Mapping Impervious Surface Changes In Watersheds In Part Of South Eastern Region Of Nigeria Using Landsat Data

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INTRODUCTION

- According to the most recent United Nations projections (Civco et al., 2005), the urban population of the developing countries is now growing at the annual rate of 2.3%
- Based on current settlement practices, this implies that, on average, cities in the developing countries will most likely double their built–up areas

INTRODUCTION cont.

- Nigeria has experienced some sort of rapid development – urbanization and industrialization
- All these will gave rise to increase in impervious surface cover within urban and suburban areas in Nigeria.

What is Impervious Surface?

- Impervious surfaces are defined as surfaces that prohibit the movement of water from the land surface into the underlying soil
- They are mainly constructed surfaces - rooftops, sidewalks, roads, and parking lots - covered by impenetrable materials such as asphalt, concrete, brick, and stone.

Implication of Impervious Surface

- More storm water runoff and less ground water recharge.
- More runoff, in turn, increases stream flows during storm periods.
- Stream banks erode, more sediment is carried into the streams from surrounding lands
- Aquatic habitats are disrupted and degraded.
- Less recharge means less ground water discharges to streams during dry periods.
- The reduced stream flow and more extreme stream temperatures will stress aquatic ecosystems.
- In addition, pollutants tend to be more concentrated because dilution is reduced.
- When storm water moves more quickly into streams, it also has a greater capacity to carry non-point source (NPS) pollutants into the water bodies
- NPS includes nutrients, pathogens, metals, sand, and other materials that are picked up by water as it runs across the landscape

Hydrologic impact of urbanization

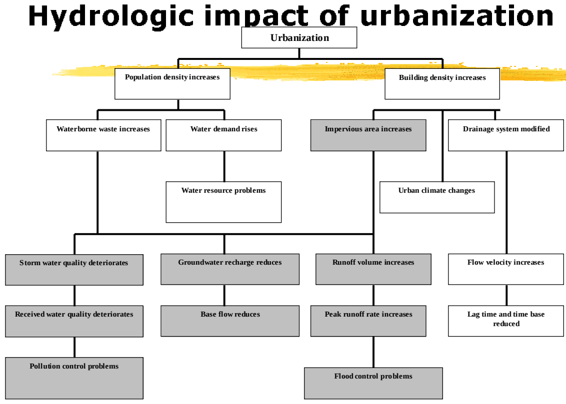


Figure 1: Hydrologic impact of urbanization. Gray boxes identify impacts directly related to impervious surfaces (adapted from (Hurd and Civco, 2004).

Percent Watershed Impervious Cover and Water Quality

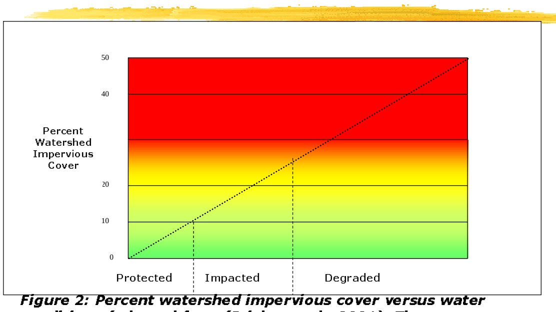


Figure 2: Percent watershed impervious cover versus water conditions (adapted from (Prisloe et al., 2001). The background colors correspond to stream quality conditions, from unpolluted and natural (green) to polluted and degraded (red).

Importance of Impervious Cover Information

- Estimating the environmental status of a particular watershed.
- Creation of future development plans and water resource protection programs.
- Important component of overall watershed management.
- Develop appropriate watershed management and/or NPS mitigation plans.
- Mapping and geoinformation of impervious surface cover will promote better land administration and therefore good governance

Geospatial Technology

- Provide effective tools to map and quantify impervious surfaces
- Monitor impervious surface changes over time
- Remote sensing imagery provides an ideal medium from which to directly estimate impervious surfaces at relatively modest cost,
- Providing a mechanism for measuring "imperviousness" at frequent, repeated intervals.
- Various researchers have developed methods (Ji and Jensen (1999), Bird et al (2000), Flanagen and Civco (2001), Justice and Rubin (2002), Yang, et al. (2003), Dougherty et al (2004), and Hurd and Civco (2004).

Motivation for this Work

- Numerous forms of water bodies ranging from small natural pools of less than 0.01 ha, rivers, streams, to lakes of over 1000 ha in size are to be found in various parts of Nigeria.
- The qualities of these water bodies are certainly affected directly or indirectly by the increase in impervious surfaces.
- For most developing countries including Nigeria, research activities in impervious surface mapping are rare, and that is basically the motivation for this paper
- This paper presents the quantification of impervious surface cover and change in impervious surface cover in watersheds in Enugu area, South-eastern region of Nigeria, using Landsat data.

Procedure:

- Watershed delineation in the area of interest using the Automated Geospatial Watershed Assessment (AGWA);
- Land cover and land use classification;
- Percentage impervious surface cover computation for the delineated watershed based on the Impervious Surface Analysis Tool (ISAT);
- Impervious surface change computation between the year 1986 and year 2000;
- Prediction of change in percentage impervious surface cover within the area of interest

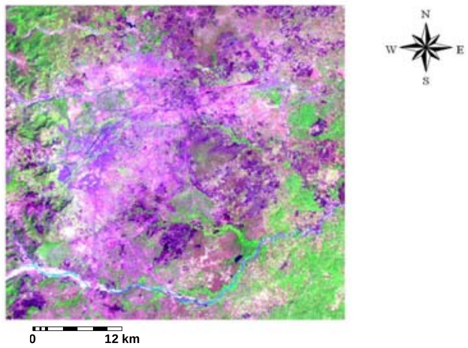
Study Area:

- Enugu city and its environs
- Composed of the urban areas and suburbs,
- Total area of about 333 square kilometers.
- Area extends from 6° 21′ to 6° 31′ North in latitude and 7° 27′ to 7° 37′ East in longitude.
- The town represents a typical city in South Eastern Nigeria and is in different developmental stages, which varies from heavily urbanized areas to a rural community, and suburban areas.

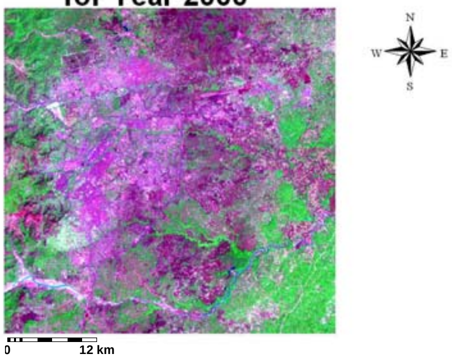
Data Used

- Landsat TM (Path 188, Row 56) images from December 19, 1986 bands 3, 4, 5,
- Landsat ETM+ (Path 188, Row 56) images from December 17, 2000 bands 2, 4, 7.
- Data were obtained courtesy of the Tropical Rain Forest Information Center (TRFIC), who disseminate the Landsat 2000 ETM+, 1990 TM, and 1970 MSS ortho-rectified datasets to the global community
- These images have been geometrically corrected and resampled to a UTM/WGS84 projection

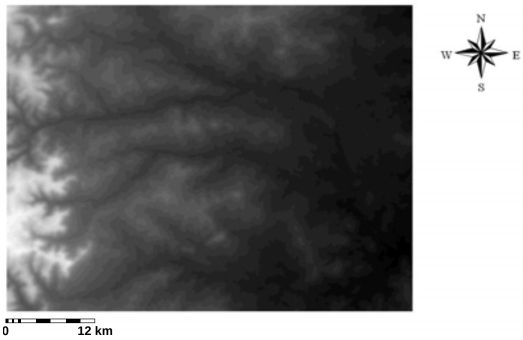
RGB Composite of Landsat bands 3,4,5 of Project Site for Year 1986



RGB Composite of Landsat bands 2,4,7 of Project Site for Year 2000



SRTM DEM of Enugu Area



Land Cover Classification

- Training data sets for use in supervised image classification were collected based on image interpretation of old aerial photographs of Enugu city and its environs.
- Nine land cover classes were identified
- Two sets of 30 samples of training data sets for each land cover class, for the years 1986 and 2000 were obtained.
- One set was used for maximum likelihood supervised classification, and the other was used for classification accuracy assessment.

Land Cover Classes

Value	Class Name	Description
0	Unclassified	Unclassified areas
1	High Intensity Developed	Highly developed zones in Enugu city
2	Low Intensity Developed	Scattered development in the urban and suburbs
3	Bare Land	Bare land, mostly sand and asphalt
4	Mixed Barren Land	Combinations of sands, gravels, grass mixed, etc
5	Tarred Road	Major tarred road
6	Lake	Lake
7	Stream	Stream
8	Red soil	Red soil, no vegetation
9	Mixed Forest	Vegetation, Trees, shrubs, herbaceous plants, etc,

Watershed Delineation

- Carried out using the Automated Geospatial Watershed Assessment (AGWA) tool,
- Divided the area into 10 sub watersheds.
- AGWA is a GIS- based multipurpose hydrologic analysis system for use by watershed, water resource, land use, and biological resource managers and scientists in performing watershed and basin scale studies
- AGWA was developed by the United States Department of Agriculture (USDA-ARS) Southwest Watershed Research Center and the United States Environmental Protection Agency (U.S.EPA) Office of Research and Development.

19

Impervious Surface Computation

- Implemented by using the Impervious Surface Analysis Tool (*ISAT*)
- *ISAT* is designed to calculate the percentage of impervious surface area of user-selected geographic areas (e.g., watersheds, municipalities, and subdivisions).
- The tool was developed by the National Oceanic and Atmospheric Administration (*NOAA*) Coastal Services Center and the University of Connecticut Nonpoint Education for Municipal Officials (*NEMO*) Program.

20

ISAT Computations

$$IS_w = \frac{\sum_{i=1}^{n} Area_i * IS_i}{Total\ Area}$$

Where: IS_w is the impervious area percentage for each polygon

IS_i is the impervious coefficient for each land cover class

$Area_i$ is area for each land cover class.

Green <10% impervious surface (Protected),

Yellow 10%-25% impervious surface (Degraded),

Red >25% impervious surface (Impacted).

21

Impervious Surface Coefficients

Value	Class Name	High	Medium	Low
0	Unclassified	0	0	0
1	Low Intensity Developed	41.3	30.2	22.9
2	High Intensity Developed	59.5	39.1	30.2
3	Bare Land	18.6	42.2	11.8
4	Mixed Barren Land	18.6	42.2	11.8
5	Tarred Road	30.5	20.1	12.5
6	Lake	0	0	0
7	Stream	0	0	0
8	Red soil	18.6	42.2	11.8
9	Mixed Forest	3.9	4.9	2.1

22

Accuracy and Reliability of Classification (1986)

Land Cover Class	Reliability	Accuracy
Bare land	0.77	1.00
High density developed	0.97	0.94
Lake	0.91	0.89
Low density developed	1.00	0.99
Mixed barren land	0.99	0.76
Mixed forest	1.00	0.99
Red soil	1.00	0.71
Stream	1.00	0.75
Tarred road	0.77	0.86

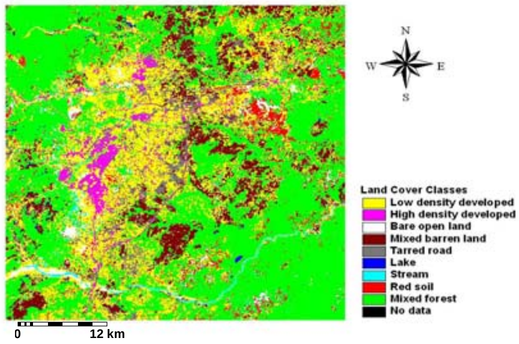
23

Accuracy and Reliability of Classification (2000)

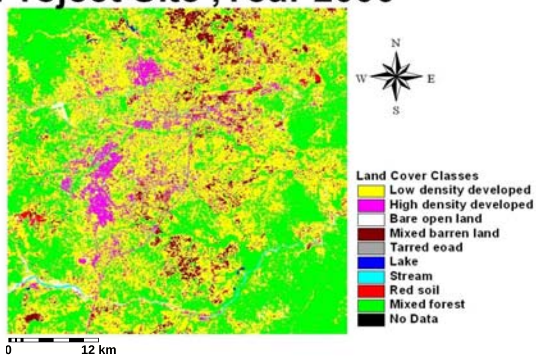
Land Cover Class	Reliability	Accuracy
Bare land	0.90	1.00
High density developed	0.99	0.56
Lake	1.00	0.54
Low density developed	0.57	0.99
Mixed barren land	1.00	0.39
Mixed forest	1.00	0.94
Red soil	0.31	0.99
Stream	0.77	0.96
Tarred road	1.00	0.42

24

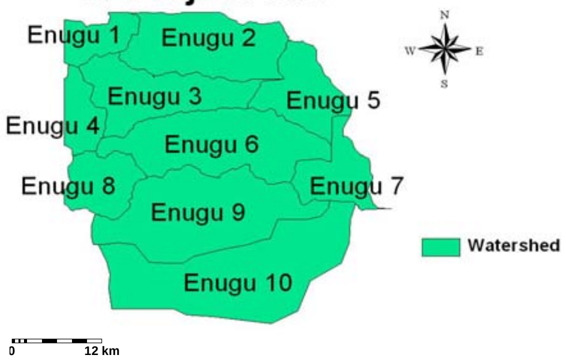
Land Cover Classes of Project Site , Year 1986



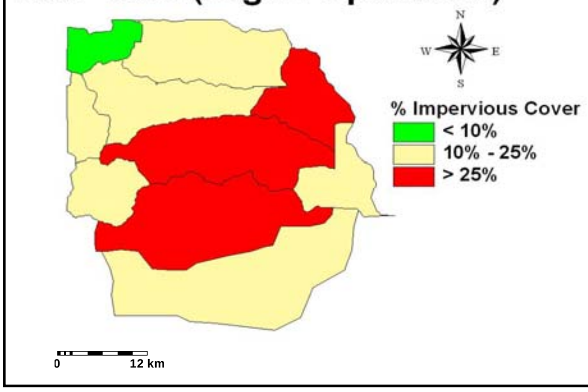
Land Cover Classes of Project Site ,Year 2000



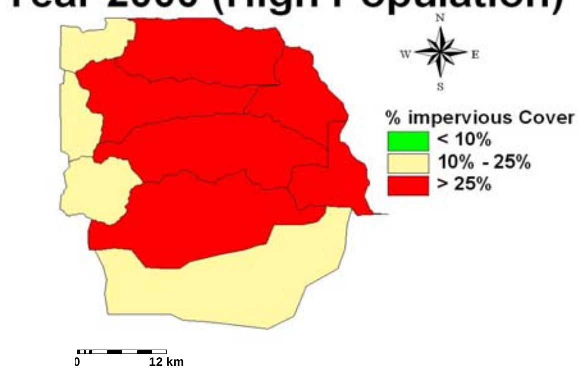
Watershed Boundaries of Project Site

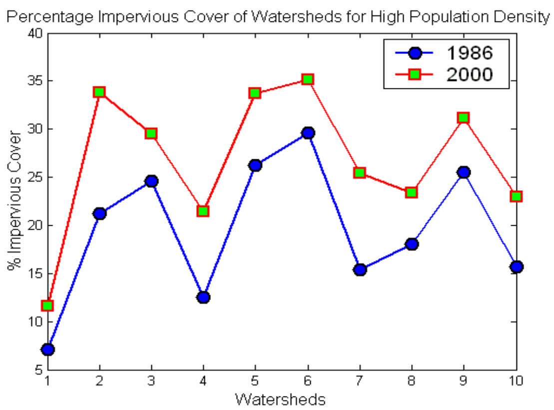


Impervious Surface Cover Year 1986 (High Population)

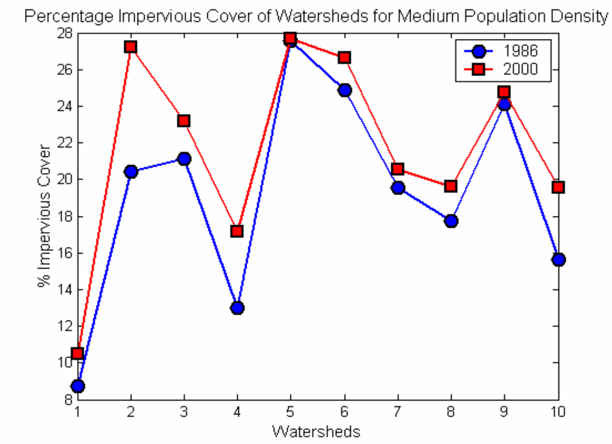


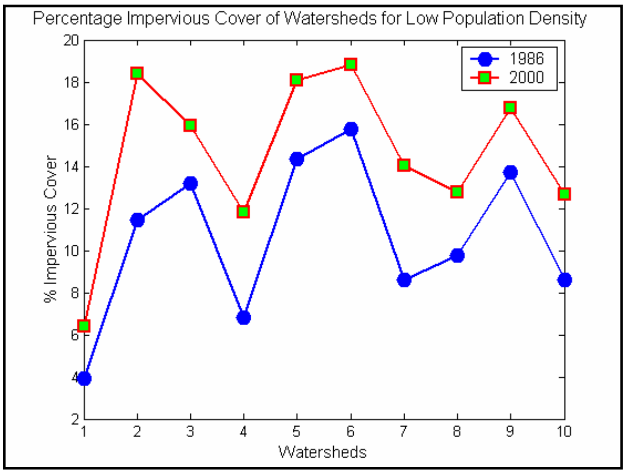
Impervious Surface Cover Year 2000 (High Population)



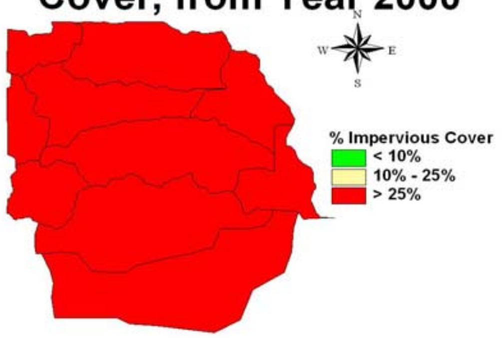


30





Predicted Impervious Surface Cover, from Year 2000



Conclusion

- This work demonstrates how remote sensing data (Landsat, SRTM DEM) in combination with GIS software (ArcView) and it's extensions (AGWA, ISAT) are used for the computation of impervious surface cover and changes in impervious surface cover within a period of time.
- Percentage impervious surface cover within part of southeastern Nigeria increased over the period between 1986 and 2000.
- While these results are not surprising, this study provides the first quantitative estimate of the extent of the change
- The same conclusion could be drawn for most cities and urban areas in Nigeria.

34

Thank you very much for listening

35