# Modeling land use change for Ejisu-Juaben district of Ghana

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**Abstract:** Prediction of land use/cover change for future date is important for management and monitoring the resources. Ejisu-Juaben district of Ghana turned out to be the best choice of study as it is observed that the northern part of the district is undergoing rapid changes and is in close proximity to the Kumasi Metropolitan. Further rapid changes are noticed near Kumasi located in the northern part of the district. Landsat Images of 1986 and 2007 were classified separately and a land use/cover prediction for 2020 was made which gave a transition matrix. The results show that forest and settlement/bare land have 0.5978 and 0.6456 probabilities respectively. The land use /cover map for the year 2020 indicated various changes with the controlling aspects such as weather conditions, human activities etc. remain the same as that of 2007.

**Keyword:** land use/land cover, Markov Chain Analysis, Cellular Automata and Prediction

## 1. Introduction

Prognosis of a scenario due to change in environmental aspects help us in monitoring and managing the ill effects that might arise. Markov chain analysis is one of such prediction tools which enable us to model the change in land use/cover for future date. The main focus in the field of land use/cover has up till now been on efforts to diagnose the changes in the land use/cover classes. Much is talked presently, about climate change on global scale and its results in destruction/ depletion of our forest zones. In the past predictive models have been used for urban sprawls (Bell 1974, Bourne 1976), forest and vegetation succession modeling (Horn 1975, Van Hulst 1979) and more recently in modeling landscape change.

## 2. Study Area

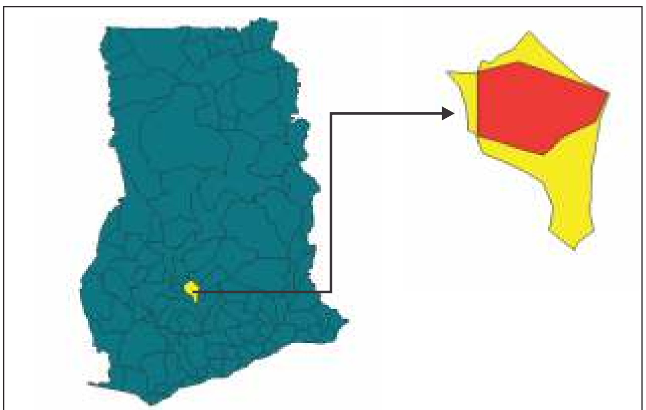

*Figure 1: District map of Ghana showing the Ejisu- Juaben district and the portion thereof used for the Study*

Ejisu-Juaben district (Figure 1) is located in the central part of the Ashanti Region. It lies between 1° 15' and 1° 45' N latitudes and 6° 15' and 7° 00'W longitudes. It shares boundaries with the Kumasi Metropolitan area an Kwabre district to the east, Sekyere East and Asante Akim North districts to the west and the Bosomtwe-Atwima-Kwanwoma and Asante Akim South districts to the south. The district stretches over an area of about 637.2 $km^2$ constituting about 10% of the entire Ashanti Region with Ejisu as its capital.

The district falls within the forest dissected plateau terrain. The vegetation of the area is mainly semi-deciduous with the Bobiri forest being part of the district. The district experiences tropical rainfall, i.e. bi-modal rainfall pattern and wet semi-equatorial climate. This region is underlain by the Pre-Cambrian rocks of the Birimian and Tarkwaian formations.

## 3. Methodology

Landsat images of 1986 and 2007 were radiometrically corrected to remove atmospheric and sun angle effects. They were geo-referenced and resampled to 30 m pixel size. The images were classified depicting six different land covers, viz.; forest, bush/fallow, farmland, riparian, grass and settlement/bare land.

Markov Chain Analysis is a convenient tool for modeling land use change when changes and processes in the landscape are difficult to describe. A Markovian process is one in which the future state of a system can be modeled purely on the basis of the immediately preceding state (Zubair, 2008). This idea is easily transferred to the case of an area subdivided into a number of cells each of which can be occupied by a given type of land use/cover at a given time. Transition probabilities are then computed on the basis of observed data between time periods which show the probability that a cell will change from one land use/cover type to another within the same period in the future. This probability is dependent only on the state in which a cell is at any given point in time - i.e. its current land use/cover type and not on the land use/cover types by which it was occupied in the past. Obviously, the plausibility and acceptability of this assumption depends on the time span considered (Briassoulis, 2000).

Markov also assumes that after N transitions, equilibrium matrix would be possible i.e. driving forces of the change over the period the transition matrix is constructed will remain the same over the future time periods thus land use/cover will remain constant. It is not implied that this 'equilibrium' will ever be reached. Rather, the equilibrium distribution serves to illustrate clearly the process of land-use change between time periods (Muller and Middleton, 1994).

This method is also a postmortem method because; before any modeling can be done there is the need to determine the degree of changes that have occurred. Therefore, the accuracy of the model is dependent on the accuracy of the individual classifications. The classified images 1986 and 2007 were used as input for the Markov module in the Idrisi software. The module produced a transition probability matrix, transition areas matrix and a set of conditional probability images. The matrix in this study is a result of cross tabulation of the two images adjusted by proportional error of 0.15.

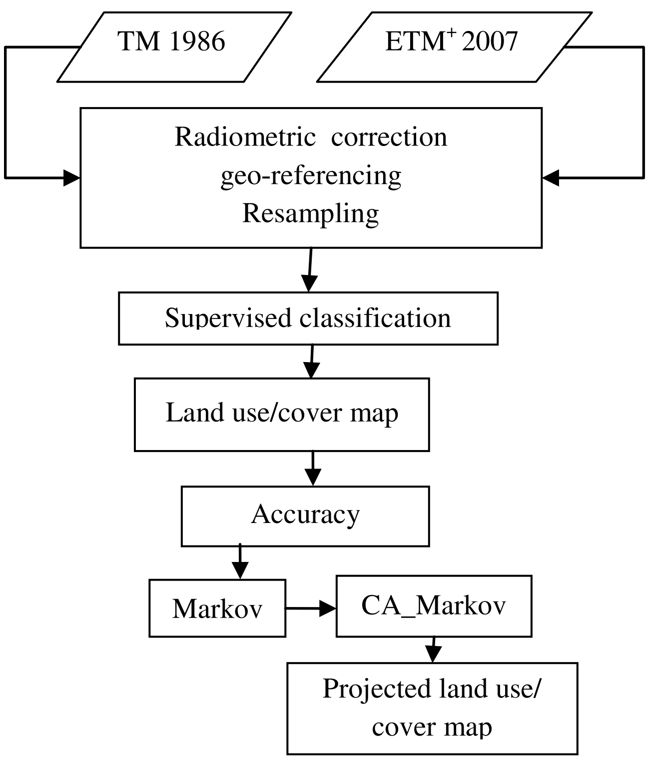


*Figure 2: Flow chart of methodology*

Cellular Automata (CA) uses the output from the Markov Chain Analysis particularly transition area file and the conditional probability images to predict a future land cover map over a specified period which is 13 years for this particular study to apply a contiguity filter to "grow out" land use/cover from 2007 to 2020. This will ensure that land use/cover change occurs proximate to existing land use/cover classes, and not wholly random (Eastman, 2003). Integrating a Markov chain model and a CA model provides a means of predicting temporal and spatial changes of land use/cover (Fan et al., 2008).

**4. Results**

The maps in Figure 3 and 4 are produced as a result of supervised classification for six (6) land use/cover classes. The total area covered by this study is 328.4km$^2$ which is about 52% of the total area of the Ejisu-Juaben district. Figure 3 and 4 show land use/cover classes for 1986 and 2007 respectively.

The overall accuracy and kappa of the classified 2007 ETM+ image were 80.15% and 0.7466, respectively. This was obtained from an error matrix which was done with 262 reference points collected from the study area. The accuracy of the 1986 classification could not be evaluated due to lack of reference data.

*Table 1: Transition probabilities matrix for land use /cover changes from 1986 to 2007*

| | | 2007 | | | | | |
|---|---|---|---|---|---|---|---|
| | | Forest | Bush/fallow | Farmland | Riparian | Grassland | Settlement/ bareland |
| 1986 | Forest | **0.5978** | 0.2115 | 0.1414 | 0.0459 | 0 | 0.0034 |
| | bush/fallow | 0.0109 | **0.3017** | 0.4132 | 0.1396 | 0.1199 | 0.0147 |
| | farmland | 0 | 0.2289 | **0.3036** | 0.1951 | 0.2336 | 0.0388 |
| | riparian | 0.0736 | 0.3623 | 0.3905 | **0.1003** | 0.0684 | 0.0049 |
| | grassland | 0 | 0.1396 | 0.2413 | 0.2173 | **0.2541** | 0.1477 |
| | settlement/ bareland | 0 | 0.0004 | 0 | 0.0615 | 0.2925 | **0.6456** |

Table 1 is a transition probability matrix for different land use/cover types of Ejisu-Juaben for the periods 1986 to 2007. The diagonal of the transition probability represent the self-replacement probabilities whilst the off diagonal values indicate the probability of change occurring from one state or class to another.

Table 1 shows that forest and settlement/bare land have 0.5978 and 0.6456 probabilities respectively, maintaining their various categories from 1986 to 2007. Bush/fallow and riparian each had high probabilities of 0.4132 and 0.3905 of changing to farmland. Based on this analysis, land use/land cover has been predicted for 2020 using Markov Chain/CA method. The projected land use map is given in Fig. 5. Table 2 shows statistics of land use/ cover for the years 1986, 2007 and 2020. The areas covered by each land use/cover type were computed by the software from the land use/cover maps (Figures 3 and 4) produced.

*Table 2: Areas of land cover/use classes for 1986, 2007 and 2020*

| Land use/cover classes | 1986 | | 2007 | | 2020 | |
|---|---|---|---|---|---|---|
| | Area(ha) | % | Area(ha) | % | Area(ha) | % |
| forest | 8019.63 | 24.42 | 5252.67 | 15.99 | 3551.22 | 10.81 |
| bush/fallow | 6873.75 | 20.93 | 7961.13 | 24.24 | 7804.35 | 23.76 |
| farmland | 7733.07 | 23.55 | 9512.91 | 28.97 | 9590.13 | 29.20 |
| riparian | 6551.1 | 19.95 | 4176 | 12.72 | 4662.72 | 14.20 |
| grass | 3294.63 | 10.03 | 4300.02 | 13.09 | 5032.35 | 15.32 |
| settlement/bareland | 368.1 | 1.12 | 1637.55 | 4.99 | 2199.51 | 6.70 |
| Total | 32840.28 | 100.00 | 32840.28 | 100.00 | 32840.28 | 100.00 |

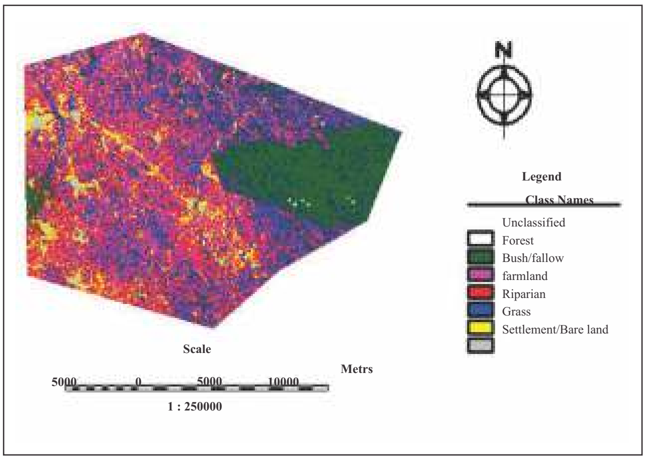


*Figure 3: Land use/cover for 1986*

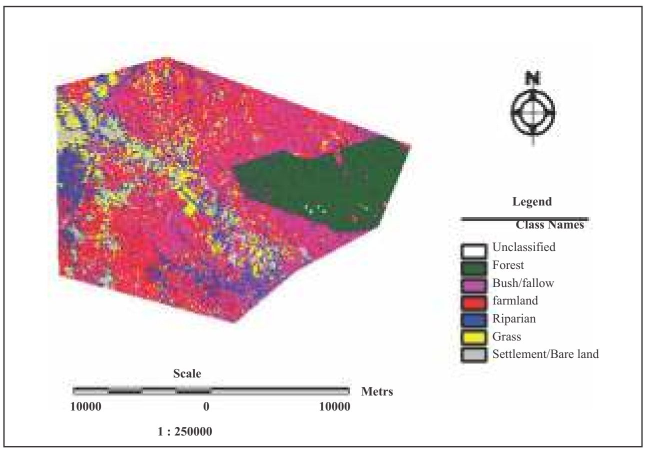


*Figure 4: Land use/cover for 2007*

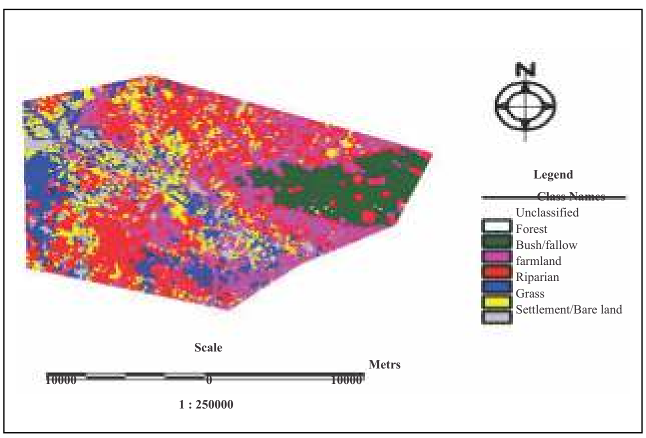


*Figure 5: Projected land use/cover map for 2020*

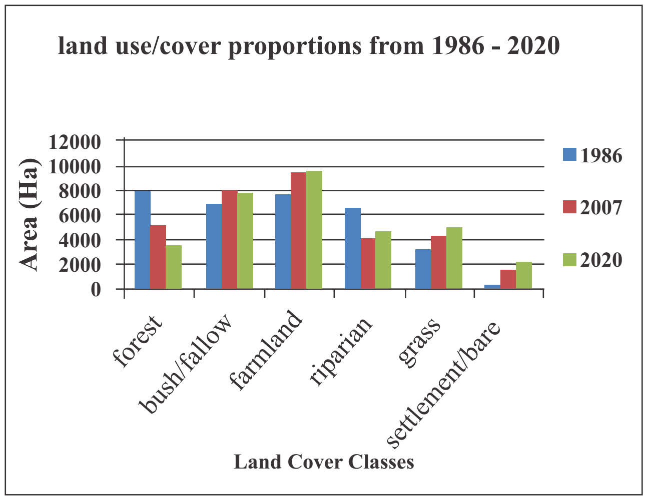


*Chart 1: Land use/cover proportions for 1986, 2007 and 2020*

Comparing the various representations of Table 2 in Chart 1 there seems to be some form of trends for individual land use/cover. A careful look at the chart shows forest decreasing as the years pass by whilst farmland, grass, settlement/bare land keeps increasing. Riparian and bush/fallow have mixed trends.

## 5. Conclusion

Anthropogenic activity appears to be a major cause for land use/cover change in the Ejisu-Juaben district. The transition of riparian to farmland or settlements/ bare land takes place when water ways change their course or dry up. Most people do farming in riparian area because of proximity to water resources available throughout the year.

The demographic growth resulted in dependence on the industrial and service sector, hence, urbanization. This has promoted construction work as a part of infra-structural development as the area is close to Kumasi metropolis. Urbanization had a toll on the forest cover. Government policy also affects the land use/cover pattern. For instance, subsidies and incentives for cocoa and orange farmers had aided the change in the complexities of land use/cover. The continuity of subsidies may lead to increase in plantation cover prediction for 2020.

Markov and cellular automata has indeed facilitated the predictive model for land use/cover for the year 2020. The model is easy to build. However, the validation of such model is a Herculean task to evaluate. Never the less, the predictive pattern gives an idea of what the future is in store. And helps to gear for managing the changed land use/cover and avoid disaster in resource management. Further, the present research shall serve as a stimulant for studies in the direction of prognostic models.

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