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Historical footprints in contemporary land use systems: forest cover changes in savannah woodlands in the Sudano-Sahelian zone

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Abstract

The paper analyses land use trajectories in savannah woodlands in the Central-West Region, Burkina Faso and the Upper East Region in northern Ghana by use of satellite images and historical archives. Observed trends differ in terms of spatial location and correlation with population pressure from normally accepted characterizations. Colonial forestry policies are proposed as key determinants of present-day land use patterns. However, these reinforced pre-colonial land use patterns inasmuch as land gazetted as forest reserves were tracts affected by vectors of human and livestock disease. It is suggested that the transformation of wooded agricultural landscapes in the Sudano-Sahelian region is the outcome of historically and culturally embedded interactions between complex social, economic and ecological processes which operate at widely varying scales and which change over time; the implications hereof for modelling of global environmental issues is discussed.

Keywords: Deforestation; Remote sensing; Colonial history; Land cover changes; Ghana; Burkina Faso

1. Introduction

European interest in tropical forest resources grew significantly during the expansion of colonial trading in the eighteenth century. By the middle of the nineteenth century it had already become clear that the forests of the colonies were not an inexhaustible resource (Cleghorne et al., 1852). Institutional and jurisprudential forestry models were developed in response to the deforestation 'problem', initially, in India and Burma. By the early twentieth century the 'empire forestry mix' had been replicated in several anglophone countries of Africa (Barton, 2001).

The interest in tropical deforestation has been sustained over the last 150 years. The continuing loss of forest resources throughout the tropics continues to be highlighted (FAO, 1982, 1993, 1995, 1997, 2001; Richards and Tucker, 1988; United Nations, 1993; Koop and Tole, 2001; Williams, 2003) although the quality of aggregated global, regional and country-level data and analytical techniques used have been seriously questioned (Grainger, 1996; Matthews, 2001). In spite of rapid developments in the use of remote sensing techniques in the past 30 years, global and regional assessments of land cover and land use remain poorly quantified (IPCC, 2000). Innumerable country and local-level 'deforestation' case studies have been conducted with the key aims of either determining the spatial extent and rate of land cover changes and/or improving our understanding of the causes of these changes. The persistence of interest in tropical 'deforestation' has generated and perpetuated "myths" which represent over-simplifications of cause-consequence relationships (Reenberg et al., 1998a, b; Lambin et al., 2001). These have become increasingly embedded in broader land and environmental degradation narratives and continue to shape environment and development policies even though they are difficult to support empirically.

Many recent studies of tropical deforestation have focused on the humid tropics with comparatively limited attention given to the semi-arid regions (Gillis, 1988; Westoby, 1989; Shepherd, 1992; Brown and Pearce, 1994; Grainger, 1997; Lambin et al., 2001). This discrepancy is equally valid in countries such as Ghana which include both moist 'High Forest' resources and dryland savannah woodlands (Hawthorne and Abu Juam, 1995; Mayers et al., 1996; Fairhead and Leach,

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1998a; Amanor, 1997). In the Ghanaian case, this has cumulatively resulted in ''the relative paucity of information on forest resource condition and use in northern Ghana'' (Kotey et al., 1998, p. 21). Similarly, the temporal dimension of the relationship between trends in driving forces such as population and forest area changes in countries or regions of countries has received relatively little attention in the literature (Mather and Needle, 2000; Bassett and Zuéli, 2000).

This paper provides a contribution to the current debate concerning the human dimensions of land cover and land use changes in developing countries. It specifically addresses the issue of forest cover changes of savannah woodlands in the Sudano-Sahelian region of West Africa, a region which, in terms of land degradation processes, has been characterised as 'the quintessence of a major environmental emergency' (Raynaut, 1997; Batterbury and Warren, 2001).

The aim of the paper is to challenge the tendency to relate changes in savannah woodland areas to parameters such as population pressure and ease of human access to the resources in a far too simplistic way. This is done by investigating land use trajectories with specific attention to deforestation versus natural regeneration processes in Central-West Region (CWR), Burkina Faso and Upper East Region (UER) in northern Ghana, respectively. The study combines empirical mapping of land use changes based on satellite imagery analysis with historical archival 'reconstruction' studies. Emphasis is placed on the frequently overlooked historical dimensions. Specifically, pre-colonial determinants and the colonial forestry interventions which may have influenced current land and natural resource management regimes are investigated.

2. Background

2.1. Moving beyond deforestation myths

Population growth and human access have consistently been assumed to be drivers of land use and land cover change in general, and deforestation in particular. These assumptions have been reinforced and perpetuated by widely referenced works (Ehrlich and Holdren, 1971; Myers, 1984; Allen and Barnes, 1985; Harrison, 1992) even though the theoretical and empirical underpinnings of the relationships between population, access and environmental resources have been contested over the same period (Harvey, 1976).

Recent studies continue to reaffirm that population pressure is one of the universal underlying causes of pantropical deforestation (Palo and Lehto, 1996) or that population growth is the most important explanatory variable (Lambin, 1997). This persistence can be partially understood in terms of the historical influence of established ecological and social 'equilibrium' theories (Mazzucato and Niemeijer, 2000), the attractive simplicity and political expediency of (Neo-) Malthusian crisis narratives (Malthus, 1803; Holdren and Ehrlich, 1974) and the comparative ease of using demographic parameters as a basis for modelling forest trends (Meyer and Turner II, 1992). The latter has tended to create a self-perpetuating loop which over-emphasises negative forest trends at the expense of determining the positive relationships between population and forest expansion through, for example, natural regeneration, abandonment of agricultural land, afforestation and reforestation (Mather and Needle, 2000) or human agency (Fairhead and Leach, 2001). The accuracy of data on forest resources and methodological weaknesses associated with the use of different demographic variables and different measures of deforestation have also clouded the evidence (Palo, 1994; Lambin, 1999; Tucker and Townshend, 2000; Matthews, 2001; Turner, 2003).

The theoretical underpinnings of the deforestation discourse remained essentially a-political, a-historical and a-cultural until well after independence in many developing countries. Many challenges to the over-emphasis on population as a key determinant of deforestation have subsequently come from both historical and local-level studies. Researchers from a broad range of disciplines have increasingly focused on identifying the underlying causes or processes associated with 'forest degradation' and 'deforestation' by trying to understand the socio-political, economic and institutional settings in developing countries. No interdisciplinary consensus has yet been reached. However, global, regional and local-level studies have repeatedly revealed that the relationships between population dynamics and resource degradation are much too complex to support reductionist generalizations about cause and effect (Repetto and Holmes, 1983; Myers, 1992; Bilsborrow and Okoth Ogendo, 1992; Turner et al., 1993; Mortimore and Tiffen, 1994; Bilsborrow and Geores, 1994; Barraclough and Ghimire, 1996; Rudel and Roper, 1996; Benjaminsen, 1997; Lindblade et al., 1998). In some cases positive relationships between population growth and tree resources have been documented (Tiffin et al., 1994; Holmgren et al., 1994). In others dominant environmental narratives have been refuted—''…the savanna has become more wooded over the past thirty years'' (Bassett and Zuéli, 2000, p. 89)—or have been qualified by the complexities of ''…deeper historical and cultural precedents that shape present disputes over the meanings of boundaries that separate villages from state and private forests'' (Walker and Peters, 2001, p. 414).

Counter-narratives to constant forest and ecological decline have developed as more socio-anthropological, agricultural and ecological information has emerged and new practice discourses have been established (Leach and Mearns, 1988; Sprugel, 1991; Pretty and Chambers, 1993; Sullivan, 1996; Arnold and Dewees, 1998; Campbell et al., 2000). The emergence of different perspectives to shape deforestation debates and to challenge the 'received wisdom' (Leach and Mearns, 1996) has fostered the growing acknowledgement of the fact that 'deforestation' is a value-laden term with clearly discernible historical precedents and contemporary repetitions. This is exemplified by the deforestation discourse in West Africa. Land degradation processes such as shifting cultivation practices, bush fires and extensive pastoral land use systems were already described in 1937 as the "three evils" in terms of their influence on the forest resources of West Africa (Stebbing, 1935, 1937, 1938). The same value-laden tenets underscored the adoption of the "trois luttes" by the Government of Burkina Faso in 1985 and continue to appear regularly in journal articles, project and programme documents, and in contemporary environmental planning throughout West Africa (Ofori-Sarpong, 2001; Ministère de l'Environnement et de l'Eau, 1999; World Bank, 2001; Bassett and Zuéli, 2000).

Several recent surveys of tropical deforestation have concluded that there is no conclusive evidence linking population increases, poverty or access and rates of deforestation (Intergovernmental Panel on Forests, 1996; Kaimowitz and Angelsen, 1998; Angelsen and Kaimowitz, 1999; Mather and Needle, 2000; Geist and Lambin, 2001). These studies do not exclude population as a possible driver of deforestation but highlight the need to consider variables such as population or access in a broader agricultural landscape (Reenberg, 1996, 1998), within a wider developmental context (Bernstam, 1991), and with a longer temporal perspective (Batterbury and Bebbington, 1998).

2.2. Historical determinants of forest and woodland resources

A number of researchers have highlighted the critical importance of historical factors in explaining the outcomes of different colonial regimes with regard to either present-day land-use patterns and/or the institutional arrangements for the conservation of forest and woodland resources (Ofcansky, 1984; Bassett, 1988; Schabel, 1990; Koponen, 1994; Parren, 1994; Buttoud, 1997; Ibo, 2000; Firmin-Sellers, 2000; Bassett and Zuéli, 2000; Barton, 2001; Becker, 2001; Walker and Peters, 2001).

Other scholars have used historical data to question forest conservation orthodoxies which have failed to recognise both the important roles played by local farmers and the extent to which they have been influential in managing and enriching agricultural landscapes (Fairhead and Leach, 1996, 1998a, b), and the value of forest histories in terms of "… how one understands both forest ecology and people's social and political relationships with currently forested land" (Fairhead and Leach, 1995, p. 2). However, the analytical value of this approach has been questioned due to the 'symptomatic avoidance of processes of commoditization and differentiation in African farming systems' in explaining environmental change (Bernstein and Woodhouse, 2001). Local-level studies, furthermore, increasingly highlight the need for multiple approaches to determine spatial and temporal dynamics, and to understand the complexity of vegetation-change patterns (Bassett and Zuéli, 2000; Turner, 2003). An important perspective of this article is to investigate the way in which past land use management practices may have had a significant bearing on consecutive land use patterns by combining the use of remotely sensed and archival data.

2.3. The study areas

2.3.1. Generic characteristics

The empirical basis for this paper is two cases from Ghana and Burkina Faso that represent two different colonial historical backgrounds but approximately the same agroecological conditions. The study areas border major rivers which form part of the Volta River basin located close to the international boundary between the two countries (Fig. 1). The pairs of villages studied in each country were selected on the basis of their ethno-linguistic similarities (the *Gurunsi* group in Burkina Faso and the related *Fra-Fra* group in Ghana), their proximity to forest reserves gazetted during the colonial era, and the contrasts between each village notably in terms of population characteristics and dynamics (Tables 1 and 2) and location in relation to existing road infrastructure. The villages studied are

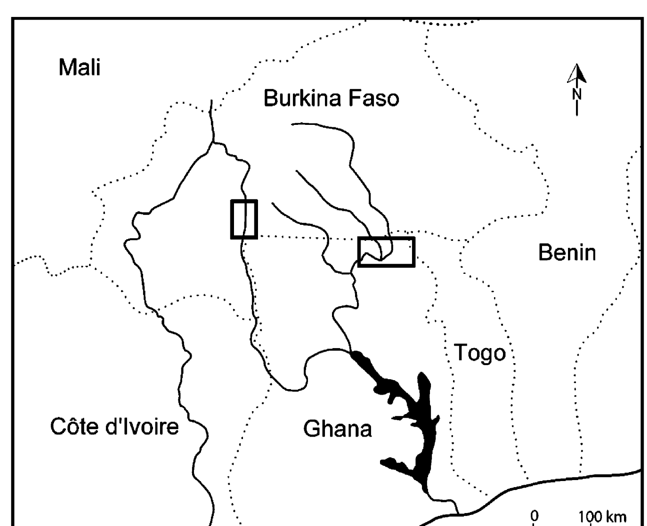

Fig. 1. Approximate location of the study areas in Ghana and Burkina Faso—the Volta River Basin.

Table 1
Population figures from Ghana; available census data from national level and relevant regional, district and village census units[a]

Level	Territory	Census year						
		1921	1931	1948	1960	1970	1984	2000
National	Ghana[b]	2,296,400	3,160,386[c]	4,118,450	6,726,815	8,559,313	12,296,081	18,412,247
Regional	UER[d]	257,949	365,465	453,188	470,453	542,858	772,744	917,251
District	Bolgatanga[e]	—	133,981	163,474	150,028	172,202	241,921	225,864
Village	Sekoti Benzure[f]	—	—	1569	798	276	634	n/a
Village	Biung[g]	551	363	214	87	70	87	n/a

[a] The key references for the population counts and censuses for the Gold Coast Colony and Ghana between 1891 and 2000 are:

* Colony of the Gold Coast, 1891. Report on the Census of the Gold Coast Colony for the year 1891.
* Colony of the Gold Coast, 1902. Report on the Census for the year 1901. Waterlow and Sons Limited, Printers London Wall, London.
* Gold Coast Colony, 1911. Census of the population, 1911 (Parts I–III). Government Press, Accra.
* Gold Coast Colony, 1923. Census Report 1921 for the Gold Coast Colony, Ashanti and the Northern Territories and the Mandated Areas of Togoland. Government Press, Accra.
* Gold Coast Colony, 1931. Appendices (Comparative returns and general statistics of the 1931 Census). Government printer, Accra.
* Cardinall, A.W., 1931. The Gold Coast. Government Printer, Accra.
* Mandated Area of Togoland Census Report Northern Section. Report from CCNT to Chief Census Officer, Accra. Ref: 941/66/1930 dated 15 July 1931 (NRG 8/34/1, PRAAD, Tamale).
* Gold Coast Colony, 1950. The Gold Coast Census of Population 1948. Report and Tables. Government Printing Department, Accra.
* Census 1948. Letter from CCNT to Colonial Secretary, Accra. Ref: N.T. 0357/15 dated 8 July 1947 (NRG 8/34/2, PRAAD, Tamale).
* Omaboe, E.N., 1959. Counting the people of Ghana. Economic Bulletin 3(2), 20th February 1959, Accra.
* Census Office, 1962. 1960 Population Census of Ghana. Vol. 1. The Gazetteer. Alphabetical list of localities with number of population and houses. Census Office, Accra.
* Regional Census Office Enumeration Return: Northern Region. (NRG 8/34/3, PRAAD, Tamale).
* Census Office, 1973. 1970 Population Census of Ghana. Vol. 1. The Gazetteer. Alphabetical list of localities with number of population and houses. Census Office, Accra.
* 1970 Population Census: Historical events to assist in the estimation of the ages for respondents in Gambaga, Walewale, Damongo and Tamale Districts, February–March 1969 (NRG 8/34/4, PRAAD, Tamale).
* Statistical Service, 1989. 1984 Population Census of Ghana. Special report on localities by Local Authorities—Upper East Region. Statistical Service, Accra.
* Ghana Statistical Service, 2000. 2000 Population and Housing Census. Provisional Results. Ghana Statistical Service, Accra. 22pp.

[b] The 1891 and 1901 population counts were conducted by a customary method which involved each head of family placing into a calabash, an Indian corn (*Zea mays*) for each male and a cowrie for each female. The calabashes were brought to the chiefs who then entered the figures onto special schedules. These were transmitted to the District Commissioner who subsequently prepared a summary return for the whole district. The count for the Gold Coast in 1901 excluded a separate *estimate* for the Northern Territories. A first ad hoc Census Ordinance was passed in 1911 and a Census night was fixed for the population count which now included the Northern Territories. The 1921 Census followed a similar pattern to that of 1911. In December 1930 the first 'permanent' Census Ordinance No. 21–"to make provision for taking a Census of the inhabitants and livestock of the Colony as and when required" was passed. A similar Ordinance, Northern Territories No. 5 of 1930 was enacted to apply *mutatis mutandis* to the Protectorate. In 1931 counting by cowries was abandoned and, for the first time, total village populations were counted and the Census report was accompanied by a statistical analysis and evaluation of its accuracy. In 1948 the country was divided into Enumerator's Districts, a Census Office was opened in Accra and the Census report included a more detailed list of localities. The 1960 Population Census was the first to be conducted in independent Ghana and witnessed the first real application of modern census techniques.

[c] The 1931 Census included estimates of immigrants who were subjects of either other British West African Colonies (70,536) or French West African Colonies (196,282). The total number of 'migrants' residing in the Gold Coast Colony and Ashanti but who were originally from the Northern Territories was, in comparison, relatively small in the same year (44,013).

[d] The 1921 population figures for Upper East Region are based on the populations of Navrongo, Zuarungu and Kusasi within the former Northern Mamprusi District (Cardinall, 1931, pp.151–152). The 1931–1948 population figures are based on the populations of the Mamprusi Administrative District and which, following the introduction of 'indirect rule' in 1932, comprised three Native Authorities, viz., Builsa, Kassena-Nankanni and Mamprusi (limited to the Frafra and Kusasi areas of the Mamprusi NA). The 1960 population figures are based on four Local Authorities created in the Northern Region after the Local Government Ordinance of 1951 (Builsa, Kassena-Nankanni, Frafra and Kusasi). The 1970–1984 population figures are based on enumeration areas convering seven Local Councils and two Urban Councils from the former Upper Region and present-day Upper East Region (Sandema, Navrongo, Chiana-Paga, Bongo-Nabdam, Kusanaba-Zebilla, Tempane-Garu and Pusiga-Pulimakum Local Councils and Bolgatanga-Tongo and Bawku Urban Councils).

[e] The population figures for Bolgatanga District are based on estimates for Zuarungu District (1931), the Frafra Local Council (1948 and 1960) and the Bolgatanga-Tongo Urban Council and Bongo-Nabdam Local Council (1970 and 1984).

[f] Sekoti Benzure constitutes part of a constellation of Nabdam villages.

[g] The village of Biung is an old settlement close to the White Volta and was a separate sub-division in 1921 and 1931. It features on some of the earliest known sketch maps prepared by forest officer Vigne in 1939 during the preparation of the Zuarungu District Working Plan and remains home to the *Biung Dan*—the Paramount Chief of the Tallensi.

Table 2
Population figures from Burkina Faso; available census data from national level and relevant regional, provincial and village census units[a]

Level	Territory	Census year						
		1948	1961	1970	1985	1996	1998	2001
National	Burkina Faso	—	4,460,000	5,303,000	7,964,705	10,312,609	10,775,560	—
Regional	CWR	—	—	—	827,419	943,538	1,075,104	—
Province	Sanguié Province	—	—	—	217,277	249,583	293,830	—
Village	Tiogo	—	832	n/a	2979	2864	2432	3048
Village	Négarpoulou	—	n/a	n/a	1020	1478	1473	1573

[a] The key references for the population counts and censuses for Haute Volta and Burkina Faso between 1961 and 2001 are:

* La situation démographique en Haute-Volta. Résultats partiels de l'Enquête démographique 1960–1961. République de Haute-Volta, Service de la Statistique, pp. 26–31.
* Recensement Général de la Population 1985 (Institut National de la Statistique et de la Démographie, 1996).
* Recensement Général de la Population et de l'Habitat 1996 (Institut National de la Statistique et de la Démographie, 1996).
* Recensement administratif de la population 1998 (Préfecture de Ténado).
* Annuaire Statistique du Burkina Faso 1999 (INSD, 1999).
* Monographie du Département de Ténado, Province de Sanguié (PDISAB, 2001).
* Monographie du Département de Kyon, Province de Sanguié (PDISAB, 2001, p. 17).

representative of the acephalous segmentary societies distributed throughout the upper reaches of the Volta River Basin in the two countries.

The climate of the two study areas is semi-arid, distinguished by the alternation of a distinct wet (May–October) and dry season (November–April). The soils of the region are predominantly shallow and characterised by limited availability of exchangeable cations and low levels of organic matter content. Lithosols are found on dispersed laterite and granite hills and hydromorphic soils occur in the lowest parts of broad valleys subject to ephemeral drainage. Large areas on the floodplains have traditionally not been utilized due to water logging and the historical incidence of sleeping sickness (trypanosomiasis) and river blindness (onchocerciasis).

The predominant land use systems can be characterised as rainfed subsistence arable farming on compound and bush farms, irrigated dry season 'market gardening' on small protected plots and extensive livestock grazing based on crop residues, bush farm fallows and dry season transhumance along the river valleys and within forest reserves. Farmers in both regions have developed distinctive land use patterns broadly distinguished by the intensive "ring" pattern—developed on the basis of traditional land tenure arrangements and on the increase of soil fertility around compounds (Barral, 1968; Webber, 1996)—and the "toposequential" pattern—developed on the basis of differential fertility of soils located along the toposequence (Stoop and Pattanayak, 1980). The major food crops grown include millet, red and white sorghum, maize, rice, groundnuts, sesame and bambara nuts.

Traditional protected areas have probably existed for centuries and include sacred groves, burial groves, traditional hunting 'grounds' and woodlands found at the headwaters and along the courses of rivers and streams (Blench, 1999). The local inhabitants collect a broad range of Non Timber Forest Products (NTFPs) from the parklands, savannah woodlands and gallery forests for subsistence use and/or local markets. These encompass inter alia woodfuels, thatching materials, building poles, medicinal plants for human and livestock disorders and bush meat. Complementary sources of income to sustain rural livelihoods within the case study areas include cotton, tobacco, shea nut kernels and shea butter, dry-season vegetable gardening, traditional handicrafts and skills and, recently in UER, Ghana, artisanal gold-mining.

Three main land cover classes can be distinguished in the study regions: (1) 'fringing' or gallery forest which forms a narrow (20–100 m) vegetative strip along the permanent and seasonal watercourses of the Volta River system, (2) Guinea/Sudan savanna woodlands which occupy the sparsely populated valleys and protected forest reserve areas and (3) densely populated savanna 'parklands' associated with compound farming systems in the upland areas.

2.3.2. *Specific characteristics*

UER is located in the northeastern part of Ghana. The villages selected for further study are Sekoti (densely populated and located on good all-weather roads close to Pelungu and Bolgatanga markets) and Biung (sparsely populated and difficult to access due to the poor condition of roads). The villages both border the Red Volta West Forest Reserve in Bolgatanga District. UER is one of Ghana's poorest regions (Republic of Ghana, 1997, 1999). Hydrologically the region is drained by the Red and White Volta and the Nasia Rivers. Mean annual rainfall for the period 1931–1990 is approximately 1000 mm.

UER is a densely populated, ethnically heterogeneous and predominantly rural region. In 2001 it was estimated that 80% of the population depend on subsistence farming as the mainstay for their livelihoods (Ofori-Sarpong, 2001). Population development trends vary at national, regional, district and village levels (Table 1). At the national level, the population has increased by a factor of approximately 4.5 since 1948, in the UER by a factor 2, in Bolgatanga District by a factor 1.3 whereas both study villages have experienced significant downward trends in population. The trend in the sub-village of Sekoti Benzure is suggestive of a cyclic pattern of depopulation and resettlement (Hunter, 1966; Hilton, 1966). The estimated population density (based on net land areas i.e. excluding uninhabited protected areas) in Bolgatanga District in 2000 was 144 inhabitants per km^2 (cf. averages of 126 inhabitants per km^2 in UER and 87 inhabitants per km^2 in Ghana).

In the CWR, Burkina Faso two villages were selected for further study, Tiogo (densely populated and located on a national trunk road linking two major urban centres, Koudougou and Dédougou) and Négarpoulou (less densely populated and difficult to access during the rainy season due to flooding of a seasonal watercourse). The villages both border the Tiogo Forest Reserve in Sanguié Province. The region is drained by the Black Volta, the only permanent watercourse in the country. Mean annual rainfall for the period 1931–1990 varies between 700 and 900 mm. CWR is a densely populated rural region. After independence successive waves of Mossi and Fulbé (Peuhl) migrants settled in the province (Hagberg et al., 1996). In 2000 it was estimated that 94% of the population in Sanguié Province depend on farming as the mainstay for their livelihoods (Mazzucato and Niemeijer, 2000). Population development trends vary at national, regional, provincial and village levels in Burkina Faso (Table 2). At the national level, the population has increased by a factor of approximately 2.3 since 1961. Both study villages have experienced significant upward trends in population due to migration into the area. The population of the village of Tiogo has increased by a factor of approximately 3.7 since 1961 (Barral, 1968). The estimated population density (based on net land areas i.e. excluding uninhabited protected areas) of Sanguié Province in 1998 was 69 inhabitants per km^2 (cf. averages of 49 inhabitants per km^2 in CWR and 40 inhabitants per km^2 in Burkina Faso), and as such is lower than for UER in northern Ghana.

3. Materials and methods

Two main approaches were used to acquire information on land use and land cover dynamics in the savannah woodlands and their root causes: studies of archival materials and mapping based on satellite images. The use of archival information recognises that "…general cropping systems pattern and its adaptation to local ecological conditions can be modified by social factors and historical events" (Vierich and Stoop, 1990, p. 122). The use of archival sources can also complement "…memory and land management practices of current land users…to help understand past land use" (Fairhead and Leach, 2001, p. 12). The archival sources were, in turn, triangulated by oral histories of the forest reserves and peripheral villages developed using semi-structured interviewing techniques with key informants in the study villages in February–March 2002 and January–February 2003.

3.1. Archival materials

Comprehensive historical reviews of the development of forest policy in the two study regions have been developed as archival 'reconstruction' studies (Wardell, 2002, 2003a). The archival material was studied with the aim of identifying and comparing the key determinants of colonial forest and land use policies in relation to their subsequent influence on land cover and land use changes in the two case study regions. The material was collated from a range of sources presented in Table 3.

3.2. Mapping and monitoring land cover

Satellite images were selected as the main source of information to create contemporary land cover maps and statistics as well as to monitor major directions of change. Two different types of satellite imagery were used in this study: Landsat TM (1986) and Landsat ETM+ (2001) imagery to provide regional estimates of land cover and land cover changes since the mid-eighties, and CORONA (1967/1968) data to facilitate longer term village-level forest cover change analysis. The spatial resolution offered by satellite images is well suited to detect changes between major land cover classes such as cultivated parklands and savannah woodlands (Bobbe et al., 2001). The analysis provides regional land cover statistics for 1986 and 2001; regional statistics for deforestation/woodland regeneration 1986–2001; regional maps of deforestation/woodland regeneration 1986–2001; village level statistics for forest cover 1967/68–2001; and village level maps of forest cover 1967/68–2001.

3.2.1. Satellite image sources

Emphasis is, in the current context, laid on analyses based on the Landsat TM/ETM+ images due to their higher degree of resolution. Table 4 lists the images used to study the two selected regional cases. For all imagery the data acquisition dates were selected so the data were comparable in terms of seasonality. The Landsat

Table 3
Overview of sources of archival material used in the historical reconstruction studies of forest policy and land use practice

No.	Organisation
Francophone archives	
1	Archives Nationales, Ouagadougou, Burkina Faso
2	Centre National de Recherche Scientifique et Technologique (CNRST), Ouagadougou, Burkina Faso
3	Institut National de la Statistique et de la Démographie, Ouagadougou, Burkina Faso
4	Direction Régionale de l'Environnement et de l'Eau, Région du Centre-Ouest, Koudougou
5	Direction Provinciale de l'Environnement et de l'Eau, Province du Sanguié, Réo
6	Poste forestier, Forêt Classée de Tiogo, Tiogo, Département de Ténado
7	Archives Nationales de Côte d'Ivoire, Abidjan, Côte d'Ivoire
8	Institut de Développement Rural—Sciences Sociales, Abidjan, Côte d'Ivoire
9	Centre des Archives d'Outre-Mer (CAOM), Aix-en-Provence, France
10	Centre de Coopération International en Recherche Agronomique pour le Développement (CIRAD) LaValette and Baillarguet libraries, Montpellier, France
11	French Institute of Forestry Agricultural and Environmental Engineering (ENGREF), Nancy, France
Anglophone archives	
1	District Forestry Offices, Bolgatanga, Bawku and Navrongo Districts, Upper East Region, Ghana
2	Regional Forest Office, Bolgatanga, Upper East Region, Ghana
3	Public Records Administration and Archives Department (PRAAD), Tamale, Ghana
4	Resource Management Support Centre, Forestry Commission, Kumasi, Ghana
5	Forestry Commission, Accra, Ghana
6	National Archives, Accra, Ghana
7	Oxford Forestry Institute Library, University of Oxford, Oxford
8	Special Collections, Edinburgh University Library, Edinburgh
9	Public Records Office, London
10	Records and Historical Department, Foreign and Commonwealth Office, London

Table 4
List of satellite data used to study the two regions

Sensor	Path/row	Date	Country coverage
Landsat ETM+	194/52	12-01-2001	Ghana/Burkina Faso
Landsat ETM+	194/53	12-01-2001	Ghana
Landsat TM	194/52–53[a]	27-01-1986	Ghana/Burkina Faso
Landsat ETM+	196/51	11-02-2001	Burkina Faso
Landsat ETM+	196/52	11-02-2001	Burkina Faso
Landsat TM	196/51–52[a]	14-03-1986	Burkina Faso

[a] Shifted 50% southwards.

ETM+ were delivered systematically corrected, i.e. as a product which is rectified to be free from distortions related to the sensor, satellite, and Earth but which is not corrected by use of ground truth control or relief models to attain absolute geodetic accuracy. The accuracy is considered to be approximately 250 m. The Landsat TM images were geometrically rectified to the Landsat ETM+ image using an image-to-image rectification process. The accuracy of the rectification process is at a sub-pixel level allowing for a per pixel comparison of the multi-temporal image data.

CORONA satellite photography, originating from the first generation of US photoreconnaissance satellites, was applied for the longer term land cover change assessment (Tappan et al., 2000). CORONA data from January 28, 1968 (Ghana) and December 10, 1967 (Burkina Faso) were available as paper prints (scale 1:305.000). The images were scanned (resolution 600 dpi), resampled and rectified to match the Landsat ETM. The accuracy was estimated to ± 100 m.

3.2.2. Image interpretation

Landsat images provide different options for land cover monitoring (Francklin, 1991). One widely used is an image classification based directly on the spectral signatures for the various cover classes (Thenkabail, 1999; Mertens and Lambin, 1997). Another commonly used approach is to translate multi-spectral satellite data into a vegetation index which allows for reliable monitoring of variations in phenological and biophysical vegetation parameters (Tucker and Sellers, 1986; Prince, 1991). However, most vegetation indices are based on the fact that green healthy vegetation is absorbing visible red light (Landsat band 3) while it is reflecting near-infrared light (Landsat band 4). The satellite images applied in the current context are all acquired in the dry season, when only little green vegetation is present. Thus, vegetation indices were excluded as a suitable basis for change detection and automatic and visual classification procedures based on spectral signatures were adopted. The CORONA data do not lend themselves for such analysis due to the lack of multi-spectral bands. Nevertheless, the CORONA material has a high enough resolution to observe the typical sizes of forested and unforested patches found in the study areas. Hence, human interpretation based on image display was used; grey level tones, texture and

Table 5
Description of the major land cover classes considered in the satellite-based classification (spectral characteristics for the classes are depicted in Fig. 3)

Class	Description
Parkland	Cultivated savannah. Refer to intensively cultivated areas, with limited fallowing. The major crops are millet and sorghum. Trees may be present but tree cover is typically less than 5%. The dominating tree species are *Vitellaria paradoxa* (Shea butter), *Parkia biglobosa* (Locust bean), *Andansonia digitata* (Baobab), *Azadirachta indica* (Neem), *Faidherbia albida*, *Bombax costatum* and *Lannea* sp. The parkland class also includes rural settlements and urban areas.
Savannah Woodland	Dry tropical woodlands. Refer to areas of intermediate to dense woody cover with an understorey of shrubs and grasses. The dominant ligneous species include *Combretum* sp., *Vitellaria paradoxa*, *Detarium microcarpum, Acacia* sp., *Pterocarpus erinaceus*, *Crossopteryx fabrifuga*, Terminalia, *Sterculia* sp., and *Burkea africana*. The class also includes plantations of *Tectona grandis*, *Cassia siamea*, *Anogeissus leiocarpus* and *Eucalyptus* sp. Principal grass species include *Loudetia togoensis*, *Andropogon* sp. and *Setaria pallidefusca*.
Gallery forest	Mixed vegetation formation along seasonal watercourses and around the main rivers draining the Volta River basin. More flourishing than the surrounding vegetation. The major species are *Mitragyna inermis*, *Pterocarpus santalinoides*, *Acacia seyal*, *Ficus* sp., *Daniellia oliveri, Anogeissus leiocarpus*, *Vetiveria nigritana*, etc. Permanently cropped areas based on various levels of water control are also included in this class.
Water	The main water bodies.

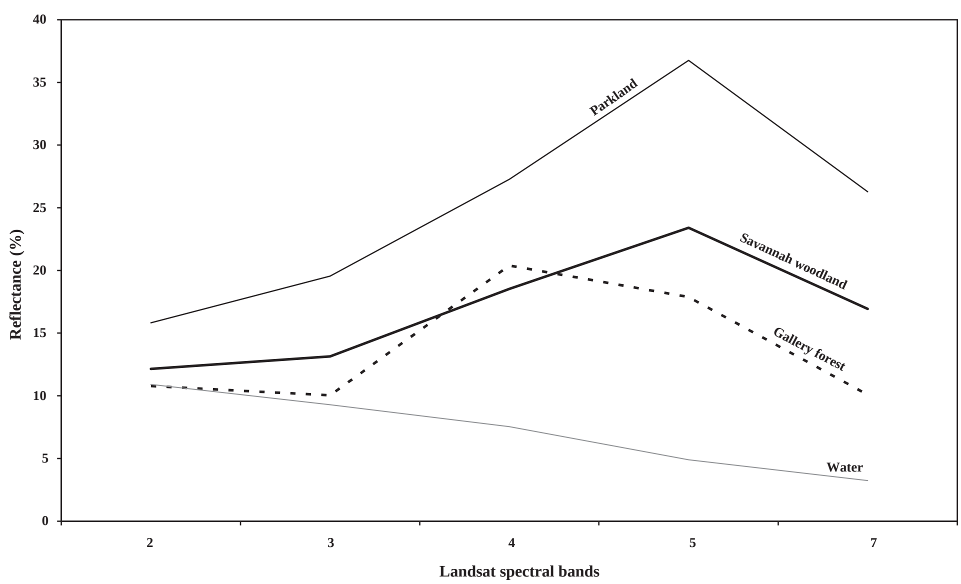

Fig. 2. Spectral reflectance curves for four land cover classes, derived from Landsat ETM data in training areas verified on the ground (samples are from the study region in Ghana).

geometric features were used to distinguish forest/non-forest land cover. It should be noted in this regard that savannah woodland areas includes gallery forests, that non-forest areas includes parklands, and that non-forest areas are not necessarily tree- or woodless.

3.2.3. Land cover mapping

A 2001 land cover classification was carried out for the two study regions. Four classes were defined as relevant for the study (Table 5). Training areas for the respective land cover classes were delineated by use of an on-screen interpretation of the satellite image supported by ground control points verified in the field and positioned by use of a GPS. The reflectance curves for the four classes are seen in Fig. 2. These training data were tested to be statistically appropriate, i.e. to be normally distributed and reasonably spectrally separable. The training data statistics provided the basis for a maximum likelihood classification of the entire region. In order to create the final land cover statistics, the classification results were further enhanced by using a 3×3 mode filter to remove ‘salt and pepper’ noise. Classification accuracy was evaluated by standard procedures using independent data collected in the field.

3.2.4. Land cover changes

Change detection based on comparison of classified satellite images is sensitive to the accuracy of the input classifications as every error in the individual classifications will be present in the final change detection map (Singh, 1989). In order to mitigate this, a binary change mask method was applied when comparing images from 1986 and 2001. A traditional classification of date 1 is performed. Spectral information from date 1 and date 2 are used to create a binary change mask. This change mask is then overlaid onto date 2 and only pixels that have been subject to change are classified in the date 2 satellite imagery. This methodology enables the analyst to consider only pixels that have been subject to change and helps to improve the accuracy of change detection (Jensen, 1996).

In the creation of the change mask, the evidence (Fig. 2) that dry woodlands have a markedly lower spectral response in all wavebands compared to parkland areas (cultivated areas) is employed. This lower response is most pronounced in Landsat band 5, and thus changes between 1986 and 2001 were detected using a simple image differencing method of Landsat band 5. The resulting change image yields a distribution of brightness values forming a Gaussian distribution with pixel values of no change distributed around the mean and pixel values of change being found in the tails of the distribution (Jensen, 1996). From visual interpretations of known change areas the change threshold was set to be 1 standard deviation from the mean, i.e. values deviating more than one standard deviation from the mean was included in the binary change mask. Subsequently, the change areas were classified in accordance with the approach described in Section 3.2.3 and using the 1986 Landsat TM images, new sets of training data were derived from field-based historical recordings and a general knowledge of the spectral behaviour of the major land covers (cf. Fig. 2).

Change detections including the CORONA data are presented both as a time series of maps (Figs. 5–8), and as tabulated statistics of the change in non-forest areas around the four study villages (Table 10).

4. Land use and land cover dynamics in the study regions

The Landsat-based analysis reveals some interesting trends as regards the land cover development in the period 1986–2001. Tables 6 and 7 show a considerable change from savannah woodland into parkland (i.e. cultivated land) and yet, the opposite direction of change is also common, documenting considerable natural regeneration of savannah woodland on abandoned farmland, long-term fallows, fire-damaged and river blindness-affected areas. The relative change expressed as both gross-deforestation (land cleared 1986–2001/forest land 1986) and net-deforestation (land cleared minus re-growth 1986/forestland 1986) is much larger in Burkina Faso than in Ghana (Tables 8 and 9).

Figs. 3 and 4 give a picture of the significant spatial dynamics of land use and forest cover changes in the study regions which are normally characterized as having a relatively permanent field pattern. Deforestation as well as regeneration are scattered throughout the study regions and are not confined specifically to the forest fringe. However, the distribution of the ‘no change’ areas is largely confined to the uninhabited belts along the seasonal and perennial water courses of the Black, Red and White Volta Rivers. These are

Table 6
Matrix of land cover change from 1986 to 2001 in the study region in Ghana (figures are in hectares)

1986	2001				Sum 1986
	Parkland	Savannah woodland	Gallery forest	Water	
Parkland	166,499	11,340	21	16	177,877
Savannah woodland	20,110	260,856	801	214	281,981
Gallery forest	293	2325	7513	65	10,197
Water	24	7	8	284	324
Sum 2001	186,927	274,528	8343	580	

Table 7
Matrix of land cover change from 1986 to 2001 in the study region in Burkina Faso (figures are in hectares)

1986	2001				Sum 1986
	Parkland	Savannah woodland	Gallery forest	Water	
Parkland	159,191	31,349	170	9	190,719
Savannah woodland	52,400	376,343	1396	28	430,167
Gallery forest	1876	2303	5190	18	9387
Water	10	0	2	113	124
Sum 2001	213,477	409,995	6758	167	

Table 8
Deforestation rates between 1986 and 2001 for a study region in Upper East Region, Ghana

Deforestation 1986–2001	20,404 ha
Regeneration 1986–2001	11,361 ha
Forest cover 1986	292,178 ha
Gross-deforestation	6.98%
Net-deforestation	3.09%
Annual rate of Gross-deforestation	0.44% $year^{-1}$
Annual rate of Net-deforestation	0.19% $year^{-1}$

Source: Satellite mapping.

Table 9
Deforestation rates between 1986 and 2001 for a study region in Central-West Region, Burkina Faso

Deforestation 1986–2001	54,276 ha
Regeneration 1986–2001	31,519 ha
Forest cover 1986	439,553 ha
Gross-deforestation	12.35%
Net-deforestation	5.18%
Annual rate of Gross-deforestation	0.77% $year^{-1}$
Annual rate of Net-deforestation	0.32% $year^{-1}$

Source: Satellite mapping.

essentially the same areas gazetted as Forest Reserves during the 1940s and 1950s by the colonial administrations (see Section 5.1).

Changes in forest cover during the period 1968–2001 at the village scale for the four selected villages are presented as maps in Figs. 5–8 and in Table 10. It is specifically worth noting that the rate of change is neither closely related to areas characterised by heavier population pressure (Sekoti and Tiogo) nor to areas characterised by poor access to markets and limited road infrastructure (Biung or Négarpoulou). Population growth rates at the village level have been significantly higher in the Burkina Faso study area due to in-migration by Mossi and Fulbé 'latecomers' after independence. This is in stark contrast to the significant out-migration from Haute Volta to the Gold Coast that occurred during the colonial period (Cardinall, 1931; Rouch, 1956; Gregory, 1974; Hart, 1974).

The relative change in forest cover during the period 1967–2001 in CWR was more significant in the inaccessible village with less population pressure (Négarpoulou) than in the village located along a national highway (Tiogo). It is suggested that several factors have ensured more effective state governance of access to the forest reserve along its southernmost boundary, i.e. the presence of a forestry control point in Tiogo; the tradition of conducting 'forest police' operations to remove illegal users; an organisational culture based on a 'history of fear' (Ribot, 1999); and the greater opportunities for revenue-sharing to meet the demand for woodfuels in the regional capital, Koudougou. In contrast, the widespread encroachment of the forest reserve along its northern and eastern boundaries can be understood in terms of state and customary boundaries being contested (Some, 1996; Gomgnimbou, 1998; Poda, 1998), inaccessibility due to seasonal flooding of the Négarpoulou river valley and the limited incentives for state forestry personnel to perform. The current illicit occupation of the Tiogo Forest Reserve in these areas constitutes the 'second wave' of cultivation following evictions by the Forestry Department conducted between 1987 and 1992.

The relative change in forest cover during the period 1968–2001 in UER was, similarly, more significant in the inaccessible village with less population pressure (Biung) than in Sekoti located on all-weather roads with good access to local and regional markets. The broad-scale determinants of contemporary land use patterns—vectors of sleeping sickness and river blindness and colonial forest reservation policy—have resulted in a distinctive settlement pattern in Sekoti in accordance with a cyclical theory of advance and retreat first proposed in the 1960s (Hunter, 1966, 1967; Meyer, 1993). However, recent changes in forest cover in Biung village have largely been driven by an influx of 'galamsey' (gold) miners after 1995 following the successful control of river blindness (Boatin et al., 1997) and the liberalisation of the mining investment code in Ghana (Awudi, 2001). Tens of thousands of prospectors have now occupied temporary settlements in areas south of Datoko Village (between Sekoti and Biung) on the western boundary of the Red Volta West Forest Reserve. Many of these prospectors were evicted by a battalion of the Ghanaian Army in 1995 from an earlier site of occupation in Bolgatanga District (Wardell, 1997). Demographic data does not capture this transient population. Furthermore, it is suggested that colonial anglophone approaches to forest reservation involved far greater consultation with local communities which has resulted in less conflictual—but still contested and negotiated—contemporary settings (Wardell and Lund, 2004).

The case studies indicate that deforestation rates are determined by a variety of local processes and can both increase and slow down over time; even when there is a decline of forest cover on average there are still other areas where the forest cover is expanding. One additional explanation for the observed forest cover dynamics is that the largest changes took place where there was more forest to begin with. This would suggest that the site specific factors influencing environmental change may be less important than the stage at which 'deforestation' finds itself i.e. initially strong deforestation followed by a slowdown as the amount of

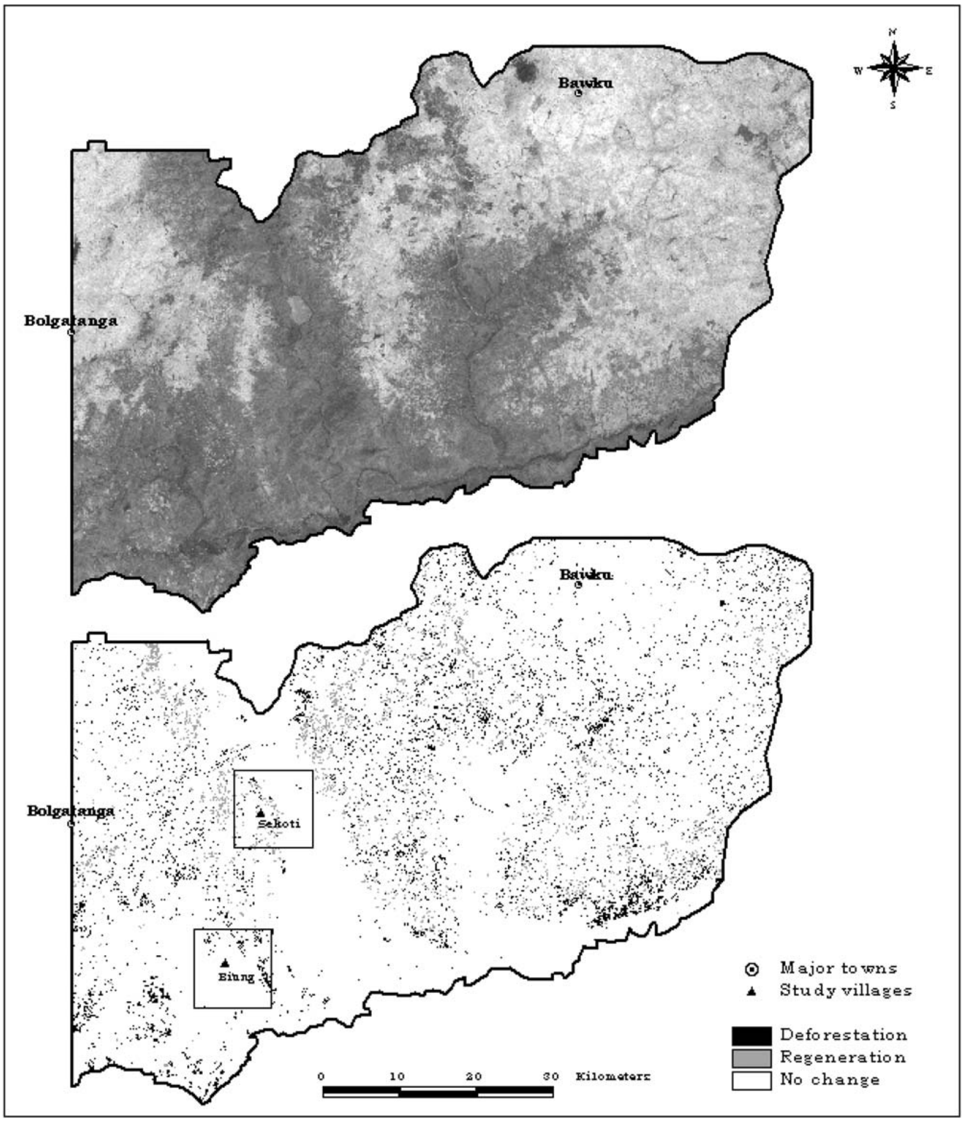

Fig. 3. Grey scale representation (Landsat ETM + band 3, 2001) of the Ghana study region (upper) and corresponding mapping of areas with deforestation and regeneration between 1986 and 2001 (lower). The two frames indicate the location of study villages which are mapped in detail in Figs. 5 and 6.

remaining forest declines. This may explain, in part, why the agrarian population has remained spatially concentrated on the upland compound farming areas in the two study areas for at least 70 years, in spite of population densities of up to 150 persons/km^2. Archival records indicate, however, that the spatial concentration of population has changed during the last century due to famine, drought and the occurrence of vectors of livestock and human diseases.

5. Historical footprints

Current land use and land cover patterns and dynamics are frequently explained as being a direct result of contemporary natural resource management strategies. However, as discussed in the following sections, the influence of colonial forestry policies may have had a significant bearing on present-day land cover and resource management regimes. In turn, colonial forestry interventions were shaped by both the biophysical endowments of the Volta River Basin, and historically and culturally embedded patterns of settlement and labour migration.

5.1. Colonial influences

A key element of the 'empire forestry mix' was the appropriation by the colonial state of large areas of land which was formally gazetted as Forest Reserves. Colonial administrations in West Africa usurped local rights to woodland resources as new state laws restricted or suspended customary communal use rights which were regarded as being inconsistent with rational forest

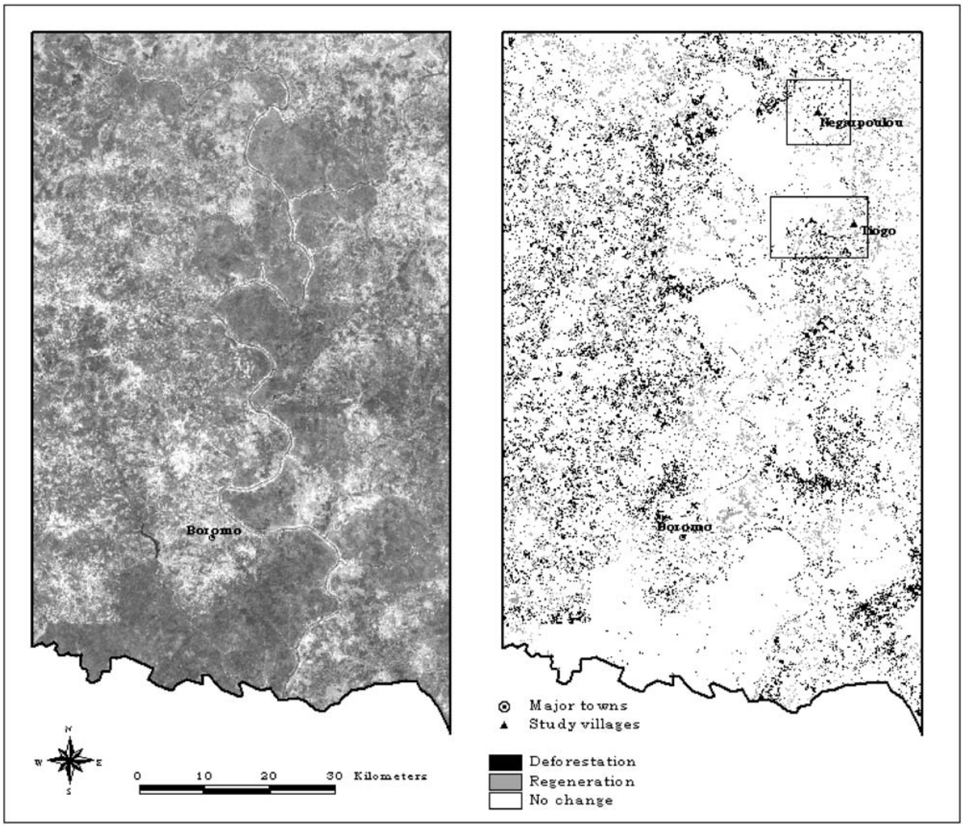

Fig. 4. Grey scale representation (Landsat ETM + band 3, 2001) of the Burkina Faso study region (left) and corresponding mapping of areas with deforestation and regeneration between 1986 and 2001 (right). The two frames indicate the location of study villages which are mapped in detail in Figs. 7 and 8.

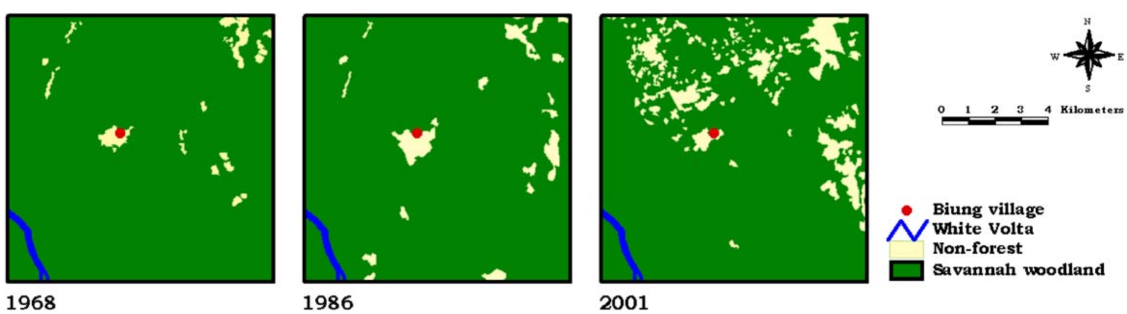

Fig. 5. Change in forest cover 1968–2001 around Biung Village in Ghana. Maps from 1968 are based on CORONA data; 1986 on Landsat TM and 2001 on Landsat ETM+. The corresponding statistics are given in Table 10.

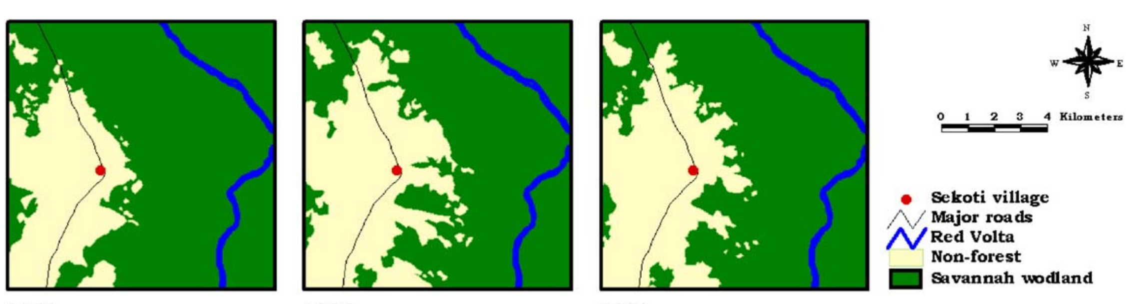

Fig. 6. Change in forest cover 1968–2001 around Sekoti village in Ghana. Maps from 1968 are based on CORONA data; 1986 on Landsat TM and 2001 on Landsat ETM+. The corresponding statistics are given in Table 10.

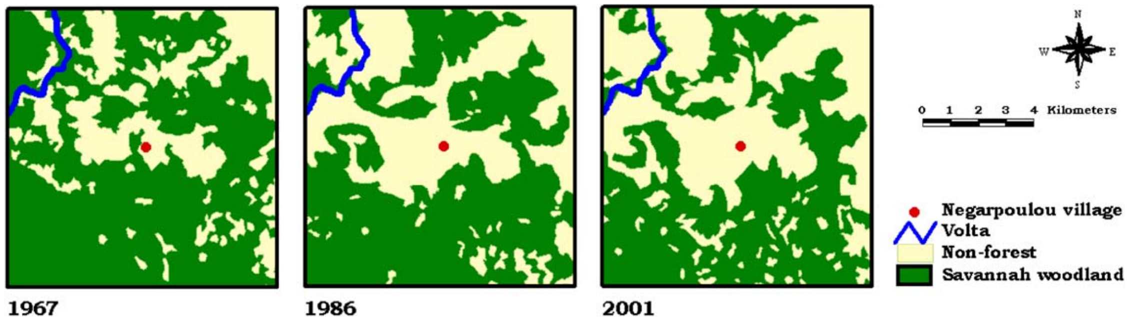

Fig. 7. Change in forest cover 1967–2001 around Negarpoulou Village in Burkina Faso. Maps from 1967 are based on CORONA data; 1986 on Landsat TM figure 2001 on Landsat ETM +. The corresponding statistics are given in Table 10.

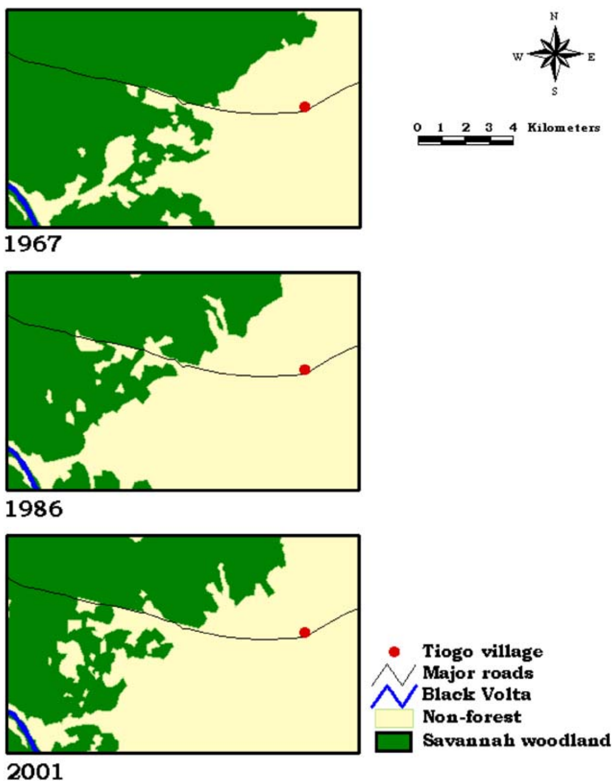

Fig. 8. Change in forest cover 1967–2001 around Tiogo Village in Burkina Faso. Maps from 1967 are based on CORONA data; 1986 on Landsat TM and 2001 on Landsat ETM +. The corresponding statistics are given in Table 10.

management. During the period 1939–1956, 99,071 ha of Forest Reserve were gazetted along the White and Red Volta Rivers in UER, Ghana (Table 11). Likewise, 119,853 ha of 'Forêt Classée' were gazetted along the Black Volta River in CWR, Burkina Faso after 1940 (Table 12). These colonial interventions resulted in more than 20% of contemporary district/provincial land areas being taken out of agricultural production.

The institutional and legislative precursors in francophone West Africa were developed in Senegal and Côte d'Ivoire during the period 1900–1935 under the auspices of the federated Gouvernement Général de l'Afrique Occidentale Francaise (Ribot, 1995; Ibo, 2000). Attempts to establish hunting areas along the Black Volta river valley in 1925 did not come to fruition and the subsequent gazetting of the 'Forêt Classées' only occurred during the period 1936–1940 after the territorial suppression of Haute Volta in 1932 (Wardell, 2003a).

The Gold Coast Government's efforts to develop a forest policy in the Northern Territories only began in earnest after the Second World War. Earlier attempts to transform indigenous systems of production by developing international trade in shea butter and silk cotton were abandoned. Later plans to evict and resettle 50,000 people from the densely populated north-east—to facilitate the establishment of headwaters protection forest reserves—were rejected at the North Mamprusi Forestry Conference in 1947. Forest reservation in Ghana's densely populated Sudano-Sahelian zone was eventually undertaken as part of a more comprehensive land use planning exercise using the opportunities provided by both the Native Administration and Forests Ordinances (Wardell, 2003a).

In both Haute-Volta and the Northern Territories of the Gold Coast Colony the process of establishing forest reserves was underscored by the prevailing apprehension of the linkages between deforestation and desiccation (Anon, 1905; Vuillet, 1907; Stebbing, 1935; Jones, 1938; Aubréville, 1938, 1949; Moor, 1937, 1939; Anglo-French Forestry Commission, 1973), and the convergence of political and economic interests in neighbouring territories (Wardell, 2003b): investment in, and returns from, savanna woodland areas were negligible in comparison to the timber-rich High-Forest Zones in both Côte d'Ivoire and southern Ghana.

5.2. *Biophysical endowments and social determinants of land use and land cover*

5.2.1. *Vectors of livestock and human disease*

Cycles of depopulation or depopulation/repopulation of farmland areas have influenced patterns of deforestation and regeneration of adjacent savannah woodlands in the study areas; yet, the vegetative 'corridors' in the river valleys have largely remained intact. This situation has historically been associated with the occurrence of

Table 10
Statistics of the change in non-forest area around the four study villages shown in Figs. 5–8

	Ghana				Burkina Faso			
	Biung		Sekoti		Negarpoulou		Tiogo	
Year	Hectare	Per cent	Hectare	Per cent	Hectare	Per cent	Hectare	Per cent
1967/68	270	2.7	2628	26.0	2882	29.9	6186	45.3
1986	451	4.4	3545	35.1	4018	41.6	7889	57.7
2001	1160	11.4	3190	31.6	4632	48.0	7984	58.4

The area covered is approximately 10×10 km for each village except for Tiogo that is 14×9 km.

Table 11
Forest reserves along the Red and White Volta Rivers, Ghana

	Forest reserve	Gazetted area (ha)
Upper East Region, Ghana	Gambaga Scarp East	12,573
	Gambaga Scarp West I	11,500
	Gambaga Scarp West II	22,222
	Red Volta West	26,159
	Morago West	3,976
	Morago East	881
	Red Volta East	21,760
	Total	99,071

Source: Forestry Commission (2001).

Table 12
Forest reserves along the Mohoun (Black Volta) River, Burkina Faso

	Forest reserve	Gazetted area (ha)
Central-West Region and Boucle du Mohoun Region, Burkina Faso	Ouoro	7,080
	Tiogo	37,600
	Tissé	21,500
	Kalio-Baporo	16,298
	Sorobouli	11,175
	Laba	17,800
	Total	111,453

Source: Ministère de l'Environnement et de l'Eau (1996).

vectors of livestock and human disease: the Glossina tsetse fly complex, vector of sleeping sickness and the Simulium damnosum blackfly complex, the vector of river blindness. These diseases have influenced land cover, land use and settlement patterns throughout the northern reaches of the Volta River basin (Edwards, 1956; Benneh, 1985).

An anti-tsetse campaign, concerned with both human and animal trypanosomiasis, was conducted in the Northern Territories during the period 1932–1949. It involved a programme of bush clearance to free hundreds of square kilometres for human habitation and cattle rearing in the Northern Territories of Ghana. This included clearings along river banks for 1 km on either side of trade route crossing points (Forestry Department, 1947). Colonial preoccupation with vectors of livestock disease (livestock constituted an important source of tax revenue after 1926) also delayed attempts to address the problem of river blindness. Prior to this several different explanations were put forward for the perceived 'anomalous' distribution of population. These included slave raids by Samori and Babatu (Holden, 1965), smallpox and cerebrospinal meningitis, land exhaustion, trypanosomiasis (Hunter, 1966, pp. 410–411) and depredations of elephants, roan antelope and monkeys (Hilton, 1968, p. 283).

The linkages between onchocerciasis, blindness and river valley abandonment were not understood until the 1940s (Richet, 1939; Waddy, 1969). However, oral data indicates that famine and drought propelled migrants to start colonizing the banks of the Red Volta already during the period 1890–1895 (Hunter, 1966, pp. 414–415). The well-watered and fertile land along the river continued to be occupied until the years 1915–1918 when, due to river blindness, the population began to retreat (Hunter, 1966, pp. 409 and 414–415). Hunter proposed a cyclical pattern of colonization of vacant land near streams, a gradual increase in river blindness and the eventual demise of the afflicted population or its withdrawal to higher ground out of the flight range of the vector. For example, oral data collected in 1935 suggests that Sekoti was settled in the 1880s and that the newcomers found only empty bush to greet them (Ghana National Archives (GNA, 1935). In 1908 the compounds of Sekoti extended to the river (GNA, 1908) and by 1917 land along the river in the Nangodi-Sekoti-Detokko area was thickly settled (GNA, 1917, 1919). By 1949 aerial photography (Hunter, 1966, p. 409) revealed a total absence of settlement near the Red Volta River. As habitations were abandoned and farming declined, savanna scrub and woodlands regenerated to recolonise the abandoned areas.

5.2.2. *Patterns of migration*

Economic development in southern Ghana and Côte d'Ivoire depended on long-established patterns of seasonal and permanent migration of labour from northern Ghana and neighbouring Burkina Faso. This included the international, regional and national slave trade; the internal regional trade in kola nuts and salt with the Sahelian countries (Lovejoy, 1985); the expansion of the external trade in African mahoganies after the mid-1800s (Parren, 1994); the introduction and expansion of cocoa cultivation in the Gold Coast Colony after 1874 (Sutton, 1983; Acquaah, 1999); the rise and fall of the wild rubber trade between the 1880s and the 1920s (Brooks, 1947; Bourret, 1949); the staffing and active service of the armed forces and police during both World Wars (Bourret, 1949, pp. 152–153); and public works such as road building and the construction of railway lines and ports (Dickson, 1968; Bening, 1975).

Long-established migratory patterns were reinforced by the 'labour reserve' policy in the Northern Territories of the Gold Coast Colony and in Haute-Volta (Bening, 1975; Thomas, 1973; Cordell and Gregory, 1982). Densely populated regions were particularly affected by colonial regimes that required labour—Mazzucato and Niemeijer (2000) found little contemporary influence of the colonial heritage in Fada N'Gourma in eastern Burkina Faso where population densities were significantly smaller. An increase in migration to the Northern Territories probably occurred after 1901 with immigrants, initially reluctant to penetrate the country, establishing themselves close to the frontier. These patterns of migration were perceived by some colonial administrators to be due to the cumulative burdens of the French taxes, their forced labour and the extortion alleged to be practised by their Chiefs and public officers of the lower ranks (GNA, 1931). Others, however, attributed the movement to a more general 'ecological malaise' (Cardinall, 1931, p. 152).

In the post-independence era the growth of other, more localised uses of agricultural labour, for example, the interest in *galamsey* artisanal gold mining, has maintained such patterns by removing the most productive part of the subsistence agricultural labour force. Seasonal and permanent labour migration have continued to influence land use and settlement patterns to the present day as young males (15–45 years old) avail themselves of the economic opportunities outside and within the study regions. In UER, for example, the development of irrigation schemes in the 1960s and 1970s (Shepherd, 1981) and the resurgence of interest in gold mining in the mid-1990s illustrate the continued flow of people and resources to sustain rural communities in different periods.

6. Conclusion and perspectives

The colonial inheritance has been a significant determinant of present-day land cover and land use patterns in the two case study areas. The process of establishing forest reserves in the densely populated Sudano-Sahelian zone was influenced by earlier colonial models and was underscored by global apprehension of the linkages between deforestation and desiccation. The broad-scale determinants of land use and land cover were, however, initially shaped by the biophysical endowments of the Volta River Basin and historically embedded patterns of labour migration. These were subsequently reinforced by colonial forestry policies and compounded as marginalised 'resource-poor' territories were transformed into labour reserves for neighbouring colonies.

The continuing transformation of wooded agricultural landscapes in the Sudano-Sahelian region discussed in this paper is the outcome of complex interactions between social, economic and ecological processes which operate at widely varying scales and which change over time. The evolutionary 'stages' in the history of land use change described do not necessarily grade into one another as simply as frequently described (Lambin, 1994). Changing economic opportunities at the local, national and regional levels have interacted with finer-scale processes at the local level resulting in variable and location-specific patterns of encroachment of the protected forest reserve areas which differ in each country and at each locality.

Tropical deforestation is increasingly recognised as being largely driven by changing economic opportunities. These opportunities are, in turn, influenced by the changing socio-political, institutional and infrastructural endowments of particular localities. Furthermore, limited historical evidence suggests that there is no permanent, fixed or deterministic relationship linking population and forest trends. Historical factors have played a key role in shaping both contemporary land cover patterns and in determining the degree of access local communities have to natural resources in areas protected by the state.

Local-level studies tend to highlight the complexity of the specific geographical and historical situations, demonstrating the uniqueness of particular causes of land cover change. The immense diversity in settings, the scale-specific nature of the relations and the common unavailability of quantitative information make it difficult to use such locally founded relations for national, regional or global assessments. The exaggeration (or underestimation) of net rates of deforestation is significant for researchers and planners who use inflated (or deflated) statistics to model a country's (or a region's) climate, greenhouse gas emissions, carbon sequestration potentials and biodiversity. The use of incorrect data may ultimately mislead national, regional and district-level forestry and land-use policy and planning and cross-country analyses which aim to identify the underlying causes of deforestation. In the African region increases or decreases in tropical forest cover resulting from changes in assessment methodology adopted during forest resource assessments undertaken in 1980, 1990, 1997 and 2000 have been shown to be greater than the changes estimated to have taken place on the ground (Matthews, 2001, p. 7).

These issues are of particular concern given the current interest in strengthening the conservation of biological diversity in Upper East Region, Ghana (World Bank, 2001) and in harnessing the opportunities for carbon sequestration to-be-supported under the auspices of the Kyoto Protocol's Clean Development Mechanism in Central-West Region, Burkina Faso (Ministère de l'Energie et des Mines, 2000, 2001; Olsson and Ardö, 2002). The case studies illustrate that national aggregated estimates of deforestation cannot be transposed back to specific individual areas as local patterns deviate strongly from national averages. Local-scale case-studies can, therefore, provide important insights which are currently difficult to capture in quantitative models, and can inspire model builders to include new elements in their models. This highlights the need to integrate results from different disciplines and to identify new fields of research adding up to a better understanding of land use change and its drivers.

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