Detecting the Influence of Protection on Landscape Transformation in Southwestern Ghana

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Abstract
This paper examines the transitions among six land cover categories in southwestern Ghana and compares the transitions within protected areas to those outside protected areas. Landsat Thematic Mapper (TM) satellite images of 1990 and 2000 are used to create two land cover classifications, and then the two maps are compared to produce cross-tabulation matrices for both the protected and unprotected areas. These matrices are analyzed according to their various components to identify the most systematic landscape transitions. It is necessary to consider the amount of gain in each category separately from the amount of loss of each category between 1990 and 2000. The amount of gain of a category is measured relative to the distribution of the other categories in 1990 in order to compute the amount of gain that would be expected in each category due to a random process of gain. The expected gain is then compared to the observed gain to detect systematic transitions. In a manner analogous to the analysis of gains, the amount of loss of a category is measured relative to the distribution of the other categories in 2000, and then the observed loss is compared to the expected loss due to a random process of loss. A non-random gain and a non-random loss in a particular transition imply a systematic process of change. The results show that, in the protected areas, Closed Forest transitions systematically to Bare Ground but outside the protected areas Closed Forest transitions systematically to Bush & Scattered Trees. Evidently, the process of land transformation in the protected areas is different from outside the protected areas. The research highlights the need for the practical application of this methodological approach to landscape change identification in Ghana. Identifying the strong signals of forest transformation is particularly important in the light of efforts by policy makers to halt or at least to slow deforestation in Ghana.

1. Introduction

1.1. The deforestation problem

Ghana may be categorized into two ecological zones namely: the closed forest zone covering about 34% (8.2 million hectares) of the total land area and the savanna grassland zone covering an area of 15.6 million hectares or the remaining 66% of the land area (Nsiah-Gyabaah, 1996). The closed forest is found in southern Ghana. It is very rich and diverse in flora and contains a large reserve of commercial timber species. Most of Ghana's export crops are produced from the closed forest. As a means of ensuring biodiversity conservation, Ghana has created a number of protected areas (Figure 1) managed by the forestry commission and the department of wildlife.

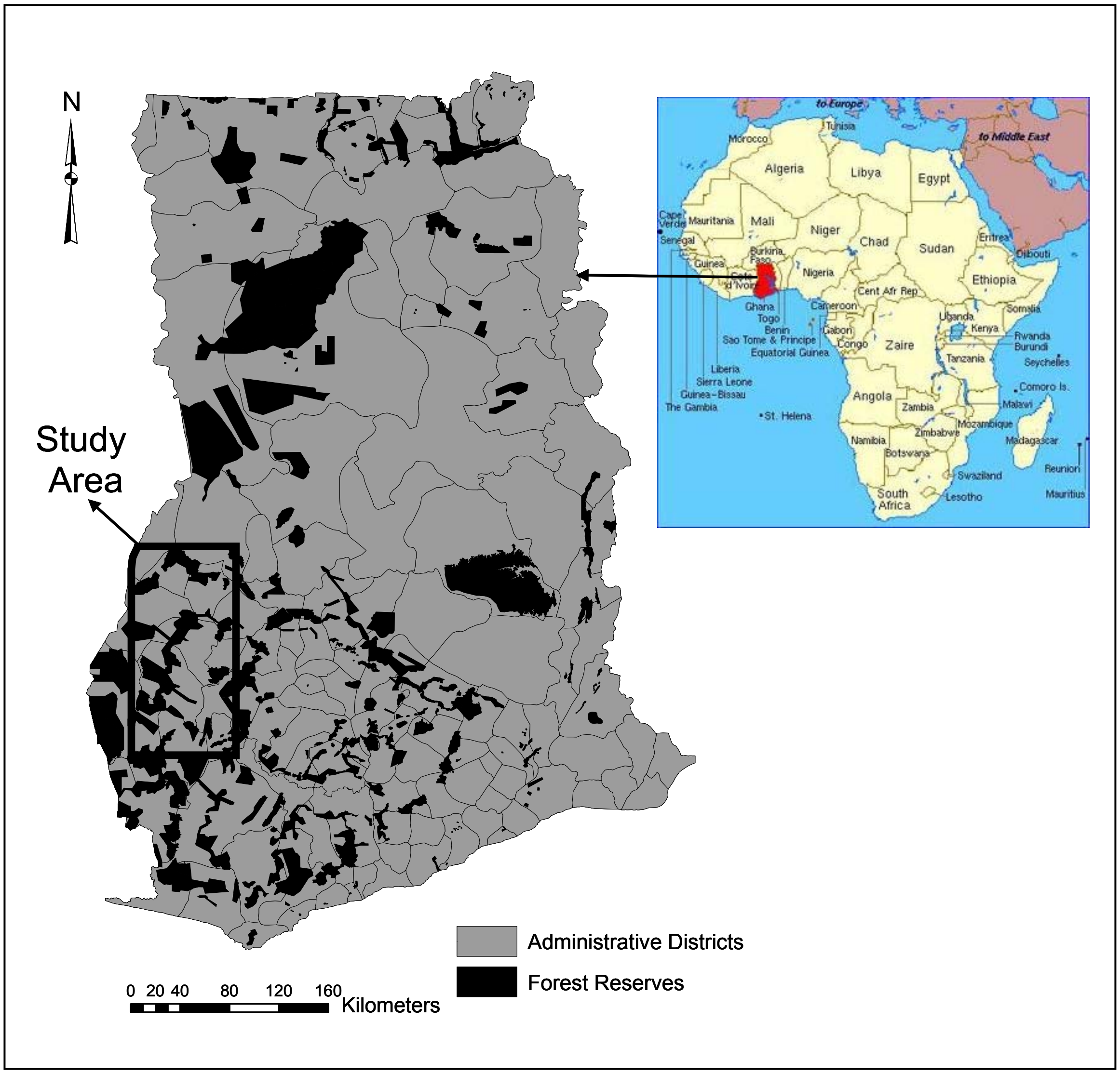

Figure 1. Map of Ghana showing forest reserves managed by the Ghana Forest commission and the location of the study area.

However, most of these protected areas have failed to fulfill the objective for which they were established (World Rainforest Movement, 2002). It is estimated that only about 2 million hectares of the closed forest have not been modified through activities such as crop cultivation, bush burning and deforestation (Nsiah-Gyabaah 1996). The unmodified closed forest is made up of about 1.7 million hectares within the 3.7 million hectares of forest reserves (protected areas) and 0.3-0.5 million outside the legally protected forests (unprotected areas). The forest reserves total about 3.7 million hectares. The World Rainforest Movement (2002) has also reported that between 1955 and 1972, Ghana lost one third of its forests and a further 5.6 million hectares between 1977 and 1997. The difficulty of reducing or completely eliminating deforestation means that there is the need for a clear identification and understanding of the systematic processes of deforestation so that policies can address the problem appropriately. In policy debates on deforestation, the impact of commercial activities such as logging are often ignored and local farmers are singled out for blame (World Bank 1981, Benneh and Agyepong, 1990). However, it is simplistic to blame local farmers for the destruction of Ghana's forest reserves (Kyem, 2003).

1.2 Approach to land change analysis

The analysis of the transition matrix, where land cover categories from two different years are arranged in a cross tabulation table, offers the possibility of analysis of changes in land cover (Eiden et al., 2002). Failure to go deep into analyzing the matrix according to its various components may result in drawing faulty conclusions about processes of change of the landscape. The continued loss of forest in Ghana testifies to how the deforestation problem has probably been misdiagnosed.

This research outlines a methodology for analyzing the cross tabulation matrix to detect strong signals of systematic landscape transition and makes recommendations to practitioners to adopt the methodology. The analysis utilizes a study area in southwestern Ghana in which land cover classifications for 1990 and 2000 based on a six-category scheme are derived from landsat TM data. The transitions among the six categories are examined to detect the most prevalent systematic landscape change. The systematic transitions in the protected area are then compared to those outside the protected areas. We then discuss the implications of the most systematic landscape transitions identified for forest management in Ghana.

2. Methods

2.1 Study Area

The study area is located in the southwestern part of Ghana (Figure 1). The northern part of this 189km x 85km area falls within the Brong-Ahafo administrative region and the southern part extends into the western and Ashanti regions. This area is a prime timber-producing region of the country with a large stock of forest reserves. There are also two mine sites in the southeastern part of the country and substantial agricultural activities over the entire area. This area is typical of the situation in Ghana where extractive activities such as logging, mining, farming and wildfires have impacted the forest ecosystem.

2.2 Image Analysis

Four 30m resolution Landsat Thematic Mapper scenes covering the study area were obtained for February 1990 and February 2000. Two scenes were required to cover the extent of the study area for each year. All the scenes were geometrically rectified to a 1:50000 scale topographic map covering the study area (Figure 2).

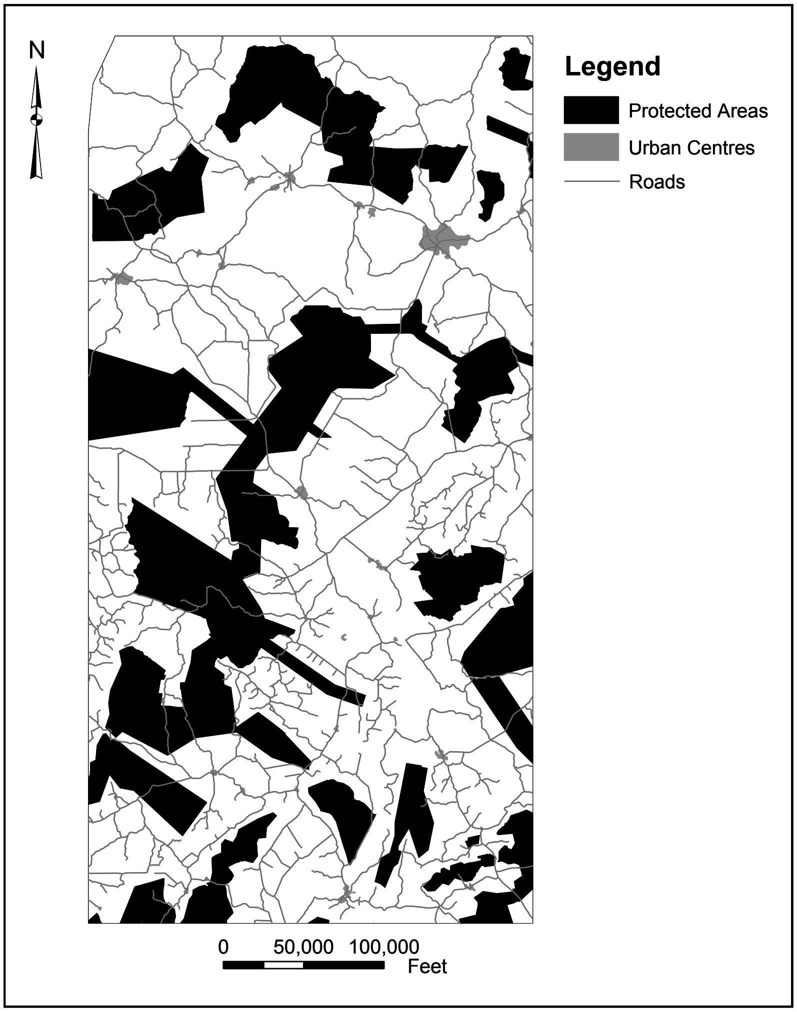

Figure 2. Map showing the protected areas, urban centers and roads within the study area.

The topograghic map was in the Ghana National Grid coordinate system. The nearest neighbor algorithm was used for the resampling (Nelson et al., 2002), and this yielded a root mean square of less than 1 pixel (i.e less than 30m). The images had earlier been pre-processed at the source for radiometric calibration and atmospheric correction. The two 1990 scenes were mosaiced and a single window of the study area made for 1990. Similarly, the 2000 image of the study area was created from the two 2000 scenes. Overlaying a vector layer of boundaries of protected areas on the 1990 and 2000 images verified that the two images overlapped closely (Figures 3 and 4). Unsupervised classification of the images for the two dates was carried out using cluster analysis. For the 1990 data, initial clustering using three non-thermal bands and retaining all clusters yielded 28 clusters. A break point of ten classes was chosen for the final clustering based on a graphic histogram of the initial clusters. Information obtained from the sprectral reflectances, composite images, and additional information from the author's familiarity with the study area were utilized in the interpretation of the clusters. The ten clusters were interpreted into six land cover classes to produce a land cover map for 1990 (Figure 3). The cluster analysis was also performed on the 2000 data. Initial clustering retaining all clusters yielded 30 clusters and with the same setting of parameters as with the 1990 data, a land cover map of six classes for 2000 was obtained (Figure 4).

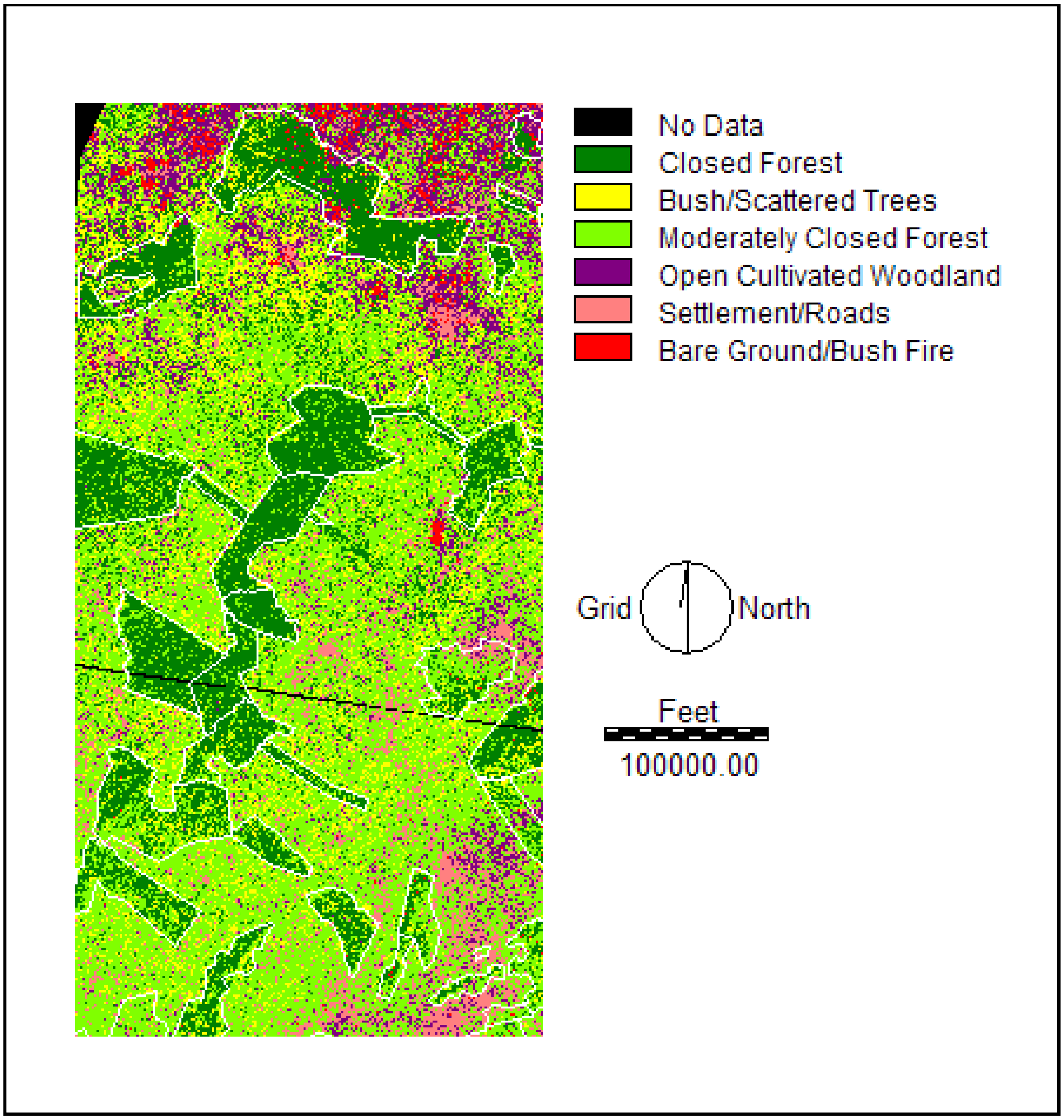

Figure 3. Land cover map of study area in 1990 according to a six-category unsupervised classification scheme. Protected areas are shown in white outline.

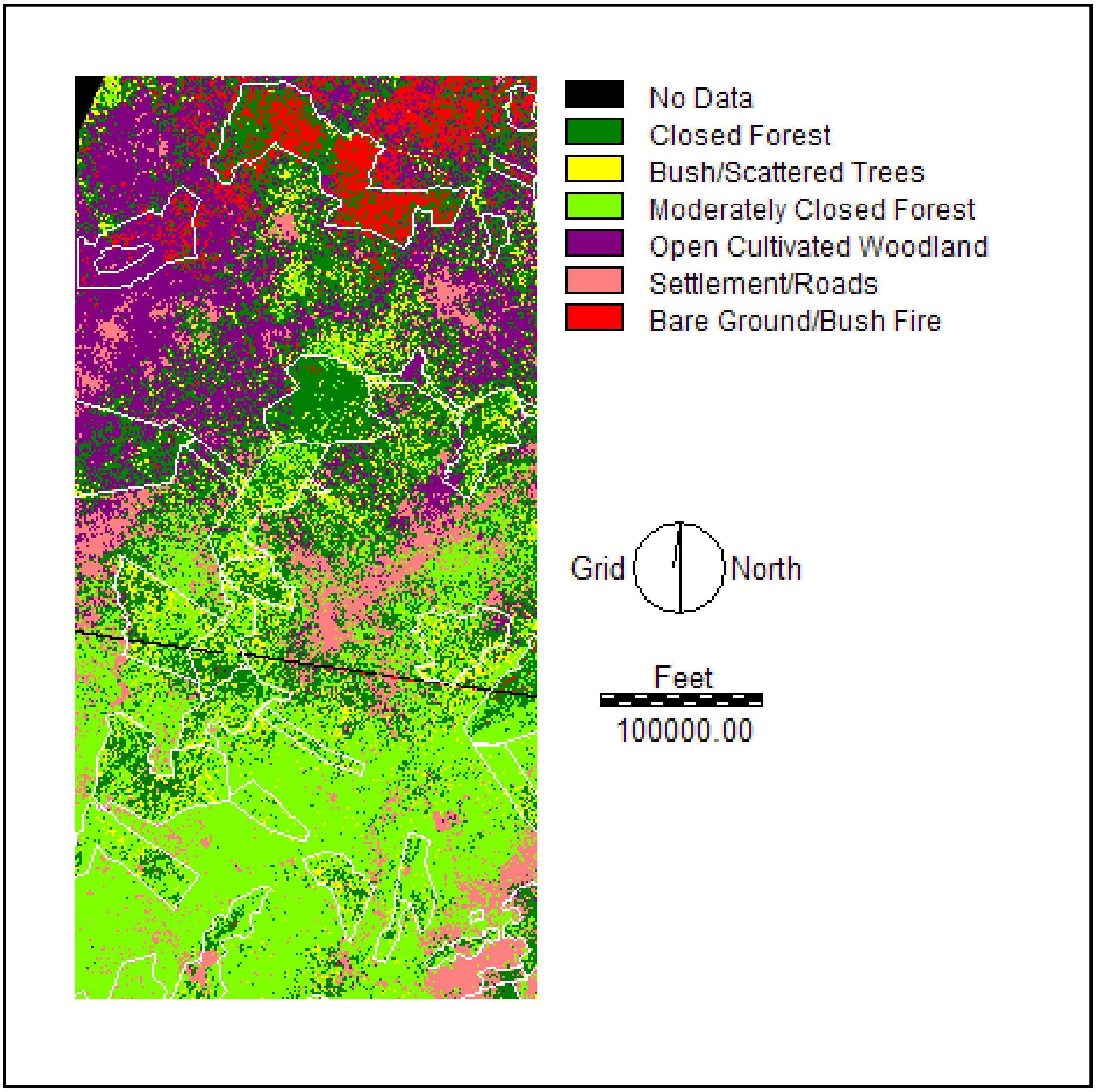

Figure 4. Land cover map of study area in 2000 according to a six-category unsupervised classification scheme. Protected areas are shown in white outline.

The six categories of the land cover classification maps are: Closed Forest, Bush and Scattered trees, Moderately Closed Forest, Open Cultivated Land, Roads/Settlements, and Bare Ground/Bushfire. Closed Forest refers to high forest or closed canopy forest of greater than 60% as defined by a reference country-wide land cover classification map produced by the Ghana Forest Service in the year 2000. Bush with Scattered Trees category consists of herb or bush cover with 15 to 20 trees per hectare. The Moderately Closed Forest category refers to a forest canopy of less than 60%. Open Cultivated Land consists of crops and has about 11 to 20 trees per hectare. Figures 3 and 4 show the land cover classification maps of the study area for 1990 and

2000 respectively. The land cover maps for the protected area for 1990 and 2000 were obtained by masking out the unprotected areas from the 1990 and 2000 land cover maps. Similarly, land cover maps for the unprotected areas were obtained by masking out the protected areas.

2.2 Transition Matrix

The categories in the 1990 map were compared with those of the 2000 map by a cross-tabulation matrix to show the percentage of the landscape in each combination of categories. The resulting table is referred to as a transition matrix. The bold numbers in Tables 1 and 2 show the transition matrices for the protected and unprotected areas of the study area respectively.

Table 1. Matrix showing observed transitions, expected losses, and expected gains for the Protected Areas in percent of the landscape.

		2000							
		CF	**B/S**	**MF**	**OC**	**R/S**	**B/G**	**Total 1990**	**Loss**
1990	**CF**	**26.86** *26.86* 26.86	**6.66** *5.91* 6.40	**14.53** *16.44* 15.15	**6.52** *6.28* 6.44	**0.66** *1.43* 1.37	**6.57** *4.89* 5.16	**61.80** *61.80* 61.37	**34.94** *34.94* 34.51
	B/S	**2.34** *2.94* 2.42	**0.65** *0.65* 0.65	**2.64** *2.13* 1.80	**1.02** *0.81* 0.72	**0.17** *0.18* 0.16	**0.53** *0.63* 0.61	**7.35** *7.35* 6.42	**6.70** *6.70* 5.76
	MF	**8.84** *8.71* 8.62	**2.72** *2.27* 2.71	**10.40** *10.40* 10.40	**2.33** *2.41* 2.73	**1.20** *0.55* 0.58	**0.73** *1.87* 2.19	**26.21** *26.21* 27.23	**15.81** *15.81* 16.83
	OC	**0.74** *0.75* 0.79	**0.10** *0.19* 0.25	**0.32** *0.54* 0.59	**0.72** *0.72* 0.72	**0.12** *0.05* 0.05	**0.41** *0.16* 0.20	**2.41** *2.41* 2.61	**1.69** *1.69* 1.89
	R/S	**0.34** *0.44* 0.46	**0.08** *0.12* 0.14	**0.50** *0.32* 0.34	**0.14** *0.12* 0.14	**0.29** *0.29* 0.29	**0.04** *0.10* 0.12	**1.39** *1.39* 1.49	**1.10** *1.10* 1.20
	B/G	**0.31** *0.28* 0.28	**0.03** *0.07* 0.09	**0.11** *0.20* 0.21	**0.16** *0.08* 0.09	**0.03** *0.02* 0.02	**0.20** *0.20* 0.20	**0.84** *0.84* 0.88	**0.64** *0.64* 0.68
	Total 2000	**39.42** *39.98* 39.42	**10.25** *9.21* 10.25	**28.50** *30.03* 28.50	**10.88** *10.41* 10.88	**2.47** *2.51* 2.47	**8.48** *7.85* 8.48	**100.00** *100.00* 100.00	**60.87** *60.87* 60.87
	Gain	**12.56** *13.12* 12.56	**9.59** *8.56* 9.59	**18.10** *19.62* 18.10	**10.16** *9.69* 10.16	**2.18** *2.22* 2.22	**8.27** *7.65* 8.27	**60.87** *60.87* 60.87	

Table 2. Matrix showing observed transitions, expected losses and expected gains for the Unprotected Areas in percent of the landscape**.**

		2000							
		CF	**B/S**	**MF**	**OC**	**R/S**	**B/G**	**Total 1990**	**Loss**
1990	**CF**	**2.94** *2.94* 2.94	**0.76** *0.38* 0.42	**1.73** *2.38* 1.99	**2.05** *1.60* 1.63	**0.71** *0.95* 0.94	**0.32** *0.25* 0.26	**8.51** *8.51* 8.17	**5.57** *5.57* 5.23
	B/S	**4.58** *3.86* 3.77	**1.02** *1.02* 1.02	**4.52** *4.97* 3.67	**3.83** *3.33* 3.01	**1.44** *1.99* 1.73	**0.31** *0.53* 0.48	**15.70** *15.70* 13.68	**14.68** *14.68* 12.66
	MF	**12.33** *11.22* 12.33	**2.62** *2.31* 2.51	**20.76** *20.76* 20.76	**8.56** *9.69* 9.85	**6.19** *5.78* 5.65	**0.84** *1.54* 1.57	**51.31** *51.31* 52.68	**30.55** *30.55* 31.91
	OC	**3.01** *2.49* 3.02	**0.43** *0.51* 0.61	**1.70** *3.21* 2.93	**4.73** *4.73* 4.73	**1.43** *1.28* 1.38	**1.25** *0.34* 0.38	**12.56** *12.56* 13.06	**7.83** *7.83* 8.33
	R/S	**1.63** *2.01* 2.39	**0.27** *0.41* 0.49	**3.37** *2.59* 2.33	**1.47** *1.73* 1.91	**2.94** *2.94* 2.94	**0.28** *0.28* 0.30	**9.96** *9.96* 10.36	**7.02** *7.02* 7.42
	B/G	**0.43** *0.40* 0.47	**0.04** *0.08* 0.10	**0.05** *0.51* 0.46	**0.88** *0.34* 0.38	**0.13** *0.20* 0.22	**0.43** *0.43* 0.43	**1.96** *1.96* 2.05	**1.53** *1.53* 1.62
	Total 2000	**24.93** *22.91* 24.93	**5.14** *4.72* 5.14	**32.13** *34.43* 32.13	**21.52** *21.42* 21.52	**12.84** *13.14* 12.84	**3.43** *3.38* 3.43	**100.00** *100.00* 100.00	**67.18** *67.18* 67.18
	Gain	**21.99** *19.97* 21.99	**4.12** *3.70* 4.12	**11.37** *13.66* 11.37	**16.79** *16.69* 16.79	**9.91** *10.21* 9.91	**3.00** *2.95* 3.00	**67.18** *67.18* 67.18	

The numbers in bold in Tables 1 and 2 are the observed transitions in percent of the landscape. The numbers in italics are the expected losses if the losses had occurred at random. The numbers in regular font are the expected gains if the gains had occurred at random. The meanings of the abbreviations are as follows:
CF = Closed Forest, B/S = Bush/Scattered Trees, MF = Moderately Closed Forest, OC = Open Cultivated Land, R/S = Roads/Settlements and B/G = Bare Ground.

The traditional transition matrix follows a format such that the rows display the categories of an initial time 1 and the columns display the categories of a subsequent time 2. The notation P_{ij} denotes the proportion of the landscape that experiences a transition from category i to category j where the number of categories is J. Entries on the diagonal indicate persistence, thus P_{jj} denotes the proportion of the landscape that shows persistence of category j. Entries off the diagonal indicate a transition from category i to a different category j. In the Total column, the notation P_{i+} denotes the proportion of the landscape in category i in time 1, which is the sum over all j of P_{ij}. In the Total row, the notation P_{+j} denotes the proportion of the landscape in category j in time 2, which is the sum over all i of P_{ij}. Usually the traditional cross tabulation matrix ends there. Tables 1 and 2, however, each show an additional column on the right called Loss and an additional row at the bottom called Gain (Pontius et al., 2004). Using the general notation, the Loss column indicates the proportion of the landscape that experiences gross loss of category i between time 1 and time 2 which is given by P_{i+} minus P_{ii}, computed for each category i. The Gain row indicates the proportion of the landscape that experiences gross gain of category j between time 1 and time 2 which is given by P_{+j} minus P_{jj}, computed for each category j.

As a first step in analyzing the transition matrices, table 1 shows that the two largest land cover categories on the protected landscape are Closed Forest and Moderately Closed Forest for both 1990 and 2000. From table 2, the two largest categories in the unprotected landscape are Moderate Forest and Bush with Scattered trees in 1990 and Moderately Closed Forest and Closed Forest in 2000. The next step in the analysis of the transition matrix is to compute the gains and losses within each category and then use these to derive the transition matrix that would be expected due to random transition. The procedure used is described in the next sub-section.

2.3 Losses, Gains and Expected Transition Matrix

The losses and the gains for each category were calculated as described in the previous section. Tables 1 and 2 display the losses in bold in the last column and the gains in bold in the last row. It is seen from table 1 that for the protected landscape, Closed Forest experienced the largest loss, about 35% of the landscape, and Moderately Closed Forest experienced the largest gain, about 18% of the landscape. For the unprotected landscape, table 2 shows that Moderately Closed Forest experienced the largest loss, about 31% of the landscape and Closed Forest experienced the largest gain, about 22% of the landscape. Analysis of persistence, losses and gains is instructive, but it fails to inform whether there are systematic transitions among the categories because this general analysis fails to examine the off-diagonal entries of transition matrices of tables 1 and 2. In order to identify systematic transitions within the transition matrix, the amount of gain of any one category is examined relative to the distribution of the other categories in 1990 (Pontius et al., 2004).

Tables 1 and 2 give three numbers for each combination of categories in 1990 and 2000. The top number in bold is the combination's percent observed on the landscape. The number in italics is the combination's percent that would be expected if the loss in each category were to occur randomly as calculated by equation 1.

$$L_{ij} = \frac{\left(P_{i+} - P_{ii}\right) \times P_{+j}}{1 - P_{+i}} \qquad (1)$$

For i ≠ j, equation 1 distributes the loss of category j across the other categories according to the relative proportions of the other categories in time 2, assuming that the loss of each category is fixed. If a category loses randomly across the landscape, it will be replaced by other categories according to the relative proportions of those categories on the landscape at time 2. The expected numbers are equal to the observed numbers for the unchanged areas (i.e. persistence shown by the diagonal entries), and so only the off-diagonal transitions are examined while holding the persistence constant.

In a manner analogous to the analysis of losses, the amount of gain of a category is examined relative to the distribution of the other categories at time 1. In table 1 and 2, the number in regular font is the combination's percent that would be expected if the gain in each category were to occur randomly as calculated by equation 2.

$$G_{ij} = \frac{\left(P_{+j} - P_{jj}\right) \times P_{i+}}{1 - P_{j+}} \quad (2)$$

For i ≠ j, equation 1 distributes the gain of category j across the other categories according to the relative proportions of the other categories in time 1, assuming that the gain of each category is fixed. If the process of gain is random, a category that gains will replace other categories relative to the sizes of those categories at time 1. Again, the expected numbers are equal to the observed numbers for the unchanged areas (i.e. persistence shown by the diagonal entries), and so only the off-diagonal transitions are examined while holding persistence constant.

2.4 Identification of Systematic Transitions

In order to identify systematic transitions within the transition matrices of Tables 1 and 2, the expected losses (i.e. numbers in italics in rows) are compared to the observed losses (i.e. numbers in bold in rows), and the expected gains (i.e. numbers in regular font in column) are compared to the observed gains (i.e. numbers in bold in columns). In Tables 1 and 2, if the observed loss (number in regular font) minus the expected loss under a random process (number in italics) is positive, then the category in the row lost more to the category in the column than would be expected due to a random process of loss in the category of the row. If the difference is negative, then the category in the row lost less to the category in the column than would be expected due to a random process of loss in the category of the row.

The comparison of the expected gains to the observed gains is analogous to comparison of the expected losses to the observed losses discussed in the foregoing. In Tables 1 and 2, if the observed gain (number in bold) minus the expected gain (number in regular font) is positive, then the category in that column gained more from the category in the row than would be expected by any random process of gain in that category of the column. If the difference is negative, then the category in the column gained less from the category in the row than would be expected due to a random process of gain in that category of the column.

The next dimension of analyzing landscape transitions is to identify the most systematic transitions. To do so, the difference between the observed values and the expected values are analyzed relative to the magnitude of the expected values. An efficient and intuitive way of doing this is to examine graphical representations of the transitions of each category in tables 1 and 2. Figure 5 is an example of such a graphical representation of the loss of Closed Forest of 1990 to five other categories of 2000 in the protected areas.

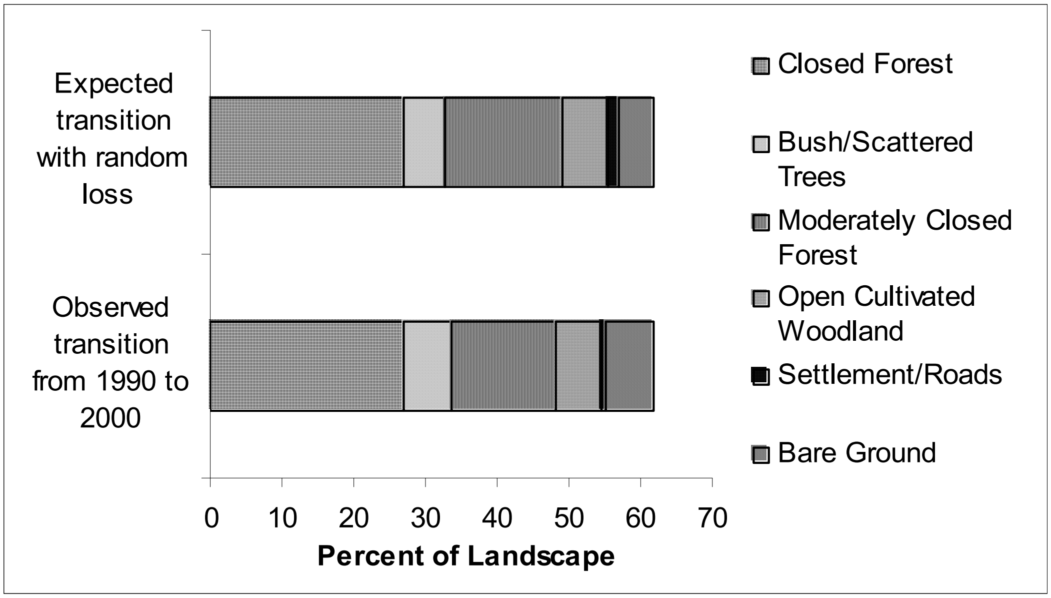

Figure 5. Analysis of the loss of the Closed Forest category between 1990 and 2000 for the Protected Areas.

The lower bar of figure 5 represents the observed fate of Closed Forest of 1990, including its losses to the five other categories of 2000 in the protected areas. This bar is plotted using the numbers in bold (i.e. observed losses) in the first row of Table 1, excluding the Total and Loss columns. The upper bar represents the expected losses of Closed Forest of 1990 to other categories of 2000 in the protected areas, if the losses were to have occurred randomly. This upper bar is plotted using the numbers in italics (i.e. expected losses) in the first row of table 1, again excluding the numbers in the Total and Loss columns. The differences between the observed and expected losses to each category relative to the total loss are then observed by inspection of the bars. It is then possible to identify visually any category of 2000 that has systematically replaced Closed Forest more than would be expected due to random loss of Closed Forest.

The gains are also analyzed graphically in order to identify the most systematic gains. Figure 6 is an example of such a graphical representation of the gains of the Bare Ground (BG) category of 2000 from five other categories of 1990 in the protected area.

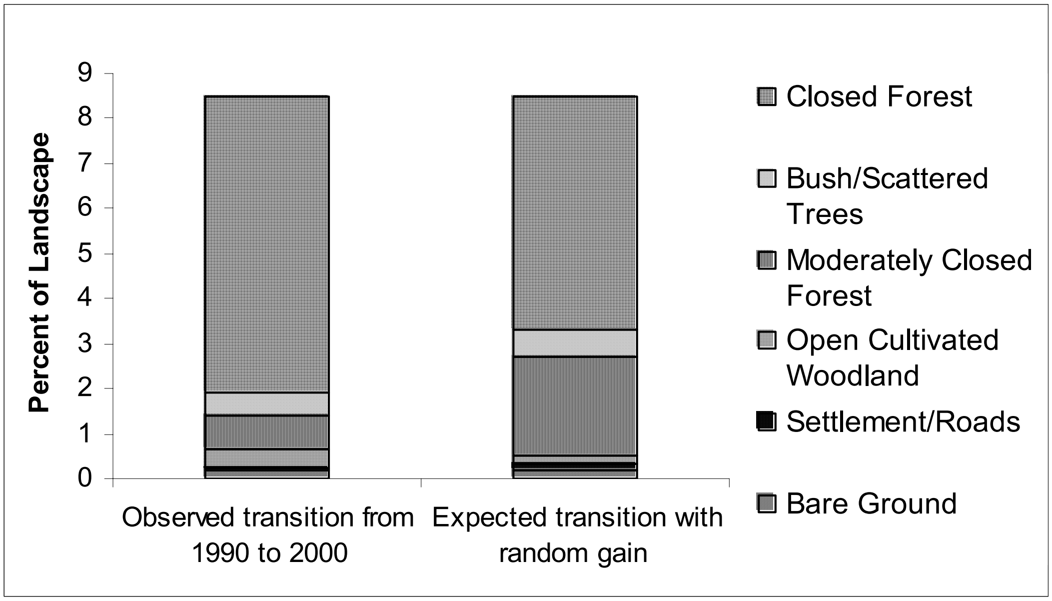

Figure 6. Analysis of the gain of the Bare Ground category between 1990 and 2000 for the Protected Areas.

The left bar of figure 6 shows the sources of Bare Ground of 2000 as observed on the landscape. This bar is plotted using the numbers in bold (i.e. observed gains) in the BG column of table 1, excluding the numbers in the Total and Gain rows. The right bar shows the expected sources of Bare Ground of 2000 if the gains from 1990 to 2000 were to have occurred randomly. The right bar is plotted using the numbers in regular font (i.e. expected gains) in the BG column of table 1, again excluding the numbers in the Total and Gain rows. A visual comparison of the two bars reveals whether or not the Bare Ground of 2000 has gained more from a particular category of 1990 than would be expected due to a random process of gain.

If a category of 2000 systematically gained from a category of 1990, that particular transition might not necessarily be of special importance. It is possible that other categories of 2000, also gained systematically from the same 1990 category. To assess this possibility, we need to analyze the loss of that 1990 category. A systematic gain and systematic loss in a particular transition will then confirm a strong signal of process of change. In other words, if a category of 1990 has systematically lost to a category of 2000, and that 2000 category has also systematically gained from the same 1990 category, then we can conclude a systematic process of transition between those two categories. The most important landscape transformations identified by using this procedure are discussed next in the results section.

3 Results

3.1 Protected Areas

The most important result based on the visual comparison of the expected transitions with the observed transitions in table 1 is that within the protected areas, Closed Forest systematically lost to Bare Ground. Figure 5 is the graphical representation of this transition. The lengths of the bars in figure 5 show that 61.8% of the protected landscape was Closed Forest in 1990. Over the duration from 1990 to 2000, 26.9% of the landscape persisted as Closed Forest, while 34.9% of the landscape transitioned from Closed Forest to five other categories as shown by the lower bar, with Bare Ground accounting for 6.6% out of the 34.9%. If Closed Forest were to have lost randomly, then we would expect the 34.9% loss to be distributed across the other categories as shown by the upper bar, with Bare Ground accounting for 4.9% out of the 34.9% loss. The comparison of the observed losses (lower bar) with the expected losses (upper bar), shows that Closed Forest lost more to the Bare Ground than would be expected due to random loss. It is thus implied that Closed Forest may have transitioned systematically to Bare Ground.

To conclude that this transition is indeed systematic, we must examine whether there is a strong signal that Bare Ground of 2000 gained from the Closed Forest of 1990. Figure 6 is the graphical representation of the sources of Bare Ground of 2000. The heights of the bars show that Bare Ground was 8.5% of the protected landscape in 2000. The persistence of Bare Ground was 0.2% of the landscape, while 8.3% of the landscape transitioned from the other categories of 1990 to Bare Ground as shown by the left bar, with Closed Forest accounting for 6.6% out of the 8.3% gain. If Bare Ground were to have gained randomly from the other categories, then the 8.3% would be expected to be distributed across the other categories as shown by the upper bar, with Closed Forest accounting for 5.2% out of the 8.3%. The comparison of the observed gains (left bar) with the expected gains (right bar) shows that Bare Ground gained more from Closed Forest than would be expected due to random gain. This is a strong signal of gain of Bare Ground from Closed Forest. It is therefore conclusive that the transition of Closed Forest to Bare Ground in the protected areas is a systematic process of landscape transformation.

3.2 Unprotected Areas

Outside the protected areas, the most important result from the comparisons of the observed transitions with expected transitions is that Closed Forest systematically transitions to Bush/Scattered trees. Figure 7 is a graphical representation of the transition of Closed Forest of 1990 to the five other categories of 2000 in the unprotected areas.

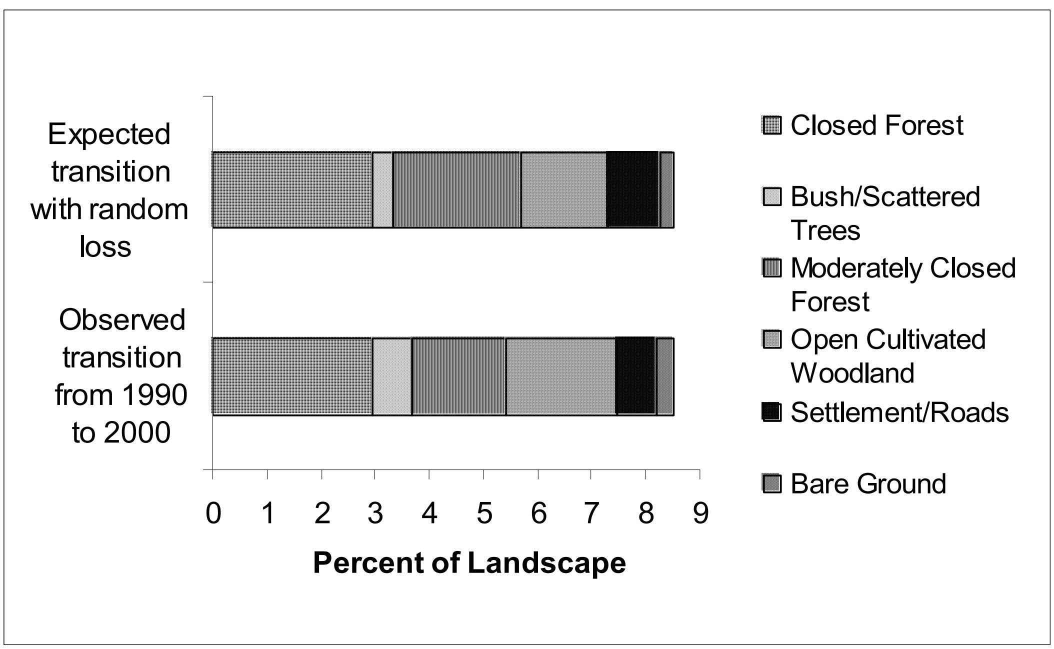

Figure 7. Analysis of the loss of the Closed Forest category between 1990 and 2000 for the Unprotected Areas.

The length of the bar in figure 7 shows that 8.5% of the unprotected landscape was Closed Forest in 1990. Between 1990 and 2000, 2.9% of the landscape persisted as Closed Forest, while 5.6% of the landscape transitioned from Closed Forest to five other categories as shown by the lower bar, with Bush/Scattered trees accounting for 0.8% and Open Cultivated land accounting for 2.1% of the 5.6% loss. If Closed Forest were to have lost randomly, then the 5.6% would be expected to be surrendered to the other categories as shown by the upper bar, with Bush/Scattered trees accounting for 0.4% and Open Cultivated land accounting for 1.6% out of the 5.6% loss. The comparison of the observed losses (lower bar) with the expected losses (upper bar), shows that Closed Forest lost more to Bush/Scattered trees and also to Open Cultivated Land than would be expected due to random loss. This shows a strong signal of loss of Closed Forest to Bush/Scattered trees and to Open Cultivated Land.

To confirm a systematic transition, the observed gains of Bush/Scattered trees of 2000 represented by the left bar in figure 8 are compared with the expected gains represented by the right bar.

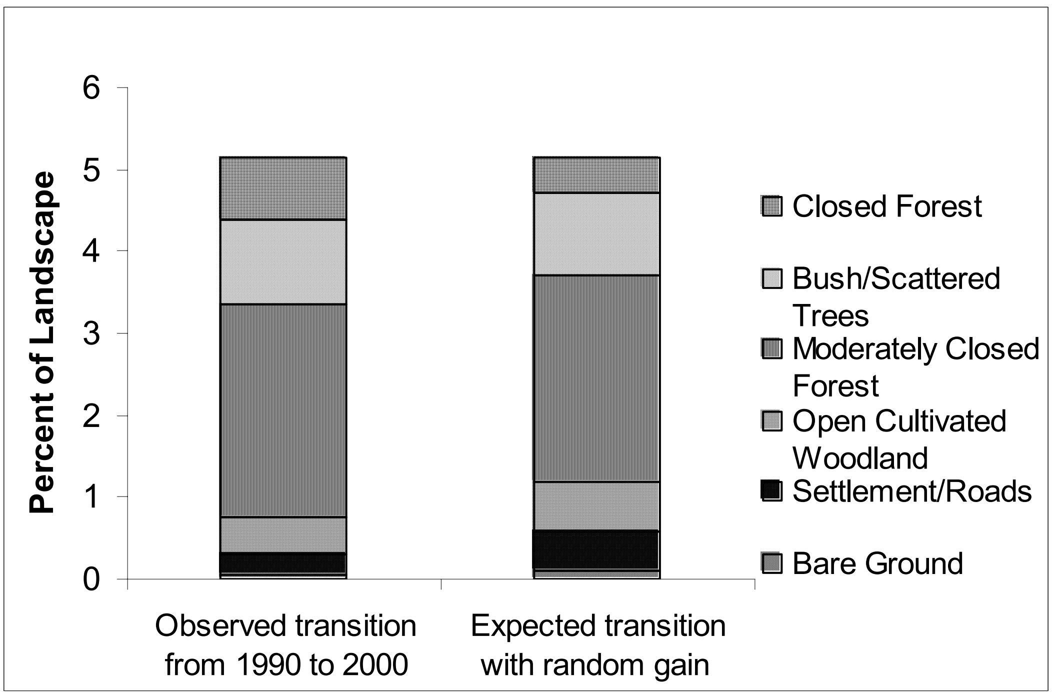

Figure 8. Analysis of the gain of the Bush/Scattered Trees category between 1990 and 2000 for the Unprotected Areas.

The height of the bar in figure 8 shows that Bush/Scattered trees was 5.1% of the unprotected landscape in 2000. The persistence of Bush/Scattered trees was 1.0% of the landscape and it was observed that 4.1% of the landscape transitioned from the other categories of 1990 to Bush/Scattered trees as shown by the left bar, with Closed Forest accounting for 0.8% out of the 4.1% gain. If Bush/Scattered trees were to have gained randomly, then the 4.1% gain would be expected to be distributed across the 1990 categories as shown by the right-hand side bar, with Closed Forest accounting for 0.4% out of the 4.1% gain. The comparison of the observed gains with the expected gains shows that Bush/Scattered trees gained more from Closed Forest than would be expected due to random gain. This shows a strong signal of gain of Bush/Scattered trees from Closed Forest. It is therefore conclusive that the transition of Closed Forest to Bush/Scattered trees in the unprotected areas is a systematic process of landscape transformation.

The observed gains of Open Cultivated Land represented by the left bar in Figure 9 are compared with the expected gains represented by the right bar. The heights of the bars in figure 9 show that Open Cultivated Land was 21.5% of the unprotected landscape in 2000. The persistence of Open Cultivated Land was 1.0% of the landscape and it was observed that 16.8% of the landscape transitioned from the other categories of 1990 to Open Cultivated Land as shown by the left bar, with Closed Forest accounting for 2.1% out of the 16.8% gain. If Open Cultivated Land were to have gained randomly, then the 16.8% would be expected to be distributed across the 1990 categories as shown by the right bar, with Closed Forest accounting for 1.6% out of the 16.8% gain. The comparison of the observed gains with the expected gains shows that Open Cultivated Land gained slightly more from Closed Forest than would be expected due to random gain but the signal is a relatively weak one. This implies that the transition from Closed Forest to Open Cultivated Land is not a strong systematic process of landscape transformation.

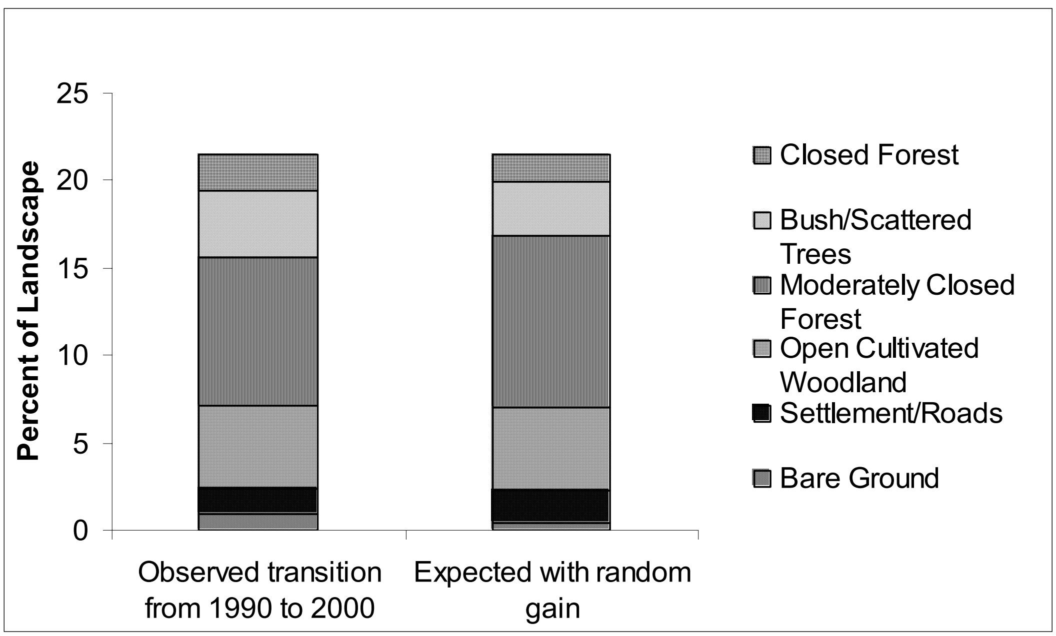

Figure 9. Analysis of the gain of the Open Cultivated Land category between 1990 and 2000 for the Unprotected Areas.

4 Discussion

4.1 Ghana and Protection

The debate on deforestation in Ghana's forest reserves (i.e. protected areas) has been one-sided, and has ignored the collective responsibility of all forest-user groups. For example, some authors blame only the country's farmers for deforestation (Kyem, 2004). Accordingly, official forest management strategies have emphasized coercion and policing of farmers, but the intimidation has done little to curb deforestation.

The most important result of this study is that, there is a systematic transition from Closed Forest to Bare Ground in the protected areas. This observation is evidence to support the hypothesis that there is intensive logging in the protected areas. This result disputes the claim that deforestation, especially in the forest reserves, is primarily caused by reckless activities of local farmers, because the transition of Closed Forest to Cultivated Land is not a strong systematic transition observed on the protected landscape. This does not mean that Closed Forest did not lose to Cultivated Land. In fact, 6.5% of the protected landscape showed a conversion from Closed Forest to Open Cultivated Land. Even though the conversion from Closed Forest to Cultivated Land is one of the processes of deforestation, scientists and policy makers should focus also on the strongest signal of forest loss, which is the transition of Closed Forest to Bare Ground. A problem must be correctly identified in order to be addressed. Thus, the continued loss of forest cover in Ghana testifies to how the deforestation problem has probably been misdiagnosed and calls into question the effectiveness of policies and approaches that Ghanaian officials have employed to manage the forest reserves.

Outside the protected areas, the transition of Closed Forest to Bush and Scattered trees was identified as the most important systematic transition. Apparently, this transition is a result of logging that is not as intensive and does not involve complete clearing like the case in the forest reserves. Most of the best commercial timber species are found in the protected areas and commercial logging in the forest reserves usually involves construction of access roads, which is a process of complete clearing. On the other hand, logging operations outside the protected areas may take advantage of existing feeder roads and farm access tracks. This probably explains why the logging in the protected areas is more of complete clearing whereas the logging outside the protected areas is more of degradation.

4.2 Importance of the Methodology

A simplistic interpretation of the cross-tabulation can fail to reveal systematic processes within a pattern of land change. For example, a less-detailed interpretation of table 1 would indicate that the most systematic process of change on the protected landscape is the transition from Closed Forest to Moderately Closed Forest. However such an interpretation fails to consider that Closed Forest and Moderately Closed Forest are the largest categories on the landscape, so even a random process of land change would cause a large transition from Forest to Moderately Closed Forest (Pontius et al., 2004). The methodology of this paper reveals that relative to the size of Moderately Closed Forest, Closed Forest actually lost less to Moderately Closed Forest than would be expected from a random process (Table 1 and Figure 5). Thus it is revealed with this methodology that Moderately Closed Forest did not systematically gain from Closed Forest, and the large transition of Closed Forest to Moderately Closed Forest is attributable to the fact that those are the two largest categories. On the other hand, a simplistic interpretation of table 1 may overlook the conversion of Closed Forest to Bare Ground, just because that transition is small, only 6.6% of the protected landscape. The methodology however reveals in table 2 that, relative to the size of Bare Ground, Closed Forest actually lost more to Bare Ground than would be expected from a random process. Thus, Closed Forest systematically lost to Bare Ground.

It is very important for scientists to consider large transitions of the landscape. However, it is clear from the foregoing that if scientists and policy makers focus on only the large transitions, they are likely to ignore the most systematic transitions. For instance, if policies are being formulated to halt the loss of Closed Forest in the protected areas, the policy makers should focus attention on the systematic transition of Closed Forest to Bare Ground too, and not exclusively on the large transition from Closed Forest to Moderately Closed Forest.

5 Conclusions

This research shows clearly that the process of land transformation within the protected areas is different from outside the protected areas. The process of Closed Forest loss in the protected areas is more of complete clearing whereas the process of Closed Forest loss in the unprotected areas is more of degradation. Practitioners responsible for forest management in Ghana should adapt this paper's new methodology for the analysis of land transformation. This will enable managers to gain maximum insights into the systematic processes of forest transition.

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