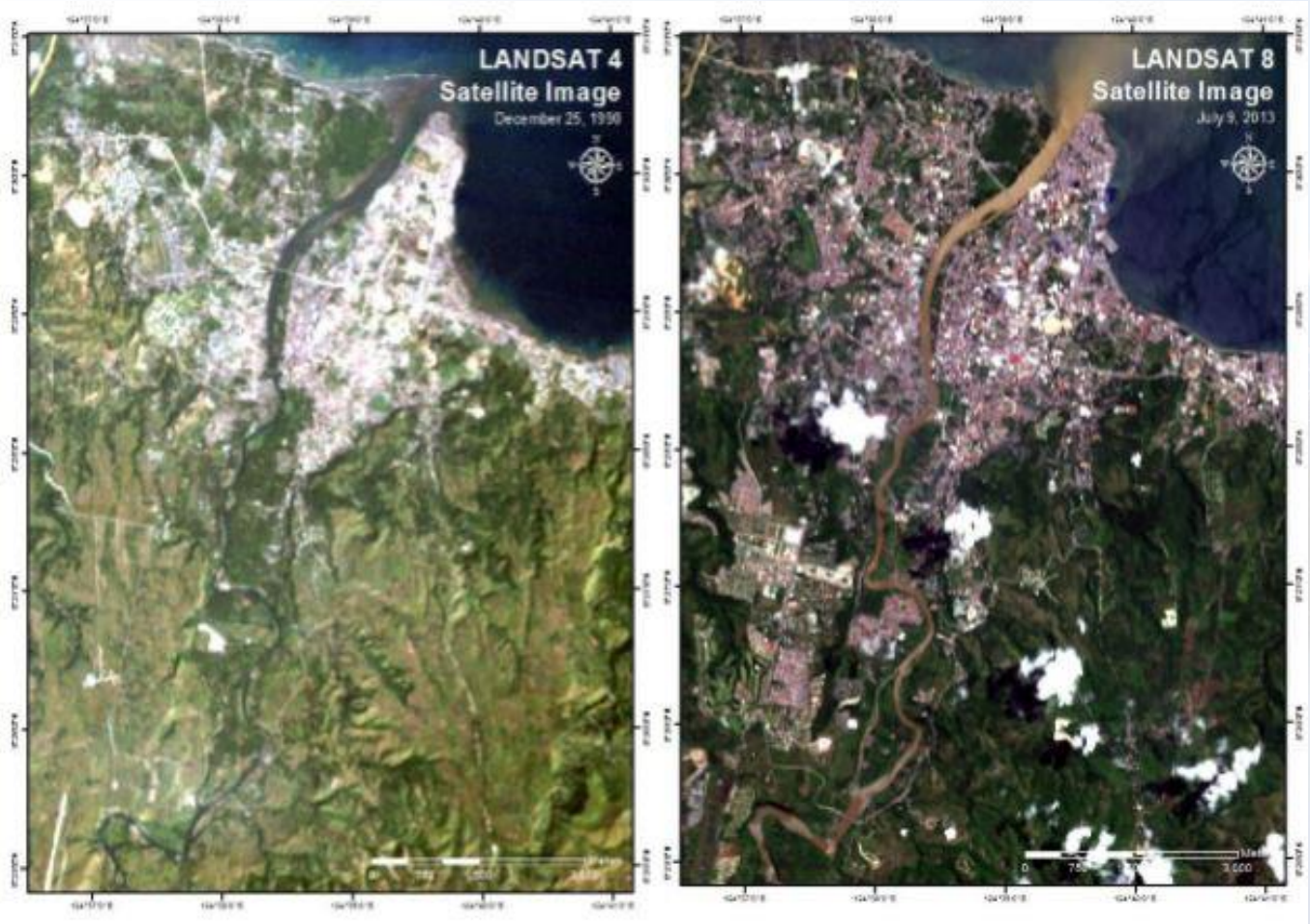
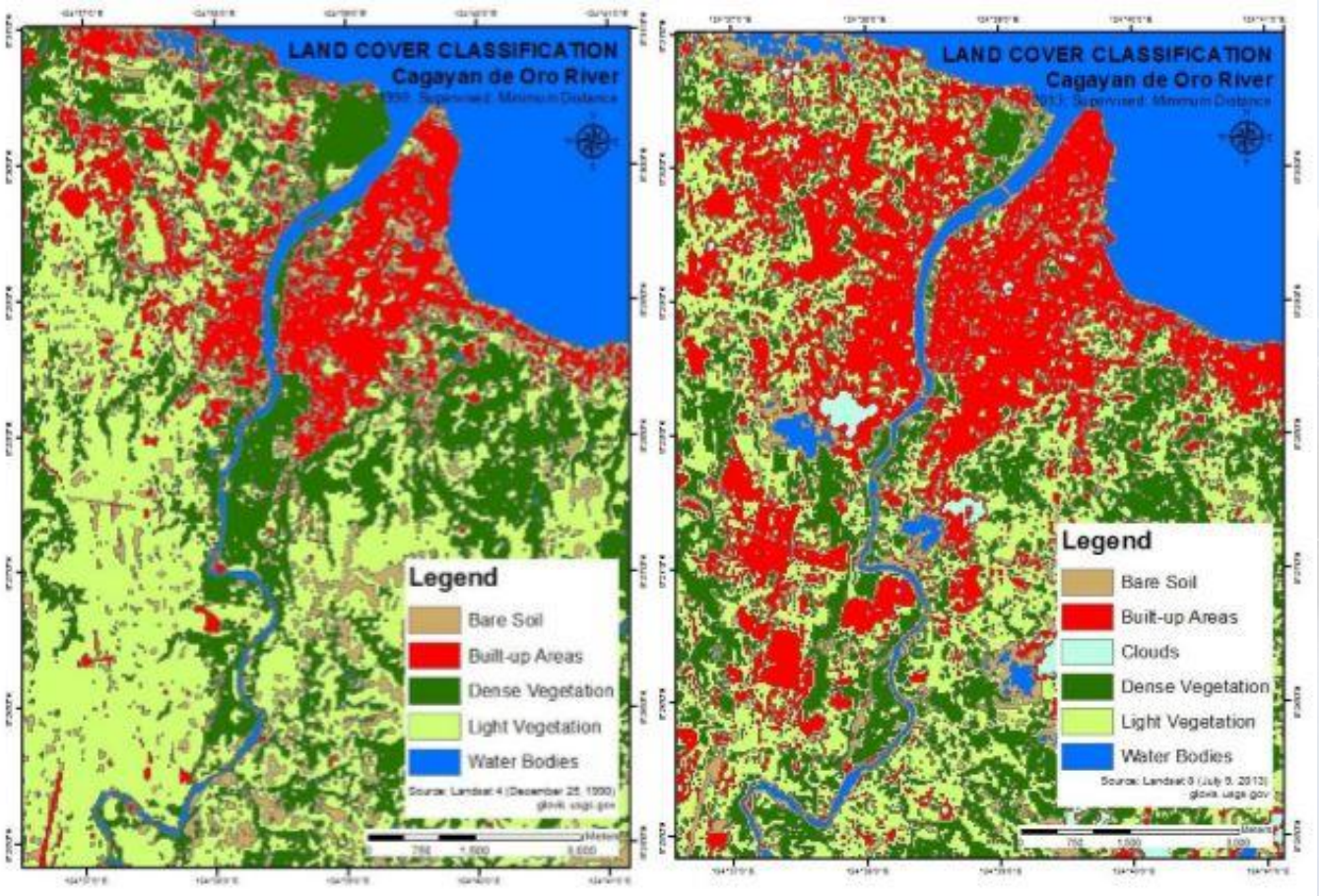


Image analysis and land cover classification



Classified Land Cover for 1990 and 2013 CDO Images (ENVI v4.8)

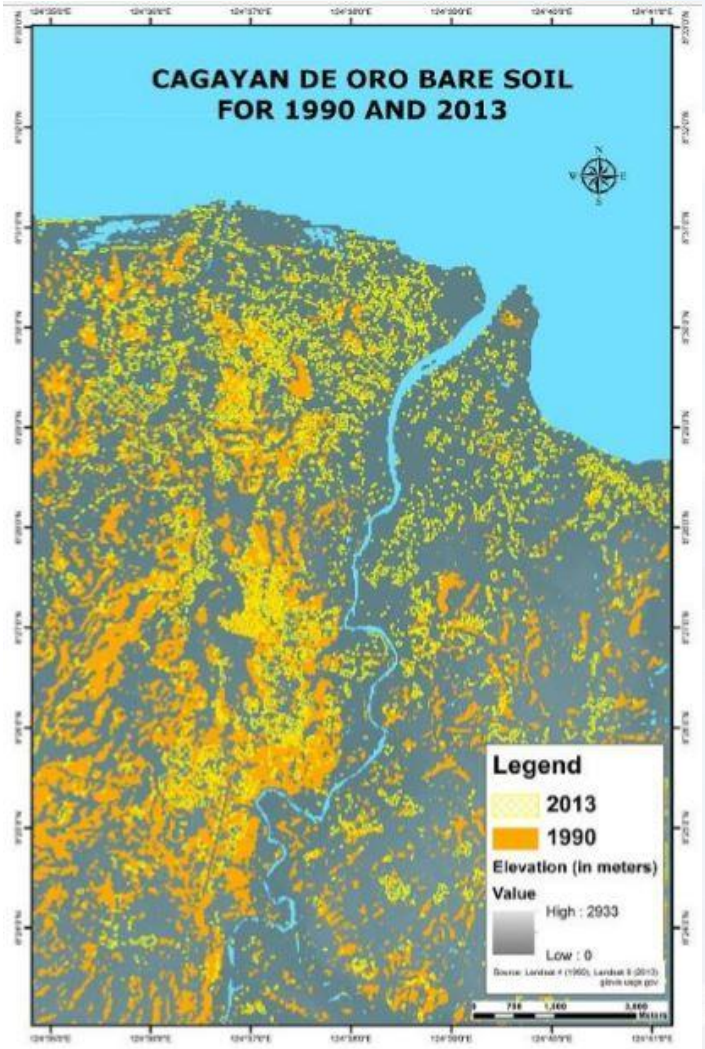


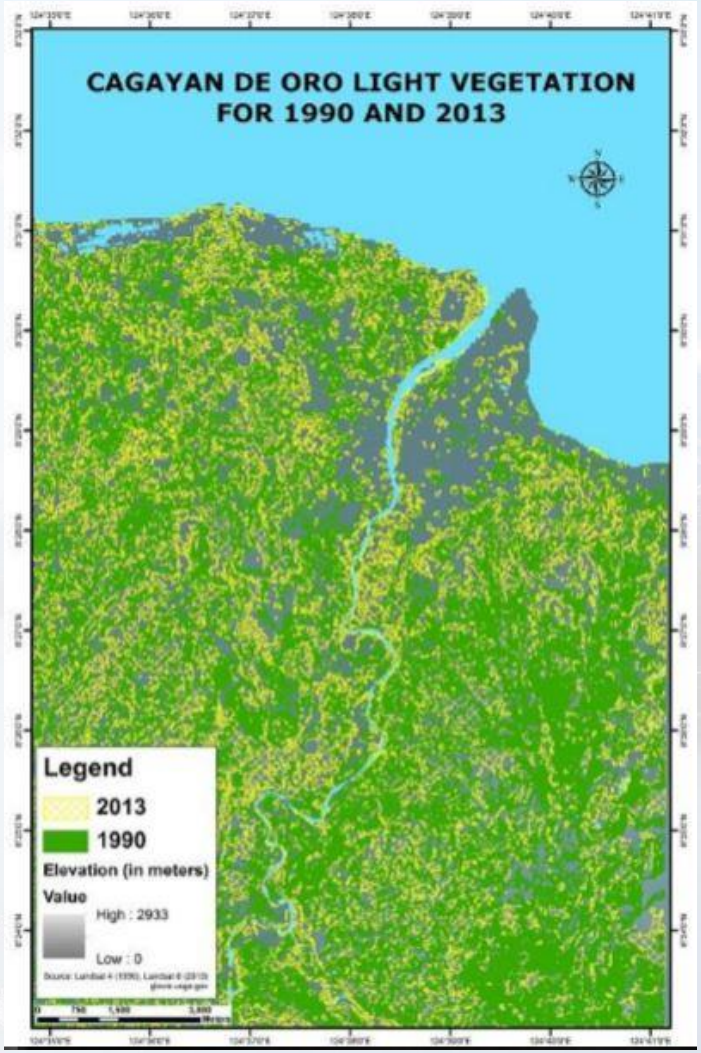
The accuracy of the land cover classes identified in the two Landsat images was computed using the following formula:

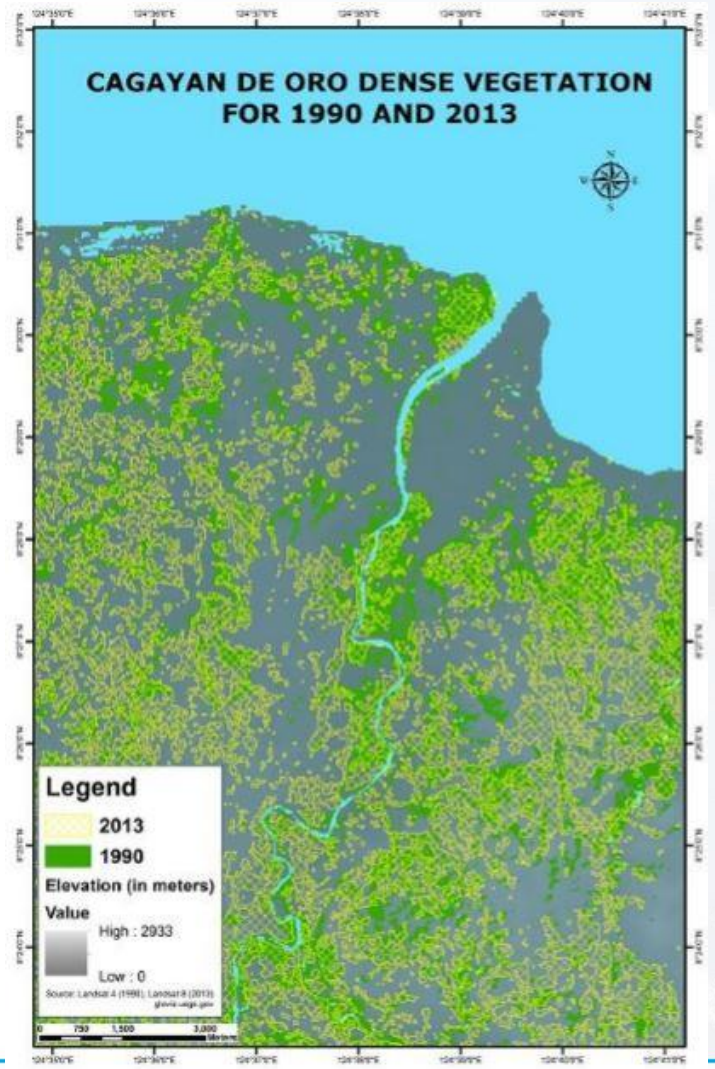
$$Total\ Accuracy = \frac{Number\ of\ correct\ plots}{Total\ number\ of\ plots}$$

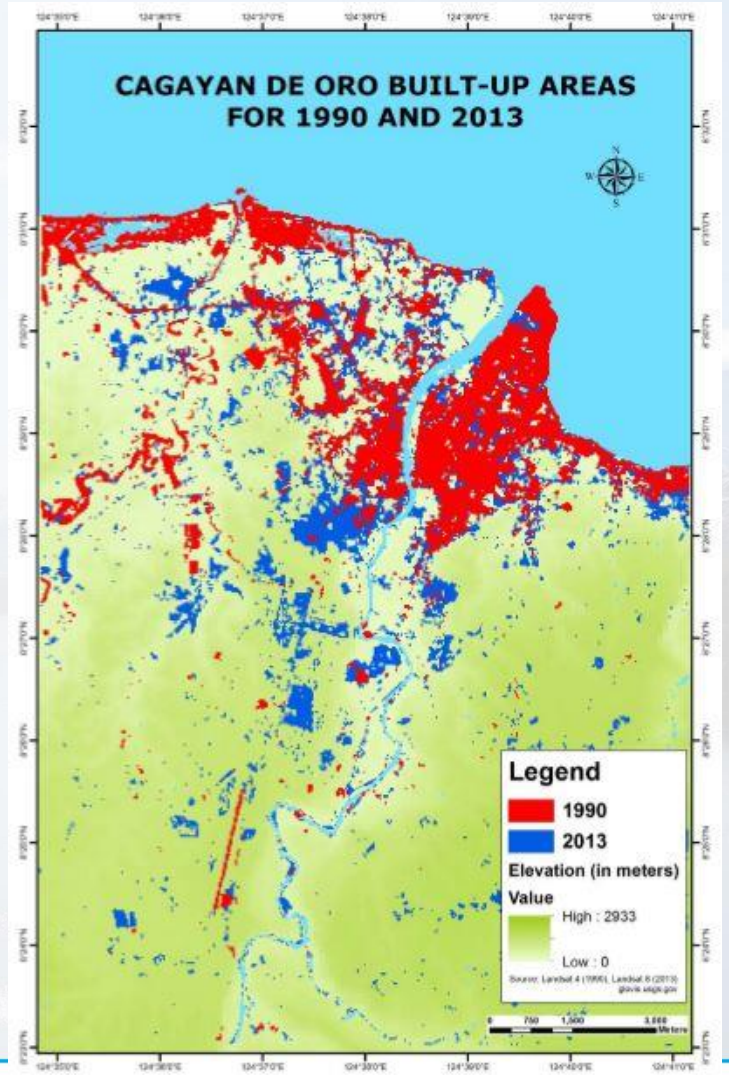
Overall accuracy for the 1990 CDO classified image is 93.39% and for the 2013 CDO classified image is 94.86%. Kappa coefficient, a statistical tool used to measure agreement was also employed and was estimated as:

$$\frac{Observed\ accuracy - Chance\ agreement}{1 - Chance\ agreement}$$


CAGAYAN DE ORO BARE SOIL
FOR 1990 AND 2013
Legend
2013
1990
Elevation (in meters)
Value
High : 2933
Low : 0


CAGAYAN DE ORO LIGHT VEGETATION
FOR 1990 AND 2013
Legend
2013
1990
Elevation (in meters)
Value
High : 2933
Low : 0


CAGAYAN DE ORO DENSE VEGETATION
FOR 1990 AND 2013
Legend
2013
1990
Elevation (in meters)
Value
High : 2933
Low : 0


CAGAYAN DE ORO BUILT-UP AREAS
FOR 1990 AND 2013
Legend
1990
2013
Elevation (in meters)
Value
High : 2933
Low : 0

Comparison of land cover type classification percentages			
Land Cover Type	*1990*	*2013*	*2013-1990*
Bare Soil	19.91%	5.91%	- 14.0
Built-up Areas	8.87%	17.25%	+ 8.38
Dense Vegetation	19.09%	25.35%	+ 6.26
Light Vegetation	37.84%	35.18%	- 2.65
Water Bodies	14.29%	15.09%	+ 0.8
Total	100%		

Generation of Flood Models

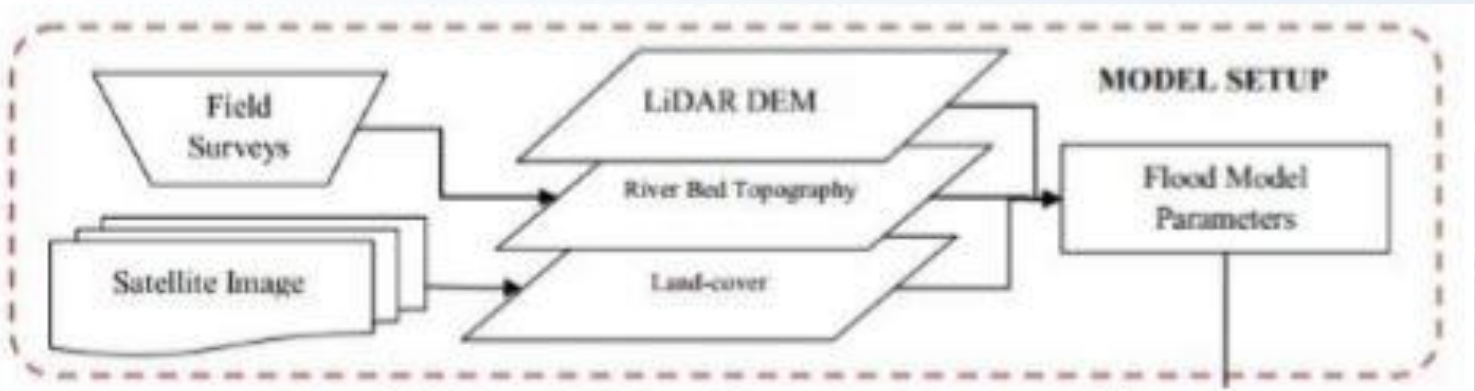
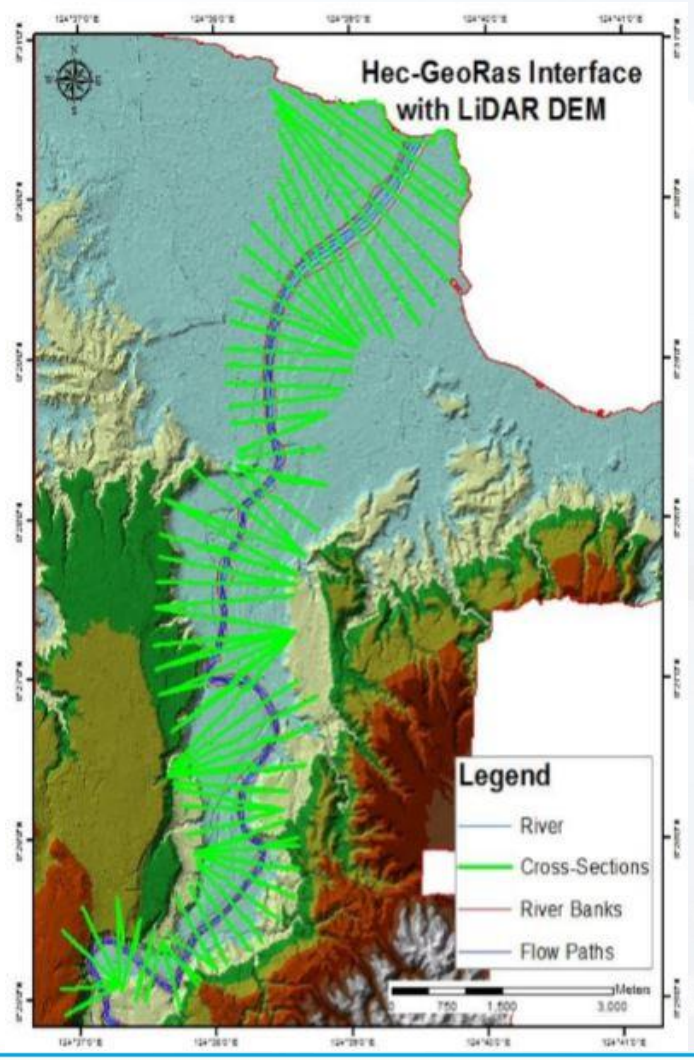
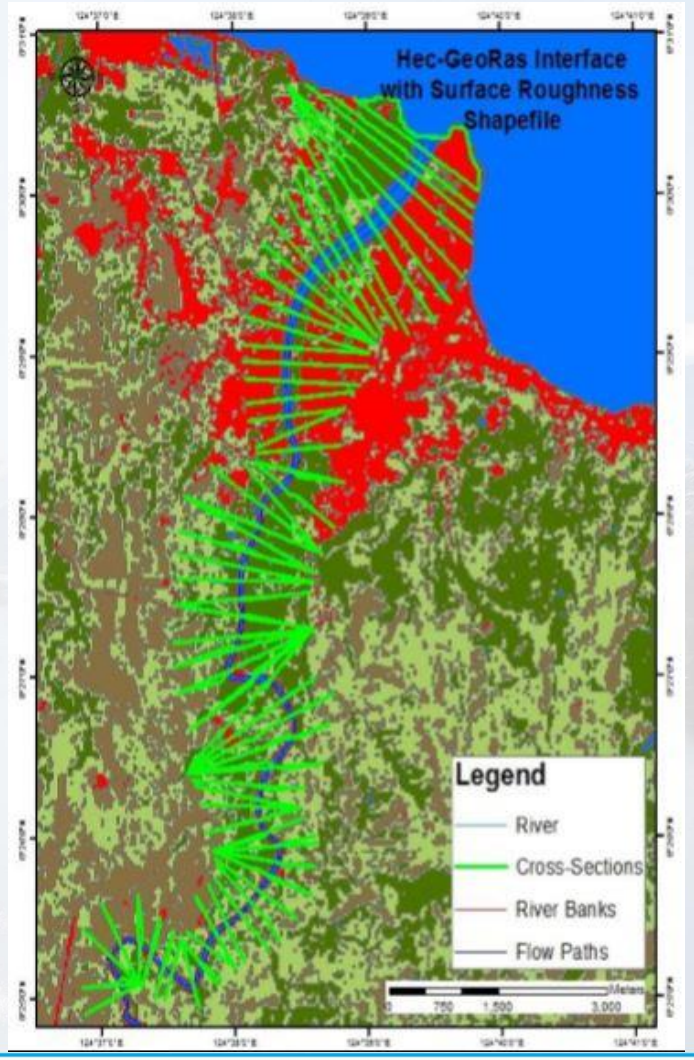
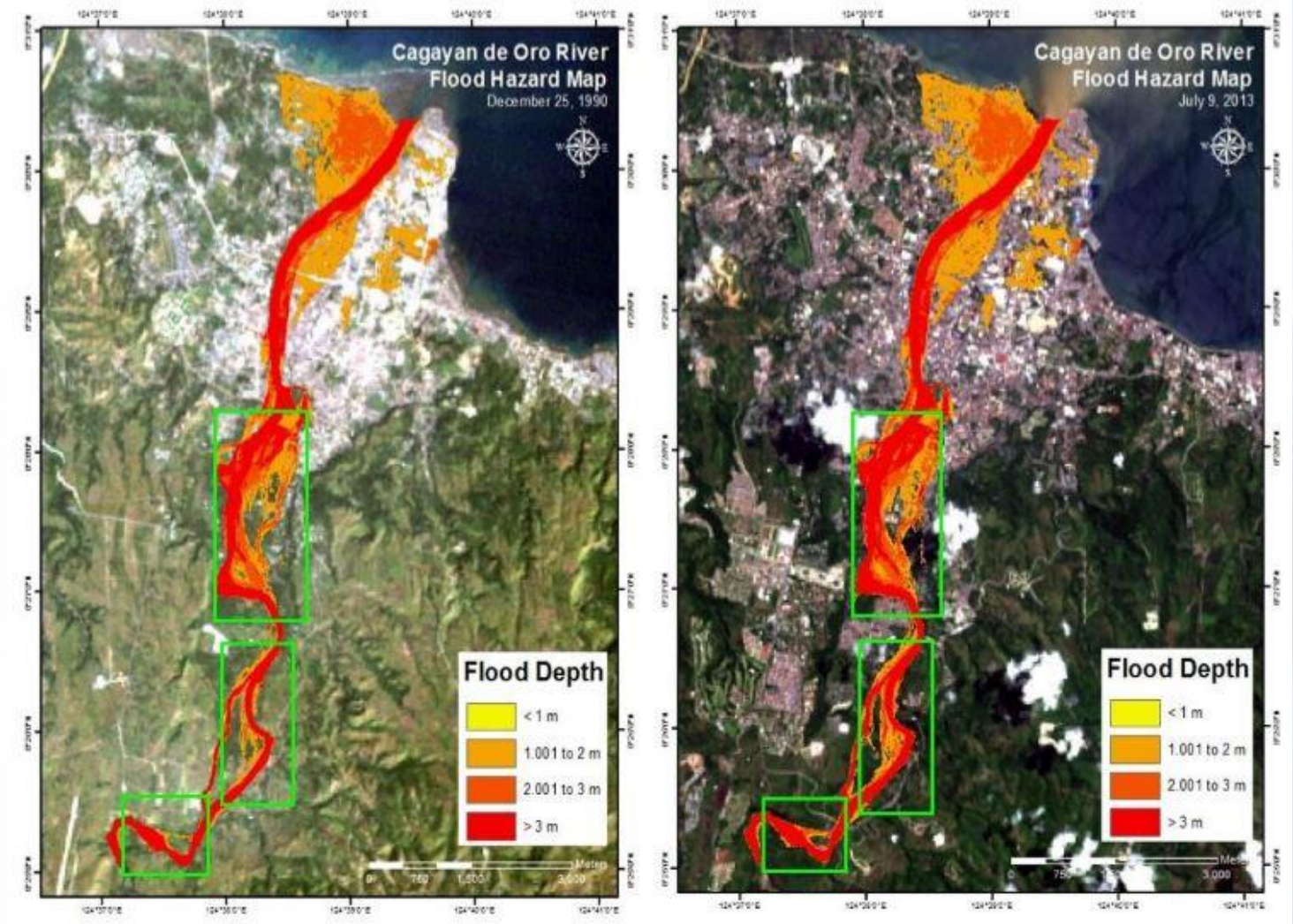
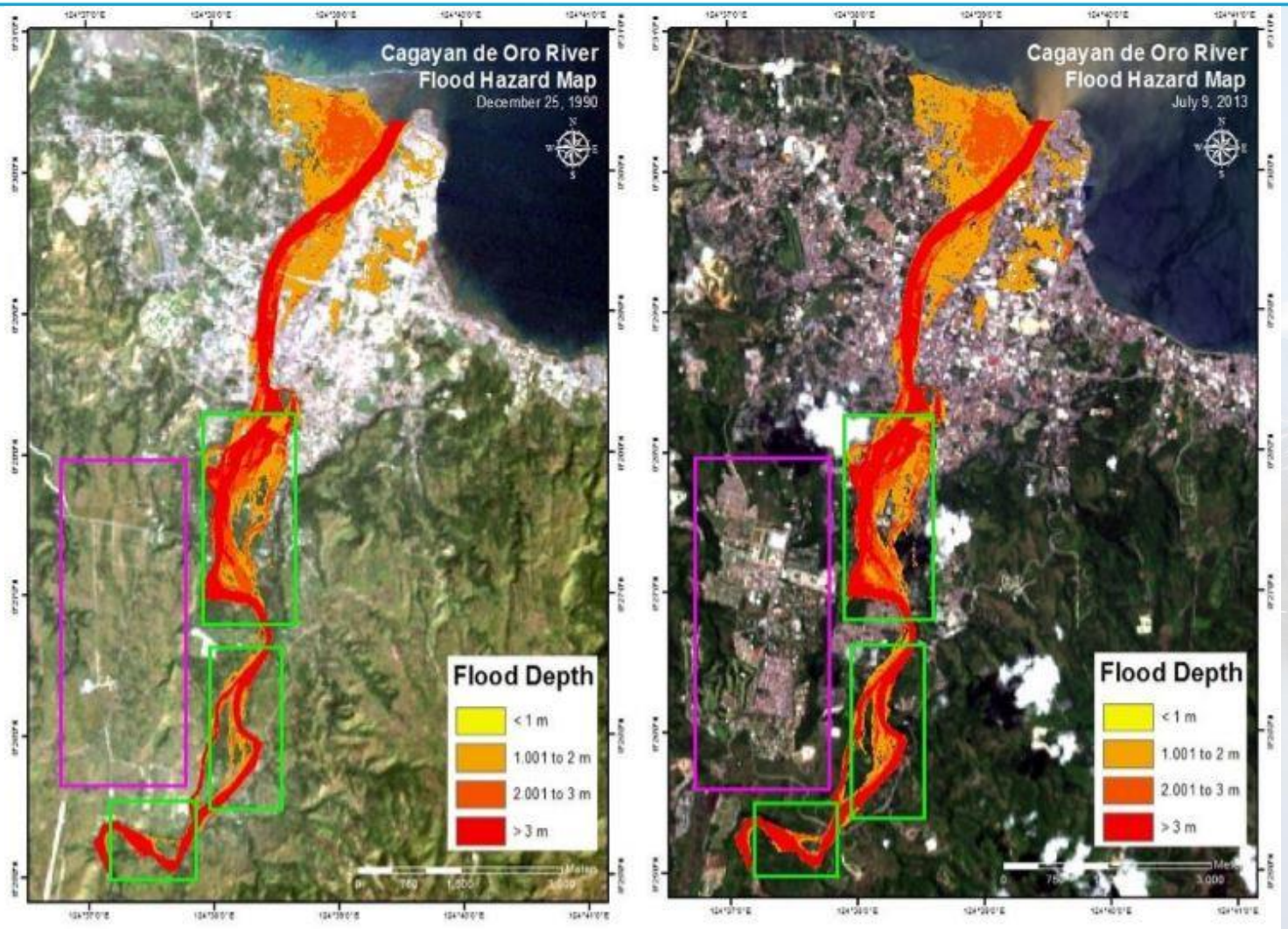


Figure 9 Workflow for flood model generation (Paringit et al 2012)


Hec-GeoRas Interface
with LiDAR DEM
Legend
River
Cross-Sections
River Banks
Flow Paths
Meters
0
750
1,500
3,000


Hec-GeoRas Interface
with Surface Roughness
Shapefile
Legend
River
Cross-Sections
River Banks
Flow Paths
Meters
0
750
1,500
3,000


Cagayan de Oro River
Flood Hazard Map
December 25, 1990
Flood Depth
< 1 m
1.001 to 2 m
2.001 to 3 m
> 3 m
Cagayan de Oro River
Flood Hazard Map
July 9, 2013
Flood Depth
< 1 m
1.001 to 2 m
2.001 to 3 m
> 3 m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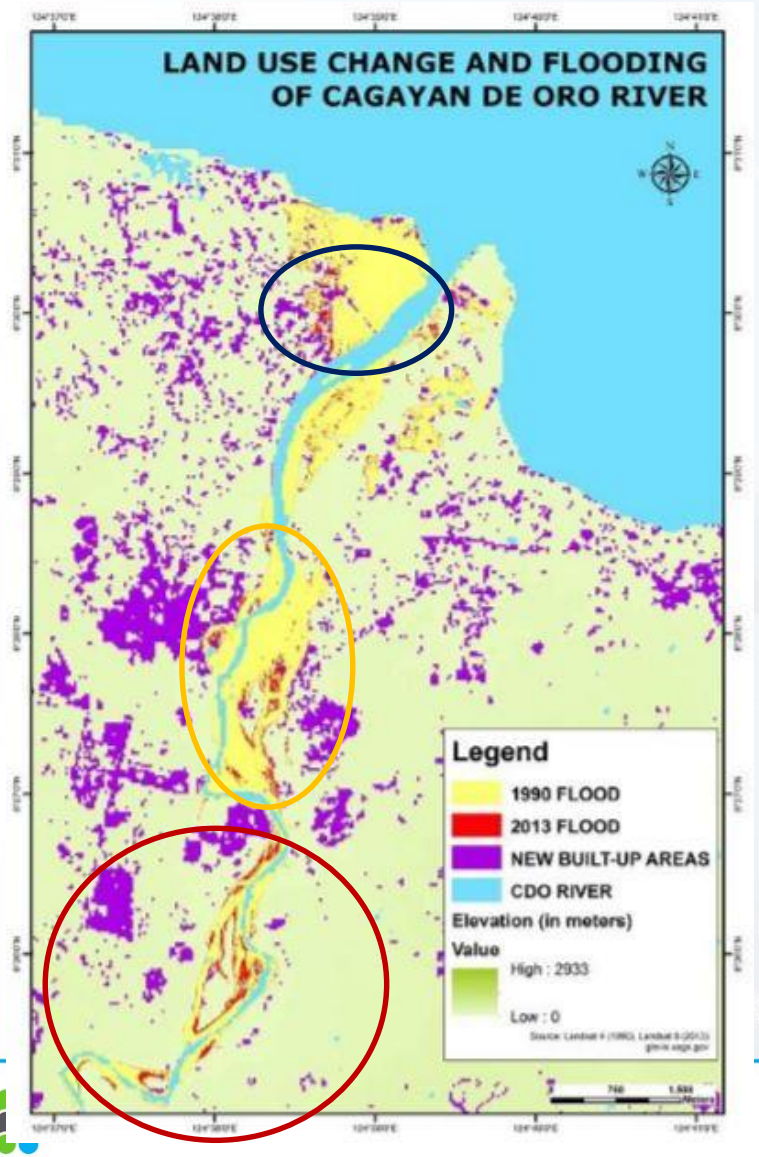
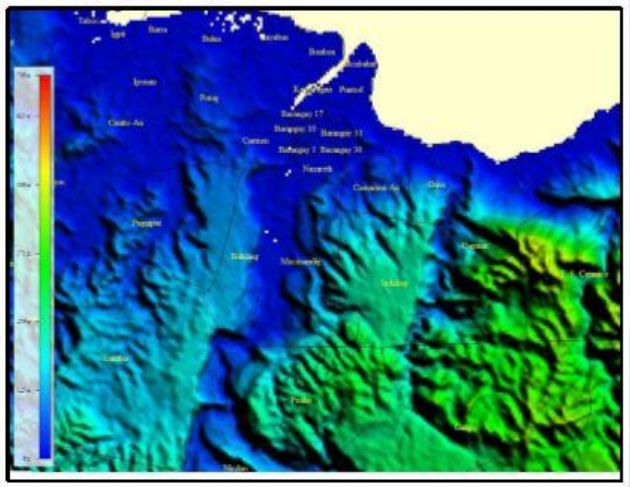

LAND USE CHANGE AND FLOODING
OF CAGAYAN DE ORO RIVER
Legend
1990 FLOOD
2013 FLOOD
NEW BUILT-UP AREAS
CDO RIVER
Elevation (in meters)
Value
High : 2933
Low : 0



The two models were compared to identify changes in flood extent and severity. Changes in the northern portion of Cagayan de Oro were not that evident. However, the variations between the two models are noticeable in the southern part of the river where significant land use changes occurred over the past 23 years. Specifically, areas previously covered by vegetation and bare soil were converted to built-up areas. To quantify the differences between the 1990 and 2013 flood extent, the following measure was applied:

$$F = \frac{Flood\ Extent\ (1990\ \cap 2013)}{Flood\ Extent\ (1990\ \cup 2013)}\ x\ 100$$

***F* = 9 %**

Current Development Plan for the City of Cagayan de Oro created in 2010

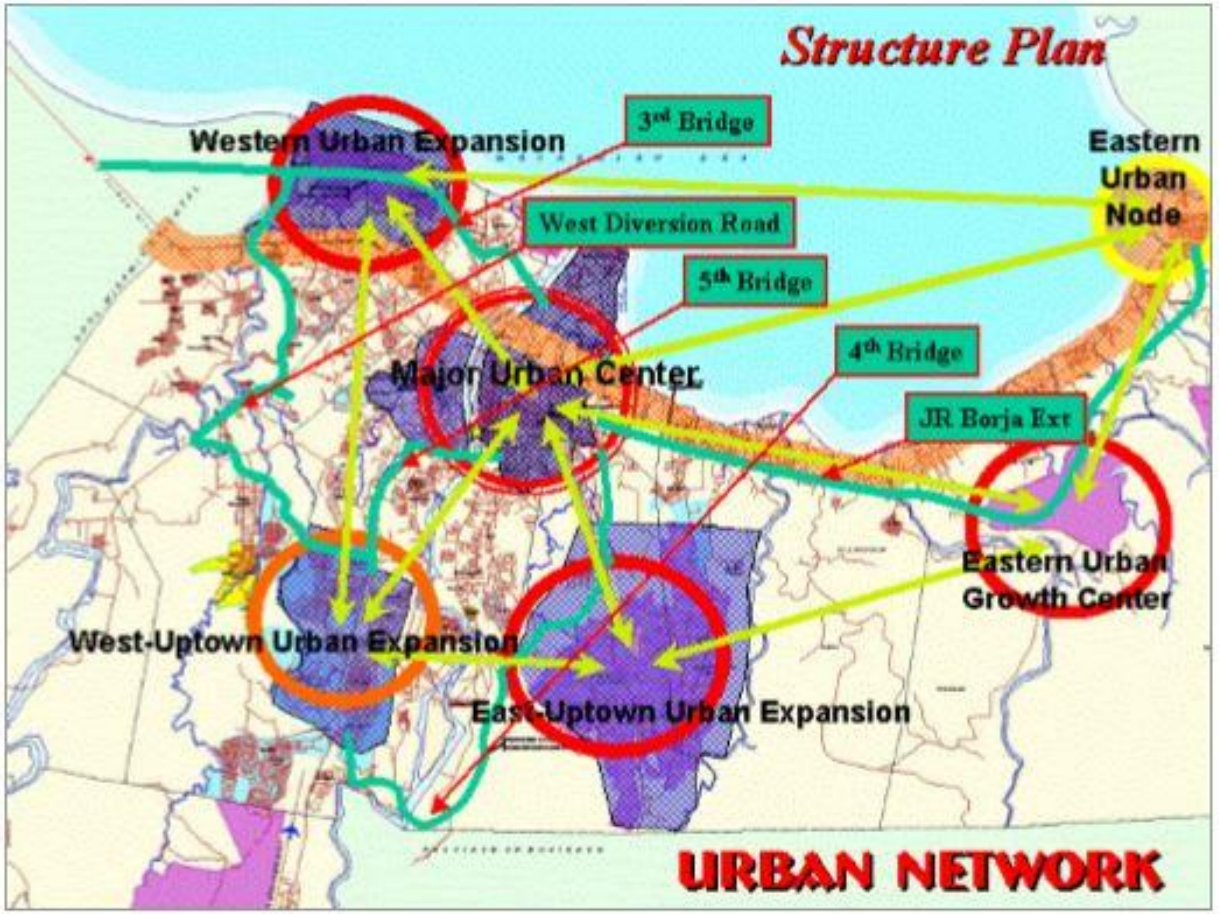


Figure 38 New nodes of urban expansion in Cagayan de Oro (CDO CLUP 2010)

Building of new infrastructures and high-end real estate in Upper Cagayan de Oro

Riverside and lowland communities

Conclusions:

- The land use of Cagayan de Oro has rapidly changed from vegetative lands to residential and commercial land uses as a result of rapid urbanization.
- These changes in land use significantly altered the land cover.
- Rapid urbanization led to congestion of the urban centers and eventually to the expansion or urban areas to uplands.
- As the upland converts to more built up and less vegetation, soil absorption capacity decreasess and surface runoff increases, leading to increased flood risks in the lowlands where majority of the populace resides.

Recommendations:

- Since CDO is both a floodplain and coastal city, further study including other flooding scenarios (tsunami, storm surge, should be done

- Policy-makers and land-use planners could utilize flood modeling methods to simulate flooding scenarios before implementing land use and development plans to ensure that all sectors of the community would benefit from development and that further marginalization of the marginalized population would be avoided