# Assessment of socio-environmental impacts of the urban expansion using GIS and Remote Sensing in the city of Guayaquil, Ecuador

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## Background

- Guayaquil is the largest city in Ecuador. Historically, this city has experienced a rapid and unplanned urban growth which caused repercussions for the population and the environment.
- The urban expansion is a complex event that involves political, social, and ecological aspects.
- The social and environmental transformations of the urbanization process can be analyzed using geospatial technologies.
- GIS and Remote Sensing are efficient tools to perform spatial analysis of urban expansion. In fact, geospatial technology and environmental and social variables can be integrated to assess land use change and socio-environmental impacts.

## Data

Satellite imagery: 1990, 2000, 2010 (Source: USGS)
Census data: 1990, 2000, 2010 (Source: INEC)

This study combines social and environmental data. The social data is divided into four variables: population, access to potable water, sewage connection, and poverty. The environmental data consists of land cover maps extracted from LANDSAT images.

## Methods

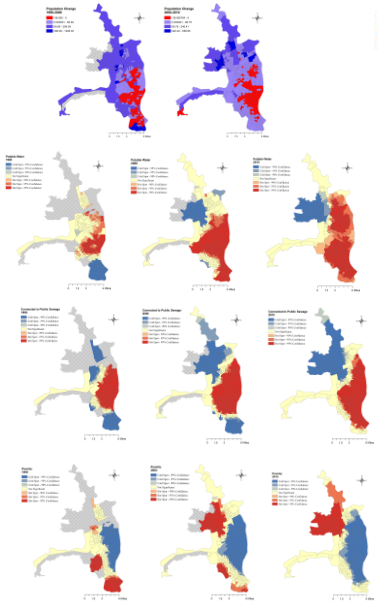
**Hot Spot Analysis:** In order to identify clusters of low and high values for the social variables, the tool hot spot analysis in ArcMap was used. Moreover, population change was mapped in ArcMap as well.

**Land cover Maps**: The LANDSAT images were classified into 5 classes: urban, vegetation, waterbodies, agriculture, others (barren land and roads). ENVI was used to process and classify the satellite imagery.

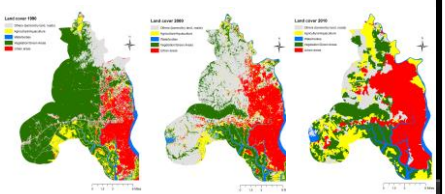
**Markov chains**: To quantify the transition between classes, a transition probability matrix was calculated using Markov model. This was computed in Python.

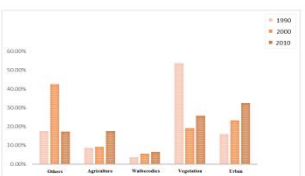
## Results

### Census Data



### Land Cover Data






Distribution of land cover over three periods: 1990-2000-2010.

| | Period | Others | Agriculture | Water | Vegetation | Urban |
|---|---|---|---|---|---|---|
| Others | 1990-2000 | **45.752146** | 10.93412318 | 2.556375 | 9.84751294 | 30.90984 |
| | 2000-2010 | **30.070721** | 21.99159607 | 0.183144 | 28.5830858 | 19.16553 |
| Agriculture | 1990-2000 | 8.6383501 | **44.42169538** | 12.05327 | 19.5550412 | 15.33173 |
| | 2000-2010 | 8.9025288 | **45.59456584** | 11.61797 | 14.2352075 | 19.64973 |
| Water | 1990-2000 | 0.3599256 | 9.96321639 | **86.05387** | 0.08701499 | 3.535973 |
| | 2000-2010 | 0.7025698 | 15.76188289 | **80.32334** | 1.7966952 | 1.410544 |
| Vegetation | 1990-2000 | 61.452626 | 4.259855428 | 0.784017 | **29.0661162** | 4.437385 |
| | 2000-2010 | 16.164741 | 11.88795696 | 3.274252 | **62.8449857** | 5.828454 |
| Urban | 1990-2000 | 4.5607487 | 4.82087822 | 2.38829 | 0.88971829 | **87.34036** |
| | 2000-2010 | 2.4121181 | 3.767287838 | 1.225894 | 0.81812869 | **91.77651** |

Transition probability matrix of land use change for the periods 1990-2000 and 2000-2010 using Markov chain.

## Discussion

Census Data:
The population change maps show that the population declines at the CBD, while it increases at the periphery. The Hot Spot maps indicate that public services such as potable water and sewage connection are high at the CBD, while it declines at the new urban areas/periphery. Therefore, urban areas are expanding, but public services in these areas are not increasing.
Moreover, areas with clusters of high level of poverty tend to be the same as those areas with clusters of low values of public services.

Land Cover Data:
From 1990 to 2000, the urban area increased by 7%, and from 2000 to 2010 it increased by 10%. Here, urban area increases steadily in the two periods.
The probability matrix shows that urban area have the highest probability to remain the same in both periods. Meanwhile, others, agriculture, and vegetation have the highest probability to change to other classes.
The matrix also indicates that others and agriculture have the highest probabilities to become urban.

## Conclusion

Historically, the urban areas in Guayaquil expanded in an unplanned manner. This analysis demonstrates that the patterns of urban expansion from 1990 to 2000 and from 2000 to 2010 are disorganized as well because new urban areas have low access to public services.
Remote sensing and GIS technologies are useful to identify these patterns and understand their distribution over the space. For example, we can see that areas with low public services are also areas with high poverty. Recognizing these patterns can help inform urban planners to create policies that ameliorate the social and environmental repercussions of unplanned urban expansion.

**References**

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