

**ASSESSMENT OF ENVIRONMENTAL DEGRADATION
IN NORTHERN GHANA:
A GIS BASED PARTICIPATORY APPROACH**

Submitted in accordance with the requirements
for the degree of Doctor of Philosophy

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Abstract

The task of understanding how human actions interact in a complex way to bring about environmental degradation requires a holistic research approach. This thesis examines the potential application of a GIS based participatory approach in the assessment of environmental degradation in northern Ghana. It is a development of GIS in participatory research earlier proposed by Abbot *et al.* (1998) and modified by Williams and Dunn (2003) to assess the impacts of landmines in Cambodia. Using the DPSIR (Driving force-Pressure-State-Impact-Response) framework of the European Environmental Agency as an assessment framework, conventional GIS techniques were integrated with participatory research tools, dubbed “*community truthing*”, to assess the state of the environment, evaluate the driving forces, assess the impact, evaluate community coping strategies and their responses towards a better environment. The developed assessment framework was tested for its robustness in the Bolgatanga and Talensi-Nabdam districts of northern Ghana. While most of the study area was a healthy environment in 1990, by 2004 about 600 km² of the land area was degraded to the point where it could not be used for any commercial purposes. Spatially, the problem was more pronounced in the mid-north of Bolgatanga and northeast of Talensi-Nabdam as identified from fieldwork and the interpretation of satellite images. It was observed that the problem of environmental degradation is aggravated by socio-economic and cultural processes that motivate individuals to engage in activities that exert many pressures on the environment. Impacts were evaluated to include threats of desertification, food shortages, cross-cultural tensions, health risk and reduction in living standards. Driving force reduction, effective environmental management practices, environmental awareness programmes and compensation to affected communities were responses participants perceived would help realise a better future environment. Based on the research findings, the thesis concludes that the developed assessment framework is an effective means of organising complex environmental information for environmental decision making.

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List of Abbreviations

AHURI.....	Australian Housing and Urban Research Institute
CDD.....	Centre for Democratic Development
CERSGIS.....	Centre for Remote Sensing and Geographical Information Services
CIFOR.....	Centre for International Forestry Research
CREED.....	Collaborative Research in the Economics of Environment and Development
CSIR.....	Centre for Scientific and Industrial Research
CSIRO.....	Commonwealth Scientific and Research Organisation
DPSIR.....	Driving force-Pressure-State-Impact-Responses
DSR.....	Driving force-State-Response
ECSP.....	Environmental Change and Security Program
EEA.....	European Environmental Agency
EPA.....	Environmental Protection Agency
ERDAS.....	Earth Resources Data Analysis System
EU.....	European Union
FAO.....	Food and Agriculture Organisation
GIS.....	Geographical Information System
GISOC.....	International Conference on GIS and Society
GNA.....	Ghana News Agency
GPS.....	Global Positioning System
GSMF.....	Ghana Social Marketing Foundation
GSS.....	Ghana Statistical Service
HIV/AIDS.....	Human Immunodeficiency virus/Acquired immune deficiency syndrome
IAIA.....	International Association for Impact Assessment
ICPD.....	International Conference of Population and Development
IDS.....	Institute for Development Studies
IFAD.....	International Fund for Agricultural Development
IIED.....	International Institute for Environment and Development
ILMAD.....	Institute of Land Management and Development
ISODATA.....	Self Organising Data Analysis
ISSER.....	Institute of Statistical Social and Economics Research
ITC.....	International Institute for Geo-Info Science and Earth Observation
IUCN.....	International Union for the Conservation of Natural Resources
KNUST.....	Kwame Nkrumah University of Science and Technology
LCS.....	Lands Commission Secretariat

MIGIS.....	Mobile Interactive Geographical Information System
MEA.....	Millennium Ecosystem Assessment
MOFA.....	Ministry of Food and Agriculture
NCGIA.....	National Centre for Geographic Information and Analysis
NDC.....	National Democratic Congress
NEAP.....	National Environmental Action Plan
NGO.....	Non Governmental Organisations
PGIS.....	Participatory Geographical Information System
PhD.....	Doctor of Philosophy
PLA.....	Participatory Learning and Action
POLIS.....	Politics and International Studies
ODI.....	Overseas Development Institute
OECD.....	Organisation for Economic Co-operation and Development
PMA.....	Private Midwives Association
PNDC.....	Provisional National Defence Council
PPAG.....	Planned Parenthood Association of Ghana
PSR.....	Pressure-State-Response
P3-DM.....	Participatory 3 Digital Modelling
RCC.....	Regional Coordinating Council
RIVM.....	Natural Institute for Public Health and the Environment
SARI.....	Savannah Agricultural Research Institute
SCOPE.....	Scientific Committee on Problems of the Environment
STD.....	Sexual Transmitted Diseases
UN.....	United Nations
UNCCD.....	United Nations Convention to Combat Desertification
UNCED.....	United Nations Commission on Environment and Development
UNCSD.....	United Nations Commission for Sustainable Development
UNECA.....	United Nations Economic Commission for Africa
UNESCO.....	United Nations Education, Scientific and Cultural Organisation
UCGIS.....	University Consortium for Geographical Information Science
UNEP.....	United Nations Environmental Program
UNDP.....	United Nations Development Program
UNFPA.....	United Nations Population Fund
UNUP.....	United Nations University Press
URISA.....	Urban and Regional Information System Association
UNRISD.....	United Nations Research Institute for Social Development

WCED.....	World Commission of the Environment and Development
WMO.....	World Meteorological Organisation
WRI.....	World Resource Institute

Chapter 1

Philosophical Setting and Justification of Study

1.1 Introduction

Environmental degradation has now become a global phenomenon that needs to be researched into and modified for better human wellbeing and development. This arises because of the realisation that the environment holds fundamental but finite resources for economic and social development and should therefore be used sustainably (WCED, 1987; Briassoulis, 2000; EU, 2003). The underlying logic is that by protecting it and maintaining its intrinsic value, the environment will serve mankind's needs for now and future generations (WCED, 1987; UNEP, 1998; Stern, 2006). According to Dregne *et al.* (1991) and Solbrig and Young (1992), regions worldwide face unprecedented environmental degradation problems particularly in savannah environments of developing countries where the natural environment is perceived to be under greatest threat.

Although natural processes such as adverse climatic conditions, earthquakes, drought, tsunamis and hurricanes have been identified as major causes of environmental and resource depletion, human activities such as indiscriminate grazing, large and small-scale mining, sand and stone quarrying, periodic bush burning and firewood harvesting, have played an increasingly important role in driving the environments of many developing countries far beyond their carrying capacity, causing unprecedented degradation and depletion of natural resources (WCED, 1987; William, 1998; EEA, 1999).

Assessment of environmental degradation and natural resource depletion has therefore become a global issue for the long-term management of natural resources and the sustenance of livelihoods that depend on them (William, 1998).

As proposed by Turner (1989), Pierce (1998), Reed *et al.* (2007) and Stringer and Reed (2007) key steps should be taken in the assessment of human driven environmental problems through research into the scientific and social determinants and the adoption of an appropriate environmental assessment procedure. The concept of participatory GIS (PGIS) emerged from such proposals as a potential tool for facilitating the integration of geo-spatial information technologies and systems with community-centred initiatives for natural resource assessment (Sheppard, 1993; Obermeyer, 1995; Pickles, 1995; Baar and Dixon, 1998; Abbot *et al.*, 1998; Barndt, 1998; Leitner, *et al.*, 1999; Pickles, 1999; Kingston *et al.*, 2000; Carver, 2001; Kyem, 2002a; Harris and Weiner, 2002; Craig *et al.*, 2002; Allen and Goers, 2002; Fox, *et al.*, 2003; William and Dunn, 2003; Bhattacharyya, 2006). PGIS have become an effective methodological approach for integrating community local knowledge into complex spatial decision-making processes in locations where infrastructure is in place and access to geo-spatial technologies already exist (Craig *et al.*, 2002).

Since its inception in the last decade, there have been numerous adoptions of the PGIS concept that specifically address the needs of communities in areas such as natural resource management, conflict resolution, demarcations of traditional land boundaries, land and agrarian reforms, watershed management, impacts of landmines, forest resource management and environmental policy planning formulation through different forms of participation (Kyem, 1998; Rambaldi and Callosa, 2000; Carver, 2001; Kingston *et al.*, 2002; Craig *et al.*, 2002; Gonzalez, 2002; URISA, 2002; Harris and Weiner, 2003; Williams and Dunn, 2003; alongside many others).

Though a concept of emerging interest, however, neither PGIS nor its modified forms have been utilised to assess the holistic and complex nature of environmental degradation (see PGIS bibliography compiled by Sieber, 2006 at <http://www.crssa.rutgers.edu/ppgis/>). This is especially true of peripheral regions in many developing countries, such as northern Ghana where there are pronounced human-driven, input-related and accelerated environmental degradation problems that need to be assessed holistically for environmental decision-making processes.

The DPSIR (**D**iving forces-**P**ressures-**S**tate-**I**mpact-**R**esponses) assessment framework formulated by the European Environmental Agency of the European Union allows for the integration of various factors of environmental related problems, thus describing the relationship between the underlying causes and impacts on the environment, identifying and assessing current responses to mitigate or reduce the pressures and impacts. The DPSIR framework is widely used to structure various factors of environmental degradation to allow for a holistic and multi-dimensional view of causal relationships in human-environmental systems (EEA, 1999).

The state of the environment can be assessed and evaluated through the design of an appropriate assessment methodology which identifies alternative options and intervention for a better environment (EEA, 1999). Despite the importance of the DPSIR framework in assessing environmental degradation it failed in its formulation and implementation to provide an appropriate methodological framework to measure the inclusive five indicators. The PGIS methodological framework and the DPSIR assessment framework have never been integrated, in any past related environmental studies, to assess environmental degradation.

1.2 Research aim

This research seeks to address the above intellectual gaps. The aim is to investigate the potential for the integration of local ecological knowledge and GIS techniques to assess the complex interplay of driving forces, pressures, the spatio-temporal state of the environment, impacts, responses and coping strategies spelt out in the DPSIR framework and prompted by the need to solve complex environmental problems in northern Ghana.

In this study, a GIS based participatory approach case study involving the Bolgatanga and Talensi-Nabdam districts of the Upper East Region of northern Ghana is presented. Environmental resources in the area are characterised by a dry savannah climate and vegetation, poor soils, and irregular rainfall patterns leading to poor yields and levels of production (see chapter 4 of this thesis). The area is one of the worst degraded regions in Ghana with high illiteracy rate, poverty stricken, complicated land tenure system and high population growth rate. It is perceived that socio-economic and cultural processes such as poverty, migration and loose land tenure system have motivated certain individuals or group of people in the study area to take on human activities such small-scale legal and illegal mining that put pressures on the environment beyond its carrying capacity. The Bolgatanga and Talensi-Nabdam districts of northern Ghana thus offer an interesting case study for the utilisation of modified PGIS and DPSIR frameworks to conceptualise the underlying forces that motivate individuals to take up activities that put more pressures on the environment leading to environmental degradation.

It is argued here that the state of the environment in the study area is determined by the interactions among several factors, the most important of which are small-scale legal and illegal mining and indiscriminate grazing which are driven by socio-economic and cultural root causes such as poverty, high population growth, migration and loose tenure system. Through the impacts on the state of the environment, the root and underlying causes push the environment towards a state of unsustainability.

1.3 Research objectives

The objectives within this thesis are:

1. Design a methodological framework for assessing environmental degradation that specifically addresses the five indicators of the DPSIR framework and an additional variable of coping strategies;
2. Test the robustness of the designed assessment methodology in a case study area (Bolgatanga and Talensi-Nabdam districts of northern Ghana) that is perceived to have undergone spatio-temporal environmental degradation; and
3. Provide recommendations for the implementation of the proposed assessment methodology in other similar environments in the light of its potential and constraints confronted during the testing of its robustness.

1.4 Research questions

The developed methodology would seek to address the following research questions:

1. To what extent have the environments of Bolgatanga and Talensi-Nabdam districts of northern Ghana been degraded since 1990? How severe is the degradation in terms of potential rate of recovery and which areas in the two districts are mostly affected?
2. What socio-economic and cultural forces usually motivate individuals to take up activities that put pressures on the environment beyond its carrying capacities? How are they interrelated, spatially distributed and ranked in terms of their relative importance?
3. What are some of the negative outcomes of the observed environmental degradation in the study area in terms of the physical, social and cultural impacts, how severe are the impacts? How are they spatially distributed, ranked and which groups are mostly affected?
4. How are the affected communities coping with the observed changes on the environment?

5. What are the possible responses to alter the impacts of stresses on the environment and their relative importance?

1.5 Significance of study

This PhD thesis research is significant in two distinct ways:

1. it demonstrates how a modified PGIS methodological framework can be utilised to assess environmental degradation in an environmental degraded community; and
2. it will demonstrate to environmental decision makers, at the strategic level, the importance of PGIS and how to apply it, within environmental planning processes, to solve those rural and peri-urban environmental problems that are prevalent in many savannah communities of Africa.

1.6 Justification

The research is timely as it was undertaken during the period in Ghana where:

1. There is great concern among various stakeholders, state government, civil societies, non-governmental organisations (NGOs), district assemblies and other related environmental agencies as to the current threat of environmental degradation (EPA, 2003, p.13).
2. It is estimated that the annual cost of environmental degradation is \$1.2 billion, (equivalent of 11 trillion Ghanaian Cedis) and representing 10% of the total Gross Domestic Product (GDP) of the country (EPA reported in GNA, 2007).
3. In northern Ghana, the estimated cost of environmental degradation is \$128.3 million (5 trillion Cedis), representing 4% of the total Gross Domestic Product (EPA reported in GNA, 2007).
4. It is estimated that in the savannah woodland vegetative zone, 14.7 million hectares of the original 15.6 million hectares are under serious threat of degradation (EPA reported in GNA, 2007) (Appendix 1.1).
5. There is a general lack of scientific data for environmental assessment in Ghana (Appendix 1.2) particular the three northern regions and all the leading institutions

responsible for data collection in the area of environmental degradation lack the very basic facilities for efficient operation (EPA, 1991).

Thus, the incorporation of local knowledge and conventional GIS in this thesis may help resolve the lack of scientific data for environmental assessment in Ghana and also facilitate the involvement of local people and encourage local participation and bottom-up approaches to environmental decision making.

1.7 Research focus

Taking into consideration that the economics of many developing countries that are land resource dependent, this study is narrowed to spatio-temporal land-use changes associated with environmental degradation. Natural causes of environmental degradation, even though relevant, do not form a major part of this study. However, meteorological data (rainfall, temperature and relative humidity) will be used to triangulate observations made by research participants concerning the indirect causes of environmental degradation.

The study is focussed on spatial and social issues of environmental problems narrowed to the Bolgatanga and Talensi-Nabdam districts as representative of all of northern Ghana. Biological and chemical measurements of pollutants in air, water and soils, and toxicology of human body resulting from the processes and operations of the various human activities in the study area, even though relevant in the assessment of environmental degradation, were out of scope of this thesis.

Three non-linear, historical and recent satellite images from 1990, 2000 and 2004 were used for spatial analysis to determine the current and recent state of the environment as made available from the Centre for Remote Sensing and Geographical Information Services (CERSGIS) of the University of Ghana, Legon. Detailed statistical analysis such as cellular automation and vector change analysis, even though of relevance in land-cover change detection analysis did not form part of this thesis. This thesis is rather based on the philosophy of PGIS (Pickles, 1995, Abbot *et al.*, 1998; Pickles, 1999; Carver, 2001; Harris and Weiner,

2002; Williams and Dunn, 2003) that advocates the empowerment of the public in spatial analysis and decision-making processes.

1.8 Research methodology

The main stages of the assessment methodology are shown in Figure 3.1 of chapter 3. The process commences with an overview of literature (chapter 2) of central themes that form the core of the study and lead to the development of the assessment methodology. Taking into consideration the nature of the research topic, the proposed assessment framework is composed of two distinctive but complementary phases which is an example of the contemporary discourses procedure of applied planning research (Cardoso, 2005). The first phase is the use of conventional GIS techniques to evaluate and assess the spatio-temporal state of the environment of the study area in terms of land-cover changes from 1990 to 2004. This is achieved through raw image data processing, post-classification change detection analysis and ground truthing.

The second phase is the adoption of a participatory research, dubbed “*community truthing*”, to critically review the first phase, verify the GIS statistical results, examine the driving forces, pressures and impacts of the observed environmental changes and what ought to be done to realise a healthier environment. The assessment methodology is based on the argument that neither a conventional GIS nor a participatory research approach can successfully be utilised singly as a stand-alone technique to assess complex environmental problems without their possible integration. The designed assessment methodology is further tested for its rigour in the Bolgatanga and Talensi-Nabdam districts of northern Ghana where the natural environment is perceived to be under serious threat of degradation.

1.9 *Research structure and interrelationships*

To achieve the aim and objectives of the study the thesis is organized into eight chapters containing:

- Synopsis of the aims, context and relevance of the chapter (introduction).
- Presentations and analysis of the various findings (analysis).
- Final observations on the chapter's outcome (conclusion).

Chapter 1 provides the philosophical setting and justification of the study. It involves a brief synthesis of relevant information on environmental degradation and participatory GIS and identifies major gaps in current knowledge of the research topic. In addition, the chapter highlights the research aim, objectives, justification, case study area and scope of study.

Chapter 2 discusses several major themes central to the derivation of an assessment methodology for environmental degradation assessment. The chapter is in two parts. The first part is a comprehensive review of options of assessment frameworks such as stress-response framework, pressure-state-response (PSR) and the driving force-state-response (DSR). The five indicators of the DPSIR framework together with a coping strategies indicator are reviewed comprehensively to justify its adoption in this thesis. The later part of the chapter reviews the GIS and Society concept through which PGIS emerged. The choice of a GIS-based participatory research approach developed by Abbot *et al.* (1998) and modified by Williams and Dunn (2003) is justified in this chapter.

Chapter 3 is central to this research and devoted to the design of the proposed assessment methodology for environmental degradation assessment. Here, three selected case studies are reviewed, in detail, to identify potential gaps and common themes that are later used to structure the assessment design. Theories of systems approach and analytical tools that form the component parts of the structured assessment methodology are reviewed in this chapter to justify their adoption.

Chapter 4 present the detailed account of the pre, actual and post-field work in the Bolgatanga and Talensi-Nabdam districts of northern Ghana. It is in two parts. The first part justifies the choice of Bolgatanga, Talensi-Nabdam districts of northern Ghana to test the robustness of the proposed assessment methodology. The changing physical and social processes of the area that can be related to the threat of environmental degradation are presented in this part of the chapter. The second part of the chapter is devoted to methods of data sourcing and analysis to meet the research questions.

The analysis of the GIS based participatory results is the subject of chapters 5, 6 and 7. Chapter 5 is the first presentation of the analysis of *GIS based participatory assessment methodology* results. Results of the extent, magnitude and trend of land-cover changes are presented and analysed in this chapter. The chapter tries to justify how conventional GIS can be integrated with participatory research tools to assess the state of the environment and pressure indicators of the five indicators of the DPSIR framework. Subsections of the chapter include participants' observations of the spatial distribution of land-cover types, spatio-temporal replacement of savannah trees and grasses, trends and patterns of land-cover types and land-uses, their relative importance, and their complex interplay to effect changes on the natural environment.

Chapter 6 focuses on the assessment of the driving forces, impacts and coping strategies of the spatio-temporal environmental changes, presented and analysed in chapter 5. The relative importance and interrelationships of the driving forces and impacts, deduced from research participants' views and comments that collectively influence the spatio-temporal state of the environment are also examined and discussed in this chapter.

Chapter 7 examines how the proposed assessment methodology could be utilised to solicit participants' responses on what ought to be done to realise a quality environment. As part of the chapter, deductions are made concerning the possibility of merging traditional

environmental management practices and the National Environmental Action Plan (EPA Act 490) for an effective environmental policy formulation.

Chapter 8 is a reflective and concluding chapter. The overall picture in terms of the scope of the thesis, research findings and their relevance in policy formulation, reflection of the proposed assessment methodology in terms of their merits and shortcomings, lessons learnt through the adoption of the assessment methodology in assessing environmental degradation and the recommendations for future research are evaluated in this final chapter.

1.10 Expectations

It is expected, at the end of the thesis, that the proposed assessment methodology, through its utilisation in a critical realistic manner, could be used to answer all the research questions as stated in section 1.4.

Chapter 2

Environmental Degradation and Assessment: Theoretical Positions and Conceptual Frameworks

2.1 Introduction

Having established the philosophical setting and justification of the research study in chapter 1, this chapter moves to establish the theoretical background and conceptual frameworks for this thesis. The chapter is in two parts. The first part reviews the complexities associated with global environmental problems and the numerous assessment frameworks put in place to address the sensitivity and resilience of environmental degradation worldwide. The second part places the research thesis within a broader GIS and Society conceptual framework and highlights the main objectives of Participatory Geographic Information Systems that forms the basis of this research.

2.2 Environmental degradation and assessment: Conceptual framework

Environmental degradation is the deterioration of the natural environment through human activities and processes and natural disasters that ultimately affect the physical and social environment (UN, 1997). According to the International Strategy for Disaster Reduction (ISDR) (2004), environmental degradation is the reduction of the environment to meet social and ecological objectives and needs and include issues such as land degradation, deforestation, desertification, loss of biodiversity, land, water and air pollution, climate change, sea level rise and ozone depletion.

Environmental degradation has recently become a matter of global concern. There is now widespread recognition that human development is a holistic concept that involves not only on economic and social aspects but also through the wise use of the natural capital stock

(Essam and Manzur, 1987). The landmark report of the World Commission on Environment and Development warned that unless mankind changes many of its present lifestyle, the world would face severe and unprecedented environmental degradation (WCED 1987). The growing realisation of the importance of environmental degradation has emerged repeatedly in many international conferences on human and his environment.

The United Nations Conference on Human Environment convened in Stockholm in 1972 and the first of its kind on the issue on the environment brought into focus the realisation that the environment has limited assimilative and carrying capacity and that control measures should be instituted to safeguard the environment for quality of human life.

The earth Summit in 1992 (20 years after the Stockholm 1972) had environmental degradation as one of its major themes and one of the main functions assigned to the Governing Council of the United Nations Environmental Programme by the General Assembly is to keep under review the world environmental situation in order to ensure that emerging environmental problems receive appropriate and adequate attention by governments ((Essam and Manzur, 1987).

The World Summit in 2004 that took place in Johannesburg, South Africa was purposed to assess the outcome of the declarations of the Earth Summit and the possible implementation of the Agenda 21 by member states. Despite these efforts to safeguard the natural environment and prevent further environmental degradation and the depletion of natural resources there is still unprecedented global increase in environmental and related problems as evidence in the report of WCED (1987).

2.3 Concept of sustainability

The popularisation of the concepts of sustainability has continued since the publication of the Brundtland Report (WCED, 1987). Sustainability is neither about the integration of ecological, social and economic issues, nor about improving quality of life. It is a socio-ecological process characterised by the fulfilment of human needs while maintaining the quality of the natural environment indefinitely (Shutton, 2000). The linkage between the environment and development was globally recognized in 1980 when the International Union for the Conservation of Nature published the World Conservation Strategy and used term “sustainable development”. The concept came into general usage following the publication of the 1987 report of the Brundtland Commission of the World Commission on Environment and Development. Set up by the United Nations General Assembly, the Brundtland Commission defined what was to become the most often-quoted definition of sustainable development as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. According to Cabezas *et al.* (2003), the concept of sustainability can be broken down into three interrelated constituent parts: environmental (ecological) sustainability, economic sustainability and social sustainability, as exemplified in the Figure 2.1 below.

Ecological	Social	Economic	
Survival sustainability			Global ↑ ↓ Local
Protection of life support systems Prevention of species extinction	Capacity to solve serious problems	Subsistence	
Maintaining quality of life			Global ↑ ↓ Local
Maintenance of decent environmental quality	Maintenance of decent social quality (eg. vibrant community life)	Maintenance of decent standard of living	
Improving quality of life			Global ↑ ↓ Local
Improving environmental quality	Improving social quality	Improving standard of living	

Figure: 2.1: Sustainability interrelationship

Source: Shutton (2000)

2.3.1 Environmental/ecological sustainability

The environment is a complex and dynamic system that displays characteristic regimes of behaviour dictated by their internal dynamics and disturbances that act on them (Scheffer, *et al.*, 2001). With reference to Figure 2.1, environmental sustainability is defined as the ability of the environment to continue to function properly indefinitely. It involves meeting the present needs of humans without endangering the welfare of future generations (Daly and Cobb, 1989; Daly, 1999). The aim of environmental sustainability is to minimise environmental degradation and to mitigate and prevent or reduce the processes they lead to (WCED, 1987).

Environmental sustainability inherently requires that the environment retain their ability to function through environmental degradation and pollution and if necessary provide the carrying capacity to form appropriate ecosystem structures and functions as the natural environment undergoes various changes (Hollins, 1973).

An unsustainable situation occurs when the environment is manipulated faster than it can be replenished. Sustainability requires that human activities only use nature's resources at a rate at which they can be replenished naturally. However, due to numerous anthropogenic pressures on the environment such as over-harvesting, over grazing, mining and quarrying the connectivity of the environmental systems declines and critical functions of the environment may no longer be provided (Kearns, 1997). The nature of disturbances on the environment that can be tolerated by an ecosystem before a change in regime occurs is a measure of the ecosystem's resilience to disturbances (Hollins, 1996; Gunderson, 2000).

2.3.2 Economic sustainability

Many development theories have equated developments in terms of an economic growth model which is seen as increasing the economic output and capacity of the national economy to generate an annual increase in its Gross National Product and Gross Domestic Product (Aubynn, 1999). However, economic sustainability is not just about achieving economic growth year on year. As observed from Figure 2.1, economic sustainability is about understanding that economic growth is only sustainable if it simultaneously improves our quality of life and the environment. Economic sustainability underscores that development that does not improve the quality of life and the protection of the environment, irrespective of economic growth is not sustainable (WCED, 1987; Todaro, 1989)).

2.3.3 Social sustainability

The Johannesburg Earth Summit in 2004 focused sustainable development onto social issues and identifies the needs of individuals and their well-being. One of the core aims of the summit was that sustainable development must take into account social factors as well as economic and environmental considerations. Social factors include things such as: numbers of people with jobs, poverty, opportunities for education and training, health and availability of medical services, human rights and equal opportunities, crime and social disorder levels, housing provisions and quality (Johannesburg Earth Summit, 2004). According to Goodland (2002), social sustainability involves the maintenance of social capital through investments

and services that create the basic framework for society that lowers the cost of working together and that include the cohesion of community for mutual benefit, connectedness between groups of people, tolerance, compassion, patient, forbearance, commonly accepted standards of honesty, discipline, ethics and regards to the intrinsic value of the natural environment. He went further by saying that social sustainability requires maintenance and replenishment by shared values and equal rights through community, religious and cultural interactions without which the social and the environmental systems depreciates.

2.4 Environmental degradation and assessment frameworks

Studies on environmental assessment and natural resource management have shown that assessing the cause-effects relationship of environmental degradation requires a multi-dimensional approach (Alcamo *et al.*, 1998; Stafford-Smith and Reynolds, 2002; Ostrom *et al.*, 2002). In line with this, several conceptual frameworks for environmental degradation assessment have, over the years, been formulated by various research agencies to address the issue of human-environment interaction and the corresponding physical and social impacts (Machlis *et al.*, 1997; Luzadis *et al.*, 2002).

2.4.1 Stress-Response framework

A large number of assessment frameworks of the relationship between humans and environment lie scattered throughout the literature. The concept of stress at the crossing point between human and the environment was first introduced in the 1950s to mean something acting on and influencing human well-being. Examples included the stress on people caused by disasters (Janis, 1954) or human migration as an adjustment to environmental stress (Wolpert, 1966). Recently, an important conceptual advance has emerged from state-of-the-environment reporting. The UN Statistical Office in the mid 1970s developed a general framework of environmental statistics through a joint initiative with Canada that led to the development of the Stress-Response Environmental Statistical System (STRESS) (Rapport and Friend 1979). By means of concepts of environmental stress and environmental response, this focuses on the interface between production-consumption activities of humans and the

transformation of the state of the environment. Four categories of statistics were identified that dealt with activity stressors, environmental stresses, environmental responses, and collective and individual human responses. Friend and Rapport (1979) linked indicators of environmental stress and response with indicators of economic performance and indicators of demand and supply of natural resources.

The stress-response approach has had a major impact on environmental reporting around the world (Hodge, 1991). This is seen in the current DECD approach to environmental policy analysis (Comolet, 1992). Rapport and Friend (1979) initially incorporated a category for extreme natural events such as storms, floods, drought, volcanic eruptions, earthquakes, landslides and outbreaks of disease but now the focus is on the effects of human activities such as mining and grazing on the environment. The exclusion of natural influences is but one of several serious limitations to current expressions of the stress-response concept, one that reduces significantly its usefulness for sustainability reporting and assessment.

2.4.2 Pressure-State-Response framework

The Pressure-State-Response (PSR) assessment framework of OECD (Organisation for Economic Cooperation and Development) (OECD, 1994) was a step further from the stress-response framework of Rapport and Friend (1979). The framework, illustrated in Figure 2.2 (Jesinghaus, 1998), is used by OECD, SCOPE and some other organisations working in the field of environmental and natural resources management. The PSR framework is the most widely accepted of the many frameworks advocated, having been adopted by the OECD for its State of the Environment group. The European Environmental Agency of the European Commission has also used the PSR approach in assessing various environmental problems (Jesinghaus, 1998). The PSR was the framework used in the Environmental Indicators of the OECD Core Set document (OECD, 1994) and is also used in the methodology of the World Bank's Land Quality Indicator programmes.

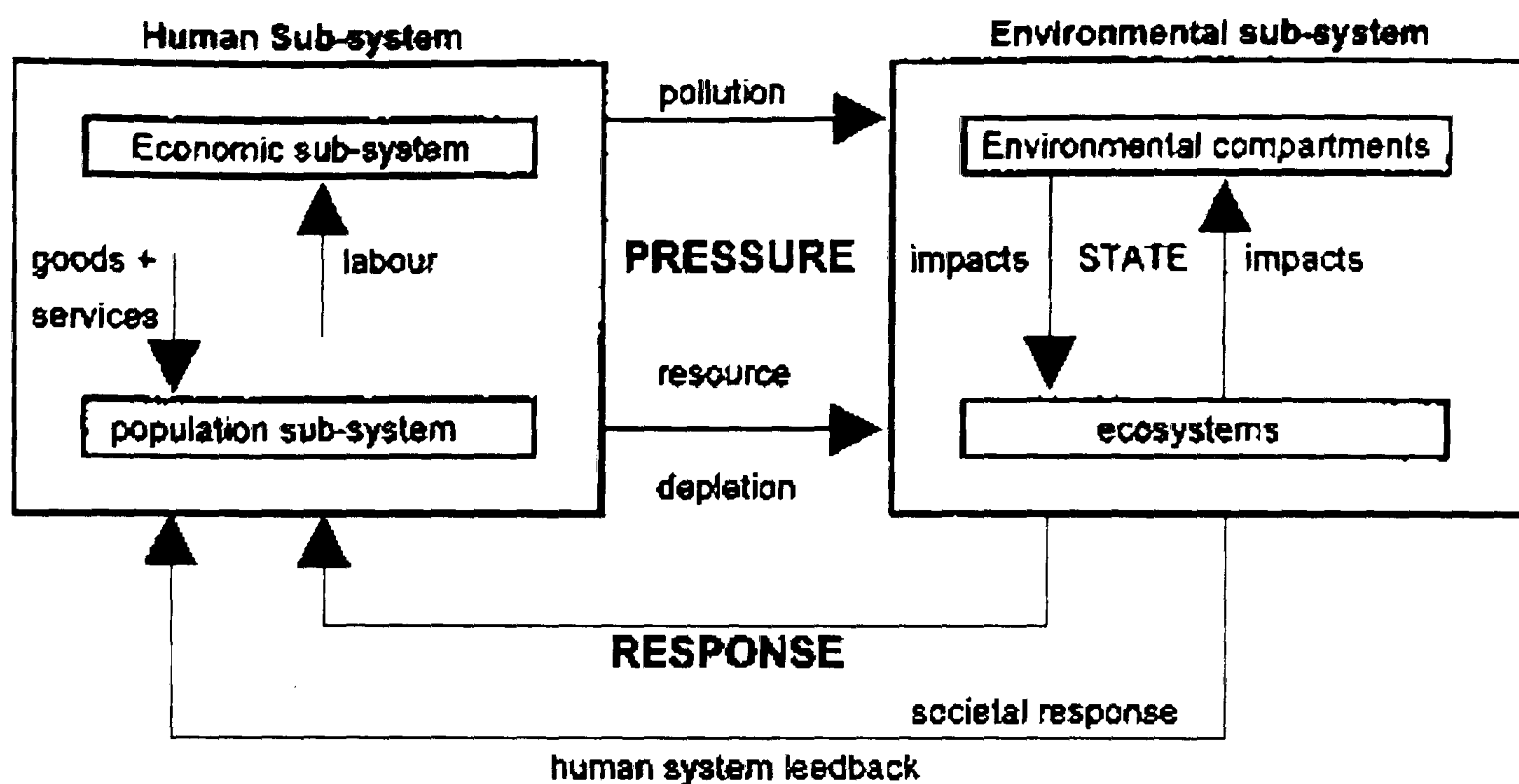


Figure 2.2: Pressure-State-Response Framework

Source: RIVM/UNEP (1995).

The PSR framework takes into consideration, the “*pressures*” which describes the intensity and extent of human activities acting directly on the environment beyond its carrying capacity. Pinter *et al* (1999) gave examples of pressures that include energy consumption, transportation, and industry as engine of growth, intensive agriculture, forestry and logging. The “*state*” refers to the baseline state of the environment as judged from areas relatively unaffected by direct human activities. Examples include air pollution, water contamination, land degradation, depletion of renewable and non-renewable natural resources, and expansion of human settlement (Pinter *et al*, 1999). The “*responses*” deals with the impacts of stresses on the environment and assess the human actions, such as legislation, new technology, economic instrument, economic expenditures, changing consumer preferences and international conventions, undertaken to protect the environment (Gallopín, 1997, p.22). The PSR assessment framework, despite its potential capability for assessing environmental problems, was devoid of a methodological approach. In addition, the discontent with the idea that only human actions cause changes to the environment which prompts society’s responses is one of the motivations for the development of other assessment frameworks.

2.4.3 Driving force-State-Response framework

The Driving force-State-response (DSR) framework relating to indicators of sustainable development was first initiated by UNCSD (1997) to consider the shortcomings of both the stress-response and the PSR framework. The framework, instead, considered the driving forces (poverty, migration, land tenure system, human attitude and behaviours and economic policies such as structural adjustment programs) of environmental problems that did not feature in both the stress-response and PSR frameworks. The replacement of the term “*pressure*” in the PSR framework by the term “*driving force*” was motivated by the desire to include economic, social and institutional aspects of environmental problems (UNCSD, 1997; EEA, 1999). The World Bank adopted the DSR framework in its work on indicators of environmentally sustainable development (World Bank, 1995a), even though in 1997 it published World Development Indicators (World Bank, 1997) which used the PSR framework.

A major advantage of the DSR framework is that it organizes information on sustainable development systematically in a way that guides the user of the framework through all aspects of sustainability. In distinguishing between the social, economic and environmental aspects of sustainable development, the framework ensures that no aspects of sustainability indicators are automatically excluded. The inclusion of the economic and social aspects is particularly important for developing countries with economies in transition, for which an equal balance between the developmental and environmental aspects of sustainability is important in order to ensure future sustainable growth patterns (UNCD, 1997).

The DSR works perfect when an environmental stress has been identified and linked to a causative set of human activities. However, there are circumstances where environmental changes are not predictable. The real need in terms of achieving progress towards sustainability is to achieve some degree of anticipatory capacity so that issues can be recognized before they become concern not simply to take action after there are crises. The DSR framework does not encourage the development of such a capability. The DSR approach

also failed to distinguish beneficial from harmful environmental impacts. As explained by Berger and Hodge (1998), flooding of farmlands may destroy crops and property but it may also be the main source of nutrients to enhance the productivity of the same farmland. Wildlife destroys forests, plants, animals, and property, but it is now seen that they may also be required for forest regeneration.

2.4.4 Driving force-Pressure-State-Impact-Response framework

The European Environmental Agency (EEA), within the legal basis of the European Union Environmental Policy, Acts 95, 174, 175 and 176 of the consolidated version of the Treaty on European Union and under the auspices of the European Commission, in their effort to introduce environmental issues in their developmental agenda, further improved the existing assessment frameworks into a five indicator framework (which includes PSR and DSR as special cases) dubbed the “DPSIR assessment framework” (Jesinghaus, 1998; Pierce, 1998; EEA, 1999).

Within the Driving force-Pressure-State-Impact-response (DPSIR) framework (Figure 2.3), each indicator conveys its own distinctive meaning and application.

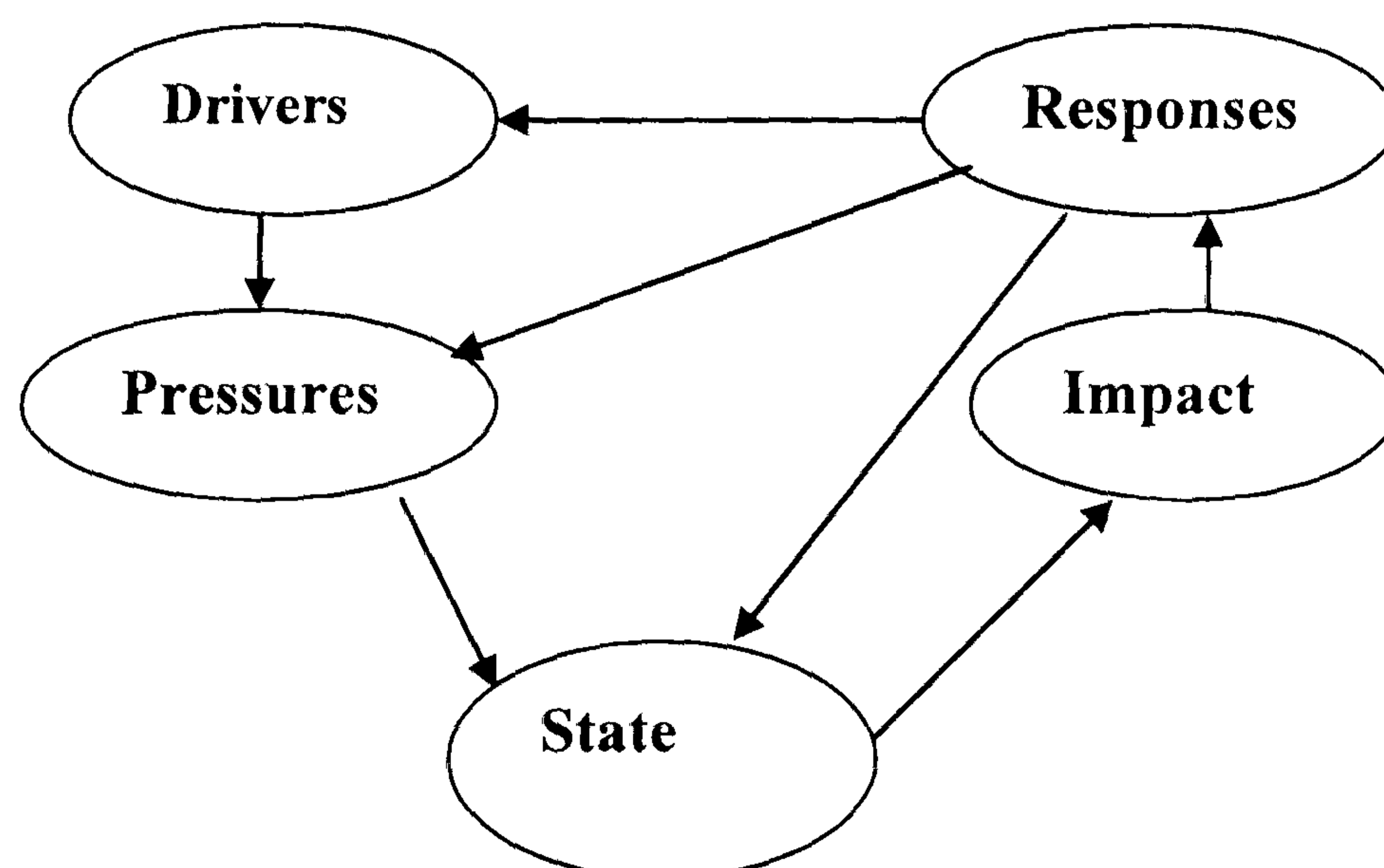


Figure 2.3: DPSIR assessment framework.

Source: Modified from Pierce (1998).

With reference to the objectives of this study, “*driving forces*” are social processes that cause either the increase or mitigation of pressures on the environment. Examples of such social processes are population growth, migration, poverty, level of production, human behaviours and attitudes and consumption pattern (Rigby, *et al.* (2000). “*Pressures*” are represented by direct human activities on the environment, such as exploitation and excessive consumption of natural resources, beyond its carrying capacity, carbon dioxide emission into the environment, the use of fluorocarbons, use of mercury, lead, arsenic and cyanide in the purification and smelting of gold ores and the use of lead as an ingredient of gasoline (Rigby, *et al.*, 2000). The “*state*” relates to the spatio-temporal changes to the environment that include rising global temperatures, ozone layer depletion, environmental degradation, soil erosion, soil compaction, desertification, deforestation, global warming, acidification and eutrophication. The “*impacts*” are the consequences of observed changes on the environment that include fall in agricultural production, percentage of children suffering from lead induced problems, food insecurity, malnutrition, mortality due to noise-induced heart attacks and number of people starving due to climate-change induced crop losses. The “*responses*” are what the society perceives to be done to realise a better environment and that include introduction of energy taxes, polluter pays principles, environmental conservation, environmental movement, environmental awareness programmes, environmental capacity building and mitigation measures (Pierce, 1998).

It is argued in this thesis that the DPSIR framework provide much better indications on how to analyse and assess environmental degradation despite its failure to provide an appropriate methodology to assess the five-partite indicators. The following sections are detailed review of theoretical and empirical evidences of the five indicator DPSIR framework of relevant to this thesis.

2.5 State of the environment

Environmental degradation has become a matter of global concern as recently witnessed by the United Nations Environmental Program (UNEP) through the launching of the “*World Atlas of Satellite Images*” to mark the world environmental day in 2005. Before then, statistical evidence of the global state of the environment by the United Nations had estimated that of the 8.7 billion hectares of arable land, pastures and forests worldwide, nearly 2 billion of them have been degraded over the past 50 years, of which 18% are of forest land, 21% of pasture land and 37% of arable land (Haafte *et al.*, 2004).

The third assessment of the world status of desertification undertaken by UNEP in 1990-1991 (UNEP, 1991) estimated that about 43 million hectares of irrigated lands or 30% of the total area in the world’s dry lands (145 million hectares) are affected by various processes of environmental degradation, nearly 216 million hectares of rain-fed croplands or about 47% of their total area in the world’s dry lands (457 million hectares) are affected by various processes of environmental degradation and about 3,333 million hectares of rangeland or nearly 73% of its total area in the world’s dry lands (4,556 million hectares) are affected by degradation of vegetation. It is also documented in the Brundtland report of the “World Commission of Environment and Development” that, each year, 6 million hectares of productive dry lands turn into worthless desert (WCED, 1987).

New scientific evidence indicates that many global ecosystems are reaching dangerous thresholds especially in many developing countries. Environmental degradation is leading to more severe natural disasters which have already cost the world over \$608 billion in the last decade, killed and displaced over 8 million people, mainly poor people in most developing countries in 1998-1999 alone (Worldwatch, 2001). The FAO/UNESCO/WMO (1977) also gave an estimation that the annual loss of productive land due to environmental degradation amounted to US\$26 billion with annual cost of reclamation measures estimated at US\$388 million.

Other statistical evidence has established that the highest rate of savannah forest loss in Africa has occurred in the West African sub-regions of between 1.3% and 1.5% per annum (FAO 1997; WRI 1994). In Ghana, , the estimated cost of environmental degradation is \$1.2 billion, equivalent to 11 trillion Cedis and representing 10% of the total GDP (as already stated in section 1.6 of chapter 1).

Theories concerning the agents of these global vegetative losses are placed within the natural and human context. Berry and Kim (1988) attributed the loss to global socio-economic transformation, cultural, political and technological changes. The Tragedy of the Commons, that involves a conflict over finite natural resources between individual interests and the common good, (Hardin, 1968) has also been used to illustrate the intense influence of human actions on the recent observed global environmental changes (Haafte *et al.*, 2004).

On the issue on the debate of agents of global environmental change, Sandford (1976) distinguished: (i) *the structuralist school* that identifies social and economic structures as directly responsible for global environmental changes; (ii) *the natural events school* that attributes global environmental problems to uncontrollable climatic changes; (iii) *the human cause argument* where human actions, activities, policies and programmes are perceived to be directly responsible for global environmental problems; and (iv) arguments concerning *population growth* as the direct determinant of environmental degradation. It is maintained in this thesis that the structuralist school, the human cause argument and population growth models fall within the human cause argument.

2.5.1 Natural events school

Even though it is beyond the scope of this thesis to discuss in detail, it is worth noting that natural disturbances occur spontaneously or are usually induced by human actions. The few who support the natural spontaneous reaction have argued that global environmental problems are exacerbated through extremes of climatic variations, (such as changing in solar radiation, global climatic changes, extreme weather events, droughts, floods, hurricanes, and cyclones,

fires, volcanic eruptions, earthquakes), local infectious agents, physical disasters and local-nutrient deficiencies (Tucker *et al.*, 1991; Hulme, 2001, among others). On the contrary, such occurrences, as reported by UNECA (2001) are often necessitated by human actions such as deforestation and urban expansion. This thesis will argue in favour of human manipulation of the environmental systems to bring about environmental degradation.

2.5.2 Human causes argument

Many have argued in favour of the human causes of global environmental problems. The Brundtland Report, “*Our Common Future*” (WCED, 1987) focuses on the possible human causes to global environmental problems as it maintained that such causes are aggravated by continual unsustainable use of the environment by human actions as illustrated in Figure 2.4 where human activities such as mining, grazing and mechanised farming affect the environmental quality and human well-being through degradation, depletion of natural resources, waste disposal and pollution. Other individuals and research organisations who have, in diverse ways, supported the human cause argument have presented a general outlook on the human-environment nexus included Goudie (1992); Anderson (1988); RIVM/UNEP (1995); Lindberg (1996) and Wood *et al.* (2000); Bartelmus (1986).

Most of them attributed the major causes of global environmental degradation to social transformation and urban expansion. For example, Essam and Manzur (1987), in their studies on desertification in arid regions of Africa, concluded that social processes are the main agents of the continual threat of desertification in these regions. Schreckenberg *et al.* (1990) and Bennet and Dalberg (1990) did similar studies and came out with research findings that supported the human cause argument of global environmental problems. Later on, Mather and Chapman (1995) supported the argument and asserted that the pace of global environmental problems has accelerated as a result of human indiscriminate actions on the environment and its finite natural resources. Recent observation was made by Harris (2004) who asserted that human issues cannot be exempted when one is assessing the agents and causes of environmental degradation.

The following research findings put more emphasis on the human cause argument of global environmental changes:

1. In Australia, it has been observed that human activities such as mechanised farming and coal mining, despite their contribution to the macro economy, have to severe degradation of the environment (Campbell *et al.*, 1994).
2. In the Brazilian Amazon forest, land-cover changes are affected by human institutions such as government mining policies and agricultural subsidies (Wunder, 2000).
3. In the Sudan Sahalian area, land-cover changes were partly attributed to responses to adverse climatic conditions but to a larger extent by human socio-economic such as poverty, population growth, migration and the adoption of the structural adjustment programmes (Ahlcrona, 1988).
4. In Tanzania, deforestation is associated with human population and infrastructural development (Misana and Nyaky, 1993).

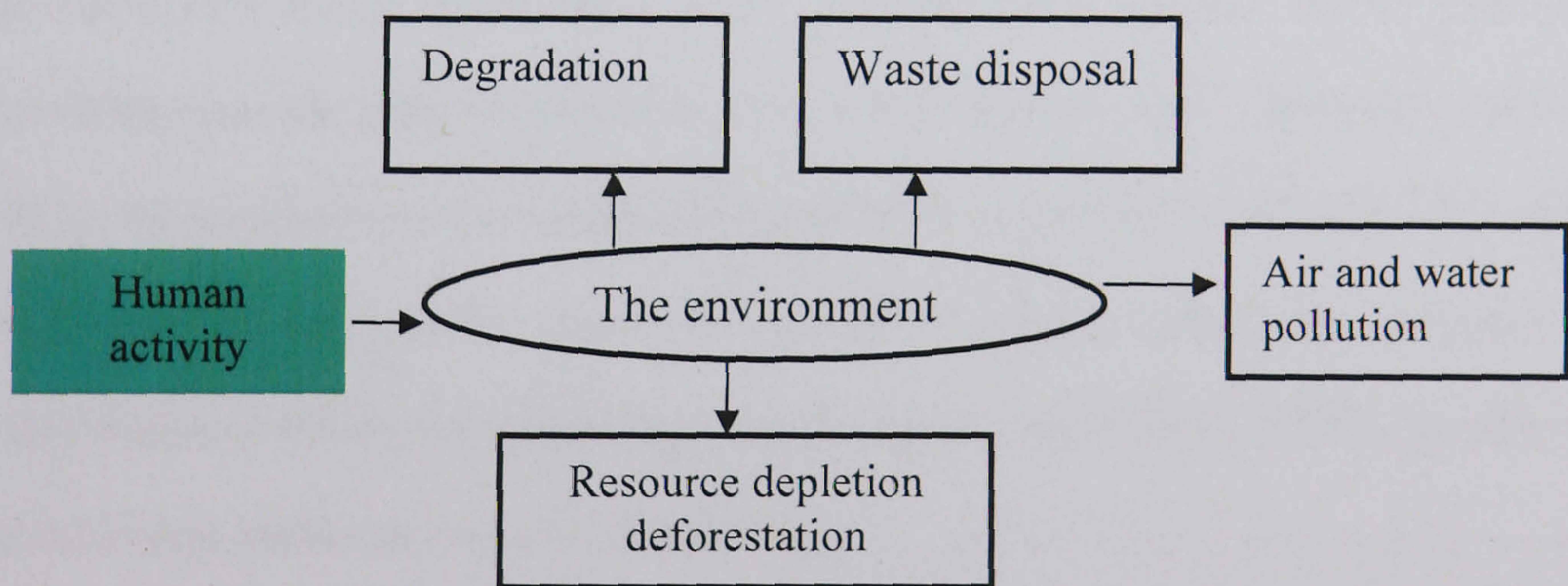


Figure 2.4: A model of human interaction with the environment.

Source: Modified from RIVM/UNEP (1995).

The aim of the section had been to examine the nature and characteristics of global environmental degradation as well as human actions that are perceived to have contributed, either directly or indirectly, to the problem. The following subsections review the most likely causes and effects of environmental degradation prevalent in most developing countries and justify a multi-faceted approach for its assessment.

2.6 Driving forces of environmental degradation

By and large the characteristics of driving forces of environmental degradation are becoming clearer. Precise definition is, however, not easy to determine. As a result, a diversity of definitions of driving forces has emerged characterised by:

1. the involvement of complex and diffuse interactions of institutional or cultural influences (Young, 2002);
2. the involvement of human and natural factors that directly or indirectly bring about a change on the environment (Millennium Ecosystem Assessment, 2003); and
3. fundamental social processes that underpin proximate causes and either operate at the local, regional or global level to bring about a change on the environment (Geist and Lambin, 2002).

Linear relationships of driving forces of environmental degradation have been proposed to include the poverty-environmental degradation nexus (Durraippah, 1996); the population growth-environmental degradation nexus (Ehrlich and Ehrlich, 1990); the migration-environmental degradation nexus (Darkoh, 1982; Ibrahim, 1987; Bilsborrow and Delargy, 1991); the urbanisation-environmental degradation nexus (Nsiah-Gyabaah, 2004); the culture-environmental degradation nexus (White, 1976; Tuan, 1986); the common property institutions-environmental degradation nexus (McCay and Jentoft, 1998); and the economic policies-degradation nexus (O'Connor, 1988).

However, the IPAT formulation (Impact=Population-Affluence-Technology) was an initial attempt to acknowledge the multiple-complex interrelationships of driving forces and their effect on the environment. The IPAT formulation explained that the causes of environmental degradation stemmed from multiplicative rather than individual additive forces and that an increase in one driver is often mitigated by either the changes in the direction or the scope of other observed drivers to bring about significant changes on the environment (Dietz and Rosa, 1994). A typical example, in most developing countries is the increase in population growth

which leads to poverty and that force individuals to cultivate on marginal lands leading to environmental degradation.

Various researchers have tried to differentiate driving forces into biophysical forces of environmental degradation and socio-economic forces of environmental degradation (Barbier, 2000; Briassoulis, 2000; Young, 2002) The bio-physical drivers include complex interplay of various characteristics and processes of the natural environment such as weather and climate variations, landform, topography, geomorphic processes, volcanic eruptions, plant succession, soil types and processes, drainage patterns and the availability of natural resources. The socio-economic drivers, on the other hand, comprise characteristics such demographic, social, economic, political and institutional factors and processes of population change, industrial structure and change, technology and technological change, the family, the market, public sector bodies, economic policies, human attitudes and behavioural values, community organization and norms and property regimes all acting in a complex structure to affect the quality of the environment.

In further clarification of the socio-economic driving forces, Moser (1996) and Geist and Lambin (2001), on separate occasions, categorised driving forces of environmental degradation into three: (i) *human driving forces*, or macro-forces which are the societal forces that link humans to nature and which bring about global environmental changes: Examples of those forces include: population change, technological change, socio-cultural and socio-economic organization (economic institutions and the market, political economy, ecology, political institutions) (ii) *human mitigating forces* which are forces that impede or counteract human driving forces (Moser, 1996). Examples of these are local to global economic policies, market adjustments, use of appropriate technology, and informal social regulation through societal norms and values: and (iii) *proximate driving forces* which are aggregate final activities that result from the interplay of human driving and mitigating forces to directly cause environmental transformation, either through the use of natural resources (e.g. as input

to agriculture, mining activities, or as raw materials for industrial production), the use of space, output of waste (solid waste, emissions, pollution) or the output of products that in themselves affect the environment (Moser, 1996).

It seems plausible to argue that complex interrelationships of human driving forces such as poverty, population growth, migration and urbanisation tend to increase pressure on scarce natural resources in most developing countries, leading to environmental degradation. However, there exists a large and growing literature which counters the above argument as other factors such as land tenure system, community level institutions, macro economic policies and institutional structures are also found to be significant contributors to environmental degradation. The intention of the next section is not to argue in favour of the linear relationship between environmental degradation and individual driving forces but to examine the analytical and empirical arguments and assumptions made by various social and scientific commentators on drivers of environmental degradation and how they relate to the views and opinions of research participants presented and analysed in chapters 6 of the thesis.

2.6.1 Poverty

The assumption of a vicious circle relationship between poverty and environmental degradation in developing countries has long prevailed in the debate on poverty-environmental degradation nexus and is worth reviewing in this thesis to help conceptualise the research topic and design an appropriate structure for environmental degradation assessment. The assumption was first launched in the Brundtland report (WCED, 1987) and later echoed by a wide range of organisations such as the World Bank (1992) and UNEP (1995). The predominant school of thought argues that there is an automatic link between poverty and environmental degradation and if policy makers want to address environmental problems they must first tackle the issue of poverty prevailing in most developing countries (Durraippah, 1996). Another school of thought seems not to favour the straightforward linear relationship and they maintain that poverty is linked to environmental degradation through

complex interrelationships with other driving forces such as poverty, population growth and migration to bring about a change on the environment as documented by Leach and Mearns (1995) and Geist and Lambin (2002).

Supporting the earlier assertion, the Brundtland Report, WCED (1987) was rather emphatic that, in many developing countries, the poor and the marginalised are usually seen as the victims and direct agents of environmental degradation as their main aim is to make ends meet with less regard to the depletion of the environment. Lele (1991) also alleged that the poor, in their effort to meet personal and societal needs, intentionally embark on various kinds of activities that are detrimental to the sustainability of their immediate natural environment. In reports of many international environmental forums, conferences and workshops, organised to address the problems of environmental degradation worldwide, the issue of poverty has been a major focus especially when discussions centre on developing countries (UNDP, 1990; World Bank, 1992; IFAD, 2002).

On the contrary, those in support of the complex interplay of driving forces of environmental degradation base their argument on the vicious cycle where different variables interact with each other in a complex manner to bring about a change on the environment (Ravenborg, 2003). Mortimore (1993), using the Malthusian network of complex environmental-poverty nexus, explained that a poor farmer in a developing country driven by intense pressures from population and migration resulting from various economic policies and weak tenure system tends to extend his or her farming activity into marginal, unproductive lands that leads to vegetative loss, soil infertility and decrease in farm output that consequently affects his or her wellbeing and development (Dasgupta and Maler, 1994; Pearce and Warford, 1993; Mink, 1993).

Reardon and Vosti (1995) also observed that the link between poverty and the environment, in a given socio-cultural setting, depends upon the level of poverty, its spatial distribution and gender disparity. According to them in a society where poverty is endemic and where social

norms discriminate against women, environmental degradation becomes an issue of importance. Research conducted in Asia and other parts of Africa into the poverty-environment nexus shows that the increase in environmental problems is as a result of extreme poverty, scarce natural resources, economic policies, weak tenure systems and lack of technical know-how (Lieu, 1991; Rozelle *et al.*, 1997 alongside many others).

Recent literature points to two major shortcomings related to the hypothesis of poverty as a major cause of environmental degradation (Ravenborg, 2003). First is the view of the poor as short-term maximizers unable to sacrifice immediate economic gains from natural resources exploitation or to make long-term investments in sustained productivity (Broad, 1994). Second, the hypothesis of a poverty-environmental degradation nexus is typically based on anecdotal evidence as no evidence exists to establish the relative importance of the activities of the poor and the nonpoor in explaining environmental degradation (Boyce, 1994; Durraippah, 1996; Reardon and Vosti, 1995). An example of anecdotal evidence was provided by Durning (1989) who suggests that the immediate agents of environmental degradation are the nonpoor, not the poorest.

In summary, it appears that poverty is related to environmental degradation in two different dimensions: (i) the popular poverty-environmental degradation relationship which sees poverty as having an automatic link to environmental degradation in most developing countries (Duraiappah, 1996); and (ii) the complex interrelationship of poverty and other forces to bring environmental degradation (Boyce, 1994; Chilensky, 1994; Durning, 1989). This thesis will argue in favour of the complex interplay of poverty and other forces to bring about environmental degradation.

2.6.2 Population growth

The proceedings of ICPD in Cairo (1994), sections 3.24; 3.25; 3.26, stipulated that:

“Meeting the basic human needs of growing populations is dependent on a healthy environment and that human dimensions need to be given attention in developing comprehensive policies for sustainable development in the context of population growth”.

“Demographic factors, combined with poverty and lack of access to resources in some areas, and excessive consumption and wasteful production patterns in others, cause or exacerbate problems of environmental degradation and resource depletion which inhibit sustainable development”

“Pressure on the environment may result from rapid population growth, distribution and migration, especially in ecologically vulnerable ecosystems”.

Despite these, there have been several controversies surrounding the nature and direction of population growth and environmental degradation. One school of thought is of the opinion that the likelihood of the impact of population growth on the environment is minimal and that the observed global environmental problems are attributed to variables other than population growth. This has been the view of the United States National Research Council (1986) who has questioned the evidence to support the growing realisation that population growth is automatically linked to global environmental problems. In contrast, others such as Ehrlich and Ehrlich (1977); De Sherbinin (1993) and Gilbert (1999) have argued in favour of the direct link between population growth and environmental degradation.

A popular hypothesis that has been used to describe population growth and environmental degradation is the Malthusian model that maintains that population growth poses greatest threat to the environment and that the productivity of environmental resources is influenced by population growth to cause a change in both the physical and the social environment. This is illustrated in Figure 2.5 where population growth brings about an increase in built-up and

barren environment and decreases in soil fertility with corresponding food insecurity. Supporters of the model emphasised that population growth tends to have severe impacts, not only on the natural environment, but also on human welfare (Daily and Ehrlich, 1992; Ehrlich and Ehrlich, 1990; Holdren, 1991; Green, 1992).

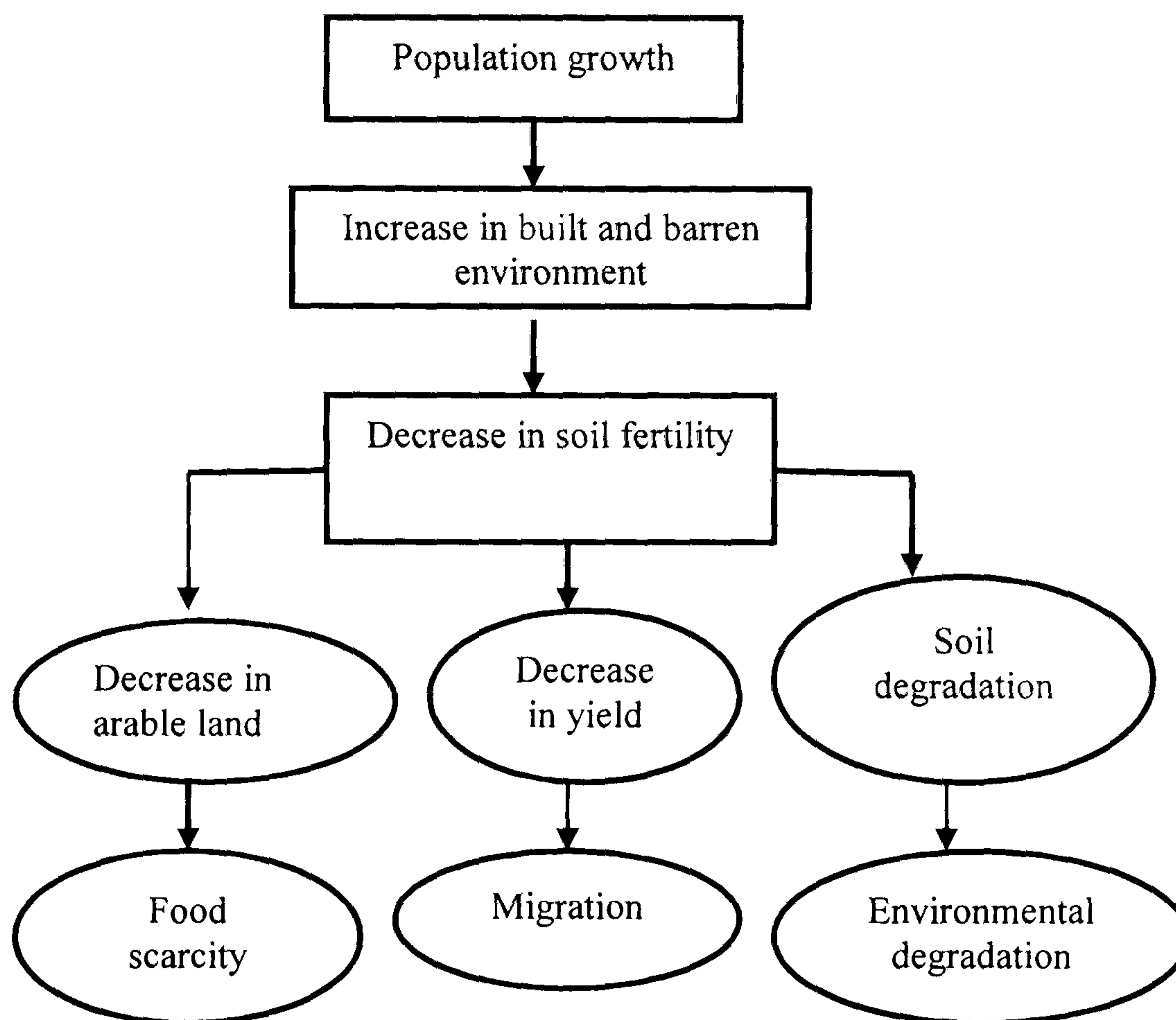


Figure 2.5: Malthusian view of population-environment nexus

Source: Modification from Mortimore (1993).

Boserup (1980), in his contribution to the population growth-environmental degradation nexus debate, earlier on acknowledged that population growth and economic development act together to bring about a change on the environment. She asserted that the desire to satisfy human needs and wants usually results in the search for substitutes and efficiencies which consequently increase human pressures on the environment beyond its carrying capacity. However, her critics were of the opinion that individual objectives on environmental resources utilization is not to maximise leisure but under the constraints of basic needs that unintentionally affect the environment (Mortimore, 1993).

Others have postulated that population growth is not a dominant force of global environmental problems but merely a contributing force that acts in complex interaction with other social processes to bring about a change on the environment. This has been the views of Ridker and Cecelski (1979); Barkin (1991); Commoner (1992); Ridker (1992); Jolly and Torrey (1993); Keyfitz (1993); and O'Connor (1998) who argued that, even though population growth have contributed immensely to global environmental degradation, greater impact has resulted from forces such as macro-economic policies, urban growth, infrastructural development and choice of technology.

Ehrlich and Holdren (1970) structured a simple equation to explain the population-environmental degradation nexus using the IPAT equation that places environmental impact (I) under the influences of population (P); affluence (A); and technology (T) but which was criticised by Shaw (1993) in its failure to provide an adequate framework for engaging other variables perceived to bring about environmental degradation. This thesis will position itself in the Malthusian model that emphasised the effect of population growth on both the physical and natural environment.

2.6.3 Migration

The movement of human beings from areas of origin to area of destination is a natural phenomenon among human societies (Bilsborrow, 2002). However, its relationship with environmental degradation has been subject to debate. While the majority have argued that migration is directly linked to the environmental degradation of areas of final destination, others are of the view that migration does not necessary bring about a change on the environment unless it is interlinked with other socio-economic forces.

Those in support of the automatic link of migration and environmental degradation such as Darkoh (1982); Ibrahim (1987); Bilsborrow and Delargy (1991) hypothesised that the link between migration and environmental degradation is linear without any mediation of social processes. This hypothesis is examined with the help of citing many instances in sub-Saharan

Africa, Asia and Latin America where migration from places of origin to final destination has directly impacted negatively on the environment. For example in Tanzania, it is documented that 45% of the country's arable land resources were rendered derelict in the 1980s due to migrant populations from other regions along with their herds (Darkoh, 1982). Sudan lost three quarters of its original savannah forest resources due to the displacement of pastoralists from their traditional seasonal grazing ranges to other areas of final destination.

A few other researchers, such as Ericson *et al.* (1999) have observed that migrations do not necessary bring about a change on the environment in areas of final destination unless they are interlinked with other forces such as micro-economic policies, infrastructural development, international politics, natural resource endowments, local institutions, tenure systems, and government economic policies that indirectly motivate the movement of migrants from places of origin to final destinations on either a temporary or permanent basis.

Preston (1998) proposed the positive influence of migration on the environment of places of origin using the decrease in person-land ratio. According to him, as people migrate from their places of origin, the pressures exerted on the environment tend to minimise, bringing about a reduction in the degradation of the environment. However, contrary to that assertion, Collins (1986) observed that out-migration does not necessary bring about an improved of environment. He cited an instance in South Africa where the movement of male workers from places of origin to mining cities in other parts of South Africa led to severe environmental stress in the places of origin. According to him, the vulnerable that were left had nothing to do but cultivate extensively on marginal lands to bring about a change on the environment.

From a different perspective, environmental degradation appears as a proximate cause of migration. According to Kane (1995); Myers (1997) and Bilsbarrow (2002), most people faced with severe environmental problems in their places of origin tends to migrate to other areas and, through various activities, put more pressure on the environment of the final destination leading to its degradation. For instance, in Haiti, deforestation was principally a

result of population growth in a political economy which led to soil erosion with an accelerating effect on poverty which in turn produced large-scale out-migration for several years (Catanese, 1991). In the Sahel region, expanding commodity production encroached on land traditionally used by pastoralists, forcing them into smaller areas. This combined with rapid demographic and livestock growth to produce intense pressure on the land leading to drought, desertification and out-migration. In large parts of northwest of Brazil, continual conversion of land-use from peasant farming to cattle ranching and the increase in population brought about drought that forced most people to migrate (Suhrke, 1991).

Accepting migration as, at least, a proximate cause of environmental degradation, the logic then yields several kinds of population movement. Levitt (1998) distinguished three types of migration that are directly related to environmental degradation. These are (i) *forced migration*, where natural or human made disasters such as war and harsh environmental conditions force people to migrate from places of origin to other destination (ii) *free and mass migration* where a group of people with the same socio-economic reasons migrate to areas of final destination for economic gains. He also made distinction between (i) *permanent*, (ii) *semi-permanent* and (iii) *seasonal migration*. According to him *permanent migration* is where the movement from place of origin to final destination is permanent and such migrants do not consider the possibility of returning to their places of origin. *Semi-permanent migration* involves the return to their places of origin after a very long period stay in their destination and *seasonal migration* is where people migrate temporarily to a destination with the hope of returning to their place of origin within the shortest possible time.

More systematically, it has been suggested that several motives drive people to migrate from places of origin to final destinations. These include (i) *depressed social conditions* where people are forced to migrate to avoid numerous social problems at their place of origin (Ewusi, 1986). (ii) *community neglect* where people, out of frustration and lack of recognition, tend to move to other areas where they believed would be accorded social recognition (Nabila, 1986), and (iii) *infrastructural development* and urban expansion in

another area that motivates people to move from places of origin to final destinations (Chopra, 1997; Ewusi, 1986).

Easy access to *transportation and communication* is also noted to motivate people to migrate from places of origin to final destinations (Beals and Menezes, 1970). Such a view is based on the extension of road networks from major towns to peripheral-urban and rural areas that resulted in the decrease in transportation cost and improved communication systems (Abdulai, 1999). *Dominant sex of a society* is also a determining factor of migration as societal norms and traditions favoured the movement of men to their female counterparts and reflected in the migration decision-making (Treveh, 1997). *Policy reforms* have also been documented as a driving force of migration. A typical example is in Ghana where structural adjustment and economic reforms altered the domestic terms of trade in favour of the peripheral-urban and rural sectors. This encouraged reverse migration as urban dwellers returned to the rural areas that were hitherto neglected (Anarfi and Awusabu-Asare, 2000; Anarfi, *et al.*, 2003). The overwhelming conclusion of most studies seemed to be that people migrate for *economic reasons*. It is the probability of getting a job that determined the decision to migrate or not. Greenwood's (1971) studies in India found that migration was related positively to destination wage and negatively to wages at the place of origin. It was also found in some studies (for example, Lipton, 1976 and Connell *et al.*, 1975) that internal migration may affect adversely the environment and welfare of the source areas.

To summarise, it seems reasonable to believe that the interrelationship between migration and environmental degradation is non-linear and varies by situation and socio-economic and cultural factors such as natural resource endowments, local institutions, tenure systems, infrastructure developments and government economic policies. Some of the above hypotheses on migration and environmental degradation are examined in the context of Bolgatanga and Talensi-Nabdam districts using the proposed GIS based participatory approach.

2.6.4 Urbanization

Urbanisation is the gradual transformation from natural ecosystems to a built-up environment resulting from a shift of people from rural to urban environments (Nsiah-Gyabaah, 2004). It involves the replacement of natural habitats by built-up areas that support human growth and development. According to UNUP (1996), urbanisation is the outcome of social, economic and political developments that lead to urban concentration, growth of large cities, changes in land use and transformation from rural to urban patterns of organisation and governance.

Urbanization is increasingly becoming a natural phenomenon in both developing and developed countries (Nsiah-Gyabaah, 2004). To substantiate that claim, it is estimated that more than half of the world's 6.6 billion people are currently living in urban areas, crowded into 3% of the earth's land area (UNFPA, 1993). Also the proportion of the world's population living in urban areas, which was less than 5% in 1980 increased to 47% in 2000 is expected to reach 65% in 2030 (UN, 1990; 1991). A recent United Nations (2002) report projected that more than 90% of future population growth will be concentrated in cities in developing countries and a large percentage of that population will be living in absolute poverty. For example in Africa, Asia and South America the current urbanisation rate is observed to be about 40% but expected to rise to 54% by 2025 (UN, 2002).

Many scholars have, however, questioned the sustainability of urban sprawl in terms of scarcity of natural resources, human resource development, environmental degradation employment, food security, water supply, shelter and sanitation (UNCED, 1992; Bryan, 1995; Martin, 1998). As they have observed the rate at which urbanisation is advancing in both developed and developing countries might have long-term negative implications on the natural environment. For instance, Wackernagel and Rees (1996) and Lee and George (2000) discussed the enormous stress placed on the natural environment through continuous urban expansion. The United Nations Environmental Program (UNEP), (1994) also pointed out the vulnerability of urbanisation to natural disasters through atmospheric pollution, destruction of watersheds and wetlands, contamination of water bodies and environmental risk associated

with low income housing and slum areas and human diseases such as, HIV/AIDS and malaria. The widely accepted assertion that urbanisation is directly linked to environmental degradation is thus tested in this thesis.

2.6.5 Community level institutions

Community level institutions surround, connect and manage communities. As institutions, they establish the rules within specific geographical and cultural spaces and interact with other institutional systems, such as local government. Because community level institutions create the rules by which organisations operate and interact, it has become over time, the repository of indigenous knowledge systems and the foundation by which local society organises itself (Donnelly-Roark *et al.*, 2001). Such rules are continually and dynamically updated, sometimes in diverse and contested ways (.Donnelly-Roarck *et al.*, 2001).

Community level institutions integrate many different kinds of indigenous organisations and functions which include village level governance, accepted methods of community resources mobilization, social and mutual aid societies, security arrangements, asset management, conflict resolution councils, management committees for infrastructure and sector services, conflict and legal adjudication committees, agricultural production cooperatives, religious associations, music societies and lineage organisations, among others (Donnelly-Roark *et al.*, 2001).

The World Bank (2001) identifies three categories of institutions active at the community level that include: (i) value institutions that focus on activating and maintaining the stability of local governance, cultural, and values of the society. it involves chieftaincy groups, and all religious oriented or mutual aid institutions active in community life and place emphasis on solidarity, equity, and consensus-directly shape the functioning of institutions; (ii) production institutions which is made up of the majority of economic development organisations with the objective of accessing resources from the national government in order to increase agricultural production; and (iii) service-asset management institutions that integrate

productivity and growth values with the societal principles of solidarity, equity, and consensus with the objective to manage and expand local assets for development in a culturally sustainable manner.

Contextually, community level institutions are connected to the norms and societal values, beliefs and aspirations that are embedded in the culture or community way of life. They are particularly important in establishing rules on land ownership and environmental management. While the argument on local culture and environmental degradation is plausible, existing evidence is equivocal. For example, Tuan (1986) and Ellen and Fukui (1995) have argued that environmental problems are usually shaped by different belief systems, religion, political ideologies and cultural knowledge. Wilbert (1996) also advocated the concept of bio-cultural inquiries where the use of natural resources is related to the way in which societies live and behave.

The social structure of a community or a group of people in a particular locality or region may have indirect influence on the use of the environment and its natural resources. This has been the case in many developing countries where societal norms have played a leading role in bringing about a change on the environment (Dietz and Rosa, 1994). As in the case of many African countries, poverty, social injustice and skewed distribution of goods and services characterised with community level institutions tends to reduce people's awareness of the intrinsic value of the natural environment leading to its depletion. Amin (1974) and Stokes and Anderson (1990) developed the concept of dislocation of resources, which is closely related to inequality and tends to have strong links to environmental degradation. As they observed, the marginalised people in the community tend to degrade the environment the most. Few scholars have also attributed environmental degradation to gender differences, especially, in most developing countries. In those instances and social settings, women, who are perceived as frontrunners of environmental management, are often discriminated on issues concerning environment (Stern, *et al.*, 1993).

In the case of religion, numerous studies have found a significant negative relationship between diverse measures of religiosity and various indicators of environmental concern (Guth *et al.*, 1995; Eckberg and Blocker, 1996), even though other studies have found little relationship between religious factors and environmental concern (Boyd, 1999; Hayes and Marangudakis, 2001). Some environmental researchers have contended that religion might have generated a pro-environmental stewardship effect (Kearns, 1997; Woodrum and Wolkomir, 1997), or support other pro-environmental orientations (Kearns, 1996). According to White (1976) environmental degradation has resulted from some elements of Judeo-Christian culture where there has been special concern on how those religions can help shape human attitude concerning the environment. In many parts of developing countries, traditional religious beliefs have played both positive and negative role in environmental degradation. In their studies on indigenous institutions and environmental assessment, Appiah-Opoku (1997) and Korem (1985) stated that in some rural communities in Africa, trees are regarded as gifts of nature that should be allowed to grow through natural process without human intervention.

Dietz and Rosa (1994) proposed three distinct frameworks for studying culture and the environment. These are: (i) the development of crude indicator of public environmental concern using public opinion data to measure environmental values and attitudes (Dunlap *et al.*, 1993), (ii) the adoption of social movements as principal mechanisms through which public concern is translated into policy (Dietz and Kalof, 1992) and (iii) the cultural history of a community that is used to shape human actions towards the environment such as the prohibition of the entry into forest reserves by community members during certain days and as practice in many West African countries.

2.6.6 Land tenure system

Land tenure refers to the way in which rights to land are obtained and distributed among people (Kasanga, 1988; Acquaye and Murphy, 1973). Several schools of thought have been developed on land ownership in most developing countries. The most popular one is the predominantly *communal ownership type* where land is collectively owned by an extended family, clan or community of ancestrally related people, with the control or administration vested in the leader or his appointee, who may give portions of the land to the community or non-community members to be used on an individual basis, on a more or less nucleated family basis, on a co-operative basis or through some other recognised arrangements, for a specific period of time (Kasanga, 1984; Gyasi, 1994). As in many parts of Africa, land is generally owned communally by people with common ancestry or owing allegiance to a symbol of collective authority (Ollenu, 1962). Under such a system the community, group or family constitutes the basic medium of access to land with individual members possessing free inheritable usufruct rights over the communal land on the basis of kingship. Strangers or non members may have access to the communal land through the transfer of rights of use by the land-owing community, usually through the leaders or chief. The “*free for all*” communal title of land with nobody taking responsibility for the proper management of the land resources is noted as a prime factor of environmental degradation in many areas of communal land entitlement (Nsiah-Gyabaah, 1994).

Another medium of access to land is the modern state *land policy reform* represented by the state government, which may acquire statutory land from the original land-owners, through legislation, for Government’s own use (Bassett, 1993; Gyasi, 1994). This new land reform is based on the premise that the customary system is ill-defined, inherently conservative, and incapable of adapting fast enough to changes and does not provide the necessary security to ensure productive use of land due to the absence of clearly defined and enforceable property rights. Despite the advantages of state government intervention in customary land issues, the intention has failed on many occasions to (i) achieve the expected increase in land

productivity; (ii) facilitate the use of land as collateral for peasant workers; (iii) encouraged acquisition of land by outsiders, thus displacing local users (iv) exacerbated conflicts by ignoring overlapping and multiple rights of land uses; (v) reinforced patterns of unequal access to land based on gender, age, ethnicity and class; and (vi) increased the degradation of the environment (Lund, 2000).

One can therefore conclude that landholdings in most peri-urban communities in developing countries are directly related to environmental degradation especially when a communal tenure system is practiced with nobody taking absolute responsibility for the title of the land.

2.6.7 Macro-economic policies

Many development theories and practices have equated developments in terms of an economic growth model which is seen as increasing the economic output and capacity of the national economy to generate an annual increase in its Gross National Product and Gross Domestic Product (Aubynn, 1999). They are also often based on neo-classical economic growth models, where emphasis is placed on capital and labour with less regard to the sustenance of the environment (Todaro, 1989; Hetne, 1990; Daly, 1996; Glasbergen and Corvers, 1996). According to Aubynn (1999), the issue of economic development and environmental protection is contentious and problematic, particularly in developing countries, where it is difficult to prioritise environmental protection amidst an increase in production costs compared to most developed countries who have reached their present development level at lower production costs.

Many economists have questioned the practicability of environmental sustainability in most developing countries amidst more basic and pressing developmental needs (Todaro, 1989). However, given the numerous environmental problems in many developed countries such as global warming through ozone depletion, acidification, eutrophication and loss of biodiversity, it stands to reason that good development strategies in most developing countries should try and avoid the same trajectory as those of developed countries.

The emerging consensus is that development is about qualitative improvements in living levels while economic growth is quantitative change in economic production (World Bank, 1992; Bartelmus, 1994; Daly, 1996). The Brundtland Commission (WCED Report, 1987) defined of sustainable development as “*development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs*”. What the report sought to underscore was that economic development that does not, necessarily, bring about human well-being unless environmental resources are taken into consideration.

There are other theories proposed to explain macroeconomic policies and environmental degradation include: (i) *The village economy wide model* represents the main link between economics and the environment as a key input in production system (Gueorguieva, 2000). The model explains that external shocks such as structural adjustment programmes tend to encourage individuals to maximise their productive ventures resulting in environmental degradation (Holden *et al.*, 1999); (ii) *There is the social dimension* that relates to the processes of socio-economic policies and their negative impacts on the environment. The approach suggests that socio-economic policies tend to affect the environment directly and are transmitted through the society via changing class structures, shifting social relations and evolving processes such as urbanisation, poverty and migration (Reed, 1996); (iii) The *second best theory* illustrates how macro-economic policies relate to market imperfections to bring about a negative change on the environment. The theory explains that price and wage policy reforms that do not include environmental management practices may have limited positive impact on national income unless environmental management is considered (Maler and Munashinghe, 1996); (iv) *Four dimensional analysis* is a simple structured approach to analyse the environmental effects of economic reform within the four dimensions of spatial coverage, scale of production, product mix and production techniques. The approach allows extensive analysis of the effect of macro-economic policies on the environment and concludes that macro-economic reforms tend to have a negative impact on the environment through the

intensity of economic and infrastructural development for economic growth (Cromwell and Winpenny, 1993). (v) The *integrated market for natural resources approach* is a framework for examining macro-economic policy effects on the environment and proposes that the environmental sector should be managed in the same way that other sectors of the economy are modelled for a better environment (Girma, 1992); and (vi) The *accounting for chaotic effect approach* observed that macro-economic and environmental linkages require a multiple and comprehensive assessment that is accompanied by extensive deliberation between experts and local people who are usually the direct agents of environmental problems and are those affected most through negative impacts on the environment and are yearning for a better quality environment (Mearns, 1991). One can conclude that given the numerous environmental problems in many developing countries, it stands to reason that macro-economics policies are formulated and implemented without adequate assessment of environmental impacts.

Having established the fact that environmental degradation is a result of complex interplay of numerous driving forces such as poverty, population growth, migration, the land tenure system, institutional arrangements and macro-economic policies, the next section reviews various human activities that usually exert pressures on the environment beyond its carrying capacity. The intention is to see how such pressures interact in complex ways to bring about a change in the environment.

2.7 Pressures resulting from land uses

Pressures on the environment, according to Geist and Lambin (2002) are human activities or actions, usually at the spatial level, that originate from intended land-use and directly impact negatively on the natural environment. Just like the driving forces reviewed above, the pressures of environmental degradation are usually multivariate but for the purpose of this study, four selected pressures perceived to have contributed to environmental degradation in northern Ghana are reviewed to help structure the assessment methodology and triangulate both ground and community truthing presented and analysed in chapter 5.

2.7.1 Small-scale mining

Small-scale mining is a critical livelihood activity, employing more than 13 million workers and sustaining 80 to 100 million people worldwide (Heemskerk, 2002). The activity, despite its recent recognition as a potential source of income generation for the poor, is known to be a leading cause of environmental degradation in many developing countries (Barry, 1996; Clearly, 1990; United Nations, 1996). Small-scale mining is a term used to describe all formal and informal, manual and mechanised mining activities that adopt unscientific and/or primitive technologies to extract minerals, usually gold, from either secondary or primary ore bodies (Heemskerk, 2002).

Despite its importance in income generation, the negative environmental impact of such activity in developing countries has been well documented (see earlier research studies by Hollaway, 1993; Mireku-Gyimah and Suglo, 1993; Lacerda and Salomons, 1998; Meech *et al.*, 1998). Empirical evidence of environmental degradation, in most developing countries, attributed to the operations and practices of small-scale mining are abundant (Amegbey, *et al.*, 1997). For example, in the Choco region of Colombia, gold production increases 7.2% each year resulting in an estimated deforestation rate of 1,000 hectares per year (Lacerda and Solomons, 1998). In Zimbabwe, it is estimated that 100,000 hectares of arable lands are degraded annually due to the intensive operation of small-scale mining activities (Maponga and Anderson, 1995). In the Liptako-Gourma region of West Africa (which includes Burkina

Faso, Mali and Niger) the intensity of small-scale mining operations has led to a widespread irreversible degradation of the environment (Traore, 1994). Prevalent small-scale metal and mineral extractions in the Brazilian Amazonian and southwest Colombia have contributed to environmental degradation (Lacerda and Solomons, 1998). Last but not the least, in most sub-Saharan African countries, such as Ghana, Nigeria, Liberia and Burkina Faso, the activity of small scale mining has accounted for the destruction of vegetative cover and serves as breeding grounds for malaria-infected mosquitoes (Agyapong, 1998).

Acid mine drainage (AMD), cyanide contamination, siltation, river dredging, alteration, degradation and erosion are known to be associated with the activities of small-scale mining activities in most developing countries (Hilson, 2001). In addition to its physical impacts, small-scale mining is also known to be associated with socio-cultural impacts such as crime, armed conflict, litigation, school drop-outs, child labour, prostitution, prevalence of malaria and sexually transmitted diseases (Faas *et al.*, 1999; Forte, 2000).

Two theories have been proposed concerning the socio-economic and cultural merits and demerits of small-scale mining activities. One theory is based on the assumption that small-scale mining is the hope for the poor, marginalised, unemployed and uneducated people in the society who, through the mining, hope to escape social marginalisation and acquire a sense of social belonging (McMillan, 1995; Heemskerk, 2001; Mwaipopo, 2004). The other theory is based on the assumption that people usually go into the small-scale mining business because they do not consider, seriously, the cost and benefit of the activity in a more realistic manner. Small-scale miners usually exaggerate their chances of improving their economic gains with less regard for environmental implications, population size and associated health hazards (McMillan, 1995; Barry, 1996; Rawana, 2000). As others have critically examined, the recklessness, lack of realism and undefined mineral fever usually compel the youth in such societies into small-mining activity without a thought for the more negative socio-economic and cultural aspects (De Vletter and Hakstege, 1998; Rawana, 2000).

It seems reasonable to believe that in most developing countries such as Ghana, small-scale mining is seen as a lucrative area with less regard of the impact for the activity on the natural environment.

2.7.2 Grazing

Two distinct issues have emerged concerning the grazing and environmental degradation nexus. The first is the sustainable grazing of livestock and its positive impact on vegetation through the use of animal manures that serve as major source of organic fertilizer (FAO, 1994). Supporters of that assertion have argued that grazing, per se, does not necessary constitute environmental degradation, although it can be symptomatic of the degradation of vegetative and grassland environment in arid and semi-arid regions (Parr *et al.*, 1990; UNEP, 1992; Stocking, 1995).

Perhaps the most important and probably the most studied issue on grazing is its continual destruction of farmlands, compaction of soil structure and depletion of savannah vegetative woodlands (Perkins, 1991). Numerous ecological studies have confirmed the negative effects of indiscriminate grazing on natural vegetation. For example, data presented by Fourie *et al.* (1987) and Perkins (1991) in savannah ecological regions of Africa, show phenomenal decrease in savannah grass species and soil destruction due to intense grazing. It has been studied that indiscriminate grazing mostly in the Sahelian countries of Africa, notably, Burkina Faso, Chad, Mali, Niger and Sudan are the major cause of environmental degradation and potential threat to desertification (Cloudsley-Thompson, 1977). The Global Assessment of Soil Degradation estimated that 680 million hectares of rangeland has been degraded since 1945 due to indiscriminate livestock grazing (Oldeman *et al.*, 1990). Dregne *et al.* (1991) also estimated that about 73% of the world's 4.5 billion hectares of rangeland is severely degraded as a result of continuous grazing.

Arguing on motive, Blench (1994); Franz (1975); Tonah (2000) asserted that the presence of tsetse flies at places of origin, the availability of veterinary services at places of final destination and the increasing use of crossbreed cattle at destination areas usually motivate the movement of herders from places of origin to final destination for grazing purposes leading to the degradation of the environment. Noy-Meir and Seligman (1979) also argued on rainfall intensity and distribution in areas of final destination and socio-economic, cultural and political setting of areas of final destination as motivation factors of herders' migration.

Grazing of livestock is also known to be associated with conflicts and violence. As noted by Breusers *et al.* (1998) competition usually exists between local land users and nomadic herders concerning grazing and its associated environmental problems, especially in areas where there are comparatively high population densities and a scarcity of resources. Following the argument above, it can be assumed that indiscriminate grazing of livestock is one of the major causes of environmental degradation in most savannah environments.

2.7.3 Bush burning

There has been less researched on the impact of bush burning on the socio-economic and environmental survival in many savannah ecosystems (Nsiah-Gyabaah, 1996). Ironically, most literature on bush burning tends to focus on the spatial destruction of vegetative cover (West, 1965; Korem, 1985; Nsiah-Gyabaah, 1996; Ravenborg, 2003) and there is a lack of comprehensive research on the behavioural, socio-economic and cultural motivations of such human actions. As noted in many traditional African societies, including those in sub-Saharan Africa, bush burning is embedded in the cultural values and farming systems of many traditional communities as land for farming is usually set to fire prior to farming through the "slash and burn" cultural practice (FAO, 1981; 2002).

One popular hypothesis that has been used to describe bush burning and environmental degradation is that bush fires are usually caused by human especially for agriculture, grazing and hunting purposes to facilitate growth of crops, fresh grasses for livestock and game. In

those circumstances burning is seen as an easy way of clearing land and managing crops and is particularly attractive to poorer farmers who often lack both labour and cash at the time of land preparation (Ravenborg, 2003).

As explained by Blench and Dendo (2004) bush fires in the tropical rainforest and savannah regions are usually exacerbated by local hunters, herders and peasant farmers who engage in burning activity as a means of creating ash (potash) to fertilise low yielding soils. Kirby (1999) argued along cultural lines and observed that in most traditional settings in sub-Saharan Africa, the practice of bush fires is seen as an initiation into farming practices and blessings from traditional gods for a bumper harvest. Such motives explain why attempts to increase public awareness on bush fires in most communities in developing countries have failed in their attempts to bring about environmental awareness.

Another hypothesis was suggested by Dwumfour (1994) who attributed frequent bush fires to natural phenomena through spontaneous lightening. Such occurrences have been documented to be predominant in drought stricken areas where the natural vegetation is savannah and dominated by grasses with a prolonged dry season (Drysdale, 1985; Nsiah Gyabaah, 1996).

To summarise then, it seems reasonable, based on this review, to suggest that bush burning has played a major role in the degradation of tropical environments through natural and anthropogenic causes.

2.7.4 Quarrying

Not much research has been carried out on the social and spatial impact of quarrying on the environment. Quarrying aimed at breaking rocks into small pieces as in-situ rock is initially reduced in size by blasting and later crushed into required size (Kuzu and Ergin, 2005). Quarries are mainly established to cover the aggregate demand of the construction industry and the deposits are mainly composed of limestone, sandstone and granite. Despite the positive benefits of quarrying activities on income generation and employment creation, Calaforra (1998) and Kuzu and Ergin (2005) in their studies elaborated the possible negative

impacts of quarrying activities on the environment. According to them, ground vibration and dust generations are the two undesirable and important side effects of the use of explosives to loosen the rocks. There are also impacts produced by noise which are mainly due to blasting, drilling, crushing, loading, unloading, and transportation (Naik and Somashekar, 2004).

Friends of the Earth Scotland (2003) also acknowledged that quarrying activities has severe impacts on local community life (affecting both local residents and outsiders) and the environment. According to them, the extractive activity affects the morphogenetic processes, changing the drainage network caused by an imbalance in surface runoff and infiltration, and impacting on ground waters and the aesthetic environment of the area where quarrying is done.

This thesis will argue that quarrying activities usually do not act alone to bring about a change in the environment as most environmental degradation in many developing countries stemmed from the cumulative effects of quarrying activities and other human actions. The next section reviews various controversies surrounding the impacts associated with environmental changes to help conceptualise the research topic.

2.8 Environmental impacts

According to Gilpin (1995, p. 5) the word impact means the effect of one thing upon the other. Impact can also be described in terms of its magnitude and significance. Wathern (1988, p. 7) described environmental impacts as the change in environmental parameters, over a specific period of time and within a defined area, resulting from a particular activity compared with the situation which would have occurred had the activity not been initialised. Touching on its significance, Kate *et al.* (1990, p.6) and Briassoulis (2000) noted that it is usually the negative impacts that stimulate scientific researchers and policy makers to take keen interest in environmental degradation.

Environmental impacts, according to Briassoulis (2000), are broadly categorized into physical and social impacts with the argument that the physical impacts are more pronounced than the social impacts. She also observed that the physical and social impacts are closely interrelated with each other with the former causing the latter which then feeds back to the former again, potentially causing successive rounds of spatio-temporal land-cover changes. Fons-Esteve (2003) also argued on the same line and observed that the physical and social impacts of environmental degradation are closely related to each other. The direct impacts, according to them, are usually manifested in changes in physical environment, including vegetative loss, and the indirect impact is the effect of physical impacts on the human population.

Another hypothesis to describe environmental impacts was that of the working group on erosion of the European Union (2003). They made a distinction of “on-site” and “off-site” impacts of environmental degradation. Whilst the on-site impacts are associated with land-cover changes on the environment, off-site impacts are those transmitted through other media of the environment such as sedimentation in downstream water resulting from soil erosion.

Impacts of environmental degradation are also distinguished according to spatial levels through which they are manifested. Global environmental impacts have been referred to as *systemic* forms of environmental change as the impact at one point on the global scale can affect other areas of the global ecological system (Turner and Meyer 1990). Ozone depletion, global climate change, desertification and sea-level rise are examples of systemic forms of observed global environmental problems (Kates *et al.*, 1990).

Sub-global scale impacts, broadly referred to as *regional level* impacts are specific to a particular locality where impacts are not transported to other areas. Eutrophication of water bodies, acidification of aquatic and terrestrial ecosystems, floods, soil nitrate pollution, land degradation, groundwater pollution are environmental alterations that follow either directly or indirectly from land-cover-changes of a specific area (Brouwer *et al.*, 1991; Briassoulis, 1994).

Environmental degradation is also known to cause a multitude of environmental impacts at the *lower spatial levels* in urban, suburban, rural and open space areas. Such environmental impacts include changes in the hydrological balance, increase in the risk of floods and landslides, air pollution, water pollution, soil erosion, sedimentation, groundwater contamination and salinization, extinction of indigenous species, marine and aquatic pollution of local water bodies, coastal erosion and pollution (Wood *et al.*, 2000; Wunder, 2000).

One would therefore infer that environmental impacts usually manifest themselves in both the physical and social impacts that cumulatively affect the well being and development of those victims of degradation.

2.9 Coping strategies

Coping strategies are often short-term responses to specific environmental problems resulting from human activities (John and Catherine, 1998). The United Nations Research Institute for Social Development (UNRISD), (1994) in their study on coping strategies of environmental problems, elaborated how affected individuals or groups strategise to cope with various environmental stresses. As stated in the report, individuals and households, faced with various environmental stresses usually adapt by changing production and consumption patterns while at the same time intensifying in other productive activities. Others attempt to find alternative sources of livelihood in the same degraded community without necessarily migrating to other nearby communities. Some, with limited resources at hand, indulge in petty trading, herding and seasonal farming or work as hired labourers in mining companies or road construction. Those with no alternative tend to migrate temporarily or permanently to other areas for gainful employment. In some circumstances, affected community members tend to organise themselves to undertake production, investment activities and environmental awareness and conservation programmes to help reduce the incidence of environmental degradation and to improve their standard of living. Such collective actions usually enable community members

to take control over their natural resources and regulatory institutions leading to a change on the pressures on the environment.

A few studies, notably, Lazarus and Folkman (1984) identified two such coping mechanisms that are problem-focused and emotion-focused coping mechanisms. According to them, communities faced with severe environmental problems either see it as an obstacle to their socio-economic development and adopt various measures to counteract the problem without necessarily taking decisions to migrate to other destinations for employment or rely on their decisions to migrate either temporarily or permanently to other destination for a better living. Another hypothesis to describe a community coping strategy was by Amirkhan (1990) who observed that community members who see environmental problem beyond their capability usually call for external support in the form of aid packages to help tackle the problem either in the short or long term (Amirkhan, 1990).

To summarise then, it seems reasonable to accept that community members when faced with severe environmental problems developed strategies to cope with the situation through various means and how they relate to the case study area is one of the subjects of this thesis.

2.10 Response to environmental degradation

The UNRISD (1994) proposed three primary approaches to address environmental degradation. These are: conservationism, primary environmental care and the monetary cost-benefit approach.

2.10.1 Conservationism

The issue of human activities as detrimental to the natural environment has been high on the global environmental agenda over the last two decades (Solon, 1994). According to UNRISD (1994), natural resources management and environmental conservation usually take the form of regulations that prohibit the exploitation of natural resources and that mandate environmental protection measures to be carried out in conjunction with economic productive

activities. The successful implementation of the conservation approach is observed to be limited by the problem of coherency where contradictory policies are implemented through state governments simultaneously promoting economic growth and environmental management, leading to a situation of “*one step forward and two steps back*” (Solon, 1994).

2.10.2 Primary environmental care

The primary environmental care approach to environmental degradation calls for investing in local level resources for environmental management (Carl, 1992). The approach is based on the observation that several environmental groups have come to the realisation that environmental protection must go hand in hand with development policies and programmes that provide alternative livelihood opportunities for the rural poor (Carl, 1992; UNRISD, 1994). Primary environmental care is supposed to address the root of environmental problems, and thus be more efficient than a curative or disaster relief approach (UNRISD, 1994). The approach stresses the empowerment of marginalised communities and locating the source of many environmental problems.

2.10.3 Monetary cost-benefit approach

The fundamental assumption of the monetary cost-benefit approach, as proposed by the UNRISD (1994), is the prosecution of individuals or groups who benefit from overexploitation of natural resources and overuse of environmental sinks but are not the ones who suffer from the adverse effects. This approach argues that if those who damage the environment are forced to bear the full costs of their activities, environmental exploitation would cease to be profitable and environmental degradation would be reduced. In economic terminology, this process of rationalizing decisions by matching total costs to benefits is referred to as internalizing the externalities (UNRISD, 1994).

An aspect of this thesis is to evaluate how research participants perceived their natural environment and what they think ought to be done to realise a better environment and how community responses relate to that of UNRISD (1994).

2.11 Summary

The aim of the above sub-chapter has not only elaborated on various assessment frameworks, analytical and empirical evidences of environmental degradation but has also demonstrated the multiple factors of environmental degradation (driving forces, pressures, impacts, coping strategies and responses) that call for an integrated, more holistic methodological approach for its assessment. This forms the basis of the next sub-chapter which reviews the conceptual framework of GIS and Society from PGIS concept emerged and of which this thesis is situated.

2.12 GIS and Society: Conceptual framework

As the social implications of GIS have come into critical debate, dialogue around critical GIS and 'GIS and Society' (Sheppard, 1995; Harris and Weiner, 1996) has become established in scientific literature and international conferences (Dunn, 2007). Debates around the theoretical assumptions and social implications of GIS as a tool are thus well rehearsed and have been the subject of a number of recent research studies (Pickles, 1995).

2.12.1 Starting point: Historical and spatial context

In the early 1990, as the potential use of GIS began spreading out, many social scientists and human geographers felt that more critical analyses of the technology were needed. As a result, GIS researchers and human geographers began an intellectual assessment of the use of GIS and its impacts on society as it was felt that the society should be the fundamental benefit of the use of the technology (Goodchild, 1991; Pickles, 1995). Human geographers began to ask questions that aimed to hold the technology accountable socially, economically, politically and ethically (Harris *et al.*, Pickles, 1995, Sheppard, 1993). Within the discipline of geography, these critiques of GIS technology formed a broadly defined 'GIS and Society' conceptual framework that serves as the basis of this thesis.

As GIS became more popular in its application in the early 1990s, some scholars began an argument that presumed that GIS was leading geography back into a form of "naïve empiricism" where facts and objectivity were replacing new knowledge formation (Taylor, 1990). Geographers such as Pickles (1995) and Sheppard (1993) were further concerned that the continual adoption of GIS was weakening geography as a discipline in that the technology were being used for high technology displays of information with little theoretical advantage.

Proponents of GIS responded to the initial critique of GIS and argued that GIS is most useful precisely when it is guided by geographers and that the technology is structured to be used in complement with knowledge rather than a substitute for it (Goodchild, 1991). Goodchild defended these early aspirations on the intellectual integrity of GIS but the debate continued

thus exposing hostility between members of the GIS community and human geographers. He argued further that GIS could be looked at as a science in which the major issues surrounding the use of GIS could be continually examined and critiqued to improve GIS capability and to examine the impacts of GIS on society.

Openshaw (1991) intimated that people in GIS have felt censured by other geographers and their misinformed speculation about what GIS is and what it does and how it either fits or does not fit comfortably within geography. He berated critics of GIS technology for qualitative methodologies that had little relationship to maps or spatial processes. While initial critiques of GIS covered a range of perceived shortcomings, positivism and epistemology emerged as a basis for scrutinising GIS. Human geographers critics felt that GIS failed to accommodate less rational, more intuitive analysis of less rational, more intuitive analysis of geographical issues and that its methodology, by definition, excluded a range of inquiry.

GIS scholars, meanwhile, saw the value of their techniques being denigrated without really realising why. There was a sense of puzzlement that human geographers refused to acknowledge the predictive or explanatory power of GIS as a way of offsetting critiques. The debate continued with vigour for three years until several GIS scholars and human geographers arranged a conference to bring together antagonists and defenders of GIS at Friday Harbour in Washington State in November, 1993. The conference marked the beginning of increased cooperation between the two opposing groups. The group brought to the table arrange of perspectives about GIS thus creating an opportunity for interdisciplinary communication which had thus far eluded debates over GIS.

Participants at the GIS and Society conference claimed that more democratic uses of GIS can be achieved by giving groups access to GIS data, hardware, and software (Craig and Elwood, 1998; Craig *et al.*, 2002; Harris and Weiner, 1998; Openshaw, 1998). Oftentimes, individuals and organisations with power and resources control information and the tools for accessing

spatial data and information, which places those who do not have access at a disadvantage (Craig *et al.*, 2002; Weiner *et al.*, 1995). As observed by Taylor and Overton (1991), the first law of geographic information which states that in areas where the need for information is needed the amount of information is the least which hampers the democratic uses of GIS. The law suggest that places that do not have access to information are marginalised. Participants to the Friday Harbour conference call for broader access to geographic information and geo-spatial tools for analysing information in order to ensure more democratic uses of GIS.

Understanding the social processes that create geographic information systems is an important theme under the GIS and Society conceptual framework (Craig *et al.*, 2002; Harris *et al.*, 1995; Pickles, 1995; Sheppard, 1993). By recognising the role of a hidden technology, Obermeyer (1995) also stresses the social processes involved in creating GIS. Businesses that create GIS packages, according to Obermeyer, have the sole influence on what questions can be addressed with the technology. She, however, cautioned GIS users to remember that GIS functionality is controlled by the hidden technocracy. The assumption was that GIS are created through social processes in which the people who control the software, hardware and data dictate which questions can be addressed using the technology (Obermeyer, 1995).

Another important theme of the GIS and Society conceptual framework suggested that GIS impose a certain way of thinking on the user (Sheppard, 1993). He compared GIS to the first universal Turing machine, which was limited to reading and writing symbols on a tape. The Turing machine could perform only one operation at a time, imposing a certain way of answering a question. Sheppard parallels GIS to the machine because GIS impose one way of thinking on the user.

The GIS and conceptual framework also suggested that certain knowledge distortions occur due to the implementation of GIS (Taylor, 1991). According to Taylor (1991), a biased database occurs due to the values and objectives held by the person who create the systems. Taylor suggests that these biases create a structural knowledge distortion. He suggested that

such distortions occur intentionally by people who hope to push their own agendas or because some types of data are difficult to represent in GIS. By challenging the subjectivity of GIS data and the representations of data included in GIS, Taylor and others show that GIS have serious limitations that needed to be addressed.

GIS and Society researchers also argued that the use of GIS raises serious ethical concerns and creates certain biases (Obermeyer, 1995). For example, geo-demographic information systems organise extensive data about people's lives in order to predict consumer behaviour. One serious implication of these extensive geo-spatial databases is that they can be cross-referenced by space and location to gain a detailed description of an individual identity (Goss, 1995). Another ethical concern with data collection is that large datasets are collected; yet, people are often not allowed access to this highly personal information unless they pay for it. Crampton (1995) believes that individuals should be allowed free access to the personal data stored about themselves in GIS.

In the present, both critics and defenders of GIS are better informed about the agendas and implications of each others work. The outcome of the debate was the urgent need to seek redress to the understanding of the interrelationship between conventional GIS and Society and how the two can be compromised for use on scientific issues of relevance. The evolution of the concept of GIS and Society emerged from that outcome.

2.12.2 Principles of GIS and Society debate

The GIS and society debate is drawn from four principal approaches of the University Consortium for Geographic Information Science (UCGIS, 1998) that seek to facilitate a broad interest and involvement in GIS and society research. The first approach focuses on ways that population, conflicts and natural resources management are represented within GIS and the extent to which those issues can be remediated by extending geographic information technologies to include societal issues (Harris and Weiner, 1998). The second approach investigates the adoption of GIS by institutions and targets the enumeration of

implementation costs and benefits. The approach develops economic and social theories, tools and techniques for determining the impact of GIS on policy decisions and on expectations about the agencies implementing them (Ventura, 1995). The third approach to GIS and society research focuses on legal and ethical perspectives, the changing institutional processes, and pricing mechanisms governing access to spatial data and information (Onsrud, 1995). The fourth approach examines public participation in GIS and broadening the use of GIS by neighbourhood, community, and grassroots groups. This approach is premised on incorporating community perceptions and aspirations into the design and implementation of GIS through problem definition and resolution to make GIS more inclusive, participant driven, and empowering (Craig and Elwood, 1998; Craig *et al.*, 2002; Elwood and Leitner, 1998; Jordan, 1999; Kyem, 1999 and Talen, 2000). PGIS emerged from the fourth approach with the goal to overcome the limitations of present GIS technologies and address constraints in the institutional settings within which GIS is practiced and produced. The approach situates GIS analytical tools within an expanded framework of communication and discourse, opening opportunities for public participation in the processes of problem identification and resolution (Koti, 2004).

2.12.3 PGIS and participation: Meaning and representation

Research from the GIS and Society conceptual framework helped form a new body of literature entitled Participatory Geographic Information Systems, which explores issues related to GIS implementation (Abbot *et al.*, 1998 and Craig *et al.*, 2002).

The very nature of PGIS has forced researchers not only to tackle GIS and Society concerns, but to propose and adapt geographic information systems that specifically address the needs of communities. One of the more critical elements of PGIS is the nature of the public participation process itself. Participatory research is a widespread research field and an application field in its own right (Abbot *et al.*, 1998). An important issue in PGIS research is the integration of qualitative information and expert quantitative data in GIS (Abbot *et al.*, 1998; Craig *et al.*, 2003; Harris and Weiner, 1998; Obermeyer, 1998; and Weiner *et al.*,

1995). While traditional GIS data is needed for community research projects, PGIS researchers argue that local knowledge held by members of a community is usually absent from traditional geographic information systems. Local knowledge of place and opinions from the community can be included in GIS to complement or strengthen existing geo-spatial information (Howthorne, 2005).

PGIS practice is geared towards community empowerment through measured, demand driven, user friendly and integrated applications of geo-spatial technologies. GIS-based maps and spatial analysis become major conduct in the process. A good PGIS practice is embedded into long-lasting spatial decision-making processes, is flexible, adapts to different socio-cultural and bio-physical environments, depends on multidisciplinary facilitation and skills and builds essentially on visual language. The practice integrates several tools and methods whilst relying on the combination of expert skills with socially differentiated local knowledge. It promotes interactive participation of stakeholders in generating and managing spatial information and its uses information about specific landscape to facilitate broadly-based decision making processes that support effective communication and community backing (Rambaldi *et al.* 2005).

GIS users, researchers, and community groups had suggested that there are numerous avenues to solicit local knowledge with the formal, technical data already represented in GIS (Craig *et al.*, 2002; Harris and Weiner, 1998 and Weiner *et al.*, 1995). In PGIS research work, local knowledge is often solicited through local meetings, small focus groups, and in-depth interviews, transect walks, community mapping exercise and visual techniques and interpretations (Howthorne, 2005).

As defined by Rambaldi *et al.* (2005) PGIS is a technique that combines a range of geo-spatial information management tools and methods such as sketch maps, aerial photographs, satellite imagery, global positioning system and geographical information system to represent people's spatial knowledge in the form of virtual or physical and dimensional maps used as

interactive vehicles for spatial learning, discussion, information exchange, analysis, decision making and advocacy

Integrating multiple perceptions in a GIS is also an important area of research within PGIS (Abbot *et al.*, 1998 and Craig *et al.*, 2002). It is argued that multiple opinions and perceptions of place must be represented in GIS to highlight different views of community members. One of the core aims of PGIS is to gather together those dissimilar views through an interactive setting to help identify areas of potential consensus and contentions between communities members while at the same time retaining the uniqueness of each participant's perspectives.

The adoption of PRA (Participatory Rural Appraisal) techniques in PGIS provides conventional GIS results with qualitative information held by the general public and local community members who usually possess valuable ideas, opinions and perceptions about the environment they live in and are used to (Kyem, 2002a and Leitner *et al.*, 2002).

Another theme of PGIS research is the integration of participatory methodologies into community projects (Kyem, 2002). Participatory methodologies such as transect walks, oral history and community mapping exercises are implemented to provide traditional GIS with qualitative information held by local people who live in a particular area and possess valuable insights, opinions and perceptions about the community and the local environment.

PGIS also take into much consideration the issues of access, control and owner of data and the technology. Assessing the appropriateness of the GIS tool in community project is of utmost important to the success of a community GIS project (Craig *et al.*, 2002). One of the known limitations of GIS projects is that organisations often chooses advanced GIS software and hardware, when a lower technology approach may in fact be more appropriate for community participation (Weiner, *et al.*, 2002).

PGIS researchers are also concerned with exploring the relationship of GIS to local political and community contexts. PGIS researchers are of the opinion that the local political climate

often has an effect on the success or failure of community GIS projects (Craig *et al.*, 2002). Communities that have financial resources for GIS, have GIS capabilities and have people knowledgeable of GIS often experience the most success with GIS projects.

PGIS literature also stresses the importance of community-university partnerships in local settings (Leitner *et al.*, 2002). In these partnerships, universities provide students, facilities, hardware and software, and GIS expertise in hopes of assisting the community with its needs. Community members and groups provide universities with an avenue for entering the community, provide a huge amount of local knowledge, and provide individuals who are passionate about community issues. Together these two groups form a powerful agreement where common needs are met through action research and participatory research (Leitner, *et al.*, 2002 and Howthorne, 2005).

As noted earlier PGIS conceptual framework originated from the earlier critique of GIS and Society conceptual framework. The aim was to ensure that different community views, opinions and local ecological knowledge are included in GIS to ensure that GIS are more democratic and accessible to a wide range of user groups.

2.12.4 Access, control and ownership of geographical information and output

Of the elementary significance of PGIS implementations are the questions of access, control and ownership of geographical information and output (Dunn, 2007). Harris and Weiner (1998) proposed community-integrated GIS in recognition of the fact that, although communities may increasingly participate in GIS-related researches, they lack the political, financial and technical control of the tool. Their proposal acknowledges the expert nature of GIS as a technology but enhances the community access and participation. Sieber, (2001), advocated for a formalised approach to address questions about ownership, access, expertise and accountability whereby PGIS is recognised by local people. Cinderby (1999) argues that the ability to integrate multiple perspectives in a visual spatial medium offers a powerful representation that should enable local communities to engage in spatial decision-making with researchers on a more equal basis and to raise local peoples awareness (Dunn, 2007).

Participatory GIS has the potential to be both enabling to those whom it seeks to serve and to be misused in the wrong hands as outsiders control the technique (Abbot, *et al.*, 1998). In seeking to reduce power imbalances and external control and interventions, the inputs and outputs of GIS data should be processed participatory as a deliberate means of empowering local communities (McCall, 2003).

2.12.5 Local knowledge and spatial accuracy

In the process of representing different geographical understandings and in attempting to reveal contradictions and similarities in spatial thinking and activity (Williams and Dunn, 2003), PGIS seeks not to privilege any one type of information but to grant equal validity to all (Dunn, 2007). In this way local technical knowledge can grant poorer groups an equivalent standing to outsiders (McCall, 2003) and in participatory spatial planning such knowledge may be the only resources that the poorest groups control while their land resources, property or labour are rapidly appropriate (McCall, 2003). Of critical relevance is the extent to which local knowledge can be portrayed in a spatial way and through the use of GIS. According to Grenier (1998) and Dunn, (2007), through generations, local knowledge is expressed through stories, songs, folklore, proverbs, cultural values and agricultural practices and usually communicated orally. McCall and Minang (2005) commented that local knowledge is normally more reliable, and may be more accurate as it embodies generations of practical essential knowledge and operates in interactive and holistic systems. While not geographical, much local knowledge has both embedded geographical context in which the natural environment is central and specific spatial associations-for example, knowledge related to location of resources, environmental hazards, ecosystems and spatial correlations between groups and resources (McCall, 2003). The thematic data layering properties of GIS facilitate representation of multiple perspectives and offer potential of a holistic view of local communities (McCall, 2003). Some local ecological knowledge can be mapped through the use of GIS for decision-making purposes (Dunn, 2007).

2.13 DPSIR assessment framework and PGIS concept

In reviewing both environmental degradation and PGIS conceptual frameworks, it is suggested that local ecological knowledge is of vital importance in assessing the complex causes and effects of environmental degradation as spelt out in the DPSIR assessment framework. In order to assess the complex interplay of environmental degradation in Bolgatanga and Talensi-Nabdam districts of northern Ghana, literature suggest that (i) local people should be given the meaningful opportunity to participate; (ii) local ecological knowledge held by local people should be given a prominent role in environmental degradation assessment; and (iii) different people and interest groups should work together to reach consensus about critical issues on environmental degradation. It is envisaged that a GIS which is vested in the interests of people through an approach based on GIS in participatory research may be more successful and achievable than a truly participatory GIS (Williams and Dunn, 2003). The aim of this thesis is therefore to use a GIS in participatory research within the DPSIR framework to assess environmental degradation in the Bolgatanga and Talensi-Nabdam districts of northern Ghana.

2.15 Conclusion

This chapter has presented and evaluated a variety of concepts and assessment frameworks which are relevant to the subject of environmental degradation and describes how well they serve the purpose of providing a comprehensive account of the research topic. Each concept and assessment framework has its own distinctive merits and shortcomings that help to situate this thesis within the state-of-art. The chapter also situate the thesis within the broader GIS and Society conceptual framework and discusses the major components of PGIS to justify its importance in environmental degradation assessment. It is concluded in the chapter that merging PGIS and DPSIR framework can improve the holistic assessment of environmental degradation at the Bolgatanga and Talensi-Nabdam districts of northern Ghana through the use of GIS techniques integrated with local ecological knowledge. This is the basis of the next chapter that seeks to design an assessment methodology that utilise PGIS methodology and DPSIR assessment framework to address the complex issues of environmental degradation as reviewed earlier in this chapter.

Chapter 3

Towards an Assessment Methodology: GIS, Remote Sensing and Participatory Approaches

3.1 Introduction

The theoretical and conceptual frameworks reviewed in chapter 2 have highlighted a number of key issues that must be considered in any attempt to design an assessment methodology for environmental degradation. This is of utmost importance as an inappropriate methodology would lead to worthless research findings and vague environmental policy recommendations. This chapter is organised into two sections. The first reviews various assessment methodologies for environmental degradation and justify the choice of methodological triangulation from which PGIS emerged for the design of an appropriate methodology for environmental degradation assessment. The design methodology is based on the general conceptual frameworks reviewed in the previous chapter. The latter parts of the chapter presents a review of the quantitative, qualitative and analytical components of the designed GIS in participatory research and justifies their adoption for data sourcing and analysis for this study.

3.2 Environmental assessment methodologies

Agenda 21; Principle 17 of the Earth Summit (1992) stipulates that: "*environmental assessment shall be undertaken for human developmental activities that are likely to have significant adverse impacts on the environment and that governments should promote the development of appropriate approaches for the assessment of environmental degradation for decision making purposes*" (UNCED, 1992).

Recent literature on practical approaches to environmental and natural resources assessment shows three major approaches.

3.2.1 Classic approach

The first is the *classic reductionist approach* that assumes technical, scientific and deductive solutions to environmental degradation and emphasis on quantitative techniques and expert opinions (Clay and Scaffer, 1984; Corell, 1999 cited by Stringer and Reed, 2007). Like many global assessment methodologies for environmental degradation, greater emphasis has been placed on quantitative, modelled scientific indicators that are developed within the confinement of constricted scientific space. According to Stringer and Reed (2007), scientific techniques such GIS and satellite remote sensing (Ringrose *et al.*, 1999), ecological assessment (Perkins and Thomas, 1993); economic analysis (Perrings and Stern, 2000), expert opinions (Oldeman *et al.*, 1990) and scientific field surveys (Reed and Dougill, 2002) have all been utilised, narrowly, to assess environmental degradation. However, the sole adoption of such classic approach has its own shortcomings as they cannot always provide accurate solutions to complex environmental problems (Fairhead and Leach, 1996; Thomas, 1997). Another weakness of the classic approach is the requirement of detailed understanding of science, considerable data requirements and potential hidden errors that usually arise from inappropriate assumptions and approximations of adopted scientific models. A typical example is the use of conventional GIS for natural resource management without local ecological knowledge (Ministry of Housing, Spatial Planning and Environment, The Netherlands, 1984).

3.2.2 Populist approach

The second approach, often referred to as the *populist approach*, adopts stakeholder participation and local ecological knowledge in environmental assessment and natural resource management (Hudson, 1991). The approach is based on Principle 10 of the Rio Declaration (UNCED, 1992) that stipulates grassroot participation on issues of environmental management and the UN Convention to Combat Desertification that put emphasis on active

participation of local people on matters concerning the environment (UNCCD, 1994). Ironically, as stated in the scientific article by Reed *et al.* (2007), environmental decisions cannot be made solely on the basis of qualitative local knowledge due to the subjectiveness and unrepresentative nature of the issue been addressed. There is also a lack of scientific bases to substantiate claims usually solicited from local ecological knowledge. Interestingly, Kothari (2001) was of the view that the adoption of the populist approach through the empowerment of previously marginalised people may lead to unexpected conflicts with existing power structures.

3.2.3 Methodological triangulation

The resultant hybrid knowledge (Reed *et al.*, 2007, cited in Fraser *et al.*, 2006) often called the *methodological triangulation* or *neo-liberal approach*, stemmed from the shortcomings of both the populist and the classic approaches. The approach allows scientific and local ecological knowledge to interact to produce useful ideas on matters relating to the environment. Borrowing from the classic reductionist approach, methodological triangulation takes the idea that natural resources need to be assessed quantitatively to assess the nature and extent of environmental change (spatial) and from the populist approach, it borrows the notion that local ecological knowledge provides reasons why certain changes on the environment have occurred (aspatial).

3.3 Review of related studies

For the purpose of developing an assessment methodology to answer the research questions as outline in chapter 1, three related case studies were carefully selected from literature on practical approaches to environmental and natural resources management. The selected case studies are by Duong *et al.* (1997); Appiah-Opoku (1997) and Williams and Dunn (2003), where, either the application of the classic, populist or methodological triangulation approaches were adopted to examine aspect of the DPSIR framework. The subsections below detail the methodologies used, their limitations and research findings.

With the framework of their research project on capacity building for environmental management in Vietnam, Duong *et al.* (1997) carried out an extensive research on land-use changes and GIS-database development for strategic environmental assessment in Ha Long Bay, Quang Ninh Province. The database used contained information on the current status of natural resources (land cover, land cover use, topography, infrastructure, population, coal mining industry and tourism) and the development plan for Ha Long city. The study made use of diverse human land use categories and interpretation supported by ground truth checking via extensive GPS fieldwork. The study adopted the *classic approach* that assumes technical, scientific and deductive solutions to resource assessment and emphasised more on the quantitative techniques and expert opinions. Based on the results of the findings, the study recommended that GIS when adopted in land-use analysis has the ability to store large multidisciplinary datasets, identify complex interrelationships between environmental characteristics, evaluate change over time, ability for systematically updating and usage for different projects, input data sources for a variety of mathematical models and capability of storage and manipulation of three dimensional data. The results of the study are criticised due to the lack of qualitative data, in the research methodology, to support the issues raised in the quantitative findings.

Appiah-Opoku (1997), in his study on indigenous institutions and environmental assessment in Ghana, adopted more qualitative participatory research methods (formal and informal interviews) with randomly selected key informants within formal and indigenous institutions, village elders and non-governmental organisations to investigate the relationship of traditional knowledge, beliefs, practices, social norms and environmental degradation in Ghana. He hypothesised that many conceptual frameworks adopted for environmental degradation are “western” in their origin and are therefore not applicable to indigenous institutions in most developing countries (p.159). According to him, local ecological knowledge can be used as a stand-alone technique to assess environmental degradation without necessarily adopting any quantitative scientific data. Despite these barriers such as higher illiteracy, language

problems, scepticism on the part of government officials and scientists and the difficulty in changing entrenched attitudes, the study found the usefulness of local ecological knowledge in assessing environmental problems in developing countries such as Ghana. For instance, the research revealed that indigenous farmers are able to use the colour, texture, and appearance of their crops to distinguish between poor and fertile soils: they know local climatic characteristics and when to prepare their farms for the rains or to mulch to conserve soil moisture using simple farm implements such as the hoe, axe, and cutlass, which minimize exposure of the subsoil to the tropical climate. Similarly, the indigenous hunters have expert knowledge of the location of certain animals, plants, water bodies, forests, and other elements of the local environment. However, for a holistic study of environmental degradation, where the five indicators of the DPSIR framework needs to be accounted for in totality (as previously reviewed in chapter 2), the final outcome of Appiah-Opoku's research methodology could be criticised based on its lack of scientific data to measure the spatio-temporal state of the environment studied.

The work of Williams and Dunn (2003) was an advanced form of both the Duong et al. (1997) and Appiah-Opoku (1997) research methodologies as it moves beyond both the populist and classic approaches and adopted methodological triangulation to address the challenges of applying *GIS participatory approaches* in post-natural resource conflict settings in Cambodia. The aim was to investigate the potential integration of local and scientific knowledge to formulate and explore spatial activities among local populations in mine-contaminated communities through the identification of improved strategies for returning refugees in re-establishing their livelihoods in landmine contaminated areas. Their approach was a step towards using GIS to provide access to geographical information for the marginalised indigenous rural poor people rather than the upper circuit, high-capital experts. Their approach produced an informed baseline contamination survey, a detailed history that revealed which resources and activities were important to the viability of the villages, and specific spatial knowledge of the location of resources, features, mine-fields and the

relationships between them. Villagers own clearance priorities were obtained by the researchers and the complex relationship between casualties and resource-use that could identify both direct and indirect means of addressing key development issues were unearthed. Even though the study is not yet subjected to public scrutiny, it is envisaged that the empowerment of the marginalised groups in the landmine areas may bring about potentially negative interactions or conflicts with existing structures as viewed by Kothari (2001) when he subjected methodological triangulation to criticism. However, its adoption in this thesis is subjected to modifications to include the other indicators of the DPSIR framework as it was designed to address, specifically, the “impacts” of “landmine activity”.

3.4 GIS based participatory assessment methodology

The designed assessment methodology (Figure 3.1) involves the utilisation of methodological triangulation to facilitate the accommodation and adjustments of two discrete but complementary quantitative and qualitative techniques (conventional GIS and participatory research) which are used to measure the five indicators of the DPSIR framework. Even though closely related to Duong *et al.* (1997); Appiah-Opoku (1997) and Williams and Dunn (2003) in terms of basic results, it differs with respect to some features as the proposed framework takes into consideration all issues of relevance to environmental degradation.

The first phase of the proposed framework is the use of geographical information to create image maps that represent characteristic features of the study area. This is achieved through the use of three remote sensing satellite images. It concerns the issue of where and to what extent degradation has taken place over a period of time.

The second phase is the participatory approach (community truthing), borrowed from Appiah-Opoku (1997), that seeks to examine, in a more qualitative way, the societal attributes of the driving forces, pressures, impacts and responses of observed changes on the environment analysed in the first phase of the assessment methodology. It provides reasons for changes observed on the environment over a period of time.

Borrowing from the adopted research methods of Williams and Dunn (2003), individual semi-structured key informant interviews, focus group discussions and unconventional GIS techniques that aim to provide opportunities for participants to reflect on the complexity of the environment and engage in a more constructive discussion on the nature and causes of environmental degradation were used. The idea here is to test the robustness of the integration of conventional GIS and local ecological knowledge in the evaluation and assessment of the five indicators of the DPSIR framework for environmental decision making. As presented in Figure 3.1, the aim of the framework is to use it to assess environmental degradation in the Bolgatanga and Talensi-Nabdam districts of northern Ghana and other similar areas of savannah environment where complex interplay of various social processes are assumed to have led to intense human pressures on the environment with severe environmental consequences some of which have adversely impacted the population (Triffen *et al.*, 1994; Pierce, 1998; Geist and Lambin, 2002).

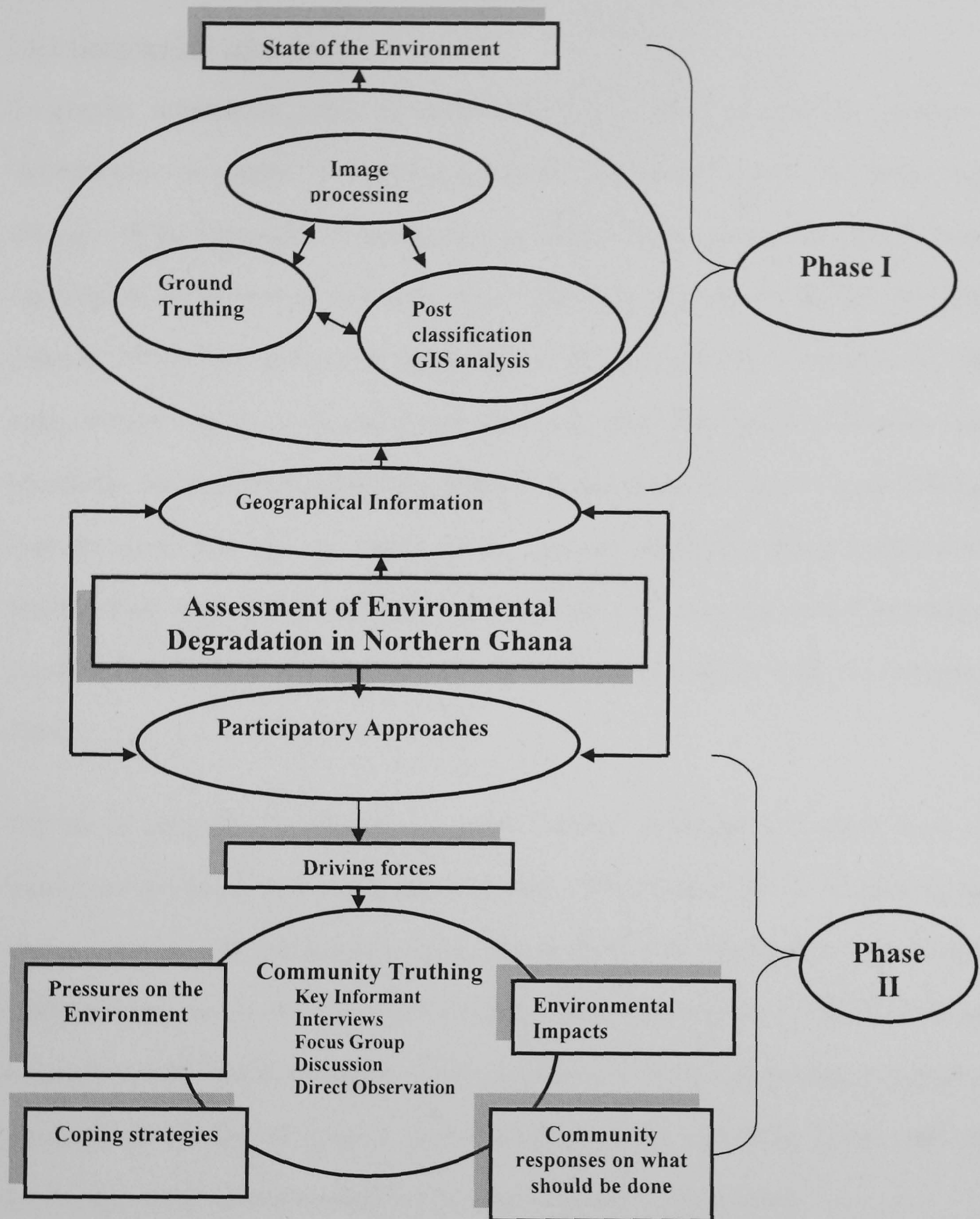


Figure 3.1: Research design: GIS and Community truthing

3.5 Component parts of the assessment methodology

3.5.1 Geographical information

Geographic information refers to information that identifies geographic locations and characteristics of natural or constructed features and boundaries on the earth's surface (Masser, 1998). Geographical information, as known by its users, often results from the combination of geo-spatial data with expert knowledge for data collection and analysis (Masser, 1998). They are usually represented in the forms like topographic maps, sketch maps, satellite images and aerial photographs with other information on land-use zoning, boundaries and land-cover categories. Effective decision making based on the information from the spatial data may also depend on the socio-economic and cultural conditions of the location been studied. This information is integrated with the geographical information to generate both location and attribute datasets for decision-making purposes (Mansberger, 2003).

The use of geographic information for natural resource management is useful when social themes are integrated with spatial data (De Man, 2000; Codjoe, 2004). In many empirical studies, such as the land-use/land-cover change project of the International Geosphere-Biosphere Program and the International Human-Dimension Program on Global Environment Change, attempts had been made to create geographical information through the adoption of geographical information systems, remote sensing, global positioning system and expert knowledge; details of which are reviewed in the subsequent sub-headings.

3.5.1.1 Geographical Information System (GIS)

GIS are tools that can be used to further human understanding of environmental problems at local, regional, and global scale. It is a technology designed to capture, store, manipulate, analyse, and visualise the diverse set of geo-reference data required to support accurate modelling of the earth's environmental processes (Goodchild *et al.*, 1993). Since its inception in the 1960s, GIS is widely seen as an effective tool for collecting, storing, retrieving, transforming and displaying spatial data from the real world through the manipulation of geo-

referenced-computerized maps (Burrough, 1986). A GIS comprises computer hardware, software, data and personnel (Maguire, 1991). It can interface with many other technologies such as remote sensing, photogrammetry, video, word processing, address information system, and terrain modelling systems (Dongermond, 1988).

From a broader perspective, GIS is seen as a means to provide users with the geographic information needed to carry out geographical tasks and to take decisions in the context of spatial problems (Burrough, 1986). The technique is widely used in the handling of information in a spatial context, facilitates data acquisition, processing and storage of spatial data for statistical analysis (Burrough, 1986). It is known to possess the ability to pre-process data into a form that is suitable for analysis and is also frequently used to calibrate, forecast and predict models (Goodchild, 1991; Beinat *et al.*, 1999).

GIS also possess the capability to fully integrate geographical and tabular data for decision-making purposes which is relevant in studies on natural resource management and environmental planning (Burrough, 1986; Maguire, 1991; Joao and Fonseca, 1996; Antunes *et al.*, 1996). This function makes it a suitable tool for environmental degradation assessment as it links maps and tabular data to create intelligent maps to use in data analysis.

Another function of GIS technology is the organisation in layers of different range of data sets (Maguire, 1991). This is made possible as the GIS data are geographically referenced in a real-world coordinate system (latitude-longitude, state plane etc), that allow accurate overlay of layers containing different data themes of the same geographic area for analysis (Maguire, 1991).

Other analytical functions of GIS include *database query* where GIS automates searches for use-specific subsets of a database and support spatial analysis that includes automatic computation of lengths and areas of a study location, recognition of adjacency, and finding spatial and thematic correlations (Maguire, 1991; ESRI, 1992; Heywood *et al.*, 2002).

Even though it falls beyond the scope of this thesis to explore the full potential of GIS, it is worth noting that GIS has been used by a heterogeneous group of individuals and organisations for a wide variety of applications (Maguire, 1991). For example, it has been used to evaluate environmental impacts, economic implications, land use changes, and resource conflicts (Parker, 1988). Other environmental GIS applications include modelling land-use change (Chuvieco, 1993), natural resource management (Bildstein, *et al.*, 1991), cumulative impact assessment (Green, *et al.*, 1993), waste disposal site assessment (Smith, 1993), habitat evaluation (Friel and Haddad, 1992), and assessing the impacts of large natural disturbances (Michener, 1992). One of the hypotheses of this thesis is that GIS is capable for assessing environmental degradation holistically when integrated with participatory research methods.

3.5.1.2 *Remote sensing*

Remote sensing is the science and art of obtaining information about an object, area or event through the analysis of data acquired by a device that is not in contact with the object, area or event under investigation. The primary focus of remote sensing is the measurement of emitted or reflected electromagnetic radiation from a target object, area or event by a multi-spectral satellite sensor (Lillesand and Kiefer, 1987).

The use of remote sensing technique in environmental and natural resource management makes use of the different reflectance from sources in different localities of the electromagnetic spectrum recorded by various sensors (ERDAS, 1999). This makes the adoption of remote sensing in land-cover mapping one of the most important applications of satellite sensor technology (Duadze, 2004). It is also particularly useful when measurements are needed in inaccessible areas, where there are difficulties in the use of aircraft-based survey methods (Tucker and Townshend, 2000) and where traditional cartographic methods are not applicable in assessing large areas (Thenkabail, 1999). Remote sensing has often been the only practical means of obtaining spatially extensive and exhaustive data on environmental and natural resources for assessment (Dungan, 1998). It has also played a

major role in numerous spatial information systems and provided a viable source of data from which updated land-cover information is obtained efficiently for change detection analysis (Wright and Morrice, 1997).

Despite the usefulness of remote sensed data, Rindfuss and Stern (1998) as cited by Codjoe (2004) are of the opinion that remotely sensed images have not been a popular data source for social sciences due to the belief that the variables of greatest interest are not readily measured. Also social sciences are more concerned with *why* (a-spatial) things happened than places of occurrence (spatial) (Faust *et al.*, 1997). There is also a problem of linking people to pixels at the appropriate spatial and temporal scales so that the responses of individuals can be linked to changes on the environment over time and space (Codjoe, 2004).

Notwithstanding these criticisms, the numerous qualities of remote sensing justify its adoption in this thesis as it is identified as a technique that can be integrated with local knowledge as well as other biophysical information gathering techniques (GIS and GPS) to bring about a better understanding of the environment. However, as cautioned by the World Bank (1993; 1995b) its use should always be supported by extensive field work and GPS ground truthing as many anthropogenic factors are usually difficult to differentiate and map out using only remote sensing satellite image data.

3.5.1.3 *Global Positioning System (GPS)*

Global Positioning Systems (GPS) are a powerful tool for determining the accuracy of digital remote sensing data through high accuracy ground-truth data for training-site development. GPS is a navigation system based on a network satellites originally used for military purposes but has become available for public use in recent times (Dana, 1997). The use of GPS is based on its principle of satellites sending signals to the earth from a precise orbit and uses a system of triangulation to calculate the time that represents the distance between the satellite and the GPS receptor (Dana, 1997).

Essentially, GPS satellites broadcast a continuously available time signal using an on-board atomic clock to calculate the distance between the satellite and a ground base receiver to establish an accurate position. The accuracy of GPS positions can vary substantially and users must be aware of the factors that influence the precision of the GPS signal. Results of GPS are influenced by the type of GPS service accessed, the type of GPS equipment used, processing techniques adopted and satellite geometry (Bobbe, 1992). GPS is adopted in this thesis for accuracy assessment and the locations and measurements of coordinate points of identified land-uses in the study area.

3.6 Participatory approaches

Qualitative approaches have been the main methodological technique of those natural resources projects where greater emphasis is required on societal concerns and responses to environmental related problems (Chambers, 1994; Innes and Booher, 1999; Brisbin and Hunter, 2004). The process of the qualitative approach, as they observed, is the way in which selected participants of a particular study location, of different interest groups and backgrounds come together to talk about diverse issues of interest. This fundamental principle is seen as a community-based research tool for soliciting data for environmental and other natural resources assessment (Innes and Booher, 1999; Laurian, 2004; Zaferatos, 2004). With the adoption of this approach, participants from different social backgrounds could come together to contribute, through focus group discussions, key informant interviews, workshops, mental mapping, household interviews and direct observation, on issues of interest. The approach takes into consideration the accommodation of other interests and the modification of ones own towards a common goal of reaching long-term objectives (Selener, 1997; Michener, 1998; Zaferatos, 2004).

Organizations such as IUCN and WCED have stressed the importance of the approach in sustainable management of natural resources through the creation of a scientific approach that includes traditional, community-based and modern approaches to environmental problem-solving (Johnson, 1992).

The Convention on Biological Diversity of the United Nations (1992), in their bid to increase environmental awareness programs, also advocated the respect of traditional and local knowledge through participatory research in the preservation of biodiversity and the sustainable use of natural resources. The World Bank (1998) also commented on the importance of local knowledge as the large body of knowledge and skills developed outside the formal educational systems and therefore its application in environmental and natural resources research becomes fundamental.

Despite the many advantages of the application of participatory research approach in natural resources and environmental related issues, many have criticised its validity in terms of its effectiveness as assessment tool. Those critics based their argument on the fact that the approach when adopted in a situational analysis tends to favour selected participants which might not, necessarily, represent the views and opinions of the entire community being researched (Talen, 2000).

Docherty *et al.* (2001) also pointed out the issue of participants' apathy and the provision of false information to suit the researcher. On the issue of empowerment, Kapoor (2002) suggested that while the participatory approach emphasises equal playing levels among participants that is not guaranteed during the dissemination of research outcomes where the few in the society are given access. Another issue of interest is the ill-defined selection of appropriate research methods and the subjective nature of participants' responses that cannot be used to test various hypotheses (Pratt, 2000; Cornwall *et al.*, 2001). These challenges of participatory research approaches, according to Reed *et al.* (2007), are met through methodological triangulation of both scientific and local ecological research methods. The subsequent subsections review and justify the adoption of some qualitative approach tools in this thesis.

Examples of participatory approaches drawn from PGIS concept are reviewed below. The aim here is not to present abstracts of various PGIS approaches and their mode of implementations but to justify the adoption of GIS based participatory approach proposed by Abbot *et al.* (1998) and modified by Williams and Dunn (2003) in the formulation of an appropriate methodology for environmental degradation assessment in northern Ghana.

3.6.1 Participatory sketch mapping

Participatory sketch mapping, as observed by Jordan (2002), is a PRA technique (Chambers, 1994) used to acquire a systematic and graphic understanding of spatial issues and which enable the participation and empowerment of communities through the provision of increased information for decision making that focuses on community needs. The technique is a slightly more advanced form of ephemeral mapping techniques that involves participants drawing maps on the ground through the use of simple materials like soil, pebbles, sticks and leaves to reproduce the physical and cultural landscapes in the manner they perceive them to be (Harris and Weiner, 2003).

The technique has been adopted in many natural resources management studies to assist in ecological data collection on issues of land cover, land use, land tenure and conflict resolution. For example, Fox (1990) applied it as a problem-solving technique to assess deforestation and forest management in Southeast Asia. Notwithstanding its simplicity, the technique has, however, been criticized on the basis that its final outcomes, in the form of sketch maps, are usually not spatially accurate and, therefore, cannot be used as a supporting document in a formal or legal context for decision making purposes. It is also observed that its adoption may contain a limited number of information sets when used for a comprehensive study of natural resource management, especially in the assessment of environmental degradation where multiple factors come to play to effect environmental changes. In proposing answers to one of these limitations, Zulu (2004) was of the opinion that sketch maps should be modelled into more precise-scaled maps before they can be used for environmental decision-making.

3.6.2 Scale mapping technique

Scale mapping is an advanced form of participatory sketch mapping aimed at generating geo-referenced data sets to facilitate discussions through participatory procedures. The technique is based on the selection of symbols and colour categories or classes on transparencies superimposed on geo-coded scaled maps. Kyem (2002b) adopted the technique to study forest management and conflict resolution processes in the Ashanti Region of Ghana where local people were involved in mapping and interpretation of GIS maps. It has, however, been established that the technique when used, for example in resource assessment, would tend to marginalise the poor, vulnerable and illiterates in the society to the advantage of the few privileged who will usually dominate the mapping exercise during group discussions (Gonzales, 2000).

3.6.3 Web-based GIS approaches

Internet GIS refers to a network-centric GIS tool that adopts the internet as primary means of providing access to spatial data and other information, disseminating spatial information, and conducting GIS analysis through a wider audience (Carver, 2001; Peng, 2001). The approach is an advanced form of the previous two techniques and seeks to improve grassroots decision making processes through reaching a wider audience of the society. Users of the technique have argued that with the potential increase in computer systems and applications, criticism levelled at GIS by Pickles (1995) and Obermeyer (1995) is no longer valid. GIS and the World-Wide-Web (WWW) are seen by users as effective and more pronounced technologies with the potential for public use allowing greater involvement in spatial and social decision making (Peng, 2001).

Relying on the merits of the technique, Batty (1993); Plewe (1997); Peng (1999); Carver (2001); Kingston *et al.* (2000); Caquard (2002) are notable scholars that have successfully adopted it to reach a wider audience in planning and natural resources research on the assumption that it allows the public to participate on issues being discussed, with web access anywhere and at anytime. However, some social commentators, such as Harris and Weiner,

(1998), and Weiner *et al.* (2003) have criticised the technique as restricted to the privileged few in the society with internet access to the neglect of the vulnerable in the society. It is argued that the technology prevents participation of certain segments of society who do not have computers or internet access. One, therefore wonders, how such a technique can be effectively utilised to assess environmental degradation holistically, in most rural and periphery-rural communities of developing countries, where computers are lacking and usage is at an infant stage.

3.6.4 Participatory 3-D modelling (P3-DM)

P3-DM is a step further in developing participatory sketch and scale mapping techniques reviewed earlier. It is a community-based mapping method developed in Thailand in the 1980s. P3DM has been conceived to support collaborative processes related mainly to resource use and tenure and aimed at increasing public participation in problem analysis and decision making. P3DM integrates people's knowledge and spatial information to produce stand-alone scale relief models that have proved to be user-friendly and relatively accurate data storage and analysis devices and at the same time excellent communication media (Rambaldi *et al.*, 2000). Relief models may display exclusively community knowledge composed from the mental maps of the participants or be enriched by additional geo-referenced information obtained from field surveys, Global Positioning Systems' (GPS) readings, and secondary sources. When linked to a Geographic Information System (GIS), the P3DM method bridges the gap existing between Geographic Information Technologies and spatial Indigenous Technical Knowledge (ITK) found among marginalised, isolated, and frequently natural resource-dependent communities.

The manufacture of a 3-D model leads participants through a collective learning process to the visualisation of their economic and cultural domains in the form of scaled and geo-referenced relief models, which can be subsequently used for different purposes. These include among others collaborative research and planning, management of conflicts bound to the territory and its natural resources, community based natural resource management,

participatory monitoring and evaluation and community cohesion and self-actualisation. One major constraint of participatory 3-D is their limited mobility due to their size and weight. Their use is therefore generally confined to those convening around them (Rambaldi and Callosa, 2001).

To upscale their utilisation, P3DM exercises are best integrated with GPS and GIS to make the content of the models portable and sharable. This allows adding precisely geo-referenced data, conducting additional analysis, and producing cartographic outputs. The synergies resulting from the combinations of the three systems add veracity and authority to community knowledge, paving the way for more balanced power-sharing in collaborative natural resource management (Rambaldi and Callosa, 2001).

Practitioners using physical 3-D models at community level have found that when informants are provided with a blank relief model instead of a blank contour map or a blank sheet of paper, they can easily depict their spatial knowledge in a scaled, geo-referenced manner and add a lot of precise details. The fact that 3-D models augment the power of mind and facilitate scaling, allows for filling in information more fully and accurately on a given area. Generally this is not the case with sketch mapping, which has been widely used to represent spatial knowledge in the context of participatory action research. The difference between a blank contour map and the corresponding relief model is the physical vertical dimension that provides essential cues for stimulating memory and for establishing spatial associations (Rambaldi and Callosa, 2001).

Participatory 3-DM has been tested for its robustness in northern Thailand to deal with conflicts among ethnic minorities and government agencies. In the Philippines, the use of the technique has been used among indigenous people to address land conflicts and other tenure issues (Rambaldi *et al.*, 2005). Also in Vietnam, the approach has been used to conserve biodiversity within the PU Mat National Park, Con Cuong, Nghe An Province through peoples participation.

The technique has yet to be tested for its robustness in environmental and natural resource assessment this may be due to its foreseen limitation in addressing social issues that are important when assessing environmental degradation in a more holistic approach taken into consideration issues spelt out in the DPSIR framework.

3.6.5 Mobile interactive GIS (MIGIS)

Mobile interactive GIS is the short form for community based planning that uses a mobile interactive GIS in conjunction with participatory rural appraisal tools to assess community natural resources (McCall, 2004). Its application is known to bring the best of indigenous knowledge and scientific data together for the provision of common ground on which local communities, government administrators and development planners can optimise their understanding of their natural resources and environment and work in a team to plan for a better future of their environment (McKinnon *et al.*, 2000). The MIGIS is purely a fieldwork technique that involves active participation of all involved through open access to laptop computers, digitisers, GPS systems, digital camera, video-projector and generator. Through this technique, computer graphics and GIS components are used to enhance the results of PRA exercises.

Materials drawn by the communities are either copied directly with digital photographs or a scanner or redrawn in a way which makes the content as clear as possible to illiterate participants by optimising the use of symbols and graphs. Sketch maps of land use are drawn to scale by participants, field checked by the team and projected onto a screen for correction, comments and used as a take off point for broad ranging discussions. The MIGIS exercise demonstrates how quickly participants can accept computer technology and see how it might help them. Users of the technique have argued that it adds new dimensions to existing PRA tools through active participation of those involved (McKinnon, 1998; McKinnon *et al.*, 2000).

The technique is based on the principle that local people are knowledgeable and capable of using computers, reading and drawing maps, understanding image maps like aerial photographs and satellite images, can draw up their own criteria, prepare trend lines, analyse institutional relationships and be able to discuss their situation on a maps or spatial data and make an informed and intelligent decision.

Despite its successful application in north Thailand and China for natural resource management (Mckinnon *et al.*, 2000), its robustness is rather limited in most developing countries for assessment of environmental degradation as computer and GIS technology are not widely available in most communities of peri-urban and rural African countries.

3.6.6 Community-integrated GIS

Community-integrated GIS has received great attention in recent years as a tool for involving local people in development and planning projects (Alcorn, 2000; King, 2002). The technique constitutes a process in which local people create representations based on local ecological knowledge and engage in the analysis of objects, relationships and issues. The technique is borrowed from PRA tools to challenge the top-down development approaches and methodologies that tend to ignore local knowledge and participation. The technique has been identified as an approach that enables communities to learn more about their environment, better organize information, plan and take necessary development action (Weiner *et al.*, 2003). This implies intensive involvement in analysis, mediating, sharing knowledge (between local persons and with external agents) and empowerment when and where decisions are made and action initiated. These characteristics have fuelled increasing recognition and the growth of community-integrated GIS as an approach to spatial planning.

The technique has, in recent years, moved from using basic sketch maps to include a range of technologies including GPS, compasses, three-dimensional modelling, photo-mapping, GIS based maps, remote sensing image interpretation, mobile GIS and utilising all kinds of multi-media graphics software in visualization (Alcorn, 2000; Gonzalez, 2000; McCall, 2002). The

technique was successfully applied in South Africa by Weiner *et al.* (2003) for studying land reforms and community forestry planning in Cameroon by Minang (2003). Despite its usefulness in involving local members in spatial analysis, it has not been applied to assess environmental degradation.

3.6.7 Spatial story telling

Similar to the community integrated GIS, “*spatial story telling*” (Aitken, 2002 cited by Howthorne, 2005) involves the empowerment of local communities, particularly the marginalized, unimportant, or left out, in local planning initiatives. One of the merits of the approach is that local community members are given an opportunity to voice their concerns in a way that is not typically possible in the usual top-down communal meeting. This approach also allows local community members to participate in the planning process in a more meaningful manner, by sharing their concerns through informal discussion and mapping exercises. Using the approach, marginalized community members that have had, historically, low levels of participation in spatial issues are encouraged to participate and share their views for inclusion in the broader spatial data analysis discussions. Participants in the spatial story telling approach are usually given the opportunity to map their community in a way that values their comments. They are able to talk openly to the research team and also made to feel empowered by the experience as researchers talk openly to local people, get their opinions and learn more about the history of the area under study. Despite the advantage of soliciting views from local people, the spatial story telling approach is best suited for research that mainly uses local, indigenous, illiterate focus group with the integration of expert knowledge from key informants as in the case of this thesis where expert knowledge from key informants is required for data triangulation.

3.6.8 GIS in participatory approach

GIS in participatory approach is quite similar to both the community-integrated GIS and the spatial story telling approach and represents an approach based on GIS in participatory research rather than a true participatory GIS. Users of the technique see it as a small step towards using GIS to provide access to geographical information (if not GIS per se) for the lower circuit of knowledge (i.e. the rural and urban poor) rather than merely for the upper circuit domain populated by the hi-tech, information and capital-rich. experts (Dunn *et al.*, 1999). The technique is borrowed from participatory appraisal techniques and grounded in the idea of using simple, inexpensive and rapid methods, that seems anathema to a technology like GIS, for soliciting first hand information for decision-making purposes. As argued by Williams and Dunn (2003), the nature of the GIS in participatory research helps expose the complexities of, and contrasts between local and technological understandings of geographical information as well as the merits and shortcomings inherent in the two methodological approaches. The approach utilises GIS technology in the context of community needs and involves communities in the production of GIS data and spatial decision making (Abbot *et al.*, 1998, p. 27-28). Users have also explained that the approach attempts to integrate official sources of spatial data and local, unconventional, ecological knowledge through PRA approaches such as focus group discussions, semi structured interviews, visual spatial representation, activity ranking and participant observation. It is on these qualities that the technique is adapted for this thesis, in a modified form, to design assessment methodology for environmental degradation in most savannah environments as in the case of northern Ghana.

3.6.8.1 Focus group discussion

Focus group discussion is seen in social sciences as an ideal participatory tool that provides valuable insights into the social, economic and institutional relations and characteristics of an area through the summation of individual opinions as obtained from structured or semi structured interviews (Goss and Leinbach, 1996). Krueger (1994) recommended focus group

discussion for a holistic study due to its potential capability of placing participants in natural, real life group interaction situations which often reduce inhibitions that might be present during individual interviews. Focus group discussion also allows participants to share and challenge opinions of others while at the same time scrutinising their own views as others share their knowledge and experience of the topic under discussion (Kitzinger, 1994; Myers, 1998). Through focus group discussions, the diversity of processes and practices that make up the social world and the richness of the relationships between people and places can be addressed and explored explicitly. A not inconsequential consideration of the approach is that group members invariably enjoy interacting with each other, offering their points of view and learning from each other (Agar and McDonald, 1995).

Concerning the procedure for organising focus group discussion, Bedford and Burgess (2001) and Hay (2004) argued that there is no agreed upon procedure in terms of participant number, types of participants, time lapses, sitting arrangement and the approach of discussion. This contradicts the views that effective learning and sharing of ideas proceed with specific number of participants not exceeding 10 people and within 1 to 2 hour session for maximum concentration (Burgess, 1996; Hay, 2004).

On the issue of the prolonged nature of focus group discussion, some social commentators are of the view that focus group discussion guidelines should not be too long so as to turn off the interest of participants. Hay (2004) suggested that in a normal focus group setting, not more than 11 issues should be presented for discussion and that the selection of discussion guidelines should take into consideration the nature of the research topic, the objectives being sought and the prior arrangements made with the participants. Swenson *et al.* (1992) suggested that issues to be discussed need to be comprehensive but not be too long to distract the interest of participants. Issues of major concern should come first which should later be followed by topics of less significance.

It is argued that selection of participants for a focus group discussion should be based on their experience related to the topic under study rather than random selection of people with no background to the topic (Cameron, 2000; Johnson and Johnson, 1996). Swenson *et al.* (1992) refer to this as purposive sampling as opposed to the random sampling that characterised many qualitative studies (Casey and Jost, 1995; Burgess, 1996).

The composition of group members for focus group discussion is the subject of debate but many are of the opinion that it should depend upon what the researcher wants to achieve and the peculiarity of the study area (Hay, 2004). Holbrook and Jackson (1996) sought to address issues of identity and thought it appropriate to select people according to characteristics such as age, sex, education, occupation and ethnicity to form a heterogeneous group. Other social commentators have noted that discussion of sensitive or controversial topics can be enhanced when groups comprise participants who share similar key characteristics and are of the same social background (O'Brien, 1993; Hoppe *et al.*, 1995).

Another issue raised towards the reliability of focus group discussion is whether people who are already known to each other should participate in the same group. In some research, it may be unavoidable to group acquainted members for focus discussion. However, confidentiality can be an issue as participants tend to over-disclose information about themselves in such situation rather than under-disclose or vice-versa (Morgan and Krueger, 1993).

Successful applications of focus group discussion in social science research are numerous and include: (i) Zeigler *et al.* (1996) who adopted the technique to find out about peoples responses to emergency procedures during a major hurricane; (ii) Burgess (1996) also applied the technique in combination with other methods to solicit information about factors that inhibit visits to and use of woodlands; (iii) Myers and Macnaghten (1998) used focus group discussions to investigate community responses to literature on environmental sustainability; (iv) Gibson *et al.* (1999) used the approach to study rapid social economic change in non-

metropolitan regions; (v) Jarrett (1994) adopted the technique to explore the daily lives of young single-parent African-American women; and (vi) Jackson and Holbrook. (1995) used it to examine the construction of identity through shopping. All these examples clearly illustrate its potential in soliciting details of social issues that are normally hidden in conventional quantitative scientific research.

A focus group discussion technique was adopted in this thesis as a method of data collection due its unique strength in placing individuals in a group context and the opportunity given to participants to express divergent views concerning the nature and characteristics of environmental problems.

3.6.8.2 Key informant interviews

Key informant interviews are content-focused conversations between a researcher and an individual who has lived in a research area for a period of time (Hay, 2004). Seidman (1998) and Dunn (2000) pointed out that individual interviews with knowledgeable members of a particular community, where interviews are to be conducted, help strengthen social science research through the sourcing of a diversity of views, opinions and perceptions from participants with different fields of expertise. Such information becomes relevant in identifying areas of agreement and difference in opinion among different key informants concerning issues being investigated.

It is widely accepted that data gathered from key informant interviews help validate data information collected from other participatory research methods, such as focus group discussion, household interviews and traditional quantitative surveying techniques (Dunn, 2000). Key informant interviews, in a semi-structured format, also allow researchers to understand issues of importance to participants, as opposed to other participatory appraisal research methods that focus on researcher-defined questions to test a hypothesis (Dunn, 2000). This is made possible as participants are allowed to reflect freely on the topic under discussion, based on their expertise, compared to conventional structured interviews where

questions are too rigid to provide for participants to express themselves in the ways they want to (Siedman, 1998; Dunn, 2000).

Tremblay (1982) had suggested that key informant interviews should be the initial contact in any social science research project as they are key informants and often possess the ability to introduce the researcher to other community members to be interviewed later and can also help structure some of the research questions with the consent of the researcher. Chambers (1994) and Limb and Dwyer (2001) supported the use of key informant interview, in participatory research appraisal, as they observed that key informants are crucial identities for constructing social reality through local experts and noted that it is the responsibility of the researcher to select key informants who are knowledgeable in the field of study.

The adoption of key informant interviews for this research work and as part of the GIS in participatory research is necessitated by the need to solicit and represent views and opinions from key community personalities. As already discussed, the advantage for opting for the technique is that it brings out valid information through one-to-one interviewing and recording and enables the researcher to cover wide range of information necessary for data analysis and recommendations (Chambers, 1994). The technique is also adopted, in this thesis based on its flexibility in clarifying complex and sensitive issues of interest, opportunity to meet key informants in the society and follow-up issues raised that need further clarification.

3.6.8.3 *Direct observation*

Direct observation involves a researcher or social worker living and working in a community for the purpose of soliciting directly information regarding his research (Cook, 1997). It involves a researcher understanding in the day to day affairs of a community under investigation, with the aim of obtaining further information to substantiate what has already been acquired through other means of participatory research (Jones, 1985; Marshall and Rossman, 1989). In support of the assertion made by Cook (1997) and Jones (1985); Eyles and Smith (1988) observed that getting oneself embedded in community daily activities,

allows a researcher to gain detailed inside knowledge of the community under investigation that would have been made difficult through other participatory research techniques.

Despite the fact that there are no laid-down rules for direct observation, it is recommended that researchers should spend an adequate amount of time in the research community to understand the dynamics of community life and also establish intimate familiarity with the community to be researched (Jones, 1985). The process of direct observation, in any social science research, involves systematic observation and recording of all activities, features and issues of interest as they happen, formally or informally, sometimes interviewing indirectly all those involved and gathering informal information related to the research plan (Creswell, 1997; Dowler, 2001). Direct observation through getting into contact with everyday community life has been adopted for a number of purposes and usually varies in terms of full direct observers and partial observers (Creswell, 1997; Dowler, 2001; Koti, 2004). Many social researchers, notably, Creswell (1997); Dowler (2001) and Jones (1985) are of the opinion that a researcher adopting a direct observation technique in social science research has a variety of modes to choose from, ranging from complete openness concerning their identity to complete secrecy. Mugendi and Mugendi (1999) argued on the basis of ethics and asserted that it is unwise to solicit information from a community without giving them adequate prior notice about the intention to collect such information.

The technique of direct observation for soliciting data has been utilised by many social scientists, anthropologists and geographers seeking to understand the meanings and social dynamics of a particular social setting within the context of day to day activities (Kearns, 2000). In such circumstances, the researcher experiences community life as an ordinary member of that community and daily experience and observations are recorded for further analysis (Creswell, 1997; Kearns, 2000; Eyles and Smith, 1988).

Numerous social researchers have adopted direct observations to gather information for analysis. For example, Ley and Mountz (2001) adopted the technique to observe the social

setting of the inner city of Philadelphia neighbourhood of Monroe. Rowles (1978) used the approach to explore the pattern of activities of older persons who have lived in the same working-class neighbourhood for many years, within their constricted physical setting. The research uncovered many aspects of their cognitive experience, psychological attachments to places and vicarious activities in other environments. Koti (2004) used the technique to investigate the complex socio-spatial dynamics of peri-urbanisation in Uganda.

Direct observation thus goes beyond the formal interactions with community members as common with structured and semi-structured interviews, household interviews and focus group discussions, to total involvement of the researcher in the real community life situation. It is upon this basis that direct observation is chosen as part of the techniques for the build-up of the assessment methodology for environmental degradation.

3.7 Analytical components of the assessment methodology

The previous sections had reviewed the various techniques of the research methodology. The following sections are the review of all the analytical procedures of the assessment methodology and the justification for their adoption. The first part is the review of satellite images pre-processing and classification and the second part is the review of the presentation and analysis of participatory research data.

3.7.1 Satellite image pre-processing

In recent years, huge databases of remote sensing images have been created. One property of these databases is that images come from different satellites and therefore have different resolutions. Pre-processing of satellite images prior to image processing and classification is essential in correcting such anomalies. Pre-processing commonly comprises a series of operations, including atmospheric correction or normalization, image registration, geometric correction, image sub-setting and initial classification (Coppin & Bauer, 1996). It should be emphasised here that detailed explanations of those scientific processes falls outside of scope of this thesis research.

3.7.1.1 *Normalisation*

The normalization of satellite images takes into account the combined measurable reflectance of the atmosphere, aerosol scattering and absorption, and the earth's surface (Kim and Elman, 1990; Du *et al.*, 2002). It is the volatility of the atmosphere which can introduce variation between the reflectance values or digital numbers of satellite images acquired at different times. Although the effects of the atmosphere upon remotely sensed data are not considered errors, since they are part of the signal received by the sensing device, consideration of those effects are important in remote sensing (Beinstein, 1983).

3.7.1.2 *Geometric rectification*

Geometric rectifications of satellite imagery resample or changes pixel grids to fit that of a map projection or another reference image. This becomes especially important when scene to scene comparisons of individual pixels in applications such as change detection are being sought (ERDAS, 1999).

3.7.1.3 *Image sub-setting*

Image sub-setting is the reduction in size of acquired image files to include only the area of interest especially where the acquired image scenes are much larger than the area under investigation. The process not only eliminates the extraneous data in the file, but also speeds up processing due to the smaller amount of data to process. This is important when utilizing multi-band data such as Landsat TM imagery. The reduction of image data is known as sub-setting. This process cuts out the preferred study area from the image scene into a smaller more manageable file (ERDAS, 1999).

3.7.1.4 *Initial image classification*

Image classification is defined as the extraction of distinct classes or themes from satellite images. There are two primary methods of image classification utilized by image analysts, unsupervised and supervised classification (ERDAS, 1999). *Unsupervised classification* is the technique in which the computer image interpretation software separates pixels in an image

based on their reflectance values into classes or clusters with no direction or interference from the analyst. The technique is usually adopted when little is known about the data before classification is performed thereby preventing the problem of the requirement for a normal distribution of pixel values needed for supervised maximum likelihood classification (ERDAS, 1999). The peculiarity of the technique is that the analyst later determines the land-cover types, for each class, based on image interpretation, ground-truthing information, topographic maps, field reports and the use of GPS and then assigns each class to a specific category by aggregation (ERDAS, 1999).

Despite the simplicity in the adoption of the technique, it is not devoid of limitations. The major limitations associated with the technique are as follows: (i) the fact that the number of categories are fixed a priori makes it not really unsupervised (ERDAS, 1999); (ii) its weakness in poor differentiation between vegetative types with similar reflectance values (Thomson *et al.*, 1998); and (iii) the lapses and inefficiency in terms of large sample size especially during classification of data of a large area (Viomy, 2000). These limitations, according to Townshend and Justice (1995), are often corrected through extensive work through GPS ground truthing, adequate knowledge of the area being researched and advised from land-cover experts.

Supervised classification is the classification often adopted for quantitative analysis of remotely sensed data (Lillesand and Kiefer, 1994). Using the technique, the analyst supervises pixel categorisation process by specifying, to the computer algorithm, class definitions, or signatures (numerical descriptors) of the various land-use and land-cover types present in a scene to train the classifier (Lillesand and Kiefer, 1994). To achieve that, representative samples sites of known land-cover types, training sites, are used to compile a numerical interpretation keys that describe the spectral attributes of each feature type of interest (Lillesand and Kiefer, 1994). During the classification process, the spectral patterns on the image data set are evaluated in the computer, using pre-defined decision rules to determine

the identity of each pixel which is thus compared numerically to each class in the interpretation key and labelled with the name of the category it looks most like. The algorithms adopted in supervised classification are either parametric or non-parametric (out of scope to give detailed explanations), depending upon whether the decision rule is based on normal distribution of the pixel values or not (Jensen, 1996).

The choice of unsupervised classification for this thesis is simple and based on the following factors: (i) it is less mathematical and more straightforward compared to the mathematical computation associated with supervised technique; and (ii) the situation of the research topic within PGIS that involves active participation of community members in the discussion and interpretation of processed image data through community truthing.

3.7.2 Change detection

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). Change detection is an important process in managing natural resources because it provides quantitative analysis of spatial distribution of the issue of interest. It is known to be very useful in diverse applications such as land-cover change analysis, monitoring shifting cultivation, assessment of deforestation, study of changes in vegetation phenology, seasonal changes in pasture production, damage assessment, crop stress detection, disaster monitoring, day-night analysis of thermal characteristics as well as other environmental changes (Singh, 1989).

Macleod and Congalton (1998) proposed four aspects of change detection which have been tested in various studies and that include the following: (i) detecting that changes have occurred; (ii) identifying the nature of the change; (iii) measuring the aerial extent of the change; and (iv) assessing the spatial pattern of the change, all based on the premise that changes in land cover result in changes in radiance values which can be remotely sensed and mapped out for further analysis. Techniques to perform change detection with satellite

imagery have become more frequent as a result of increasing versatility in manipulating digital data and increasing computing power.

A wide variety of digital change detection techniques have been developed over the last two decades to include: (i) image overlays; (ii) image differencing; (iii) classification comparison; (iv) principal composite analysis; (v) image rationing; and (vi) vegetative indices (Singh, 1989; Coppin and Bauer, 1996). The scientific literature has revealed that digital change detection is a difficult task to perform accurately, especially when one is looking at comparative evaluation, as results are usually affected by spatial, spectral, temporal and thematic constraints of the images being compared (Singh, 1989).

3.7.2.1 Image overlays

It is one of the simplest ways to produce a change image through a photographic comparison of a single band of data from two dates. The image is prepared by making a photographic two-colour composite showing the two dates in separate colour overlays. The colours in the resulting image indicate the changes in reflectance values between the two dates. For instance, features, which are bright on date 1, but dark on date 2, will appear in the colour of the first photographic overlay. Features which are dark on date 2 and bright on date 2 will appear in the colour of the second overlay. Features which are unchanged between the two dates will be equally bright in both overlays and hence will appear as the colour sum of the two dates (Singh, 1989).

3.7.2.2 Image differencing

It is the common approach to quantify image brightness change associated with land cover change. It involves the subtraction of image brightness values on a pixel by pixel basis. The image brightness values may represent spectral radiance values of like wave band images or continuous values derivations of waveband images (Su, 2000). The procedure involves the co-registration of two images of the same area taken at different times to assess the degree of change that has taken place between the dates of imaging and preparing a temporal difference

image by subtracting the digital numbers for one date from those of the other as shown in Figure 3.2. The difference in the areas of no change will be low in digital numbers and areas of change will reveal larger positive or negative values (Lillesand and Kiefer, 1994). Sunar (1998) performed change detection between dates of 1984 and 1992 and observed that areas of no change were represented by a value of 127 (mid grey), while areas that were darker in 1992 than they were in 1984 had values of 128-255 (Sunar, 1998). Gupta and Prakash (1998) also generated a difference image by subtracting 1990 image from 1994.

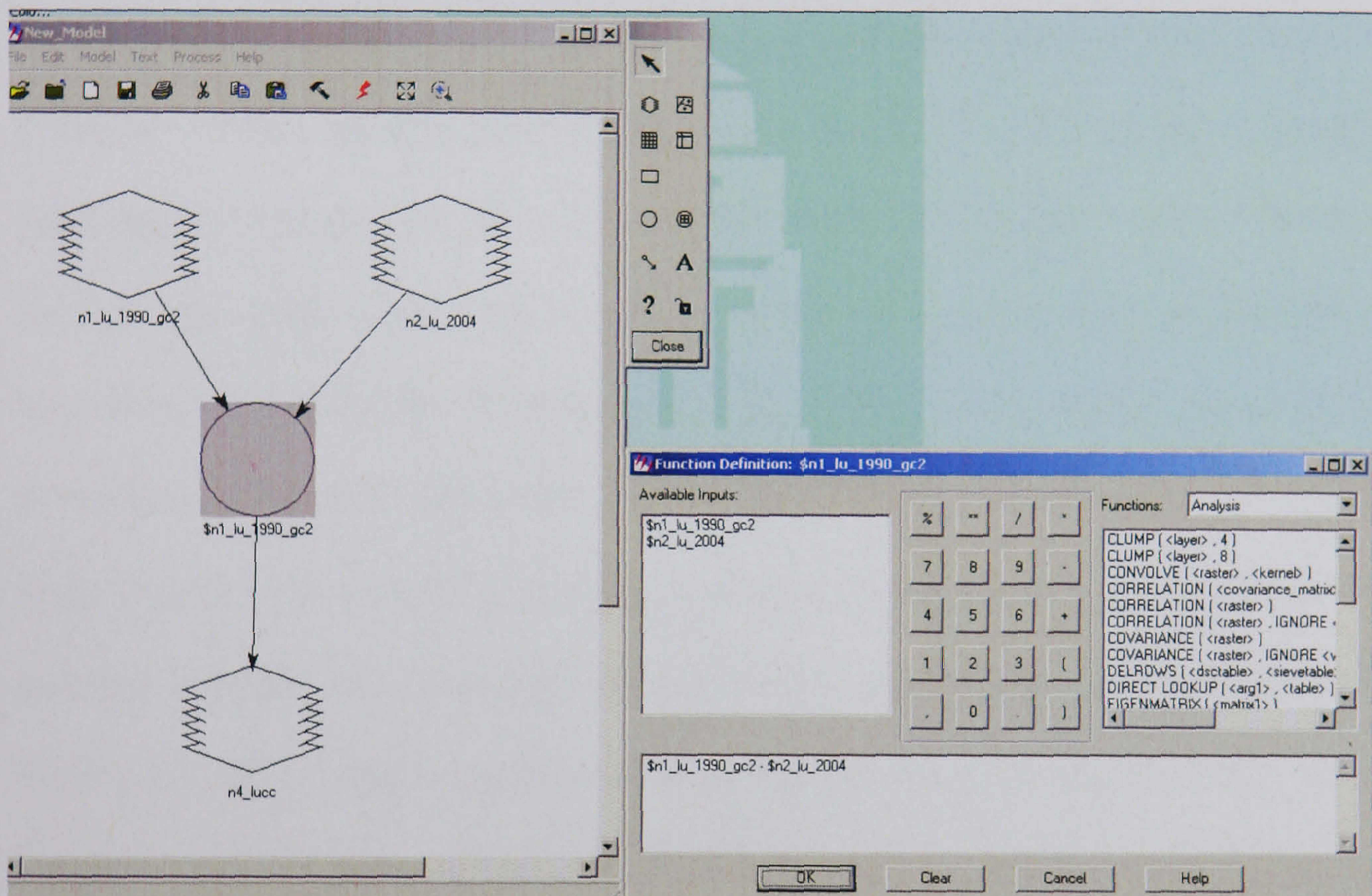


Figure 3.2: Image differencing

Source: Su (2000)

The resultant difference image is Gaussian in nature, with no change pixels centred on the mean, while the tail regions on either side contain information about the changed areas. On such an image, bare areas and areas where vegetation has decreased appeared in dark tones, while areas where vegetation has increased appeared in bright tones. No change areas appeared in grey tones.

3.7.2.3 *Classification comparison*

Classification change detection is adopted in this study because of its potential capability for comparing two or more independently prepared classified images (Howarth and Wickware, 1981). The accuracy of post-classification change detection depends on the accuracy of each of the initial classifications, the accuracy of the geometric registration of images and the spectral separability of the classes involved (Howarth and Wickware, 1981; Mas, 1999; Singh, 1989).

On the issue of statistical generation of post-classification change detection, Howarth and Wickware (1981) pointed out two important methods; the first is the calculation of the percentage of change and the second is the creation of change matrix. The first method involves the creation of a list of areas represented by each class at different dates and calculating the percentages of change in the area. Critics of this method placed their argument on the lack of adequate information of the changes been observed and calculated. A change vector matrix is the suitable alternative for measuring the results of post-classification change detection analysis. The advantage of producing a change matrix, according to Howarth and Wickware (1981) is that it describes not only the amount of changes that have taken place for a specific period of time but the type of changes that have occurred as well. For the purpose of this study, through the utilisation of a PGIS concept that seeks to promote public participation in spatial analysis (reviewed in chapter 2), the adoption of a vector matrix is not considered in this thesis with the aim to examine how local ecological knowledge could be tapped to assess the types of changes that have occurred for a specific period of time.

3.7.2.4 *Principal composite analysis*

It is used to detect and identify a temporal change when registered TM images are merged and treated as single data set. By this method, a new set of co-ordinate axes are fitted to the image data. The first new axes or component will account for maximum variance. Subsequent axes will account for smaller portion of the remaining variance. Changes to be anticipated are of

two types. The first are those that would extend over a substantial part of the scene, such as changes in atmospheric transmission and soil moisture status and those that are restricted to parts of the scene, such as the construction of roads or the destruction of green areas (Campbell, 1995).

3.7.2.5 *Image rationing*

The simple ratio of near-infra red reflectance to red reflectance is a widely used vegetation index. The method is commonly referred to as image rationing (Tucker, 1979). A strong correlation exists between the ratio of the visible red and near-infra red reflectance of vegetative cover and leaf area index and biomass. The ration (SR) of near-infra red reflectance (Rnir) to red reflectance (Rred) is calculated as follows:

$$SR=Rnir/Rred$$

3.7.2.6 *Vegetative indices*

The use of vegetative indices based on the red and near-infrared reflectance recorded in remote sensing data is a common practice (Su, 2000). Vegetative indices directly correlate with biomass or primary productivity and with other biophysical parameters, such as leaf area index, leaf water content, chlorophyll and other biophysical characteristics (Tucker, 1995).

3.7.3 Land-cover classification systems

Many land-cover classification systems are designed, specifically, for use with remotely sensed data which often resemble or incorporate other classification systems in order to maintain cohesiveness and allow for data integration. A hierarchical classification framework is often implemented within a classification system that allows level of details to vary for different research topics and for the creation of land-cover types that are compatible with other classification systems (Foti *et al.*, 1994). Based on this, Anderson *et al.* (1976) had, earlier on, developed a hierarchical land-cover classification system for utilization with remote sensing data which is adopted by the U.S. Geological Survey for 1:250,000 and 1:100,000 scale land-use and land-cover mapping. The Anderson classification system has

also been adopted in most contemporary land-cover research utilizing remotely sensed satellite data.

As a hierarchical classification framework, the Anderson classification scheme is composed of different levels of land-cover/use categories which are dependent on the level of details required within the project scope. Level I is often broad classification categories with examples such as urban, forest, agricultural land, and water classes. Level II categories offer more details and are usually sub-divisions of the level I category. Examples of level II categories are coniferous forest, deciduous forest, and possibly mixed forest classes. Level III categories are often used in local studies which incorporate detailed issues of both the levels I, which are principal vegetative and non-vegetative land cover and II, which are sub categories of the principal vegetative cover defined in terms of formation characteristics, canopy closure, tree stand density and dominant life form (Anderson *et al.*, 1976).

Agyepong *et al.* (1996) (Appendix 3.1) also presented a hierarchical scheme of land-cover/land-use that accommodates different levels of land-cover/use information starting with broad level classes. Their scheme was structured to allow further subdivision into more detailed sub-classes at higher levels. Four levels were recognised which are defined as follows: Levels I is the principal vegetative and non-vegetative landscape cover, Level II is the sub-categories of the principal vegetative and non-vegetative cover defined in terms of formation characteristics of canopy, close tree stand density and dominant life form, Level III is the land use defined in terms of the major human management systems and Level IV is the land-use categories defined in terms of products and services.

This study adopts the level I category of Agyepong *et al.* (1996) classification system with the aim, and as part of PGIS philosophy, of giving selected research participants greater opportunity to give account of all observed changes on the environment.

3.7.4 Ground truthing

Most GIS researchers are of the opinion that classified remote sensing imagery should be quantitatively evaluated for its accuracy before it can be useful to the researcher or the user community (Moufaddel, 2005; Mas, 1999; Congalton, 1996). The usual technique is the error matrix (sometimes called a confusion matrix or contingency table) (Card, 1982 and Congalton, 1996). The error matrix is a square numbers defined in rows and columns that represent the number of sample units (pixels, clusters of pixels, or polygons) assigned to a particular category relative to the actual category as confirmed on the ground. The rows in the matrix represent the remote sensing derived land-cover map (Landsat classified data), while the columns represent the reference data (Jensen and Christensen, 1986). The matrix produces many statistical measures of thematic accuracy including overall classification accuracy (the sum of the diagonal elements divided by the total number in the sample) and the percentage of omission and commission error by category, (Cohen, 1990; Congalton, 1996). According to Jensen (1996), error of omission (producer's accuracy) indicates the percentage of times a particular land-cover type on the ground is identified as that land-cover type on the map produced. It denotes how well the map producer identifies a land-cover type on the map from the satellite imagery classified data.

The producer's accuracy takes into account of individual classes and indicates the probability of cell value in map 2 being the same as in map 1. It is mathematically expressed as:

$$\frac{X_{ii} \times 100}{X_{+i}}$$

where X_{ii} is total number of correct cells in a class and X_{+i} is the sum of cell values in the column.

Error of commission (User's accuracy) indicates the percentage of times a particular land-cover type on the map is really that land-cover type on the ground. It expresses how well a

person using the map will find that land-cover type on the ground. The user's accuracy takes into account the accuracy of individual classes; indicates the probability of the cell value in map 1 being the same as in map 2. It is mathematically expressed as:

$$\frac{X_{ii} \times 100}{X_{i+}}$$

where X_{ii} is the total number of correct cells in a class and X_{i+} is the sum of cell values in the row.

The overall accuracy indicates how well classified imagery identifies all land-cover types on the ground and summarizes the total agreement-disagreement between the maps, incorporates the major diagonal and excludes the omission and commission errors. It is represented mathematically as:

$$\frac{D \times 100}{N}$$

where D is the total number of correct cells as summed along the major diagonal; N is the total number of cells in the error matrix. Usually, an "assumed-true" reference data are derived from ground truth data. However, it is typically not practical to ground truth or otherwise test every pixel of a classified image. Therefore, a set of *reference pixels* which are points on the classified image for which actual data are known, are usually used. Normally, *reference pixels* are randomly selected based on available sources of land-cover reference information, such as existing maps or aerial photos. If these sources are representative and chosen independently of those used to classify the land-cover map, an accurate assessment of error can be made (Congalton, 1991). An important factor in determining the accuracy of a classification is the number of *reference pixels* used. According to Congalton (1991) more than 250 *reference pixels* are needed to estimate the mean accuracy of a class to within plus or minus 50%.

3.7.5 Community truthing

The term was first proposed by Agyemang *et al.* (2007) to mean the empowerment and involvement of local people to review, comment and give meanings to spatial data of relevance to them. As a synonym to ground truthing, community truthing is the validation of classified remote sensing images by local people in terms of its accuracy and meanings to any observed changes. The term originated from the GIS and Society concept reviewed in chapter 2 to mean the recognition of the fundamental importance of involving local people in the evaluation of classified images for policy formulation. Through a wide range of participatory rural appraisal techniques, such as key informant interviews, focus group discussion and participants' observation, selected people from a community are given the chance to critically review classified images, identify issues and add meanings in terms of the nature and causes of observed changes. The approach is based on visual interpretation and less on participants mapping in the analysis and interpretation of image maps.

Community truthing is an attempt to make use of conventional GIS, within local ecological knowledge, to assess the spatio-temporal state of the environment, evaluate the driving forces, assess the impacts and coping strategies and evaluate responses for a better environment. It is based on an interpretative philosophy of examination of the meaning and symbol content of quantitative data (Seidel and Kelle, 1995). The approach is based on the use of reality probability statements instead of real accurate description statements by participants, meaning that the views, opinions and comments of participants are taken seriously, despite sometimes being triangulated with theories, secondary evidence and statistical data sources. The tool is based on the *hermeneutic approach* which is conceived as the philosophy of understanding and interpretation of qualitative data, devoid of detailed statistical analysis and margins of error and based purely on participants' perceptions, views and opinions of issues of interest (Glaser and Strauss, 1967; Gadamer, 1989).

This aspect of the proposed assessment methodology (Phase 2) is devoted to community truthing of classified satellite images as a step towards the utilisation of conventional GIS to

provide access and meanings to geographical information for local people rather than the populated hi-tech, information-and capital-rich 'experts' (Williams and Dunn, 2003, p. 397).

3.8 Conclusion

This chapter has justified the adoption of methodological triangulation for the build-up of general assessment methodology for environmental degradation assessment. Despite the potential importance of conventional GIS and participatory approaches in the assessment of natural resources it was argued in the chapter that none can successfully be utilised as a stand-alone technique to assess environmental degradation due to its complex nature as reviewed in the previous chapter. This was reflected in the review of the merits and shortcomings of the component parts of the proposed assessment framework (Figure 3.1) that justifies the adoption of mixed methods in the assessment of environmental degradation. The next chapter presents the case study area to test the robustness of the designed assessment methodology in this chapter and proceed to the detailed presentation of the fieldwork activities that aimed at putting theories into practice.

Chapter 4

Study Area, Data Sourcing and Analysis

4.1 Introduction

In the previous chapters, attempts have been made to place the research topic in its theoretical and conceptual frameworks and subsequently design an assessment methodology for environmental degradation. In this chapter, an explanation is given to the choice of the study area, Bolgatanga and Talensi-Nabdam of northern Ghana and research methods to collect relevant data to answer the research questions outlined in chapter 1. The chapter is in two parts. First, a description of the study area is given to justify its selection to test the robustness of the assessment methodology structured in chapter 3. This is followed by a description of data sourcing and analysis to meet the aim and research questions outlined in chapter 1.

The purpose of the chapter is to generate evidence-based information on the nature, causes and effects of environmental degradation that have prevailed in the Bolgatanga and Talensi-Nabdam districts of the Upper East Region of northern Ghana from 1990 to the present. The chapter is guided by the five main research questions outlined in chapter 1, section 1.4.

To answer the research questions, a GIS based participatory approach within a GIS and Society framework was adopted. This is because the approach offers the potential for integrating geo-spatial data information with local ecological knowledge and build on participation of local people to create an in-depth knowledge of place, while overcoming attribute limitations inherent in conventional GIS technique. The designed methodology employed in this study thus integrate geo-spatial information techniques including GIS, remote sensing and global positioning system with participatory approaches such as semi-structured key informant interviews and focus group discussions to discuss the causes and

effects of environmental degradation in northern Ghana. With the aid of referenced classified spatial data, opinions, perceptions and experiences of research participants, on issue of environmental degradation in the Bolgatanga and Talensi-Nabdam districts of northern Ghana, were manually analysed and systemised into a GIS database. using the standard procedures of Arc Info, as layers of information. The knowledge base covers the nature and extent of environmental degradation, the direct and indirect causes, the impacts, community coping strategies and responses for a better environment.

4.2 Study area

In order to test the robustness of the proposed assessment methodology, the case study area was chosen to represent a wide range of environmental, social, economic and cultural issues.

4.2.1 Location

The area of this study consists of the Bolgatanga and Talensi-Nabdam districts of the Upper East Region of northern Ghana (Figure 4.1 and 4.2) are described as one of the most deprived and degraded areas of Ghana. The districts were created through the splitting of the former Bolgatanga district into two administrative districts, namely Bolgatanga and Talensi-Nabdam with Bolgatanga as the regional capital (Crawford, 2004). They are located on the north-eastern corridor of Ghana between longitude 1°W and 0°E and 10°N and 11°N and cover an area of 1,509 km² or 16.7% of the 8,842 km² of the Upper East Region of Ghana. The estimated population is 229,768 or 24.8% of the population of the Region which was 917,251 in 2000 according to the Population and Housing Census for 2000 (Ghana Statistical Service, 2000).

4.3 Physical characteristics

The area falls within the Dickson and Benneh (1988) Guinea savannah zone that lies between 8° N and 13° N and corresponds to the tsetsefly zone known as the “*middle belt*” of West Africa. It is part of the tropical continental climatic zone characterised by pronounced dry and wet seasons (Benneh *et al.*, 1990). Rainfall is usually infrequent, discrete and largely unpredictable. The peak rainfall period is usually late August and early September with 60% of it occurring within the months of July to September (IFAD, 1990). Periods of dry season usually last for 5 to 6 months, from November to late March, with occasionally droughts at the beginning of rainy season (Bolgatanga Meteorological Service, 2003).

Temperature is consistently high with relatively small seasonal variations. The hottest months are from early March to late April, just before the beginning of the rainy season, while the major rains occur usually in August. Temperatures are usually within the range of 18 to 38°C with relative humidity of 69 to 95% (Bolgatanga Meteorological Service, 2003). Its soils (Appendix 4.1) are characterised by shallow, low in organic matter content and coarse in textured luvisols in the north eastern portion of the study area with ample evidence of the presence of minerals, especially gold. Soils are formed out of the rock types and the underlying geology which is mostly granite, birrimian rocks and sandstone producing loamy sand, sandy loam and sandy clay loam through weathering processes (Senaya *et al.*, 1998). A common characteristic of the soils is its poor filtration during the long dry season as a result of the high clay content.

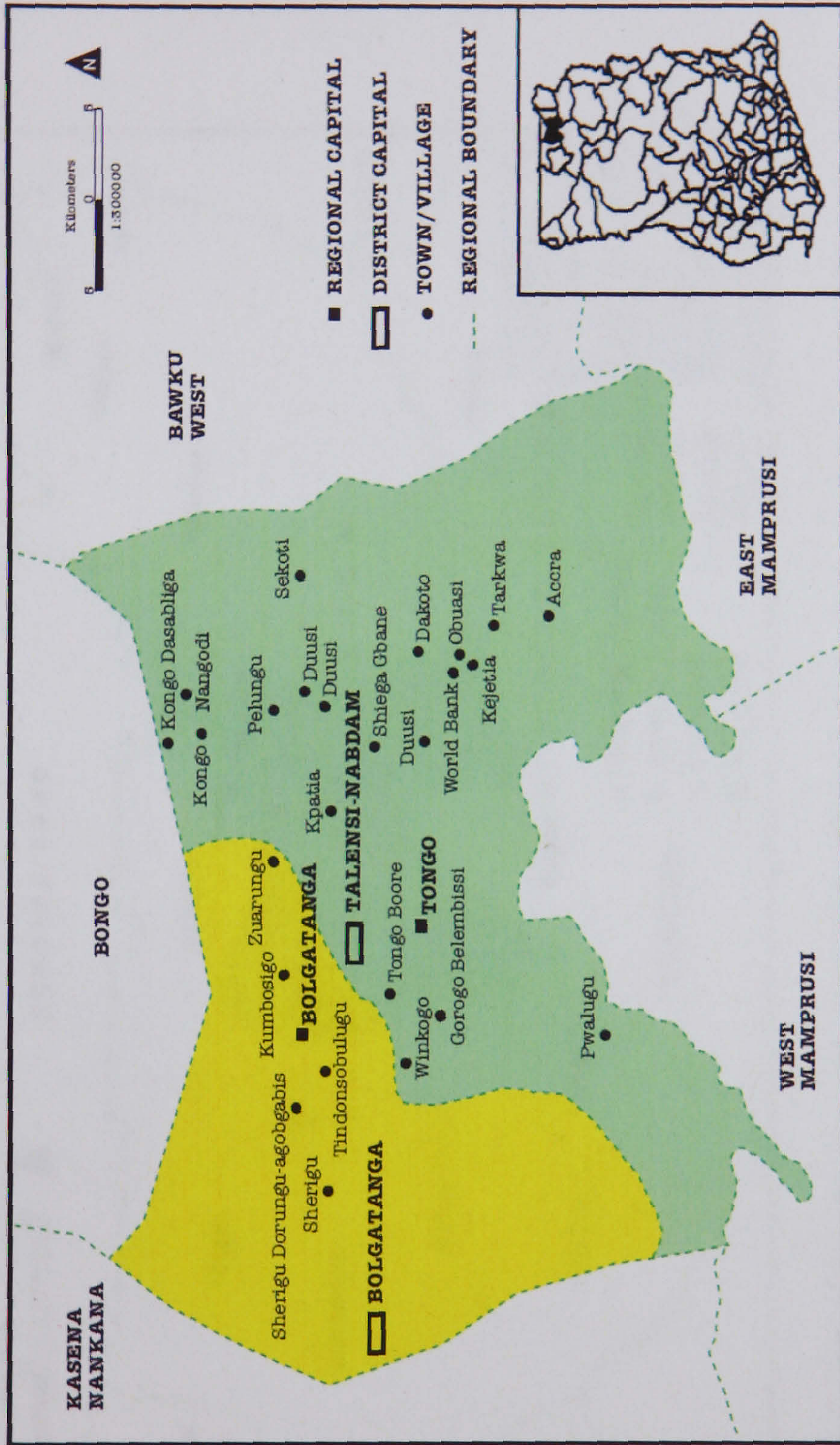


Figure 4.1: Study area
Source: CERSGIS (2005)

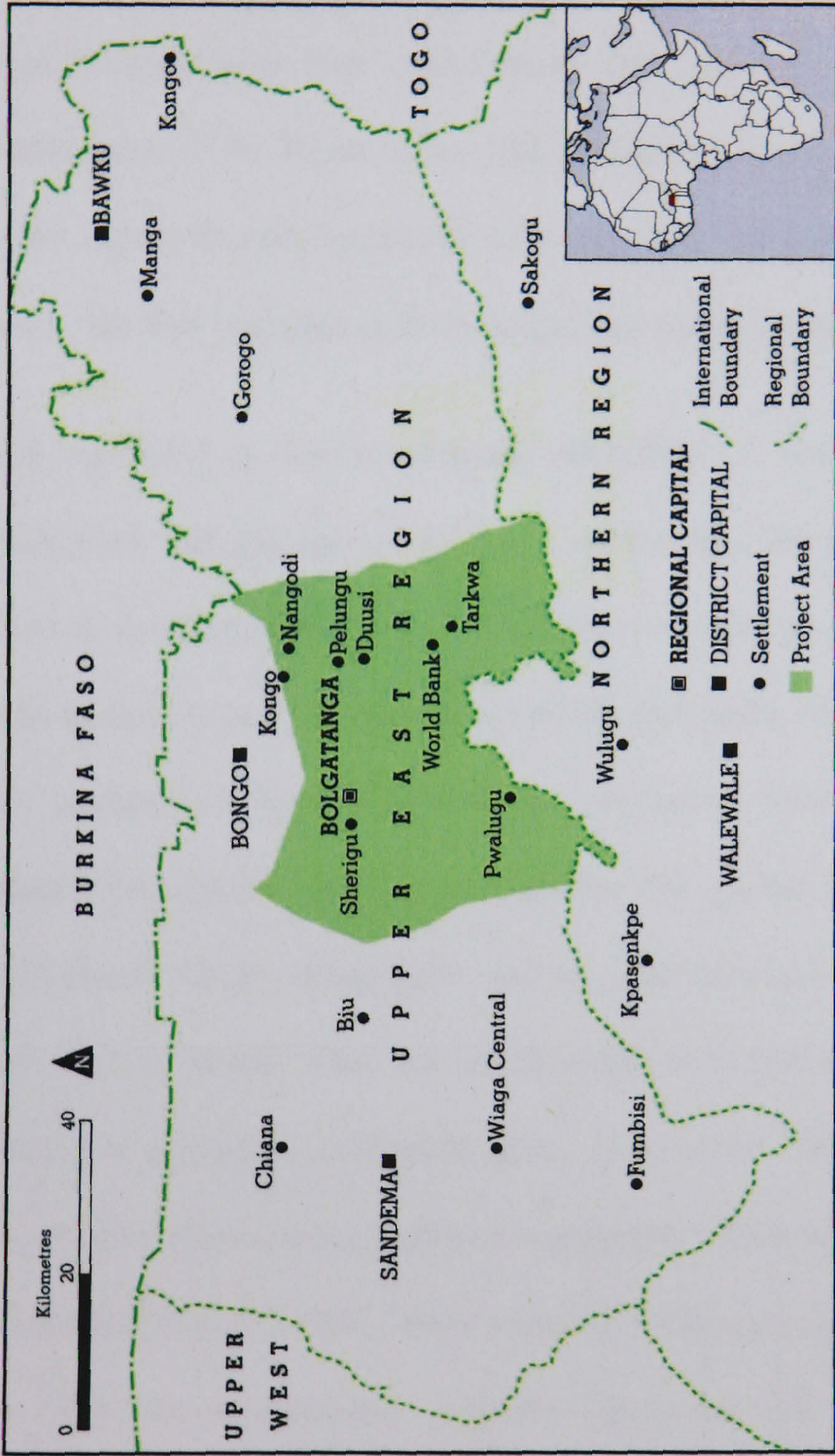


Figure 4.2: Map of Upper East Region showing study area

Source: (CERSGIS) (2005)

4.4 Land cover

The surface relief is characterised by flat to gentle slope with uplands of an average elevation of about 300m above sea level which are mostly found in the Tongo and Pwalugu areas of Talensi-Nabdam district (Appendix 4.2). The main rivers are the White and Red Volta and their tributaries. Drainage is mainly by the White, Red Volta, Sissili, Kulubiliga, Owon and Kuldage Rivers (Upper East Coordinating Unit, 2003) with Kulubiliga and Kuldage as the main tributaries of the White Volta. The Kulubiliga, Owon, Kuldage are the main sources of water for industrial and household activities. The drainage systems are supplemented with irrigation, the Vea irrigation at Bolgatanga, especially for domestic and dry season farming.

Natural vegetation is mainly savannah woodland of short, closed and scattered drought-resistant trees and grasses (of height 3 metres and above) that are frequently burnt and scorched by bushfires and the sun during the prolonged dry season. Indigenous trees found in the area include locust (dawadawa) (*Parkia biglobosa*), shea (*butyrospernum parkii*) kapok (*Ceiba pentandra*), baobab (*Adansonia digitata*), whitethorn (*Faidherbia albida*), and tamarind (*Tamarindus indica*), interspersed by exotic trees such as guava (*Diospyros mespiliformis*), mango (*Magnifera indica*), teak (*Tectona grandis*) and neem (*Azadirachta indica*). The savannah trees are interspersed with various grasses such as gamba grass (*Andropogon gayanus*), guatemala grass (*Tripsacum laxum*), elephant grass (*Pennisetum purpurem*) and guinea grass (*Panicum maximum*) which are usually tall annual and perennial (Asiamah and Senaya, 1988). Food crops of socio-economic importance in the area include millet (*Pennisetun glaucum*), sorghum (*Sorghum bicolar*), maize (*Zea mays*), beans (*Phaseolus vulgaris*), groundnuts (*Arachis hypogea*) and rice (*Oryza sativa*) (MOFA, 1997; 1998).

4.5 Social processes

It is obvious that the unfolding spatio-temporal ecological crisis in northern Ghana is essentially induced by socio-economic, cultural and political settings as in the case of the study area.

4.5.1 Population, migration and rural development

The study's area population has risen from 183,800 in 1990 to 229,768 in 2000 with 20,416 houses and average household size of 5.8 compared to the 1990 of 5,432 houses with average household size of 3.7. Population density, as at 2000 was 174 persons/ km², as against 1990 of 140.1 persons/ km², with the sex ratio of 48% males and 51% females compared to 1990 sex composition of 56% and 44% respectively (Ghana Statistical Service, 2000). On population structure, it is estimated that 1 out of every 8 persons is a child below the age of 5 compared to the 1990 where the estimated figure was 3 out of every 8 persons. It is also estimated that 19% of the population as at 2000 were youths of age between 15-19 years as against 10% in the 1990s. The percentage population by age between 20 to 55 years is about 45% of the entire population as at 2000 as against 32% in the 1990s. The older population of 65 and above forms the smallest portion of the entire population of about 9% as against 17% in the 1990s (Ghana Statistical Service, 2000).

According to the Bolgatanga District Assembly report (2002), the area received its highest proportion of Ghanaian migrants during late 1990s; most of them were between 20 to 55 years and mostly from southern Ghana. According to the Population and Housing Censuses for 2000 (Ghana Statistical Services, 2000), about 65% of the total Ghanaian migrants come from the southern regions of Ghana and mostly from the Ashanti and Western Regions. Migrants from outside Ghana make up of 7.9% of which about half of them are Fulani herders from neighbouring Burkina Faso, Mali and Niger. About 20% of the total workforces in the study area are migrant workers. In the Bolgatanga Township, about 40% of the population are Ghanaian migrants of which 15% are aged between 20 to 45 years, thus very different from the 1990 population figures, where migrant workers were 5% of the total workforce and were

mostly civil servants. The two adjacent regions (northern and upper west) do not appear to be a significant pulling factor for migrants into the study area as they account for about 22% of the migrant forces.

The area is predominantly rural (with about 85% of the indigenous population concentrated in the rural areas in 2000 compared to 97% in the early 1990s) with less economic and infrastructural development. Most of the rural communities are found in the Talensi-Nabdam district which, over the years, has received less infrastructural and developmental projects and attracted very few migrant populations. In essence, the rate of urbanisation in the Bolgatanga districts, for the 14 year period of study, far exceeds that of the Talensi-Nabdam district. Major economic and infrastructural developments that have occurred since 1990, mostly in the Bolgatanga district, and include social facilities, electricity, international communication centre, hospitals, schools, hotels and a sport stadium (Bolgatanga District Assembly report, 2002).

4.5.2 Townships and settlement

Bolgatanga, which is about 120 km² of the 1509 km² of the study area, is the largest town in the study area and district capital of the Bolgatanga municipality which is approximately 420 km². It is situated in the north-western portion of the study area and is about 40 km south of northern region. The Talensi-Nabdam district, located in the eastern portion of the study area is about 1,100 km² in size with the district capital at Tongu, 88 km² in total size. During the period of 1990 through 2004, and as part of the economic recovery programme, the study area has seen major infrastructural developments in terms of expansion of towns and settlements. Known small-scale mining communities such as Accra, World Bank, Tarkwa, Kejetia, Bantama and Obuasi were created by small-scale miners in the late 1990s. Other well known communities in the study area and of interest include Sheaga, Nangodi, Kongo, Winkogo, Pwalugu, Pelungu, Yikine, Sekoti, and Zuarungu, Gororo Yikpemeni, Tindongobulagu Duusi, Sheaga, Pelungu and Sherigu (see Figure 4.1 and Figure 4.2) (Ghana Statistical Service, 2000).

The dispersed settlement system has not changed much for the last 15 years with the exception of few settlements in the Talensi-Nabdam district where family houses are built closed to each other. The layout of a typical house and land holding is a symbolic reflection of family structure and stage of community evolution respectively (Hunter, 1965).

4.5.3 Political setting

The political setting and system of governance have also not changed much since 1990. The society is mainly patrilineal and patrilocal, based on hierarchies of clans and lineages that control access to land and other natural resources and exercise authority in marriages, funerals, religious and social ceremonies. The local level political governance is based on traditional sets of micro-states or chiefdoms. The chiefs serve as the spiritual leaders and perform the occasional traditional rites to ancestors, settle disputes and arguments and sanction evil deeds.

Despite the numerous gender awareness programmes, in the study area, some initiated by the women's wing of the former National Defence Council (NDC) regime during the 1990s and the Ministry of Women and Children Affairs of the present government, most women in the three northern regions are still marginalised in terms of resource allocation and decision-making processes. In most of the rural communities in the study area, the role of women is usually limited to household activities (Upper East Regional Coordinating Council, 2003). Most of them lack basic control over economic resources like land, labour and capital and are often marginalised to productive ventures such as petty trading and sand and stone winning with detrimental effects on growth and development. Female circumcision is still prevalent in most of the communities especially some remote rural areas in the Talensi-Nabdam District (Bolgatanga District Assembly report, 2002).

4.5.4 Tribes and migrant populace

There has been a great change in the number of ethnic groups in the area for the 14 year period of study. The original ethnic tribes in the area are Gurunne (Frafra) from Bolgatanga and the Nabte of the Talensi-Nabdam. Other ethnic migrant groups from the other areas in the north include the Builsa, Busanga, Kasena, Kusaasi, Mamprusi, Moshi, Sissalas, Wangaras, Busangas, Dagaaba, Dagartis, Mossis, Dagomba and Nankani. There are also a number of migrants from other regions of the country, especially the Asantes, Bonos, Ewes and Fantes few of whom are government workers with the majority engaged in the informal sector. Other migrants are from the neighbouring Togo, Mali, Nigeria and Burkina Faso (Bolgatanga District Assembly report, 2002). The influx of migrants started in the early 1990s shortly after the economic recovery programme that saw the initiation and implementation of major infrastructural development coupled with the legalisation and promulgation of the small-scale gold mining activities (Ghana Statistical Service, 2000).

4.5.5 Land tenure and property regime

The introduction of the structural adjustment programme as part of the conditions associated with the IMF (International Monetary Fund) and the World Bank loan packages, during the late 1980s, has brought about changes in land ownership in many parts of Ghana including the study area. Before then, in the late 1980s, land ownership, rights and tenures were originally administered under the traditional customary law under the care of the spiritual head of a clan or community. The system was later replaced with a plural legal environment with customary laws and norms operating alongside statutory government land-use policy. Under the new land policy system, the spiritual head, on behalf of a particular clan, owns 78% of the total land entrusted under his care, 20% is statutory concession, under the Lands Commission Act of 1994 (Act 483) in accordance with Article 258 of the 1992 Constitution of Ghana, is reserved for the state government for various developmental projects under the supervision of LCS (Lands Commission Secretariat) (Karikari *et al.*, 2003). The remaining 2% is held in

dual ownership between the state government and the community. Land disagreements have prevailed in many communities in the study area due to lack of comprehensive data on land ownership and well defined boundaries but the situation has changed recently as a result of state government land demarcation scheme under the Survey Department of the Ministry of Lands and Natural resources (Kasanga, 1997a). The respect and value attached to land resource, by the local indigenous people and migrants, have changed during the 14 year period of study from sacred, well cherished commodity to unconcerned attitude with inadequate management practices for preservation (Kasanga, 1997a). Particular evidence in the study area, which has not changed for the years of study, is that each parcel of land, in the trust of the spiritual leader, is owned by an extended family and a member identifies his or her portion through his family land. Allocation to individual family members is done in accordance with such individual or family needs and devoid of discrimination of common ownership principles.

Land acquisition by individual members, for any economic venture, mostly farming, is preceded with the formal presentation of a customary gift to the spiritual leader in recognition of his leadership (Kasanga, 1997b). Strangers or migrants, who wish to acquire land for economic purposes, have to do so through contractual arrangements with the spiritual head. Such arrangements are but for a specific period of time as agreed by both parties (Bassat, 1993; Kasanga, 1988). As already mentioned, during the 1990s, land allocations were specific for farming, grazing and settlements which have expanded in recent years to include developments and infrastructural developments such as the road network, water reservoirs, community housing, market facilities, hospitals, telecommunication centres, schools and colleges under the new land policy reforms.

4.5.6 Poverty

The Household Living Standards Survey carried out by the Ghana Statistical Service in 1998/99 estimated that the average Ghanaian lives less than one dollar a day, majority of whom are rural folk engaged in food production. The level of poverty has not changed much during the 14 year period of study as poverty is still endemic in the three northern regions of Ghana (Boateng *et al.*, 1992). The FAO/IFAD (1989) described the area as one of the most drought prone, resources poor and poverty stricken areas of the country. Table 4.1 is a regional poverty profile for 1992-2000. In 1992 the Upper East Region recorded the second highest figure of 66.9% of people living in extreme poverty (less than one dollar a day). The figure increased dramatically in 2000 where 88% (the highest compared to the other regions) of people living in absolute poverty were recorded. The Population and Housing Census for 2000 (Ghana Statistical Service, 2000) gave an estimation that 9 out of 10 inhabitants are poor in the Upper East Region (location of study area) compared to 7 out of 10 in the northern Region and 8 out of 10 in the Upper West Region.

Table 4.1: Ghana regional percentage poverty profile for 1992-2000

Regions	1992	2000
All Regions	51.7	39.5
Upper West Region	88.4	83.9
*Upper East Region	66.9	88.5
Northern Region	63.4	69.2
Brong Ahafo Region	65.0	35.5
Ashanti Region	41.2	27.7
Volta Region	57.0	37.7
Eastern Region	48.0	43.7
Greater Accra Region	25.8	5.2
Central Region	44.3	48.4
Western Region	59.6	27.3

* Poverty profile of the Upper East Region where the study area is located.

Source: Ghana Statistical Service (2000).

Women folks are much poorer in the area compared to their male counterparts as tradition and customs usually forbid them from taking any serious economic ventures. It is estimated that about 95% of the local women workforce are living in extreme poverty compared to about 78% of their male counterpart in 2000 which has not changed for the 14 year period of study according to the Population and Housing Census for 2000 (Ghana Statistical Service, 2000).

4.6 Land uses

4.6.1 Agriculture

The main economic activity in the study area is small-holder agriculture practiced by almost 90% of the population during the 1990s and 78% in recent times (MOFA, 1997; 1998). Most farmers indulge themselves in the cultivation of staple crops such as millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), maize (*Zea mays*), groundnut (*Arachis hypogea*) and rice (*Oryza sativa*) (MOFA, 1997; 1998). Most farming in the study area, during the 1990s to the present is usually small-scale and practiced at the peasant level by the local indigenes. The

practice of bush fallowing and shifting cultivation which was prevalent in the 1990s have given way, in recent times, to crop rotation and mixed cropping as a result of scarcity of land resources (Webber, 1996). Other income generating activities, apart from farming in the study area, include blacksmithing, crafts, quarrying and small-scale mining which has attracted a lot of youth recently (Centre for Democratic Development, 2002).

The study area is served with major market facility at Bolgatanga with minor centres located at Pelungu, Kongo, Sheaga, Sumbrungu, Pwalugu and Tongo. Places of cultural and historic interest include the Bolgatanga museum, located at Bolgatanga, Bolgatanga market, crafts and smocks at Bolgatanga, Tongo hills in Talensi-Nabdam district, elephants and other game in reserves along the Red and White Voltas.

4.6.2 Mining and quarrying

The two major forms of extractive activities in the area are mining (at the small-scale level) and quarrying (at the commercial level) that attract 4.5% of the total workforce of whom 80% are migrant workers from the Ashanti and Western Regions of Ghana. The two commercial quarries, situated in the Talensi-Nabdam district, are the Upper Quarry Limited, located at Pwalugu, and the Granite and Marbles Company Limited, located at Tongo. The former produces granite chippings for the construction industry whilst the latter cuts rocks in the form of bricks for export. About 90% of the unskilled workers are local with very few unskilled and skilled migrant workers most, of whom are technicians and supervisors. The unskilled workers are originally from the surrounding communities of Tongo, Pwalungu and Winkogo of the Talensi-Nabdam district. Sand winning and stone cracking is another major source of income for most women and children in the communities especially in the Talensi-Nabdam district. According to the Bolgatanga District Assembly report (2000), the activity has, recently, attracted more women as a result of poverty and lack of employment for most of the women in the area (Bolgatanga District Assembly report, 2002). Figure 4.3 is a stone cracking site at Kongo.



Figure 4.3: Stone cracking site at Kongo

Source: Field work, 2006

Small-scale mining of gold, which has traditionally played an important role in the economy of Ghana, has also received attention under the new liberalised mining environment. Under the minerals sector restructuring reforms, the government legalized small-scale mining activities through the enactment of PNDC Law 153 (Appendix 4.3) the small-scale gold mining law in 1989. Under this law, the Mining and Mineral Commission was made responsible for the registration and supervision of small-scale miners in the country (Hilson, 2001).

Gold was mined during the colonial days within the Nangodi environs of the Talensi-Nabdam district, about 24 km from Bolgatanga, but was abandoned in the late 1930s for political reasons. With the recent legalisation relating to small-scale mining activities under the Mining and Mineral law (PNDC 153) in the early 1989, and the redundancy of mining workers in major mining corporations in the south, notably, Ashanti Goldfields in the Ashanti Region and Tarkwa Mines in the Western Region (Blench, 2006), small-scale mining activities became rampant in most communities in the Talensi-Nabdam district especially at Nangodi, Duusi, Pelungu, Sekoti, Datuku, and Sheaga, and more recently, at Sherigu in the Bolgatanga Municipality. There is currently one legalised small-scale underground mining concession in the study area located at Duusi, with original statutory concession size of 72 km² (PNDCL 153) in the 1990 which has been encroached in recent times (see Figures 4.4 and 4.5). Illegal

small-scale surface mining sites are located at Nangodi, Sekoti and Sherigu (Bolgatanga District Assembly report, 2002).



Figure 4.4: Small-scale underground mining site at Duusi

Source: Fieldwork, 2006



Figure 4.5: Small-scale underground mining site at Sherigu

Source: Fieldwork, 2006

Small-scale mining, mostly in the Talensi-Nabdam district is highly subdivided with a hierarchy of workers with different labour relations based on a combination of ethnicity, gender, migrant status and access to capital. These include sponsors (financiers), buyers of gold (who are also often sponsors), ghetto owners (pit owners), and the different classes of workers-dynamiters, “loco boys” (who transport the blasted ore from the pit to the surface, “kaimen” (who pound the ore in the metal mortars with metal pestles), and “shanking ladies” (who sift the pounded rock with a scarf to separate powder from chippings (Awumbila and

Tsikata, 2004). Whereas sponsors, buyers, dynamiters and chisellers are migrants from outside the study area, most of the workers at the lower scale (loco boys, kaimen and shanking ladies) tend to be locals. Among the categories of mine workers, the shanking ladies (Figure 4.6), who are women, were the lowest in the hierarchy of labour relations with the lowest returns. Thus labour relations are linked to ethnic, migrant status and gender identity (Awumbila and Tsikata, 2004).



Figure 4.6: Shanking ladies at work at Nangodi

Source: Fieldwork, 2006



Figure 4.7: Loco boys at work at Duusi

Source: Fieldwork, 2006



Figure 4.8: Researcher as Kaimen at Duusi

Source: Fieldwork, 2006



Figure 4.9: Small-scale surface mining in northern Ghana

Source: Hilson, 2001

Table 4.2 shows employment and output figures of the small-scale legal mining at Duusi for the periods 1995 to 2004. With the recent geological survey of the study area indicating potential for large-scale gold mining, more efforts are being put in place by the state government and through the Mining and Mineral Commission to work out methods with the district assemblies to attract foreign mining investors.

Table 4.2: Employment and output figures of small-scale mining: 1995-2004

Item	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Registered small-scale miners	14	18	10	18	21	15	18	19	19	21
Number of sites	5	7	9	11	13	15	14	18	18	16
Number of mining work	600	400	600	650	680	600	650	630	600	620
Ancillary workers	90	120	130	130	120	120	145	130	110	130
Total output (grams)	3889	4567	3576	4688	2262	1745	1907	3678	4567	3998

Source: Mineral Commission Bolgatanga (2005)

Table 4.3 shows the number of prospective large-scale mining concerns currently registered to take up such large-scale mining in the area as in 2005. Four of such foreign investors have expressed their interest to undertake large-scale gold mining in the Talensi-Nabdam district of the study area. Hitherto, most of them have completed official formalities (registration and environmental impact statement preparation) with the Upper East Regional branch of the Environmental Protection Agency under the Ministry of Lands, Forestry and Mines.

Table 4.3: Concessions for large-scale mining

Name of company	Location	Licence type
Teberebie Gold Fields	Sekoti	Reconnaissance
Red Back Mining Inc.	Nangodi	Prospecting
Red Back Mining Inc	Talensi	Reconnaissance
Union Mining Co, Limited	Winkogo-Pwalugu	Reconnaissance

Source: Mineral Commission Bolgatanga (2005).

4.6.3 Bush burning

According to Nsiah-Gyabaah (1996), burning of bush and grass in the northern savannah woodland occurs either spontaneously by lightning or often by man for agricultural purposes and for hunting. The grasslands, by their geographic locations, have a prolonged dry period which extends from October-April which results in a more thorough drying up of vegetation and soils. The intensity of the sun is generally felt with sparse vegetation. Wind speed is generally high. Hunting is also an important economic activity in the savannah ecosystems, and most hunters set fires to drive out game in hunting. Available records show that during the 1982-83 harmattan season, about 35 per cent of crops were destroyed by bushfire in the three northern regions of Ghana. As shown on the table 4.4, in 1984-85, about 125 bushfires were reported in the Upper East Region where the study is located and the crops most affected were sorghum and millet (EPA, 1985).

Table 4.4: Bush burning statistics in Ghana

No	Region	Main Vegetation	Main Crops	Number of Fires (1984-85)	Percent of Total (1984-85)	Rank
1	Western	Semi-deciduous Forest	Timber, Cocoa, Cocoyam	46	4.6	10
2	Central	Coastal Savannah	Maize, Cassava	92	9.1	8
3	Greater Accra	Coastal Savannah	Maize, Cassava	68	6.9	9
4	Eastern	Semi-deciduous Forest	Cocoa, Oil palm	96	9.6	7
5	Volta	Semi-deciduous Forest	Cocoa, Root Crops	107	10.6	5
6	Ashanti	Semi-deciduous Forest	Cocoa, Timber, Cocoyam, Plantain	104	10.3	6
7	Brong Ahafo	Transitional Zone	Cocoa, Timber, Maize	110	10.9	4
8	Northern	Savannah	Rice/Millet Guinea Corn	145	14.5	1
9	Upper East	Savannah	Sorghum/Millet	125	12.4	2
10	Upper West	Savannah	Sorghum/Millet	112	11.1	3

Source: Environmental Protection Council (1985)

4.6.4 Grazing

Rights of grazing in northern Ghana are of a common character, and apply in the same way to indigenes and migrants. This means that all stockowners may graze livestock everywhere without restrictions, except on farms on which crops are actually growing. In areas with limited grazing opportunities, grazing areas may be reserved for the exclusive use of stockowners within a number of settlements. This practice became widespread as a result of increasing stock rustling. Stockowners allege that prior to the reservation of grazing areas and its limitation to specific settlements: it was easy for cattle that stray away from the settlement to be stolen by nomadic herdsmen. Similarly, the right to water is common. Anybody can use water from the river, streams and from wells built by the local administration. However,

individualised right to water is recognised where the water is obtained as a result of individual effort, as is the case for wells constructed by an individual (Tonah, 2000).

The most frequent cause of conflict between local people and herdsmen in the study area is the destruction of crops by cattle. This is often a result of herdsmen leaving cattle unattended to and thus making them wander unto cultivated fields. Cattle may also go on the rampage and destroy seed crops or consume food items stored in barns. This is particularly the case during the planting season and the immediate post-harvest period. In many settlements, herdsmen have their grazing areas near to fields reserved for farming thus raising the likelihood of cattle entering cultivated fields. The rising incidence of livestock destroying food crops has been attributed to the change in Fulani pastoral herding system (Breusers *et al.*, 1998; Hagberg 2001).

In summary, one can say that the study area has seen spatio-temporal land cover and land uses imbalances, population growth, polarization and economic segregation from 1990 through 2004. There has also been socio-economic and cultural dynamics, implementation of government economic recovery programmes and poverty reduction strategy making the study area a good place to test the assessment methodology.

4.7 Data sourcing and analysis

4.7.1 Types, sources and techniques of data collection and analysis

Both the primary and secondary sources of data collections were used for this study. The primary data included spatio-temporal data on land-cover types, ground and community truthing data. Secondary data were sourced from institutions and organisations in Ghana. Land-cover data were derived from satellite images processing and classification of 30m resolution from the Landsat Thematic Mapper (TM) for 1990, 2000 and 2004, acquired from CERSGIS (Centre of Remote Sensing and Geographical Information) of the University of Ghana in 2005. Ground and community truthing data were obtained through sampled ground truth points during field work at homogenous sites and through interviews, focus group discussions and direct field observations during the periods of January to April, 2006. Techniques used included the image pre-processing, post-classification and descriptive analysis.

4.7.2 Processing, classification and interpretation of satellite images

To assess the current and recent state of the environment, 30m resolution landsat TM imagery of three different scenes, 1990, 2000 and 2004, taken during the dry season, were utilized. The images were already geo-referenced to the UTM projection of the World Geodetic System of 1984 datum and with insignificant cloud coverage. The acquired images were sub-setted to include only the area of interest (Bolgatanga, Talensi-Nabdam districts of northern Ghana). Using computer software (ERDAS Imagine 8.7), the images were displayed on the computer and various enhancement techniques performed until the most appropriate pseudo colour composite band combination of the visible spectrum (4, red, 5, green and 3, blue) was arrived at.

Unsupervised classification technique was performed on the raw images using ISODATA (Iterative Self-Organising Data Analysis Technique) algorithm (Jensen, 1996). The ISODATA technique is a modified version of K-means clustering that aids in the

categorisation of pixels based on the spectral differences in each band, thus allowing for the development of unique class signatures and diminishes the spectral distances between classes (Tou and Gonzalez, 1974).

The objective of the K-means algorithm is to minimize the *within* cluster variability. The objective function (which is to be minimized) is the *sums of squares distances* (errors) between each pixel and its assigned cluster centre.

$$SS_{\text{distances}} = \sum_{\forall x} [x - C(x)]^2$$

where $C(x)$ is the mean of the cluster that pixel x is assigned to.

Minimizing the $SS_{\text{distances}}$ is equivalent to minimizing the Mean Squared Error (MSE). The MSE is a measure of the within cluster variability.

$$MSE = \frac{\sum_{\forall x} [x - C(x)]^2}{(N - c)b} = \frac{SS_{\text{distances}}}{(N - c)b}$$

where N is the number of pixels, c indicates the number of clusters, and b is the number of spectral bands.

Using the technique, the number of classes desired and a confidence threshold were input into the computer. An initial set of 20 random classes of 100 iterations and at 95% confident threshold were input to the computer for it to build the classes iteratively until the confidence threshold of 95% was reached. During the process, each pixel of spectral characteristics was examined and similar pixels aggregated into classes of 20 cover types. The result was unsatisfactory because of the large number of overlaps of the land-cover classes.

To refine the classes, manual recoding was done to further aggregate the initial spectral classes into information classes containing categories that represent land-cover features of

interest. This was made possible through the use of areas of known land cover, visual interpretation and spectral profiles compiled by CERSGIS of the University of Ghana. Seven classes were obtained after merging inseparable classes in an initial set of 20. Class names and colours were identified and assigned to the seven identified classes based on reference classification scheme designed by Agyepong *et al.* (1996) modified from Anderson *et al.* (1976) land-cover classification scheme. A brief description of the land-cover types is presented in Table 4.5. Cloud cover, which is not relevant to this study, is not included.

Table 4.5: Adopted land-cover classification scheme

Land Cover Types	Brief Description
Closed Savannah Woodland	Mainly trees over 5 metres high, riparian vegetation with not more than 150 trees per hectare
Open Savannah Woodland	Open woodland with shrubs and grasses of various species with approximately 75-150 trees per hectare
Dense Grasses of various species	Complex mixture of grasses and shrubs with or without scattered trees with less than 10 trees per hectare
Built-up and barren environment	Areas of human settlements, commercial and industrial developments, areas devoid of savannah vegetation including deserted and cleared areas
Water Bodies	Inland waters, streams and reservoirs
Burnt Areas	Burnt environment through natural causes such as lightening and anthropogenic causes through indiscriminate hunting, burning and agricultural practices (slash and burn)

Source: Adjepong *et al.* (1996) modelled from Anderson's land-use classification system (1976).

Spatial quantification and change detection analysis using post-classification image techniques (Howarth and Wickware, 1981; Singh, 1989) was adopted to detect spatial changes for the three processed images. The observed classified land-cover types were ground truthed by means of field visits, during 10th 21 of February, 2006, before community truthing. Ground reference points were collected at stratified random sites. To account for the temporal differences between imagery acquisition and ground truth data, care was taken in the selection of ground truth points in locations where the land-cover types were perceived not to have changed for the three periods of study. In all 504 ground truth points were randomly selected for accuracy assessment.



Figure 4.10: GPS exercise at Zuarungu

Source: Fieldwork, 2006

To assess the other indicators of the DPSIR assessment framework, community truthing was undertaken in the study area. Here three main participatory research methods, (i) key informant interviews (Hay, 2004) (ii) focus group discussions (Cameron, 2000) and (iii) participants observations (Cook, 1997) were used to solicit participants views regarding the observed changes on the environment for the period under study. Data collected from research participants were triangulated with existing secondary data sources for validation.

4.7.3 Preliminary survey and recruitment and training of research assistants

To pilot the key informant interviews and focus group discussion guidelines to reflect anticipated situations, a preliminary survey was undertaken at Dodowa in the Ga Damgbe East of the Greater Accra Region during late January of 2006. The survey was assisted by CERSGIS of the University of Ghana through the provision of staff. The occasion was also used to select and train research assistants for the actual field work. Four key informants randomly selected from the Ga Damgbe East District Assembly and three focus groups (local fishermen, market women and local farmers) were interviewed to determine the kind of responses that may be anticipated during the subsequent fieldwork in Bolgatanga and Talensi-Nabdam of northern Ghana. The preliminary results helped to re-structure the original content of the designed assessment methodology to meet certain challenges. For example, it was initially planned to adopt participatory mapping as one of the participatory research tools to solicit information but it was observed during the preliminary survey that selected participants were not enthused in using participatory mapping exercise to explain the nature and causes of environmental degradation in the area. One of the participants commented: *"it is better to use maps to express our views concerning the problems of the environment rather than simply making drawings which seem irrelevant to the topic under discussion"*. This was where the initial idea of *community truthing* evolved when the results of the preliminary survey were discussed with my research supervisors. It was also through the preliminary survey that concerns were raised about the composition of the focus group participants. It was felt that the quality of the results from the focus group discussion would be greatly affected if women were not separated from their male counterparts especially in areas where the socio-cultural setting prevents women from expressing their views freely in the presence of men. This led to the creation of separate female focus group in the actual study area of Bolgatanga and Talensi-Nabdam districts.

Another important issue that emerged, during the preliminary survey, was the inability to gather together all stakeholders for general discussions to reach a common goal, after the individual interviews and focus group discussion. Most of the participants, mainly the focus group participants, felt uneasy to express themselves in the presence of key informants such the district planning officer and financial controller.

Six research assistants were selected (four males and two females) based on their competence, to assist in the actual ground and community truthing processes in the study area. Two of them (a male and a female) were quite knowledgeable about GPS coordinate readings and the other four (a female and three males) were originally from the study area with good communication skills and knowledge of the local dialects of Grune and Frafra. The selection of the research assistants was based on several factors that included the ability to learn and follow research procedures and human behavioural research, to communicate effectively with other research staff and research participants, both verbally and writing, to work effectively with others and have good interpersonal skills and be willing to adhere to the principles of confidentiality governing the research work.

4.7.4 Community entry protocol and researcher's positionality

The actual field work started in the first week of February, 2006, at Bolgatanga and Talensi-Nabdam of northern Ghana, after spending some few days in Accra to make corrections to the assessment methodology and re-structure some of the interviews and discussions guidelines. Before embarking on the ground and community truthing exercise, it was felt that approaching the various communities and mining areas directly would lead to suspicion by the local people especially as a male researcher, an Ashanti by origin and a student from a UK University. The first points of contact, in the study area, were the district assemblies where the district planning officers were briefed about the purpose of the study and a copy of introductory letter from the School of Geography, University of Leeds (Appendix 4.4) was handed to them. They helped in the selection of communities to be studied and also accompanied us to the communities to officially introduce us to the community leaders. Three

(two males and a female) of the selected research assistants assisted in the community entry protocol. Meetings were held with some traditional rulers and community leaders. On most occasions, traditional entry protocols, such as the offering of customary drinks and cola nuts to the leaders, were observed as a means of recognition and acceptance into the communities. A familiarisation tour was undertaken in almost all of the communities (with the kind courtesy of the Mining and Mineral Commission, who gave us use of a mini bus and a driver) to be more acquainted with the task ahead.

During the familiarisation tour some informal discussions were held with some community members with the aim of building trust and confidence and to test our self assurance that the task ahead would be successful. In all our interactions in the various communities and the mining areas, local communities' leaders and some officials from the district assemblies acted as gatekeepers to facilitate entry into the communities for group discussions and observations.

4.7.5 Issue of geographic scale

The decision about the level at which to collect information and apply indicators depends on both the issues being addressed and data available. However as one moves up through the levels it may become more difficult to identify causal relationships, to identify desirable outcomes and to isolate choices that can be made with confidence (Pretty 1995). Pretty argues that at the community level, it is possible for actors to weigh-up, trade-off and agree on criteria for measuring trends in sustainability. But as one move to higher levels such districts, regions and countries, it becomes increasingly difficult to do this in any meaningful way (Pretty, 1995). To address the issue of scale in this PGIS study, participants were selected based on their interest and level of knowledge in environmental issues and who have travelled and worked in most of the study communities. For example, focus group participants were selected from associations who have expressed their concern on the nature and characteristics of environmental degradation in the study area. With the exception of the small-scale miners and the local representatives from Pwalugu and Tongo who were selected from specific communities such as Nangodi, Duusi, Pwalugu and Tongo, the rest were heterogeneous

groups from different communities of the study area who have formed an association such as the concerned youth group, women association and farmers association. In cases where the knowledge of participants was limited due to scale, issues raised by such participants were triangulated with the responses from other groups. Certainly the issue of geographic scale was a limitation to this study but this was address through the triangulation of participants' responses and the use of secondary and statistical data sources.

4.7.6 Time-series analysis

Another major issue considered during the study was whether issues were to be assessed at a single point in time (spatial analysis) or over time (spatio-temporal analysis). In the later case (which was adopted for this studies), a fundamental issue to address is time, where one would be interested in the historical and recent environmental changes that require an understanding of what has happened to the environment in retrospect and what is happening at recent. According to Moxey (1998), assessing environmental degradation over time, as in the case of this study, is more problematic, as information from external sources is generally required. He proposed the possibility of using secondary historical sources such public records, resource surveys, aerial photographs and satellite images, and past academic studies etc. as an aid to interviews and group discussions. Grenier (1998) noted how the physical presence of a map can be useful as a prompt to encourage discussion of a particular geographical area. In this study, classified images were presented to participants as a guide to help them think deeply on what has happened to their environment and respond, effectively, to the causes and effects of such observed changes during interviews and focus group discussions.

4.7.7 Sampling design and procedure

The actual community truthing exercise was preceded by selection of the sample size. The population universe of the study area has an estimated population of 229,768 (Ghana Statistical Service, 2000) making it impossible to involve the entire population in the study. As such, it became sensible to sample a number of individuals and groups of people such that their views, opinions and perceptions would represent the larger population group from which

they were selected. To achieve this, purposive sampling technique (Cameron, 2000) was used based on participants' local ecological knowledge, knowledge on environmental degradation and assessment related issues, retrospective land-use issues, traditional knowledge and interest in spatial analysis. Selection was done with the initial consultation with the district assemblies planning officers through the districts chief executives and the village leaders. Selected participants were, later on, contacted and the purpose, dates, times and locations (Appendix 4.5) for interviews and discussions were discussed and scheduled respectively. Almost all the key informants and some of the focus groups received the interview guidelines some few days prior to the original scheduled time with the aim of giving them enough time to prepare themselves adequately for interviews and discussions. Interviews and discussions guidelines focussed on individual perceptions on the natural environment based on the results of the classified images. The interview and discussion protocols ensured that the same questions were given to all participants and also provided flexibility to the participants to allow the emergence of new issues of relevance. All together 8 interviews and 8 focus group discussions were conducted between the months of February 26th to March 27th of 2006.

4.7.8 Key informants' interviews

A purposive sampling technique, based on participants' field expertise on environment related issues, was used for the selection of key informants after following all the necessary protocol. To ensure a broad based data collection and interpretation of image data presented, a carefully designed, open-ended questionnaire was administered to key informants knowledgeable in environment related issues. All key informant interviews were done on a one-to-one basis to ensure confidentiality and protection of the informant. The length of the interviews was varying between 30 minutes to 2 hours. Most of the interviews lasted for about 45 minutes and all discussions were aided with image maps of the study area.



Figure 4.11: Key informant interview: Minerals Commission

Source: Fieldwork, 2006



Figure 4.12: Key informant interview: Regional Surveying Department

Source: Fieldwork, 2006

All interviews were recorded to tape, except for the cases where the interviewee did not feel comfortable with tape recording. In such circumstances, the interviews were recorded by taking extensive notes, and then detailed interview summary was compiled for each interview. Some of the information data collected were overlaid on a GIS database for spatial analysis. All interviews were held in the key informants' places of choice, but mostly in their respective working offices. Eight key informants were selected to include representatives from the following organisation and agencies:

1. Regional Coordinating Council (RCC), Bolgatanga,
2. Environmental Protection Agency,
3. Mining and Mineral Commission, Bolgatanga,

4. Lands Commission,
5. Upper East Regional House of Chiefs,
6. Talensi-Nabdam District Assembly,
7. Bolgatanga Municipal Assembly and
8. Surveying Department in Bolgatanga.

4.7.9 Focus group discussion

Focus group discussions were tailored for each target group to ensure that discussions were both relevant to the research topic and the activities of the target groups. These discussions produced data and insights that could not have been obtained in one-to-one interactions. The rationale of using focus group participants, as a community truthing instrument, was to solicit broad-based information from participants chosen from a wide range of socio-cultural backgrounds with concern and adequate knowledge about environment related issues in the study area. Interactions with the focus group participants were also done with decorum through the avoidance of unnecessary comments and questions. Like the key informants, participants were sometimes allowed to go outside of the scope of the topics under discussion but only what was required was noted for further analysis. This was done to boost their confidence and enthusiasm in the research. Where clarification on aspects was needed, they were carefully asked for this. An atmosphere was created for easy flow and sharing of ideas but care was always taken to control the flow of responses and the most eloquent ones among the focus group were duly monitored. All members of the group were encouraged to contribute. Figure 4.13 and 4.14 shows two separate focus group discussions that took place during fieldwork.



Figure 4.13: Focus group discussion at Duusi



Figure 4.14: Heterogeneous focus group discussion at Bolgatanga

Most of the focus group discussions lasted for about one hour and most issues raised were based on the classified images, ancillary data, statistical and secondary data presented to each group. In situations where it became necessary to use the local dialect for discussions, an interpreter was used to make translations. The same discussion guides were tailored for each target groups to ensure achievable outcome. The number of representatives for each focus group discussion did not pose any problem but was usually restricted to a maximum 25. Each focus group discussion was welcomed with introductory remarks by briefing respondents on the purpose of the gathering and what is expected from them. All discussions were audio-tape recorded and manual notes taken were appropriate. Some of the data collected from the focus groups were incorporated into a GIS database for spatial analysis. Eight focus groups were purposefully selected as follows:

1. Concern Youth Group (Bolgatanga),
2. Women's Association (Bolgatanga),
3. Farmers Association (Bolgatanga, Talensi-Nabdam Communities),
4. representatives from Pwalugu and Tongo communities,
5. heterogeneous community focus group,
6. heterogeneous organisations focus group,
7. small-scale legal underground miners at Duusi in the Talensi Nabdam District and
8. small-scale illegal surface miners at Nangodi near Tilli of the Bawku West district.

For the purpose of soliciting more information on mining activities in the area, small-scale miners' focus groups were included in the focus group discussions. For safety and the fact that small-scale surface mining is illegal and difficult to assemble miners for discussions, it became necessary to get in touch with their leaders who later convinced others to join in the discussion. It would have been interesting to solicit views from some Fulani herdsmen but for safety this was not possible as the herdsmen were known to be aggressive and would not tolerate any form of discussions with unknown people. Focus group discussion guides were designed in a semi-structured form with the aim of giving opportunity to every member to express his or her opinion. The wording of each question was brief and clear. The lengths of the questions were not structured to long or short to prevent responses open to doubt.

Table 4.6: Characteristics of focus group participants

Focus groups	Characteristics
Concern youth group	Members from different communities of the study area. 19 participants, 12 males and 8 females, age between 18-28 years. mostly educated. Most of them unemployed. few are farmers and others in the public sector
Women association	Members from different communities of the study area, 22 participants selected. age between 30-55 years, most of them illiterates with few semi-literates at the basic school level.. Most of them are farmers and housewives. Few are engaged in sand winning activity. They are engaged in the advocacy of female rights in the society and are sponsored by the World International
Farmers association	Mostly peasant farmers from different communities in the study area. 16 of them were selected for the focus group. They are mostly illiterates and aged between 30-65 years
Representatives from Pwalugu and Tongo	They are local people selected based on their level of knowledge of the quarrying activity at Pwalugu. Consist of 20 participants (10 males and 10 females)
Heterogeneous community focus group	2 participants selected randomly from Bolgatanga, Tongo, Winkogo, Duusi, Nangodi, Zuarungu and Sumbrungu. Aged between 20-45 years and mostly semi-literates
Heterogeneous organisations focus group	2 participants selected from organisations and agencies in the study area. Participants drawn from local NGOs, Muslim community, Catholic Mission, teachers association, market women, catering services and Ghana Road and Trade Union (GPRTU) Bolgatanga
Small-scale miners (legal)	19 male workers from Duusi. Aged between 19-40 years. Mostly migrant workers with few locals
Small-scale miners (illegal)	14 male workers from Nangodi. Aged between 19-40 years. Mostly migrants with few locals

4.7.10 Key informants and focus group interviews and discussions guidelines

Interviews and discussion (Appendix 4.6) with the key informants and focus group participants followed the same steps as follows:

1. self introduction and elaboration of the purpose of study to participants;
2. presentation and brief explanation of the classified image maps and other ancillary spatial data, such topographic map of the study area and map of the study area containing names of communities to participants by the researcher and assistants;
3. discussing with participants' concerning the nature and extent of environmental degradation in the study area for the 14 year period of study, the spatial distribution of vegetative cover and the replacements of savannah trees and grass types for the period of study.
4. discussion with participants concerning the indirect or the driving forces of the observed changes on the environment as demonstrated on the images;
5. identification by participants concerning the various human activities that have existed in the study area, from 1990 to 2004, and that are known to have contributed to the changes on the environment as showcased on the image maps presented;
6. identification of areas of land uses with severe consequences on the environment and retrospective accounts of those activities in terms of when it actually started, what motivated individuals to take up those activities and why people are still engage in them recently;
7. discussion with participants how the observed changes have impacted negatively on their physical environment and social lives;
8. discussion with participants concerning the adopted coping mechanisms by the affected communities; and
9. deliberation with participants concerning the possible interventions to realise a better environment.

4.7.11 Direct observations

To gain in-depth understanding of the social and institutional realities in the field and to validate some of the issues raised during the focus group discussions and the key informants interviews, it was deemed necessary to directly experience the practical situation and dynamics in the field. The practical involvement in some of the daily activities in the area especially the operations of small-scale mining helped to verify, indirectly, some of the issues raised during the key informants interviews and focus group discussions. Coincidentally, the Mining and Mineral commission at Bolgatanga, at the time of the field visit, was having a registration exercise with the small-scale miners in the district. The research team involvement in the exercise gave us the opportunity to acquaint ourselves with the miners and their operations.

4.7.12 Spatial GPS measurement of identified land uses

Point measurements using GPS were done for various land uses at sites initially identified and roughly located on a topographic map by the research participants during interviews and discussions between 28th of March and 8th of April, 2006. All measured points were digitized and later converted to polygons for actual size calculations of identified land-uses. The results were overlaid on a digitized topographic map of the study area for further GIS spatial analysis (Figure 4.15).

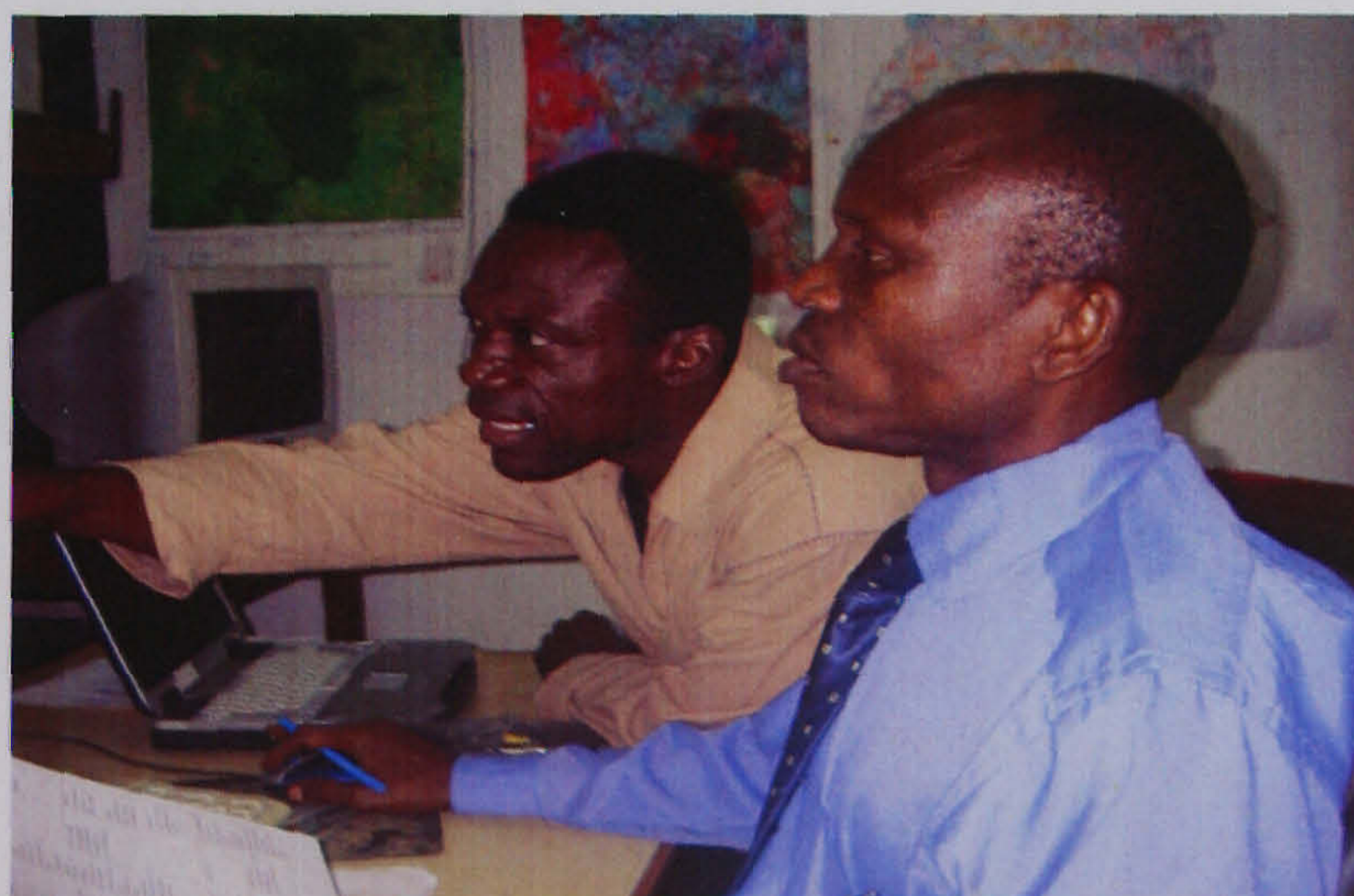


Figure 4.15: Overlay of GPS points at CERSGIS GIS laboratory, Accra, Ghana

4.7.13 Photographic presentation

As part of the fieldwork, and to represent certain features to support some arguments and issues raised in this thesis, photographs were taken to substantiate such issues. Care was, however, taken during such operation as most of the participants wanted to remain anonymous. In almost all cases, permissions were sought from the audience or participants before photographs were taken. Individuals and groups of persons whose photographs appeared in this thesis were duly asked for their permission to do so and copies sent to them as most of them requested. It must be noted that many photographs were taken during the fieldwork that could have helped to demonstrate participants' involvement in GIS spatial analysis and to improve the originality of the thesis but permission to include such photographs in this thesis were not given by those who appeared therein for personal reasons.

4.7.14 Secondary data sources

In addition to primary sources of data collected during fieldwork, secondary data sources, from a wide range sources and literature, were used in this thesis to substantiate and clarify issues raised and observed. This was done in four stages of the PhD research work and included: (i) information and materials sourced before field work; (ii) information and materials sourced during pilot work; and (iii) information and materials sourced after the field work; and (iv) information and materials sourced during analysis of results and thesis write-up. Other relevant information and comments were gathered from participations in international conferences and workshops attended as presented in Figures 4.16.



Figure 4.16: Presentation at FLUD conference at Utrecht, Netherlands

During the fieldwork, the first point of contact for secondary data was at CERSGIS of the University of Ghana, Legon. The centre is affiliated to the United Nations Environmental Programme (UNEP) and it is responsible for the storage of large volumes of geographical information including satellite imagery, digitized topographic maps (soils, geology, contours, hydrology, settlements, forest reserves, a digital elevation model (DEM), roads and district boundaries), reference data maps of land cover/land use in Ghana and the historical overview of GIS application and development in Ghana.

Others areas where secondary data were sourced included:

1. Mining and Mineral Commission, Ministry of Mines, Bolgatanga where maps of small-scale mining concession in the study area, forest reserves, photographs, and materials on historical overview of small-scale mining in the district. These were made possible through initial contacts with the district mining officer and the ministry secretariat.
2. Environmental Protection Agency library at the national headquarters in Accra where information pertaining to environmental impact statements on minerals and mining in Ghana, environmental policy and legislation are stored for public use.
3. The Upper East Regional branch of the Environmental Protection Agency where numerous publications on issues of the environment are placed for access by the general public.

4. Materials and relevant information on local cultures, beliefs, aspirations, taboos, protected areas and tourist sites were obtained from the Upper East Regional House of Chiefs through the district assembly.
5. Data and records of land-use policies, district master plans, minutes of land-use committee meetings, and other relevant district reports were obtained from the District Chief Executives and Planning Officers.
6. Reports of students' third trimester practical training programme together with some graduate theses obtained from the Faculty of Integrated Development Studies of the University for Development Studies, Tamale Ghana.
7. Additional data on the 2000 population and housing census that contained some relevant information on the analysis of district data and implications for planning in the Upper East Region as well as population, poverty and development reports 2003 were obtained from the Ghana Statistical Service, Accra.

4.7.15 Data processing and analysis

The study made use of two approaches in the analysis of the data gathered: (i) the qualitative approach where theories were used to express meanings to participants' observations to substantiate existing theories. Here analyses of the results of the GIS-based participatory approach were done manually, linked to theoretical and conceptual frameworks reviewed in chapter 2 and systemised into GIS; and (ii) conventional GIS which assisted in the inputting, processing and analysing of spatial data obtained from remote sensing satellite images. Data from false composite image maps were analysed using computer software like ERDAS imagine, Arc View and Arc Info. The adoption of GIS aided in the processing and analyses of digital data acquired.

4.7.16 Presentation of research findings

The socially and spatially differentiated data collected were digitized upon return from the field and overlaid with other GIS datasets and analysed. In this way, people's maps concerning issues on environmental degradation were represented within a GIS as a knowledge layers (Harris and Weiner, 1998). GPS points of identified land-uses were digitized, joined to form polygons and overlaid on the land-cover change maps for spatial analysis. During the analysis participants responses were triangulated with existing theories to test assumptions derived from the review of literature in both chapters 2 and 3.

4.8 Conclusion

This chapter has provided a comprehensive overview of the geographical setting of the study area. It was realised that the state of the natural environment of the area has over the years undergone complex ecological transformation through natural, social, economic and cultural processes that needs to be assessed in a more holistic terms. A summary of the main methods used in gathering data was given including GIS and remote sensing, key informant interviews, focus group discussion and participants' observations. Local ecological knowledge about the causes and effects of environmental degradation in the study area was integrated into GIS in the context of mental maps, narratives and GPS walks. Chapters 5, 6 and 7 which follows are the presentations and discussions of the study findings

Chapter 5

Analysis of GIS based Participatory Assessment Results (I) *State of the Environment and Pressure indicators of DPSIR* *Framework*

5.1 Introduction

Spatio-temporal statistical and qualitative details are of utmost importance when assessing the environmental degradation of a particular community. As outlined in the DPSIR framework, it is important not only to assess the causes and effects of environmental degradation but also evaluate the spatio-temporal state of an environment and pressures put upon it through human activities. GIS and remote sensing techniques have been widely used to assess such indicators for decision-making purposes (Burrough, 1986). However, they are limited in terms of why environmental changes occurred rather than places of occurrence (Abbot *et al.*, 1998; Carver, 2001; Williams and Dunn, 2003). In such circumstances local ecological knowledge becomes useful for assessing the causes and effects of observed environmental changes. This chapter presents an approach for integrating GIS and local ecological knowledge for assessing the state of the environment and the pressures resulting from various land uses in the Bolgatanga and Talensi-Nabdam districts of northern Ghana. The chapter thus presents an image of what is actually happening to the environment in terms of degradation as modelled on image maps and what participants perceived to be the driving forces.

5.2 GIS and remote sensing

5.2.1 Quantitative analysis

Results of the spatial extent of the various land-cover types, for the three periods of 1990: 2000 and 2004 as shown in Figure 5.1, Table 5.1 and Figure 5.2 demonstrate extensive conversion of savannah vegetative woodland types to built-up and barren land. Figures from the 1990 classified image, presented in Table 5.1, shows closed savannah woodland as the dominant land-cover type in 1990 which covered an area of 549 km² or 36.3% of the study area. This was followed by open savannah woodland that covered an area 440 km² or 29.2% of the study area. Dense herb and savannah grasses, of various types, covered an area of 342 km² or 21.4% of the study area. 34 km² or 2.3% of the land area of the study area, modelled on the satellite image, was burnt in 1990. Built-up and barren land covered an area of 154 km² or 10.2% of the total land area. 7 km² or 0.5% of the area was modelled to cover water courses. Based on these statistical results one can conclude that there was no significant threat of environmental degradation in 1990s as major parts of the land area were covered with savannah vegetative woodland, both closed and open savannah woodland, with few patches of dense herb, savannah grasses and built-up and barren environment.

Statistical results for the 2000 classified image shows distinctive characteristics in terms of degraded environment compared to the 1990 classified image statistical analysis. By 2000, the dominant land-cover type was dense herb and savannah grasses of various types that covered an area of 671 km² or 44.3% of the total area. This was followed by built-up and barren environment with spatial coverage of 436 km² or 28.3% of the study area. Open savannah woodland was the next dominant land cover, after dense herb and savannah grasses and built-up environment, and covered an area of 204 km² or 13.6% of the area. Closed savannah woodland, which was the dominant land-cover in 1990, covered an area of 150 km² or 9.9% of the area. 25 km² or 1.5% of the area was burnt in 2000. Water courses gave an unexpected, relatively small, area of 17 km² or 1.1% of the land area that needed further clarification during both ground and community truthing.

These statistical results give an indication of environmental degradation from 1990 to 2000 where it was observed that the dominant savannah vegetative woodland converted to dense herb, savannah grasses and built-up and barren environment.

The dominant cover type in 2004 remained dense herb and savannah grasses that covered land area of 550 km² or 34.4% of the area under study, as modelled on the satellite image. This was followed by built-up and barren lands with spatial extent of 546 km² or 36.5% of land area. Open savannah woodland-covered land area of 262 km² or 17.5% of the total study area. Closed savannah woodland followed the open savannah woodland with spatial extent of 93 km² or 6.3% of the total land area with 34 km² or 2.6% of the study area burnt in 2004. Water courses in the area for 2004 covered a minute space of 17 km² or 1.1% of the study area that needed truthing.

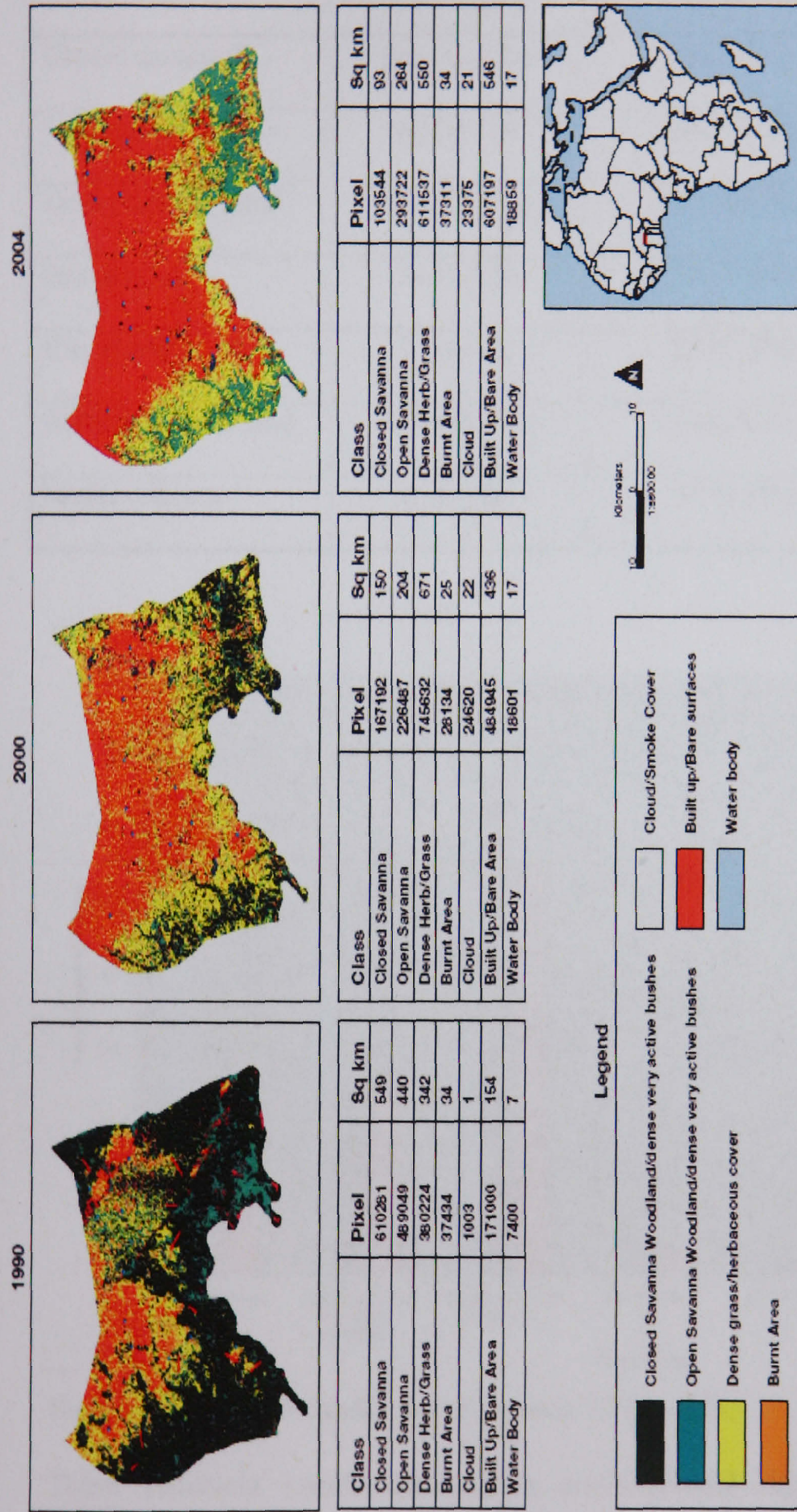
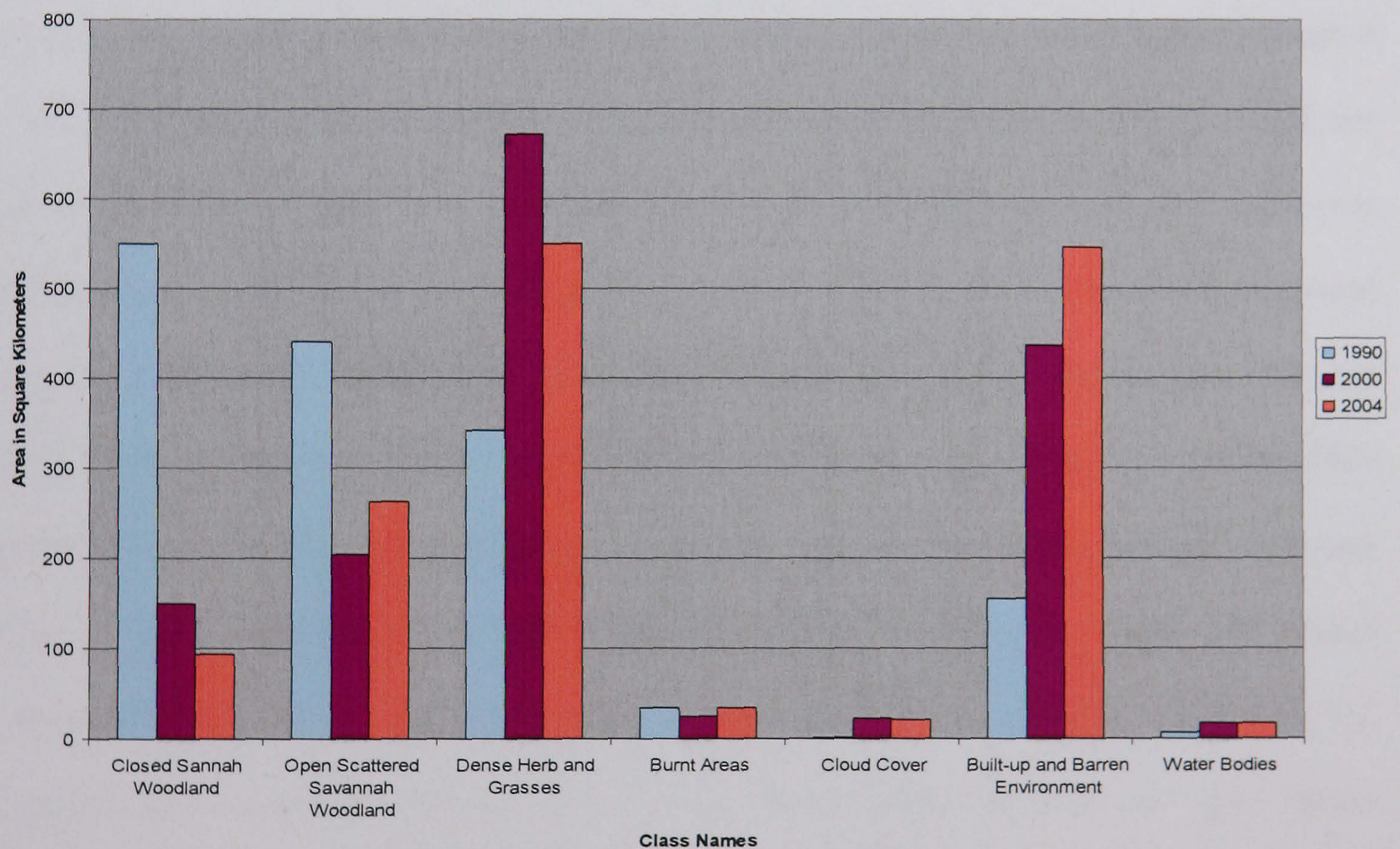


Figure 5.1: 1990; 2000; 2004 classified image maps

Table 5.1: Bolgatanga and Talensi-Nabdam Land-cover statistics

Land-cover types	1990 (km ² and %)	2000 (km ² and %)	2004 (km ² and %)
Closed savannah	549 (36.3%)	150 (9.9%)	93 (6.3%)
Open savannah	440 (29.2%)	204 (13.6%)	262 (17.5%)
Dense herb/grasses	342 (21.4%)	671 (44.3%)	550 (34.4%)
Burnt areas	34 (2.3%)	25 (1.5%)	34 (2.6%)
Cloud cover	1 (0.1%)	22 (1.3%)	21 (1.6%)
Built-up/barren land	154 (10.2%)	436 (28.3%)	546 (36.5%)
Water courses	7 (0.5%)	17 (1.1%)	17 (1.1%)

**Figure 5.2:** Trend in land-cover dynamics, 1990 to 2004

These statistical results demonstrate environmental degradation through the dramatic conversion of savannah vegetative woodland types to built-up and barren environments are also noted in studies by Whitford *et al* (1998) and Manzano and Navar (2000). The results also demonstrate the pace through which ecological changes have taken place in the study area during the 14 year period of study. The application of the observation by Reid *et*

al.(2000) that “*barren environment when left unattended for a period of time may revert initially to dense herbs, shrubs and savannah grasses and finally to the original savannah vegetative cover*” to what is pertaining in the study area is debatable and needs further verification based on the observed phenomenal transformation of savannah vegetative woodland to built-up and barren environment and to dense herb and grasses for the 14 year period of study. The pace of the observed ecological transformation in the study area as a potential threat to desertification is also noted by Behnke and Scoones (1993), Misana and Nyaky (1993), Wunder (2000) and EPA (2003) and needs further clarification from research participants.

5.2.2 Analysis of trend and pattern of change

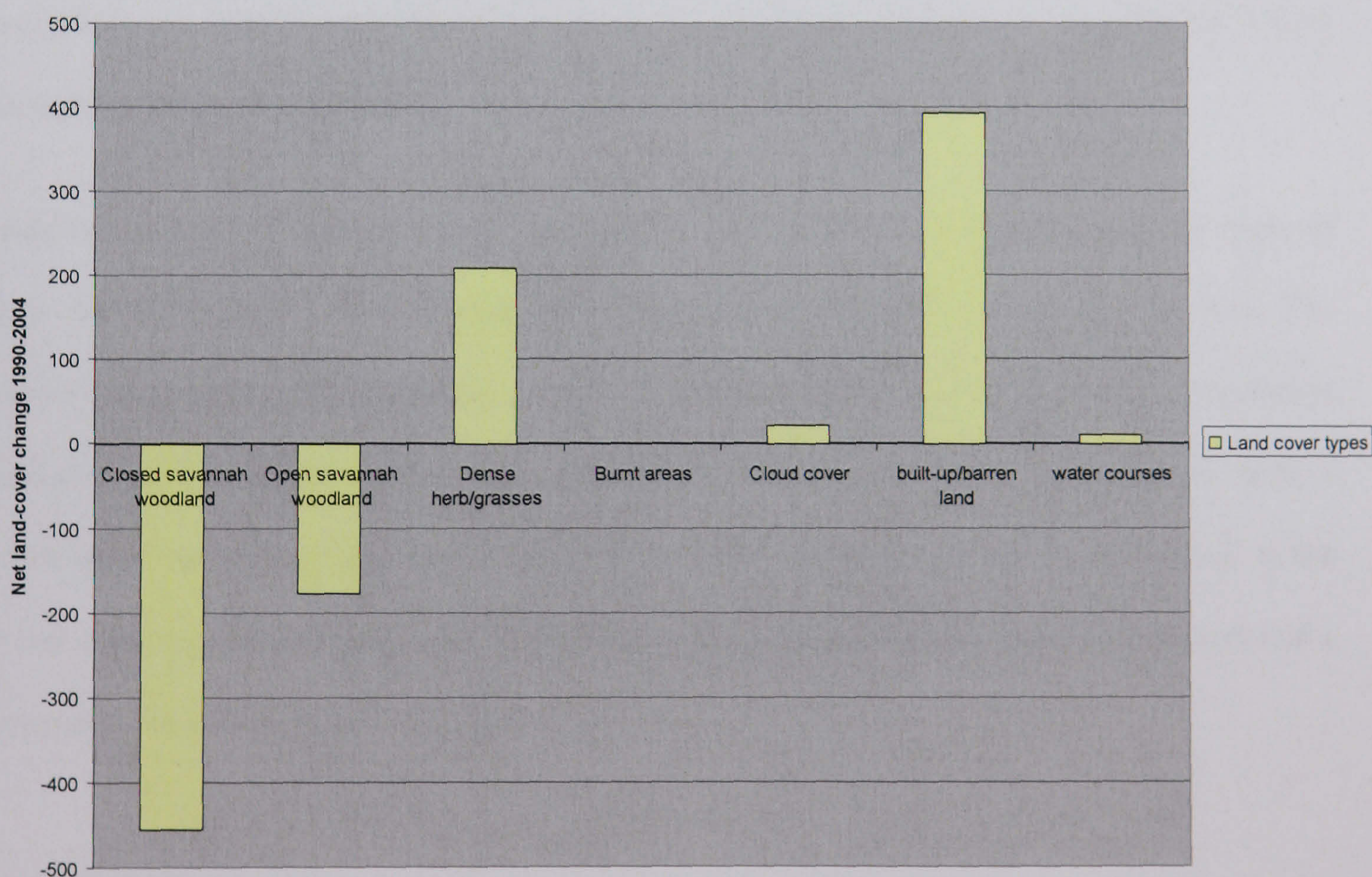
Spatial analysis of the 1990, 2000 and 2004 classified images statistical results shows a dramatic downward trend in closed savannah woodland from 549 km² to 93 km². Although it is not at this stage, possible, to establish the causes of such vegetation changes, it is clear that closed savannah woodland has undergone tremendous transformation into other land-cover types during the 14 year period. Open savannah woodland exhibits a similar downward trend from 440 km² to 262 km² from 1990 to 2004, although, there is an increase between 2000 and 2004 of 58 km² which is quite abnormal based on the nature of the study area and therefore needed further validation either through ground truthing or community truthing. Although Duadze (2004) attributed such observations to natural ecological processes and human conservation practices. Dense herb and savannah grasses, as observed on Figure 5.2, demonstrated a non-linear increase trend from 1990 to 2004. The 1990 and 2004 figures (Table 5.1) showed an increase from 342 km² to 550 km² of dense herb and savannah grasses and the corresponding decrease from 671 km² in 2000 to 550 km² in 2004. This might be attributed to either the harsh climatic conditions prevailing in northern Ghana or through various human activities identified by Lisa and Fisher (1998). The observed but questionable linear increase from 154 km² in 1990 to 546 km² in 2004 of built-up and barren environment seems to suggest that closed savannah vegetative woodland was directly converted to built-up

and barren environment for the 14 year period of study as also suggested by de Soyza *et al.* (1998) in their studies.

No significant changes for burnt areas were observed for those 3 periods of study (Figure 5.2) which is extremely debatable and needed further clarifications, from research participants, as northern Ghana is noted with its frequent fire outbreaks through either human or natural causes. The results also contradict those of Nye and Greenland (1960), Lisa and Fisher (1998) and van der Geest (2002), who had earlier on maintained that the usual conversion of savannah vegetation woodland forest in most savannah environments is partially due to frequent fire outbreak and overgrazing. The observation that burnt areas are temporal in nature and are often replaced by vegetation cover when left unattended for a specific period of time (Van der Geest, 2002) needed to be tested during the field survey. The change in the area of water may indicate an increase in the number of dams and reservoirs, but since water bodies do change in response to climate conditions in a given area, it is difficult to discuss the changes recorded here. Results of the net gain and net loss of the various land-cover types from 1990 to 2004 are presented in Table 5.2 and Figure 5.3.

Table 5.2: Trend of Land-cover changes: Net loss (-) and net gains (+)

Land-cover types	1990-2000 (km ² and %)	2000-2004 (km ² and %)	1990-2004 (km ² and %)
Closed savannah	-399 (72.7%)	-57 (38.0%)	-456 (83.0%)
Open savannah	-236 (53.7%)	+58 (28.4%)	-178 (40.5%)
Dense herb/grasses	+329 (96.2)	-121 (180.3%)	+208 (60.8%)
Burnt areas	-9 (26.5%)	+9 (36%)	0 (0.0%)
Cloud cover	+21 (95.5%)	+1 (4.5%)	+20 (91.0%)
Built-up/barren land	+282 (183%)	+110 (25.2%)	+392 (254.5%)
Water courses	+10 (142.9%)	0 (0.0%)	+10 (142.9%)

**Figure 5.3:** Net gains and losses of land-cover, 1990 to 2004

Findings from both Table 5.2 and Figure 5.3 demonstrate a net loss of 399 km² of closed savannah woodland to other land-cover types between 1990 and 2000. Between 2000 and 2004 there was a further net loss of closed savannah woodland of 57 km² totalling a cumulative net loss of 456 km² for the 14 year period. Open savannah woodland, characterised by dispersed trees shows a net loss of 236 km² between 1990 and 2000 and a net increase of 58 km² between 2000 and 2004, totalling a cumulative net loss of 178 km². In contrast to both closed and open savannah vegetative woodland, that needed validation through either ground truthing or community truthing or both, savannah grasses experienced a net gain of 329 km² for the periods of 1990 to 2000 and a net loss of 121 km² between 2000 and 2004 which resulted in an overall net gain of 208 km². It is expected that savannah woodland usually degrades directly to barren environment. Results of earlier studies by Dechart and Veldkamp (2003) stipulate that savannah areas originally occupied by either closed or open vegetative woodland are usually replaced by savannah grasses when subjected to degradation before becoming a barren environment.

Burnt areas did not experience any net gain or net loss for the 14 year period of study as indicated in Figure 5.3. This is subjected to results of ground truthing during field work. The land-cover type that demonstrating a major net increase during the 14 year period, and that is assumed to be normal in northern Ghana, is built-up and barren environment with a cumulative net gain of 392 km² from 1990 to 2004. A similar pattern was observed at the Volta watershed in Ghana from 1984 to 1999 by Braimoh (2003) who described the trend as a symptom of environmental degradation.

5.2.3 Change maps

Image differencing which is probably, the most widely used change detection algorithm (Singh, 1989), involves subtracting one date of satellite imagery from a second date that has been precisely registered to the first imagery (Appendix 5.1). One of the aims of this research is to detect savannah woodland conversion to built-up and barren land. This is achieved through the adoption of image differencing technique. Figure 5.4 and 5.5 are the results of the identification of land cover changes for the 1990 and 2004 images of the study area. A critical element of the image differencing method is deciding where to place the threshold boundaries between change and no change boundaries (Singh, 1989). In this research, the determination of change threshold values was determined by visual comparison of the difference file of the 1990 and 2004 images and subjective manipulation of change values to represent both positive and negative changes in vegetative cover.

Table 5.3 shows the numeric range of the labelled change categories of the 1990 and 2004 image differencing. Areas of vegetation gain were characterised as savannah woodland regeneration from grasses and built-up and barren environment and areas of vegetative loss were characterised as savannah woodland to grasses, built-up and barren environment.

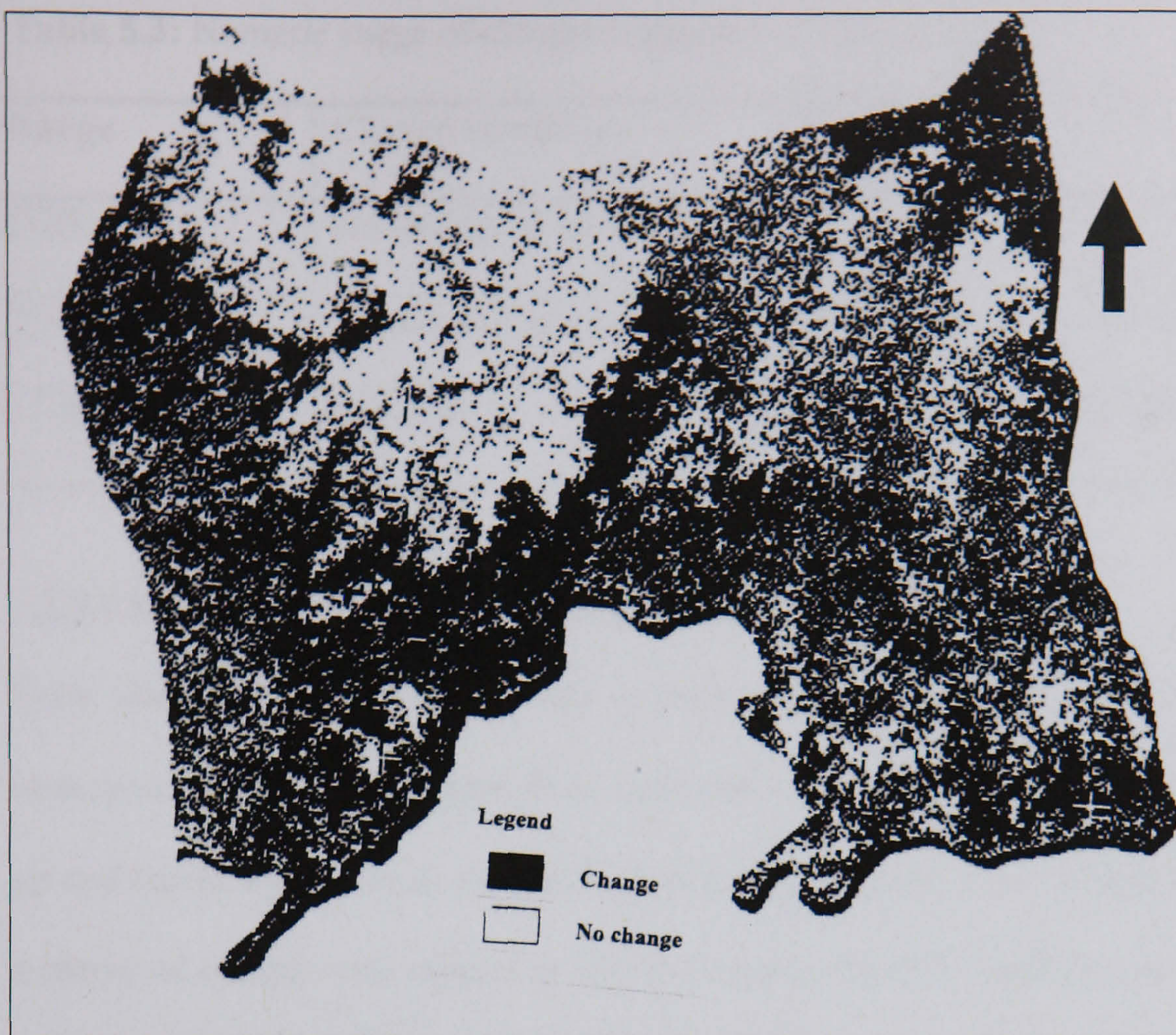


Figure 5.4: Change map of the 1990 and 2004 images

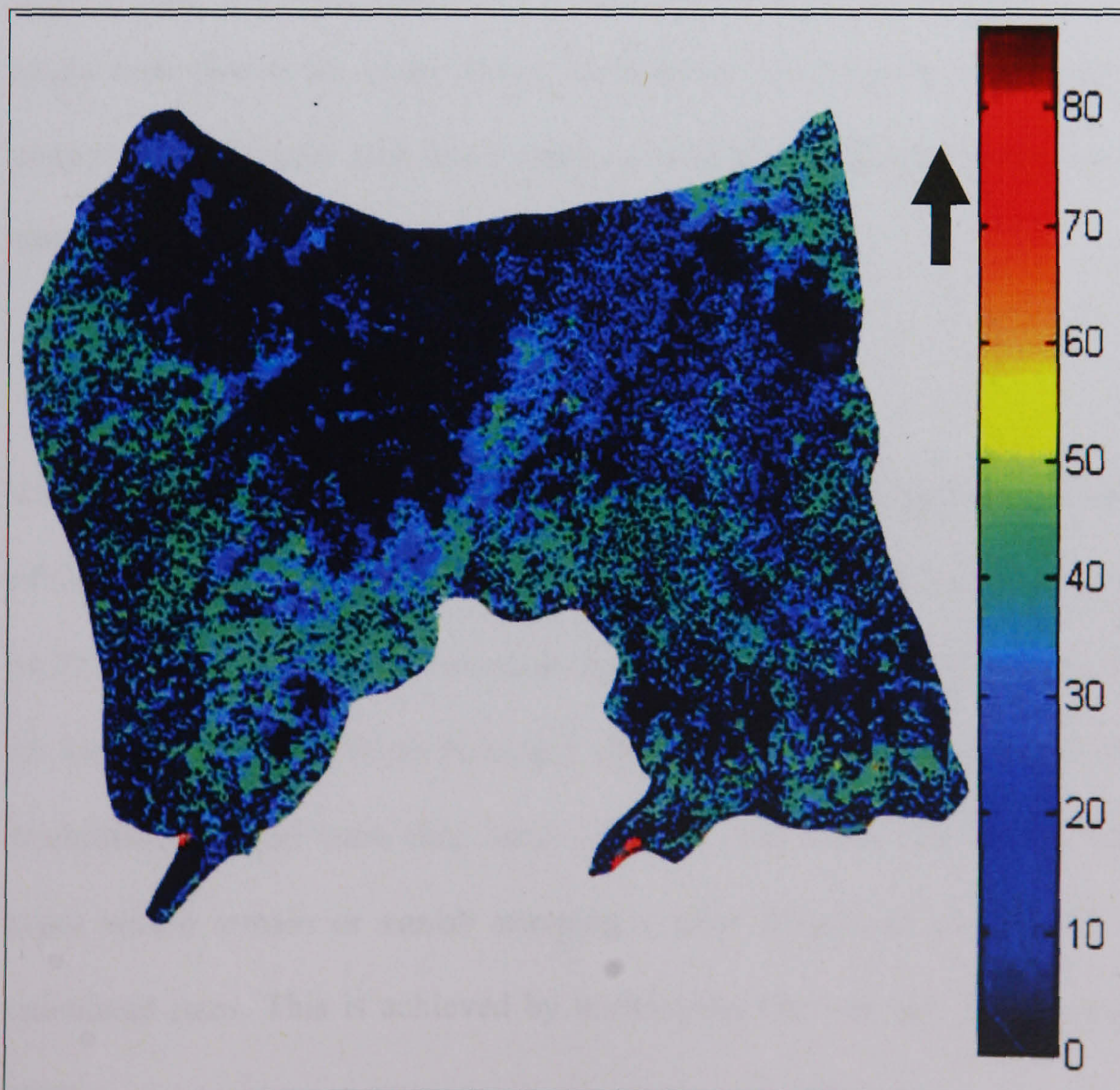


Figure 5.5: Vegetative change map of the 1990 and 2004 images

Table 5.3: Numeric range of change categories of Figure 5.5

Range	Change categories
0-20	No change of barren land
21-50	Vegetation loss from savannah woodland to barren land
51-80	Vegetation gain from barren land to savannah woodland

5.2.4 Land-cover types prediction for 2010 and 2020

From the previous sections it was apparent that the environment of the study area had undergone tremendous changes from savannah woodland types to herbs and grasses and built-up and barren environment for the 14 year period of study, even though some of the observed patterns of change were subject to debate or needed further clarification. It is also appropriate to investigate statistically, what the environment might look like in 20 or 30 years from the 2004. This is useful to provide strong evidence to support the threat of desertification as already suggested and to validate anticipated participants comments on what the environment might look like in the years ahead. To achieve that purpose, the net gain and net loss per annum of the various land-cover types (annual rate of change) using basic linear regression statistics were calculated as simplified below.

$$Y = \frac{x}{b}$$

where “Y” is the annual rate of change of one land-cover type; x is the net gain or loss (km²) of that land-cover type and b is the year’s interval from 1990 to 2004. Results yielded a value of 33 km² net loss of closed savannah woodland; 13 km² net loss of open savannah woodland; 15 km² net gains of dense herb and grasses and 28 km² net gain of built-up and barren environment which were then used to model how much the various dominant land-cover types would remain or vanish completely after 20 and 30 years from 1990 at the above calculated rates. This is achieved by multiplying the rate with the corresponding number of years.

$$Y = \frac{x.k}{b}$$

where k is the estimated number of year from 1990 to 2010 and 1990 to 2020.

Table 5.4 and Figure 5.6 show the tabular and graphical representation of the cover types for 2010 and 2020.

Table: 5.4: Land-covers changes extrapolation

Land-cover types	1990-2010 (km ²)	1990-2020 (km ²)
Closed savannah woodland	660 net loss	990 net loss
Open savannah woodland	260 net loss	390 net loss
Dense herbs and grasses	300 net gain	450 net gain
Built-up and barren land	560 net gain	840 net gain

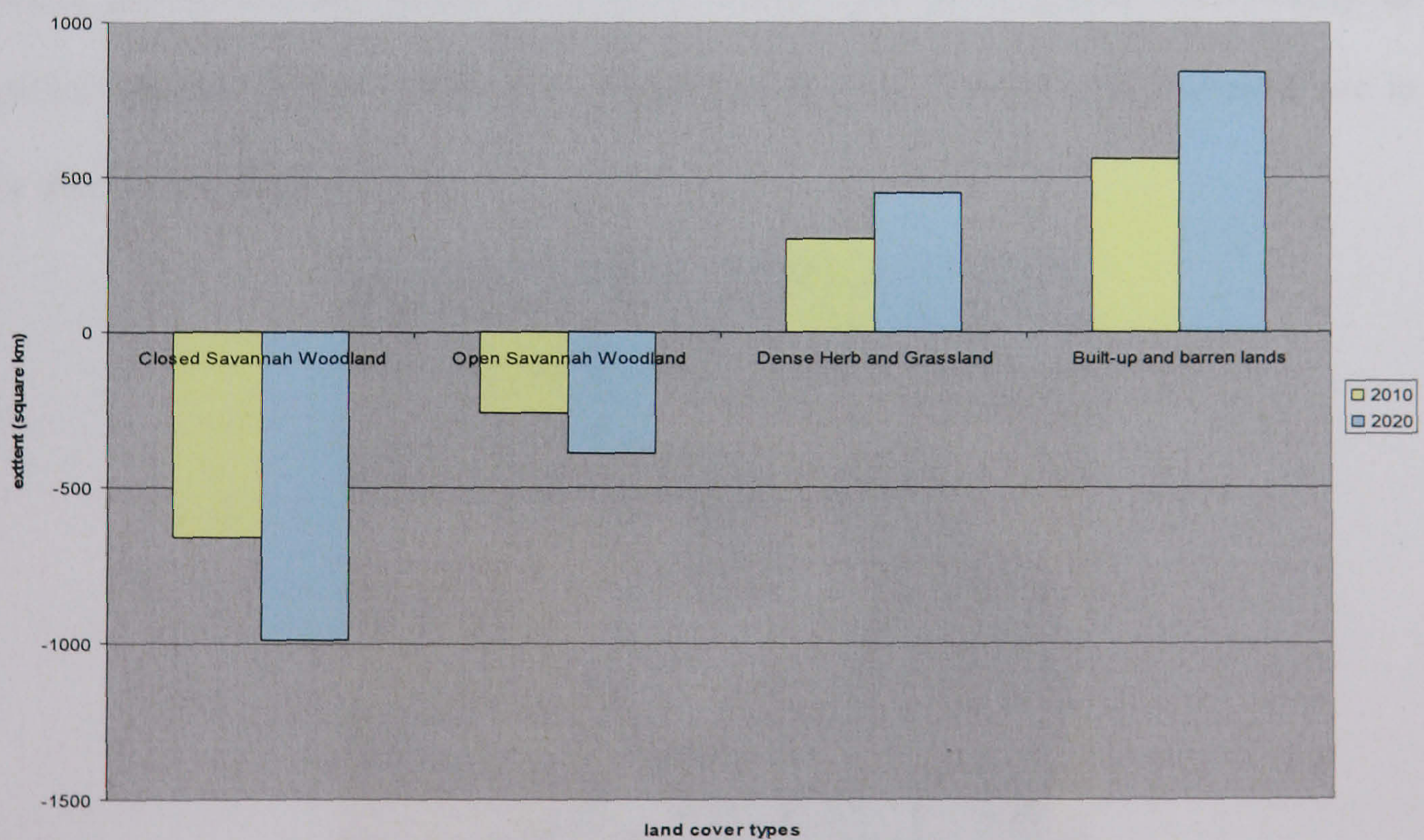


Figure: 5.6: Land-cover type changes extrapolation

Table 5.3 and Figure 5.4 show that all closed savannah woodland types would be transformed or replaced by other vegetative types by the years 2010 and 2020 if effective conservation measures are not put in place to reverse the situation. Fewer and scattered open savannah

woodland types would have remained by the years 2010 and 2020. Grasses of various types would have made a net gain of 300 km² by 2010 and 450 km² by 2020. Built-up and barren environment would be dominant in the area for the years 2010 and 2020 with net gains of 560 km² for 2010 and 840 km² for 2020. These findings echoed the assertion by WCED (1987, p2) that environmental degradation is becoming a human phenomena with each year millions of hectares of productive lands turning into built-up or barren environment, the consequences of which can easily be predicted into the near future (WCED, 1987).

5.3 Ground truthing

As reviewed in chapter 3, GPS ground truthing is an essential post-classification procedure as it gives quantitative estimates of the quality and reliability of the final classified images (Congalton, 1991). To validate some of the issues raised during the GIS and remote sensing results, GPS ground truth points were collected at different locations in the study area during the initial field work to validate the accuracy of the classified satellite images. Care was taken to select ground-truthing points in locations which had not changed substantially in the classified satellite images. Figure 5.7 shows ground truth exercise at a degraded site in the study area during field work.



Figure 5.7: GPS ground truthing at Bantama

Source: Fieldwork, 2006

5.3.1 Relative percentage of ground truth sampled data

Table 5.4 gives the true ground truthing sampled and their corresponding relative percentage to the total pixel classes for the 1990; 2000 and 2004. The relative results of the sampled ground truth data were unsatisfactory due to the large coverage of the study area (1509 km²) with large number of pixels in the classified images that made it impossible to obtain a significant percentage of ground truth data for the study area. Nevertheless, the accuracy assessment research work by Congalton (1996) proposed, for desirable positive results, a minimum of 50 ground truth samples for each land-cover category in an error (confusion) matrix, thus justifying the sampled ground truth size for the accuracy assessment.

Table: 5.5: Ground truthing points sampled against the 2004 classified image

Land cover	Pixels	Ground truth points	Percentage ground truth points
Closed savannah woodland	610281	88	0.0001442
Open savannah woodland	489049	99	0.0002024
Dense herb/grasses	380224	123	0.0003234
Burnt areas	37434	81	0.0021638
Built-up and barren land	171000	102	0.0005949
Water courses	7400	11	0.0014864

5.3.2 Accuracy assessment of the 2004 classified image

5.3.2.1 Producer accuracy

The producer accuracy is a measure of how often are the real features on the ground correctly shown on an image map. The producer accuracy (from Table 5.6) for closed savannah woodland was 79% with 21% error of commission. This means that of the 88 ground truth points for closed savannah woodland, 70 were correctly classified as closed savannah while 18 were wrongly committed on the classified image as closed savannah woodland. Open savannah woodland recorded 65% producer accuracy with commission error of 35%. This

means that of the 99 ground truth points sampled for open savannah woodland, 64 were correctly classified on the image map while 35 (18+9+4+3+1) were wrongly committed on the image map. Dense herb/grasses recorded 71% producer accuracy with 29% error of commission meaning that of the 123 ground truth points sampled for dense herb/grasses, 88 were accurately classified while 35 (3+8+14+8+2) were wrongly committed on the image map. Producer accuracy for burnt areas yielded 64% with 36% error of commission, meaning that of the of the 81 sampled points, 52 points were accurately classified on the image map while 29 (4+8+8+9) were wrongly committed on the image map For built-up and barren areas, producer accuracy was 92% with 8% error of commission, which explains that of the 102 sampled points, 94 were accurately classified while 18 (4+4+6+4) were wrongly committed on the image map. Produce accuracy for water 90% with 10% error of commission. This is attributed to the fact that of the 11 sampled points, 10 were accurately classified, while 1 was wrongly committed on the image map as water that was dense herb/grasses on the ground.

Figure 5.6: Error (confusion) matrix: Accuracy assessment for the 2004 classified image

		Ground Truthing Classes										
		Closed savannah woodland	Open savannah woodland	Dense herb/grasses	Burnt areas	Built-up and barren environment	Water courses	TOTAL	Producer accuracy	Error of commission	User accuracy	Error of omission
Remote sensing thematic classes	Closed savannah woodland	70	18	3	4	0	0	95	79	21	74	26
	Open savannah woodland	5	64	8	8	4	0	89	65	35	71	29
	Dense herb/grasses	8	9	88	8	4	1	118	71	29	75	25
	Burnt areas	2	4	14	52	6	0	78	64	36	67	33
	Built-up and barren environment	3	3	8	9	94	0	117	92	8	80	20
	Water courses	0	1	2	0	4	10	17	90	10	58	42
	TOTAL	88	99	123	81	102	11	504				

5.3.2.2 *User accuracy*

The user accuracy measures the accuracy of the classified image. The user accuracy (commission error) for closed savannah was 74% with 26% error of omission. This means that of the 95 sampled points, 70 were accurately classified as closed savannah woodland on the image map while 22 of closed savannah pixels (18+3+4) were omitted from the image map. For open savannah woodland, user accuracy was 71% with 29% error of omission, meaning that 64 pixels were correctly classified on the image while 25 (5+8+8+4+4) open savannah pixels were omitted from the map. User accuracy for grassland was 75% with 25% error of omission which means that of 118 sampled points, 88 were accurately classified on the image map while, 30 (8+9+8+4+1) were omitted from the image map as grasses. User accuracy for burnt areas is 67 with 33% error of omission. This means that of the 78 pixels on the image map as burnt areas, 52 were correctly classified while 26 (2+4+14+6) were omitted from the map. User accuracy for built-up and barren land was 80% with 20% error of omission which means that of the 117 pixels classified as built-up and barren environment, 94 were accurately classified while 23 (3+3+8+9) were omitted from the map as built-up and barren environment. User accuracy for water was 58% with 42% error of omission which means that of the 17 sampled points as water on the image map, 10 were accurately classified while 7 (1+2+4) were omitted from the image map as water course.

5.3.3 User and producer accuracy comparisons

Figure 5.8 is a graphical presentation of the producer and user accuracies. Looking at the per class accuracies, it is seen that higher percentage producer accuracy as against user accuracy occurred in the closed savannah, built-up/barren environment and water course land-cover types.

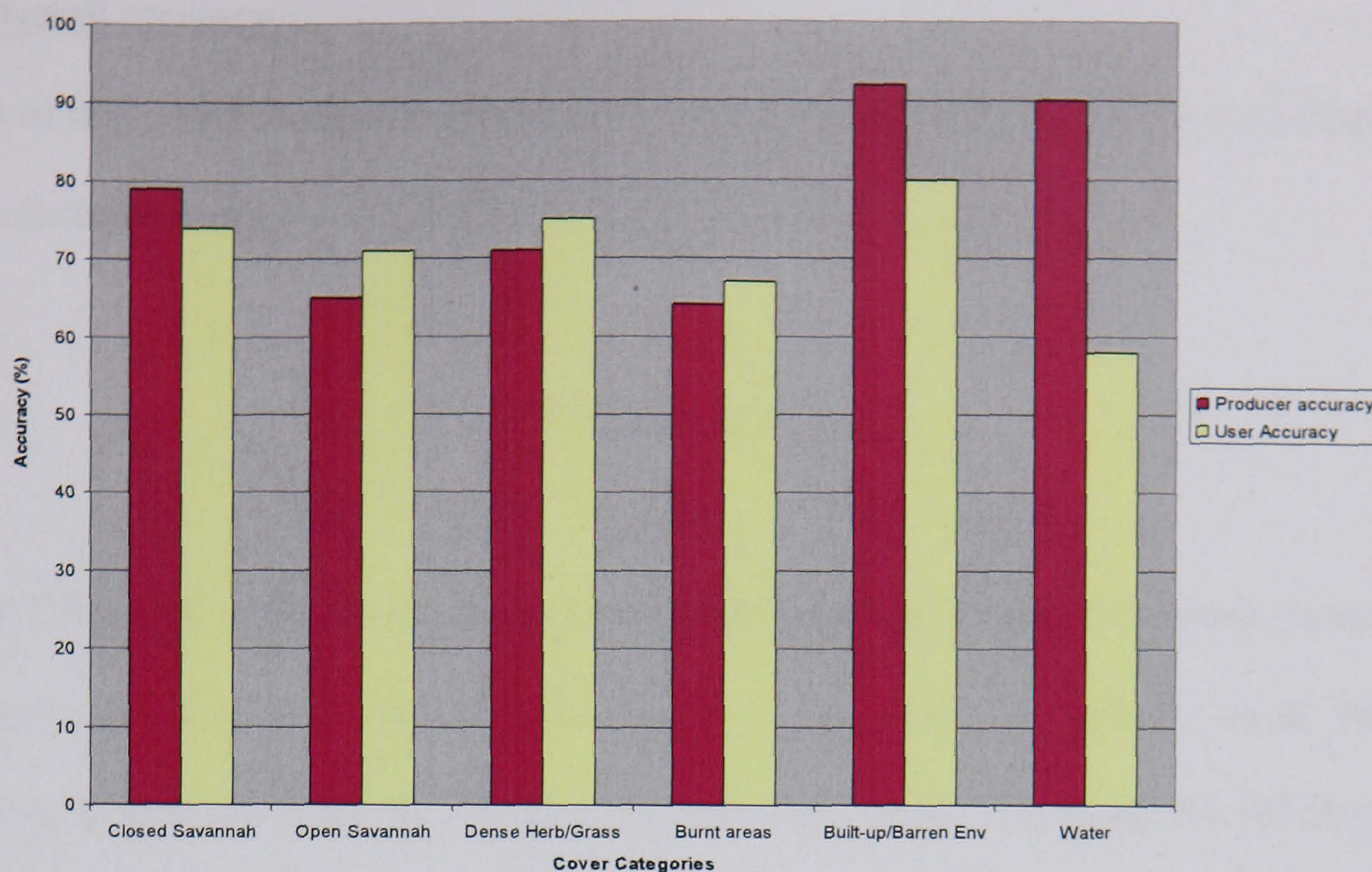


Figure 5.8: User and producer accuracy assessment for 2004

The explanation is that some of the pixels classified as closed savannah, built-up/barren environment and water, during the unsupervised image classification do not actually belong to those classes. However, the percentage errors of commission for those land-cover types were below 50% indicating higher accuracy. On the contrary, confusion between open savannah woodland, grasses and burnt areas, however, is not serious which is an indication that the pixels classified as open savannah woodland, grasses and burnt areas in the field actually correspond to the classification on the satellite images using the unsupervised image classification technique, even though some few percentage of the pixels for the closed savannah, open savannah and dense herb/grass cover categories were omitted during the ground truthing. Most importantly, non savannah woodland (barren environment) and savannah woodland were not confused thus validating the initial results of the GIS and remote sensing classified images.

5.3.4 Overall accuracy

Results of this error (confusion) matrix revealed that the overall accuracy of classification was 75%, calculated from:

$$\frac{(70+64+88+52+94+10)}{504}$$

504

Duadze (2004) did a similar study on land-use and land-cover in the savannah ecosystem in the Upper west region of Ghana. The results of his producer accuracy were: bare land (77.93%); closed savannah woodland (90.40%); Open savannah woodland (83.0%); dense herb/grasses (92.97%); and water body (99.01%). His user accuracy yielded; bare land (96.90%); closed savannah woodland (93.17%); Open savannah woodland (82.59%); dense herb/grasses (90.57%) and water body (100%). His overall accuracy was 72% was attributed to the quality of the satellite images used and the distinct characteristics of the land-cover types as they were fully separable in the unsupervised classification technique adopted.

In summary, this section has examined the potential capabilities of conventional remote sensing image processing and GIS in contributing to the assessment of environmental degradation in northern Ghana. It also ascertained the already held notion that GIS and remote sensing have the potential to produce scientific results capable for scientific analysis (Openshaw, 1991; Goodchild, 1991). Critique of the above GIS analysis, as already commented by many social commentators such as Obermeyer (1995) and Pickles (1995), is that despite its potential capabilities in identifying, quantifying and analysing spatial data and visually representing them as image maps in a GIS, results do not usually reflect the true picture of what is actually happening in the field and also there is not representation of qualitative information on the classified image maps. For this reason participatory approaches that depend on local ecological knowledge to complement the conventional GIS data become useful and that is the subject of the subsequent sections.

5.4 Community truthing

5.4.1 Spatial distribution of land-cover types

Table 5.7 contains summarised responses by participants concerning the spatial distribution of the various land-cover types in the study area for the 14 year period of study. Most of the participants were able to discuss, to the best of their knowledge, the spatio-temporal distribution of the land-cover types in the study area with reference to the image maps provided. The general observation made by most of the participants, with exception of the small-scale miners focus group, was that in communities such as Bolgatanga, Zuarungu and Kombosigo (located in the mid-north portion of the study area, Figure 4.1 and 4.2), the original land-cover type of open savannah woodland interspersed with some closed savannah woodland, has recently been replaced by grasses and barren environment. Participants attributed that to human activities. As commented by one of the women's focus group participant: *"we used to farm here in Bolgatanga town but now the land has been depleted to the extent that even a single onion when planted cannot survive"*. The popular assertion by Conteras-Hermorilla (2000) that the degradation of savannah vegetation is attributed to human actions seem to be applicable in the study area as observed by the research participants.

In the Nangodi, Kongo, Pelungu and Sekote communities of the Talensi Nabdam District. (located in the extreme north eastern portion of the study area, Figure 4.1 and 4.2) participants, mostly key informants, noted that the original closed savannah woodland has recently been replaced by dominant herbs and savannah grasses, few patches of open savannah woodland and built-up and barren environment. Participants attributed the observed changes to social processes such as population growth and migration and human activities such as surface and underground mining in Nangodi and the immediate environment.

In the south-eastern portion of the study area such as Duusi, Accra, World Bank, Kejetia, Bantama, Tarkwa and Obuasi of the Talensi-Nabdam district, participants noted that the original savannah woodland (both closed and open savannah woodland) interspersed by few

dense herb and savannah grasses have recently been cleared and subsequently replaced by dominant savannah grasses and built-up and barren environment. Most of the research participants were of the view that human activities such as mining, grazing and sand winning might have initiated such environmental changes.

Most of the original closed savannah vegetative type at Sherigu community, in the north-western portion of Bolgatanga, has also been degraded to barren environment with some few patches of scattered dense herb and savannah grasses as noted by participants. Those who responded attributed that to various human activities such as farming, grazing, human settlement and mining activities.

Table 5.7: Spatial distribution of observed land cover changes

Communities	Pattern of observed changes
Bolgatanga, Zuarungu, Kombosigo of Bolgatanga Municipality (Mid-north of study area)	Original savannah woodland of open type gradually replaced by grasses of dominant elephant type, settlement and infrastructural projects
Nangodi, Kongo, Pelungu, Sekote Communities of Talensi-Nabdam District (north eastern part of study area)	Original reserved savannah woodland of closed type gradually taken over by grasses, Settlement and through various economic activities
Duusi, Accra, World Bank, Kejetia, Bantama, Tarkwa and Obuasi (South-eastern part of study area)	Original savannah woodland interspersed with grasses of various types replaced by grasses barren areas
Sherigu (North-western part of study area)	Reserved savannah woodland with grasses recently encroach by small-scale illegal mining
Pwalugu, Tongo, Winkogo (South-western part of study area)	Original savannah woodland and grasses replaced by barren land

In the Pwalugu, Tongo and Winkogo communities, in the south-western portion of the study area and part of Talensi-Nabdam district the nature of degradation were not different from other locations as observed and noted by research participants. The original open-savannah woodland type, interspersed with a few closed savannah types have recently been degraded as a result of human activities and various government infrastructural developments initiated by the district assembly under the Local Government Act 462 of 1993 which among others, empowered district assemblies to set developmental activities as their priority to improve living standards. Figures 5.9 and 5.10 shows local knowledge on the spatial distribution of observed land cover changes converted into geo-spatial data via GIS

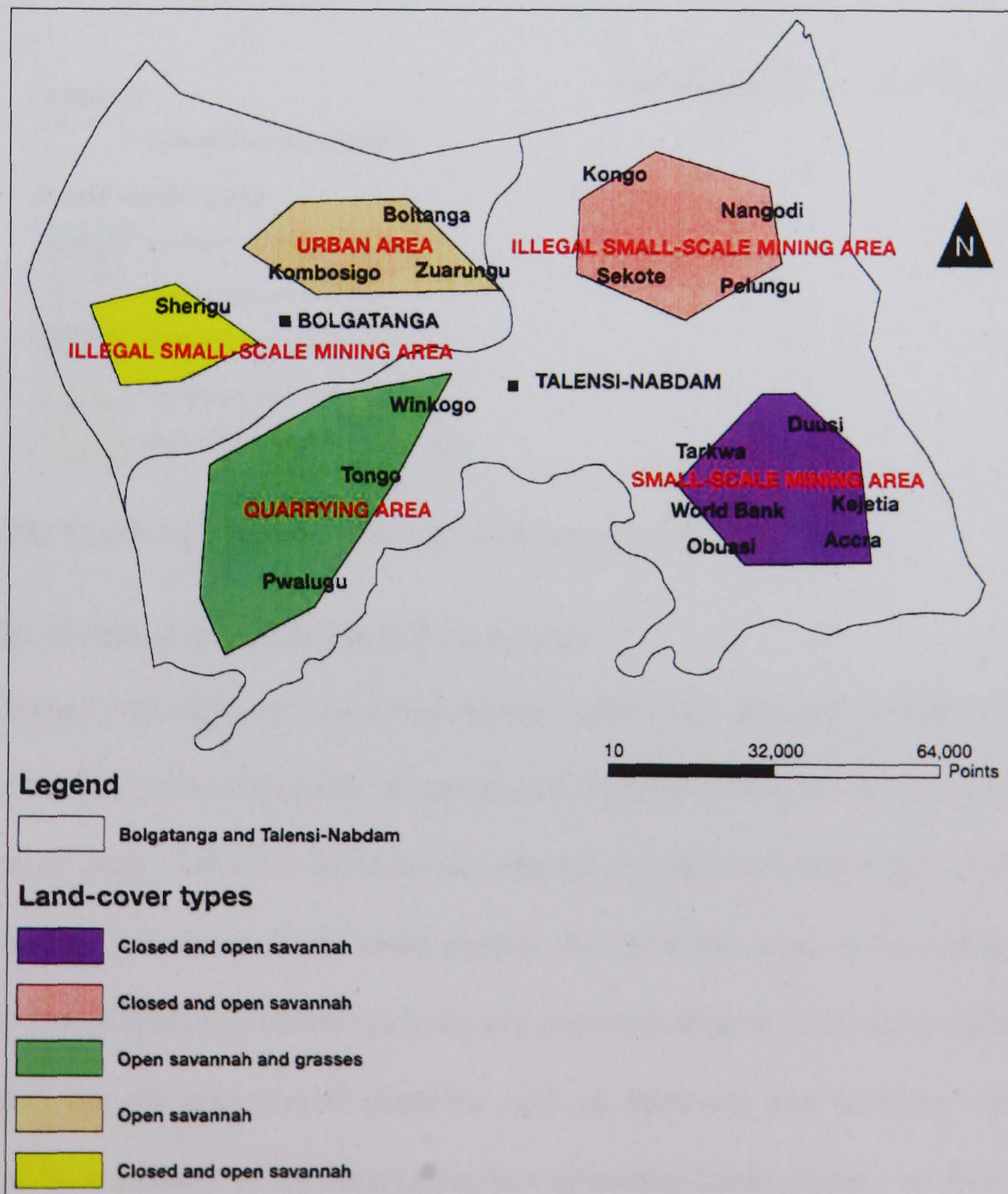


Figure 5.9: Spatial distribution of historical land-cover in GIS

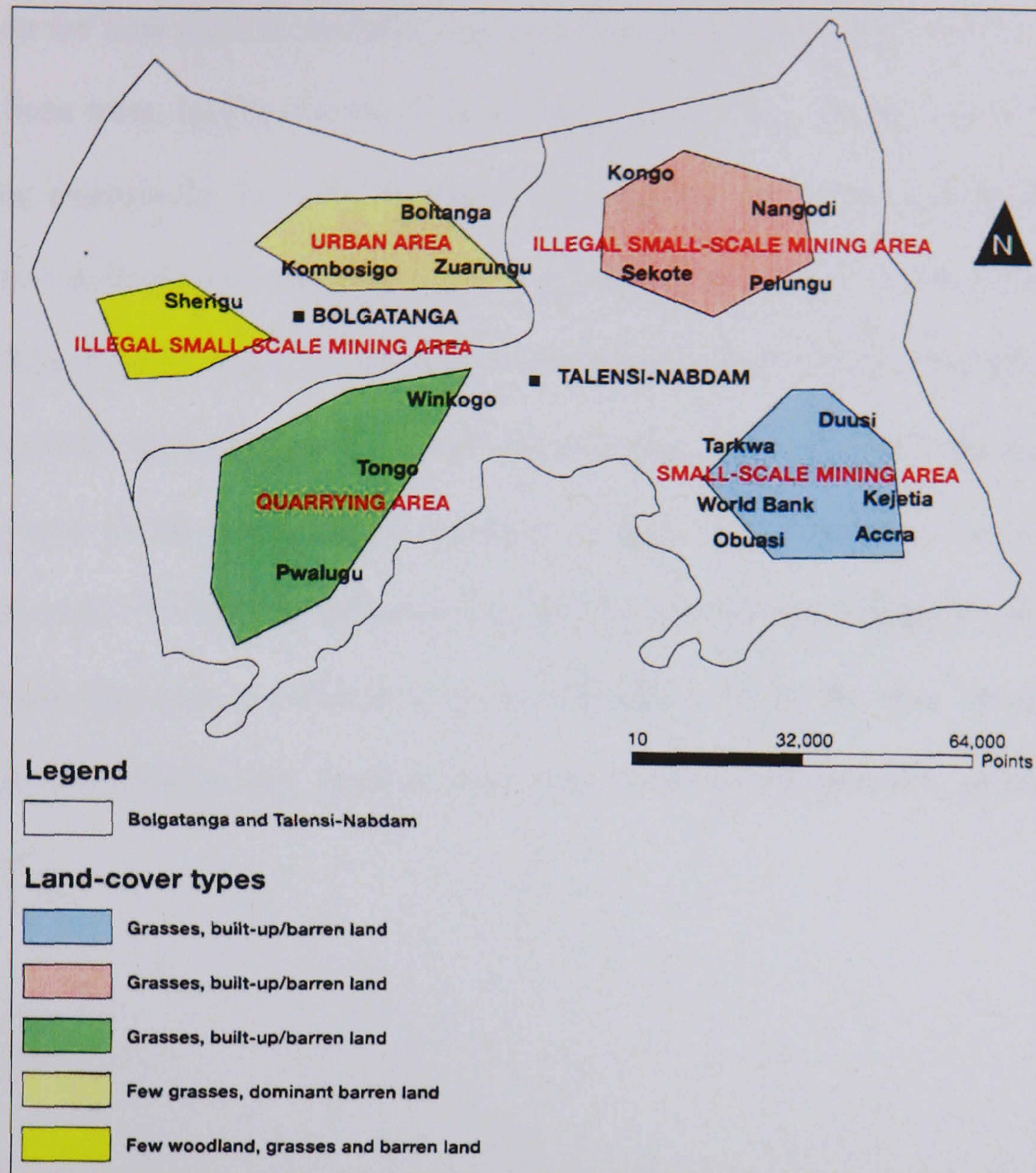


Figure 5.10: Spatial distribution of current land-cover in GIS

5.4.2 Replacements of savannah tree and grass types

During repeated interviews and focus discussions, participants were asked whether there have been any changes in the abundance of recognized indigenous and exotic trees during the 14 year period of study. Table 5.8 demonstrate research participants' responses concerning such changes and the perceived direct social causes. As noted by most of the participants, but mostly key informants, silk cotton trees, locally known as Kapok, have been depleted due to its continual use for commercial purposes such as firewood and building materials. As emphasised by a member of the heterogeneous community focus group: *"we have depended on the silk cotton tree for building our detached houses because it is strong and resistant to rot"*.

Other participants, mostly local focus groups, observed that the indigenous shea tree, which was originally used by women in making shea-butter, in small quantities, for household consumption are now used for building and road construction. As also noted by participants, the locust bean trees, locally known as dawadawa, which were originally used for firewood are now use extensively for various commercial purposes such road construction, building materials and underground mining trenches support. In contrast to the silk cotton, shea tree and locust bean tree, household and commercial use of the baobab tree is limited as the tree is believed in most communities to be sacred. There are very few of them in the study area and are mostly used for the provision of shelter as seen in every household compound visited during field work. The barks of the tree were, hitherto, used for the preparation of concoctions and traditional medicine. According to a key informant; *“if all the local trees were to be valued and respected as the baobab tree, there will be no problem of environmental degradation”*.

Table 5.8: Replacement of savannah tree and grass types

Trees and grasses	Causes of replacement
Silk Cotton tree (Kapok)	Firewood, building material, construction and infrastructural projects
Shea tree	Building material, construction, seeds used for shea-butter
Boabab tree	Sacred tree of no economic importance
Locust bean tree (dawadawa)	Firewood, construction, building material, underground mining trenches
Mango tree	Fruits sold as food, bark for medicine
Teak	Firewood, construction, building material, Underground mining trenches, electricity poles
Neem	Firewood, construction, underground mining trenches
Guava	Fruits sold as food, medicinal plant
Gamba grass	Grazing and as roofing material
Elephant grass	Grazing and as roofing material
Guinea grass	Grazing and as roofing material

Most of exotic trees in the study area such as mango, teak, neem and guava, which were originally used by local people for food, firewood and traditional medicine during the early 1990s, are now use for building and construction purposes and support of underground mining trenches. Infrastructural developments such as urban expansion, construction of commercial and feeder roads, market centres, lorry park (Figure 5.11), estate houses, school projects, an airstrip, postal houses, telecommunications, hospitals, industries. financial institutions and electricity supplies have also contributed to the depletion of the savannah vegetative forest as observed by research participants.



Figure 5.11: Newly constructed lorry park at Bolgatanga

Source: Fieldwork, 2006

In contrast to most key informants who attributed the cause of depletion of savannah grasses to intense use for grazing and as roofing materials in most of the semi-detached family houses found in the Talensi-Nabdam rural communities, most focus group participants mentioned the prevailing cultural practices such as bush burning and hunting as the main causes of the depletion of savannah grasses in the study area. Figure 5.12 is a photographic presentation of a local focus group participant (heterogeneous community focus group) observing a portion of land area originally covered with closed savannah woodland but recently depleted beyond commercial use at Duusi in the Talensi-Nabdam. As he observed, the degradation at the site is a result of intense underground mining activities.



Figure 5.12: Barren environment at Nangodi

Source: Fieldwork, 2006

Notwithstanding the diverse opinions by the research participants, the above findings demonstrate that local people's ideas and views are not based on mere assumptions but on real issues about their environment as has also been observed by Doolittle, (2003). The findings also relate to assertion by Kessler (1992); Moleele *et al.* (1996); Nangula and Oba (2004); Blench (2006) that the degradation of savannah vegetative forest in most arid and semi-arid regions is spatio-temporal in nature through extreme human exploitation of tree types and dominant grasses.

5.4.3 Pattern of land-cover changes

The suggestion that most land-cover type changes in many savannah environments are spatio-temporal in nature and are trapped in a spiral of irreversible and uncontrollable worsening degradation usually from savannah woodland to built-up and barren environment (Barrow, 1991; Rees, 1992; Rees and Wackernagel, 1994; Dreshsel *et al.*, 2001; Nsiah-Gyabaah, 2004 and Reed *et al.*, 2007), as exemplified diagrammatically in Figure 5.13 and Figure 5.14, was contrasted by deductions made from participants observations concerning spatio-temporal patterns of change and to verify some of the issues raised during the analysis of the GIS and remote sensing results.

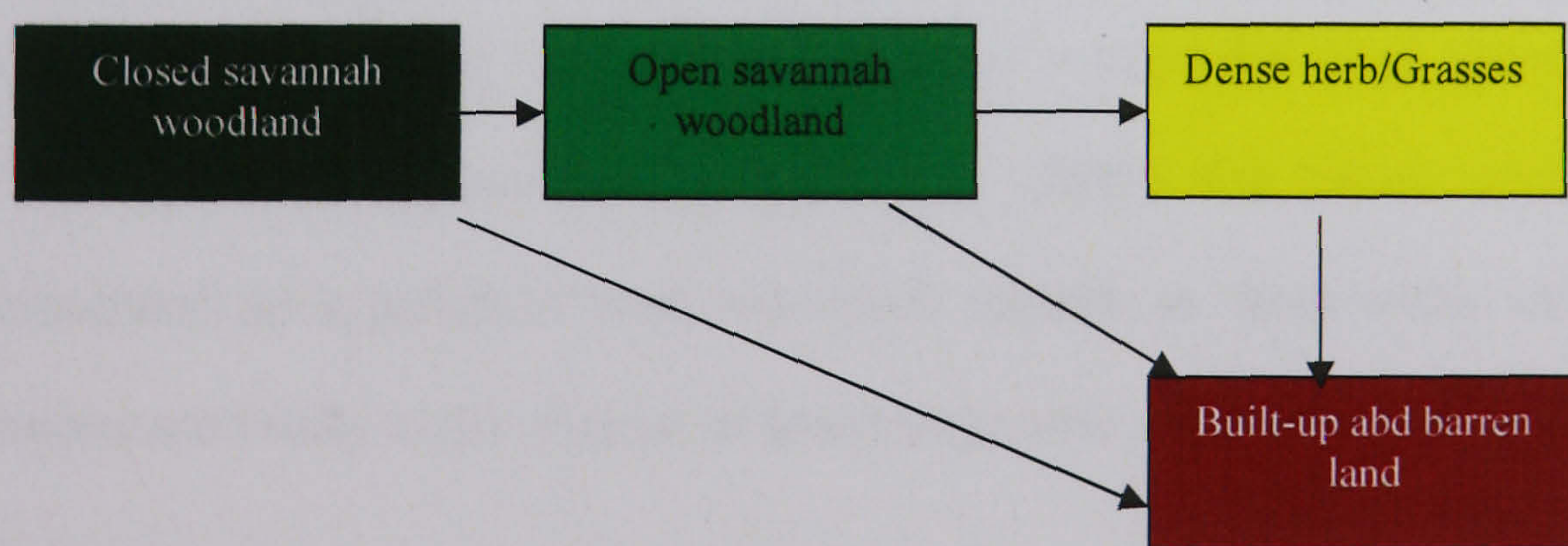


Figure 5.13: Land-cover type changes as sequential

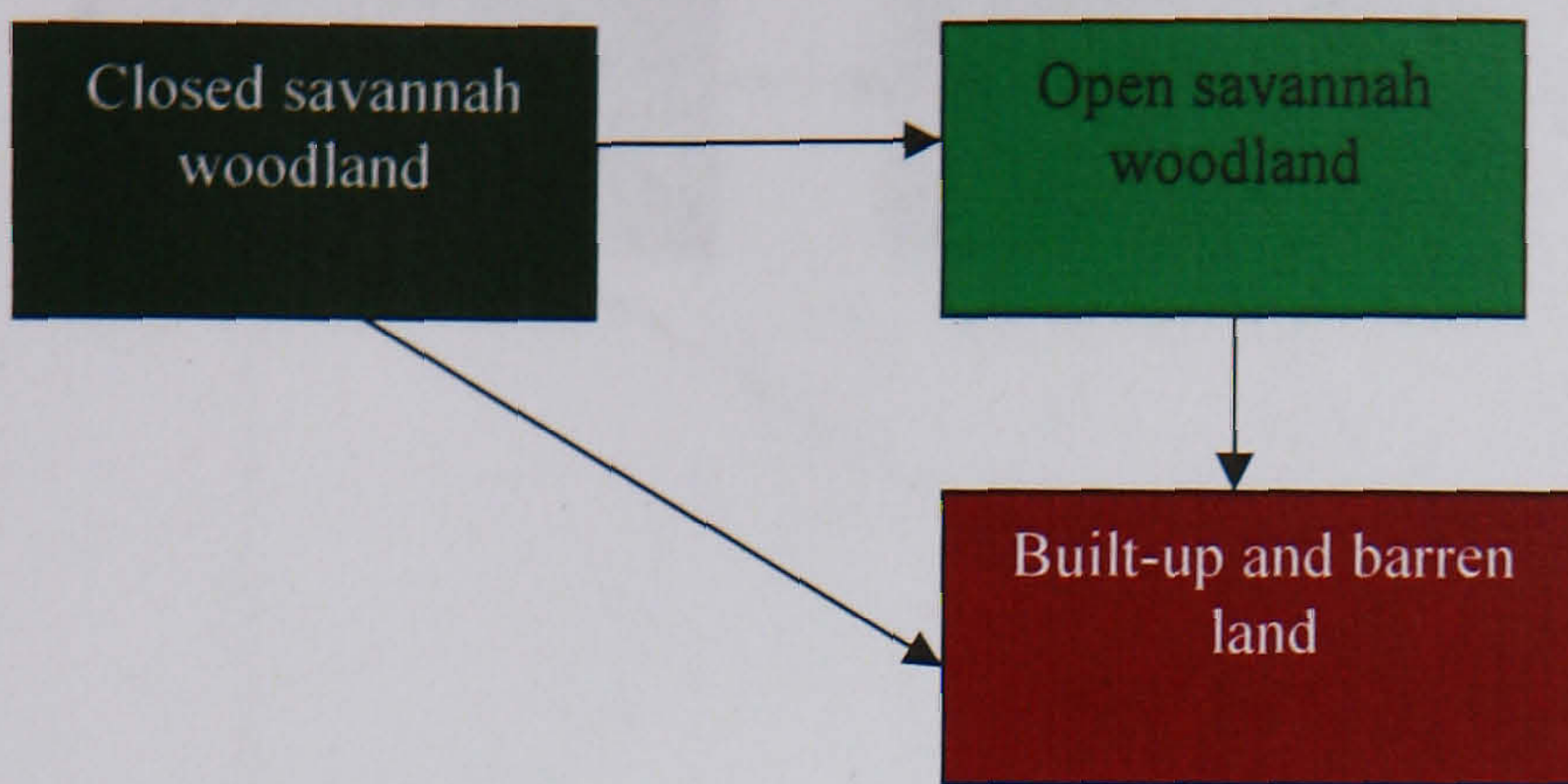


Figure 5.14: Land-cover type changes as phenomenal

Using the hermeneutic approach which is grounded in the philosophy of understanding and interpretation of qualitative data (Gadamer, 1989), most of the research participants, basing their comments on the images presented, commented that the degraded environment, as evident in communities such as Bolgatana, Tongo, Nangodi, Duusi, Sherigu and Pwalugu, where many developmental projects and human activities have, over the year taken place, can stimulate environmental innovations necessary to overcome the drastic conversion of savannah woodland to barren, degraded environment and maintain a quality environment. Their views are represented in Figure 5.15 where most of them believed in the evidence of ecological regeneration under good management practices from closed savannah woodland to barren environment and back to closed savannah woodland through grasses of various types. This support earlier assertion by Reid *et al.* (2000) that barren environment when left unattended for a period of time may revert initially to dense herbs, shrubs and savannah grasses and finally to the original savannah vegetative cover,

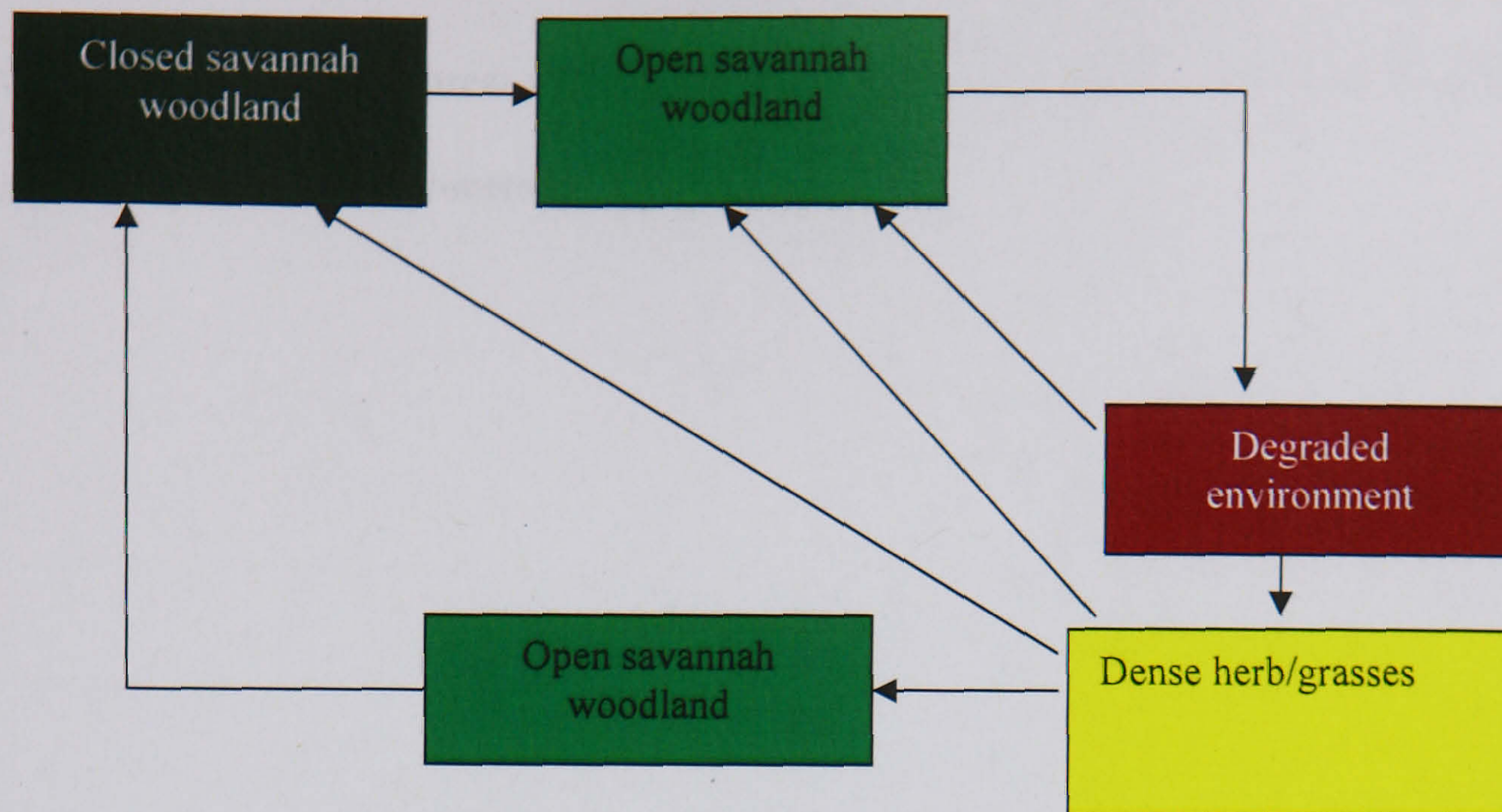


Figure 5.15: Evidence of ecological regeneration

5.4.5 Pressures from various land-uses

Numerous studies, notably, Dregne *et al.* (1991), Clearly (1990), Barry (1996), Nsiah-Gyabaah (1996) and Tonah (2000) have associated intense pressures on the environment with human activities such as mining, grazing, quarrying and bush burning (see reviewed literature in chapter 2). To relate their studies and findings to what is happening in the study area, participants were asked to identify, locate and sketch on a topographic map various human activities in the study they perceived to have contributed to the observed environmental degradation. Table 5.9 is a summary of participants' responses concerning the various human impacts on the environment through their daily activities.

With the exception of the small-scale miners' focus groups, most of the participants held the popular view that environmental degradation is as a result of human actions (Bartelmus, (1986; Anderson, 1988; Goudie, 1992; Lindberg, 1996 and Wood *et al.*, 2000). According to them, human activities such as mining, sand winning, quarrying, grazing and other cultural practices such as bush burning, hunting, firewood collection and poor farming practices have contributed to the observed changes on environment. The ability of participants to identify such human activities with serious environmental consequences confirms earlier observations made by Laurian (2004), Zaferatos (2004) and other PGIS scholars, notably, Pickles (1995);

Abbott *et al.* (1998); Williams and Dunn (2003) that local people know human activities that usually pose a serious threat to their natural environment and are prepared to take actions to address them when empowered.

Table: 5.9 Pressures (land uses)

Participants	Small-scale surface mining	Small-scale underground mining	Sand and stone winning	Quarrying	Bush burning	Grazing
Environmental Protection Agency	√	√	√	√	√	√
Mineral Commission	√	√	√	√	√	√
Lands Commission	√	√	√	√	√	
Regional House of Chiefs	√	√	√	√	√	
Talensi-Nabdam District Assembly	√	√	√	√	√	√
Bolgatanga Municipal Assembly	√	√	√	√	√	√
Regional Surveying Department	√	√		√	√	√
Regional Coordinating Council	√	√	√	√	√	√
Concerned Youth Group	√	√	√	√	√	√
Women Association	√	√	√	√	√	√
Farmers Association	√	√	√	√	√	√
Heterogeneous Community Focus Group	√	√	√	√	√	√
Heterogeneous Organisation Focus Group	√	√	√	√	√	√
Representatives from Pwalugu and Tongo	√	√	√	√	√	√
Small-scale Illegal Miners	√	√		√	√	√
Small-Scale Legal Miners	√	√		√		√

Most of the participants identified and located areas such as Nangodi, Sekote, Kongo and Pelungu of the Talensi-Nabdam District and Sherigu in the Bolgatanga municipality as well known locations of surface mining (Table. 5.10). As one of the key informants noted, *“the illegal small-scale surface mining started, before the legalisation of the small-scale mining*

(PNDCL 153), in the Nangodi community and later spread to other parts of the study area".

Participants, with the exception of the mineral commission and the small-scale miners' focus groups, noted that the spatial size of 120 km² of the small-scale illegal mining in the study area, measured and documented by the Mineral Commission in 2004 are underestimated and the fact is that there has been recent encroachment by unscrupulous miners.

Table 5.10: Areas of identified land uses

Area	Small-scale mining legal	Small-scale mining illegal	Sand winning	Quarrying	Bush burning	Grazing
Duusi	√				√	√
Nangodi		√			√	√
Sherigu		√			√	√
Kongo			√		√	√
Winkogo			√		√	√
Pwalugu				√	√	√

The Duusi, Shiega, Sekote and Pelungu environs of the Talensi-Nabdam district were noted by participants as the statutory concession as the original 72 km² site of the underground mining which according to them have been encroached recently. Few participants noted that the activity started immediately after the legalisation and promulgation of the small-scale mining in the country (PNDC law 153). According to one participant, the activity is under the supervision of the Mining and Mineral Commission of the Ministry of Mines and Forestry.

Areas also noted by participants are potential sites for sand winning of underestimated size of 5.5 km² as measured and documented by the mineral commission in 2004, in the Kongo and Zuarungu communities, and quarrying activities, of underestimated spatial size of 10 km², in the rocky areas of Kongo, Zuarungu, Pelungu Sekote, Nangodi. Pwalugu. Tongo and Winkogo, all in the Talensi-Nabdam district of the study area.

Even though grazing, hunting, firewood collection and bush burning were identified as other activities that have exerted much pressure on the environment, verification during community truthing with research participants indicated the difficulty of pinpointing the exact locations and times when such activities are usually practiced. This clarifies one of the issues raised earlier concerning the spatial extent of bush burning in the study area. As one local focus group participant commented in the local dialect and translated into English: *“you want us to tell you places of burning and grazing, that is not possible and a difficult task as they are found every where at any time and one cannot predict where and when it will be done again”*. Most participants attributed the cause to outsiders, mostly, migrant Fulani herdsmen who move freely in the area for grazing, and local people, mostly farmers who, through traditional practice of slash and burn, set fire to clear the land for farming before the onset of the rainy season. Figure 5.16 is a burnt area near Nangodi taken during the fieldwork.



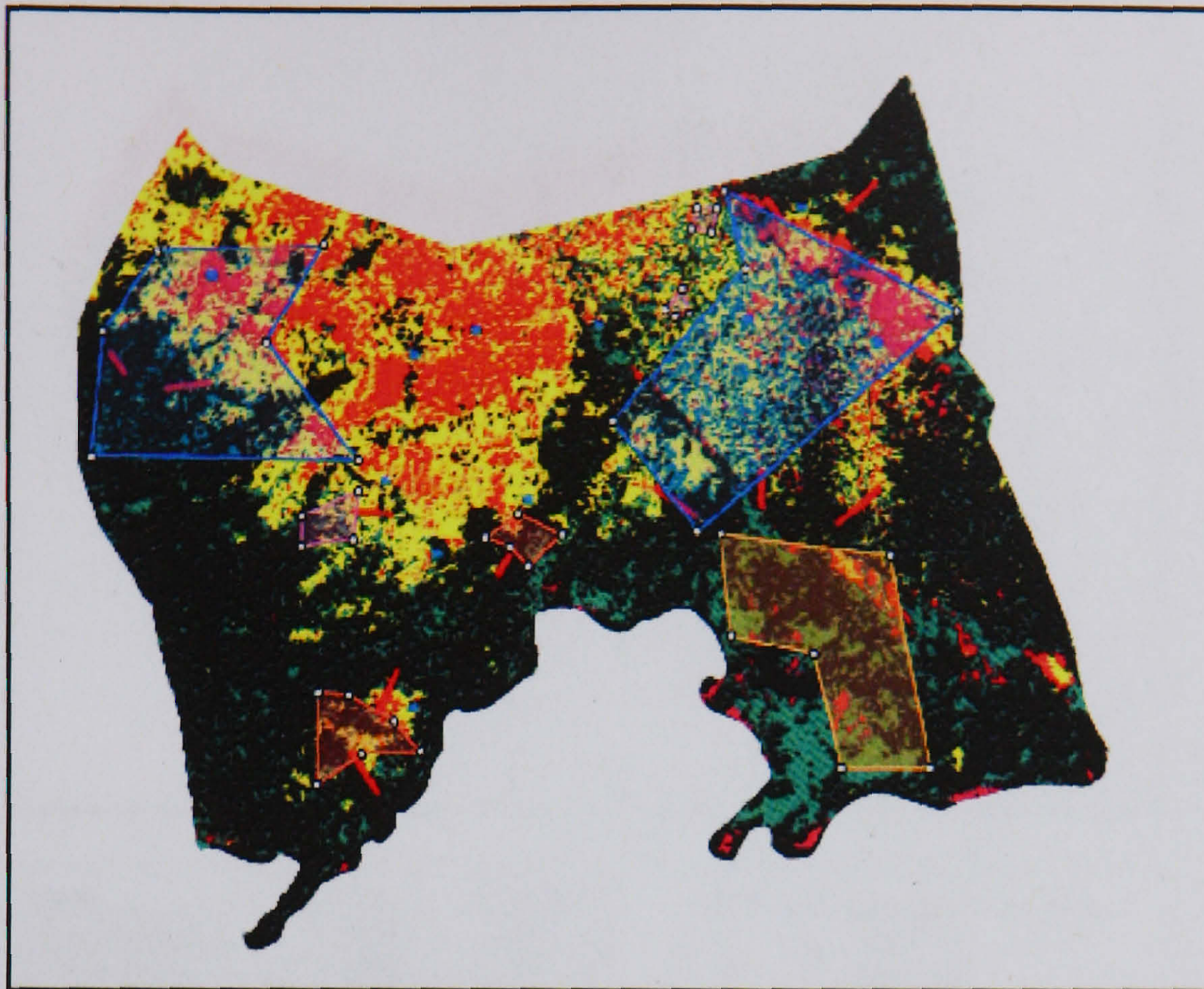
Figure 5.16: Burnt area at Sekoti near Duusi

Source: Fieldwork, 2006

5.5 GPS survey

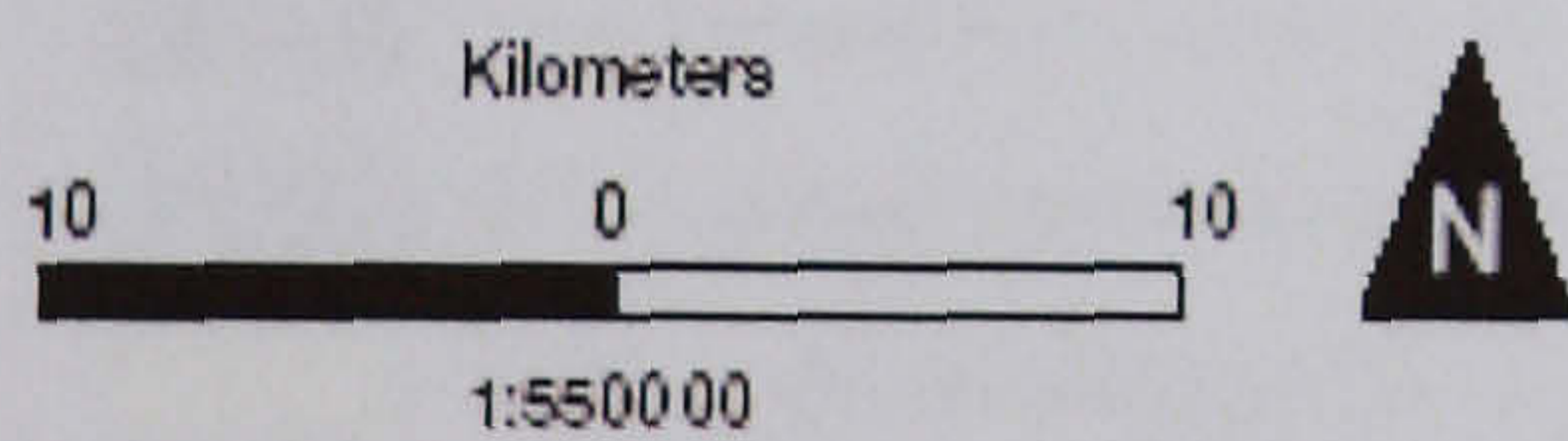
Participants' responses to the identification, locations and spatial coverage of various human activities were validated during GPS transect walk where point coordinates of the identified land uses were measured and overlaid on the three classified images. Figures 5.17, 5.18 and 5.19 shows the overlaid of the GPS points on the three images, joined to form polygons of the land uses and their approximate spatial extent (in km²).

1990



Class	Pixel	Sq km
Closed Savanna	610281	549
Open Savanna	489049	440
Dense Herb/Grass	380224	342
Burnt Area	37434	34
Cloud	1003	1
Built Up/Bare Area	171000	154
Water Body	7400	7

	Small scale mining - illegal (258.46km ²)
	Sand winning (7.4857km ²)
	Small scale mining - legal (82.279km ²)
	Quarrying sites (19.969km ²)

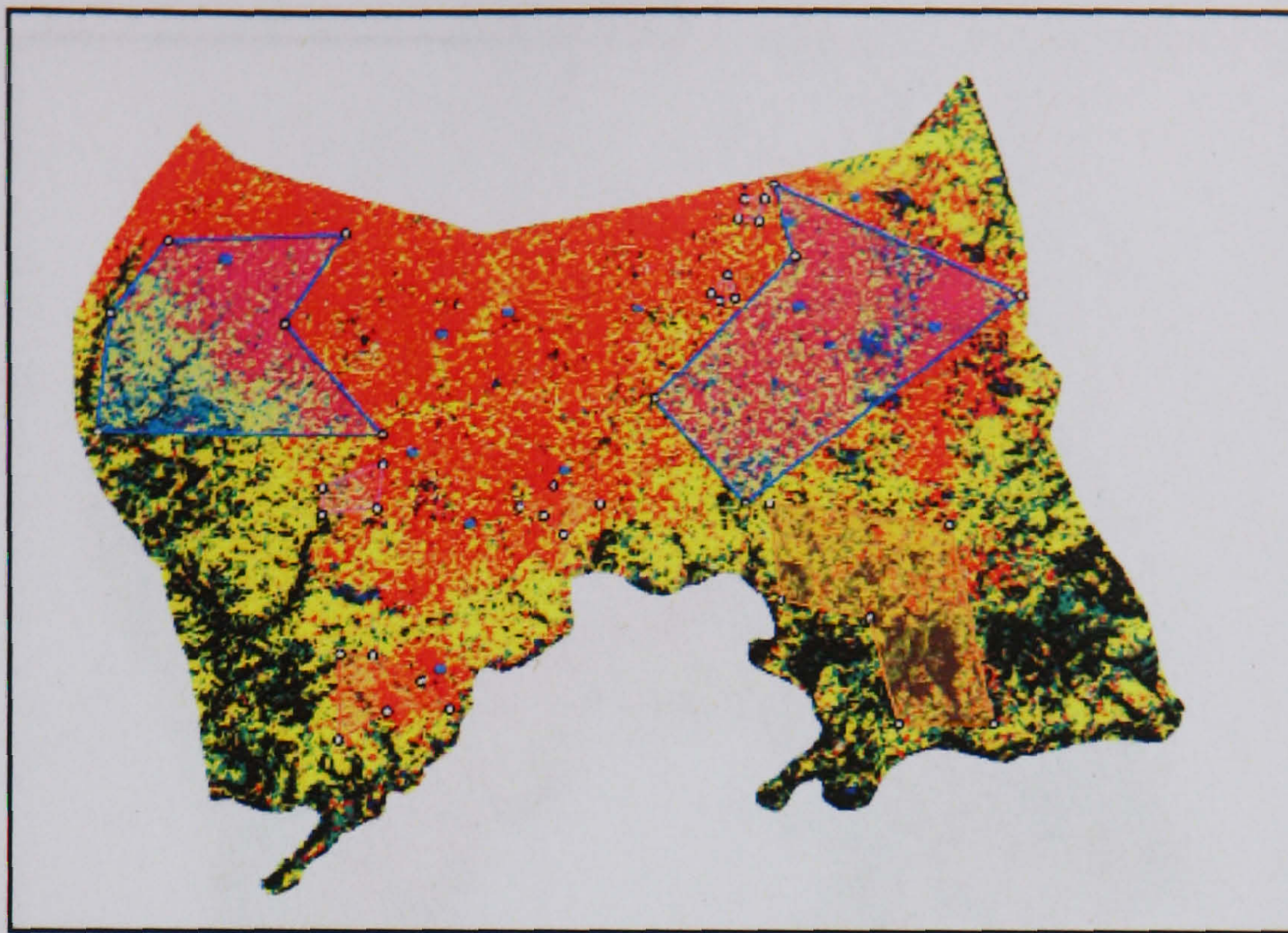


Legend

	Close Savanna Woodland/dense very active bushes		Cloud/Smoke Cover
	Open Savanna Woodland/dense very active bushes		Built up/Bare surfaces
	Dense grass/herbaceous cover		Water body
	Burnt Area		

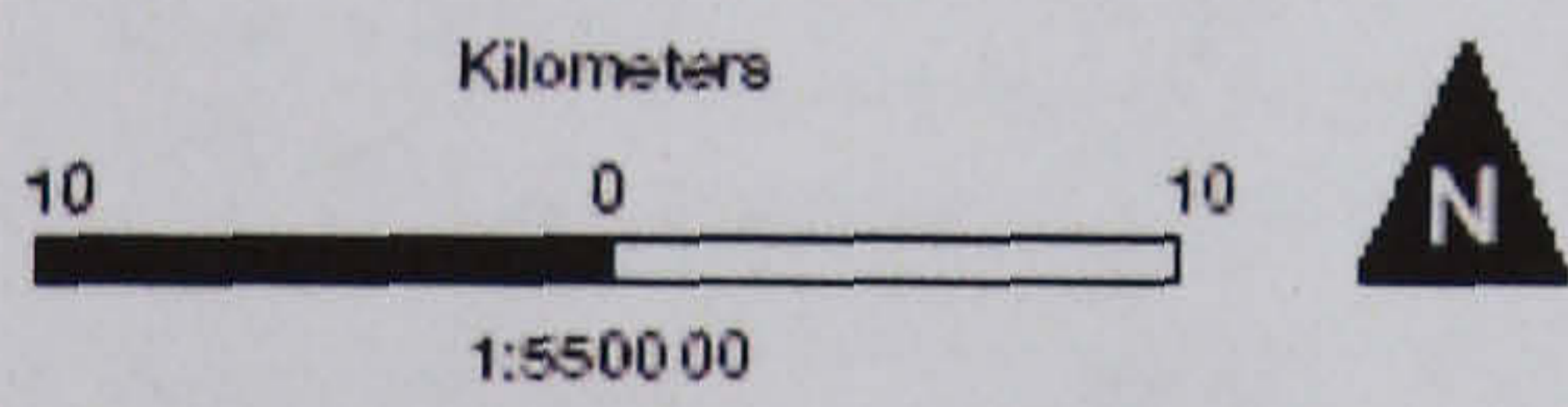
Figure 5.17: Classified map of 1990 overlaid with GPS points and polygons

2000



Class	Pixel	Sq km
Closed Savanna	167192	150
Open Savanna	226487	204
Dense Herb/Grass	745632	671
Burnt Area	28134	25
Cloud	24620	22
Built Up/Bare Area	484945	436
Water Body	18601	17

	Small scale mining - illegal (258.46km ²)
	Sand winning (7.4857km ²)
	Small scale mining - legal (82.279km ²)
	Quarrying sites (19.969km ²)

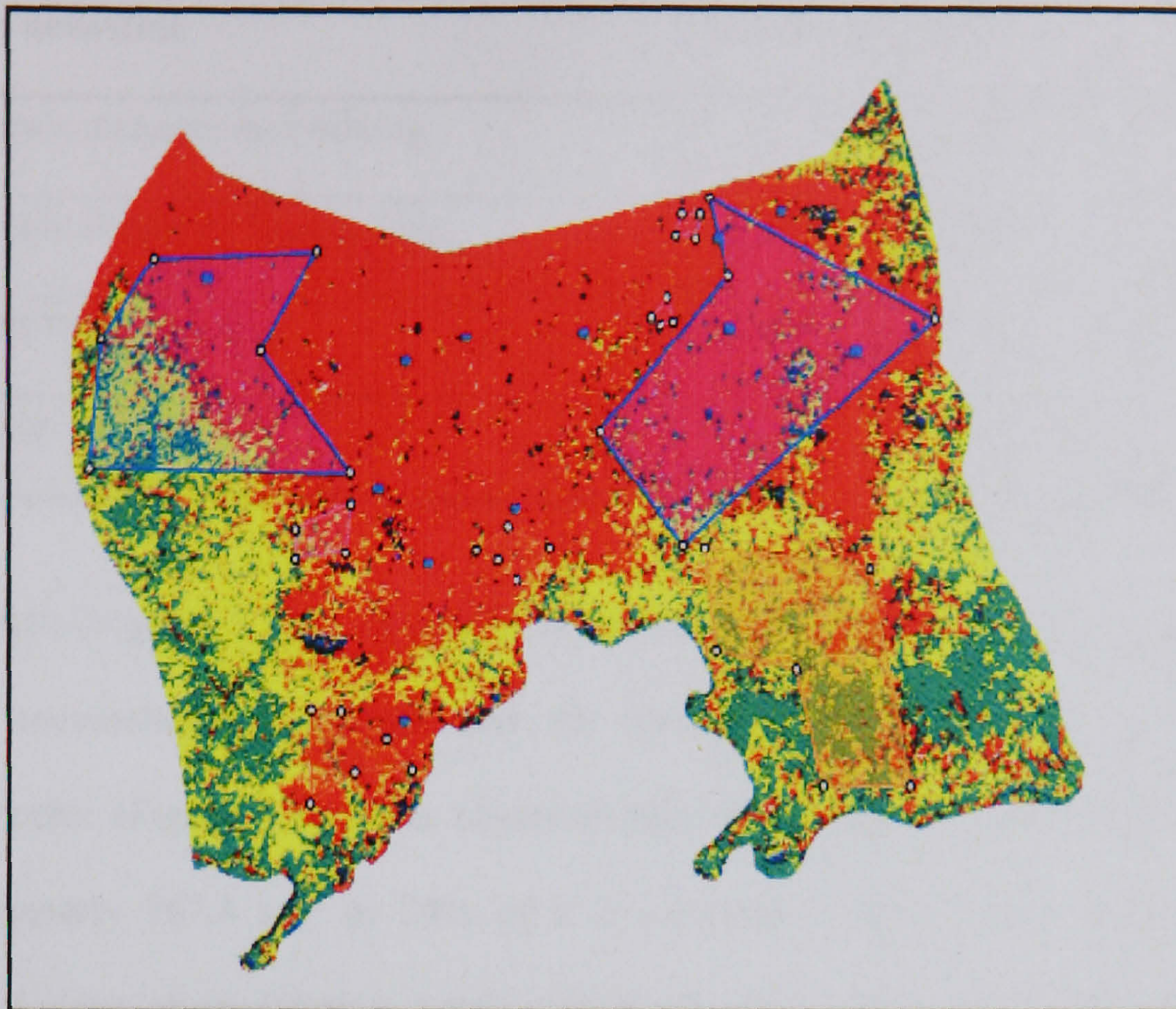


Legend

	Close Savanna Woodland/dense very active bushes		Cloud/Smoke Cover
	Open Savanna Woodland/dense very active bushes		Built up/Bare surfaces
	Dense grass/herbaceous cover		Water body
	Burnt Area		

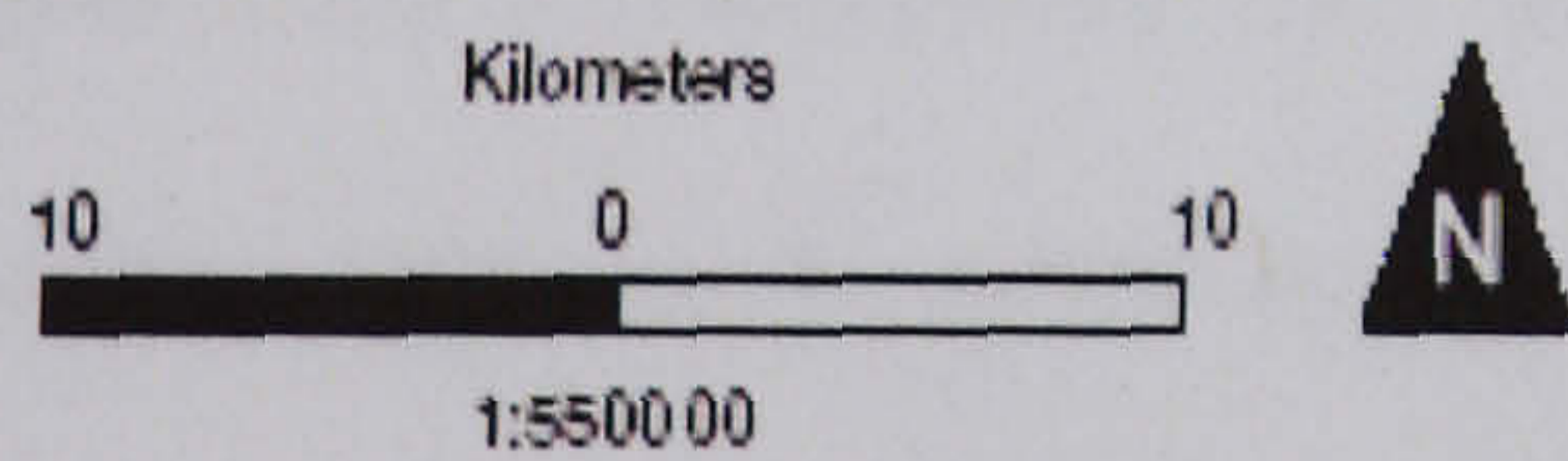
Figure 5.18: Classified map of 2000 overlaid with GPS points and polygons

2004



Class	Pixel	Sq km
Closed Savanna	103544	93
Open Savanna	293722	264
Dense Herb/Grass	611537	550
Burnt Area	37311	34
Cloud	23375	21
Built Up/Bare Area	607197	546
Water Body	18859	17

	Small scale mining - illegal (258.46km ²)
	Sand winning (7.4857km ²)
	Small scale mining - legal (82.279km ²)
	Quarrying sites (19.969km ²)



Legend

	Close Savanna Woodland/dense very active bushes		Cloud/Smoke Cover
	Open Savanna Woodland/dense very active bushes		Built up/Bare surfaces
	Dense grass/herbaceous cover		Water body
	Burnt Area		

Figure 5.19: Classified map of 2004 overlaid with GPS points and polygons

Table 5.11: Spatial extent of identified and measured land uses

Human activities	Spatial extent (km²)	Percentage (%)
Small-scale underground mining	82	5.4
Small-scale illegal surface mining	258	17
Sand and stone winning	7.4	0.5
Quarrying	20	1.3

The results (Figures 5.17; 5.18 and 5.19) validated participants' perception that there has been recent encroachment and indicated the intensity of such extractive activities on the environment (Figure 5.1). It is observed that of the total 1,509 km² of the study area, approximately 367.4 km² or 24% of it is currently used for such activities which are a potential threat of degradation. Small-scale legal underground mining, according to some few participants, started in early 1990 as part of the economic recovery program and have operated within the mining and mineral law (PNDCL 153). It was originally a 72 km² concession site and located in the south-eastern of Bolgatanga in the Talensi-Nabdam District near Duusi. The contradictory size of 82 km² as against the original 72 km² concession site (Appendix 5.2) pre-supposes that an additional 10 km² have been encroached by some unscrupulous miners. As noted by one key informant, the encroachment of the site for mining activity is due to the influx of miners from the south. What is happening in the study area is not different from what is pertaining in other mining areas in Ghana such as Agogo, Obuasi, Tarkwa, Prestea, Bibiani and Konongo. Studies done by Agyapong (1998) at Tarkwa in the western region of Ghana for example, show similar experience as underground illegal miners have encroached vast areas of vegetative lands and have rendered them derelict through their crude and unsustainable mining operations. Figure 5.20 shows small-scale underground mining activities at the concession site at Duusi with various deep openings in the earth crust in search of gold.

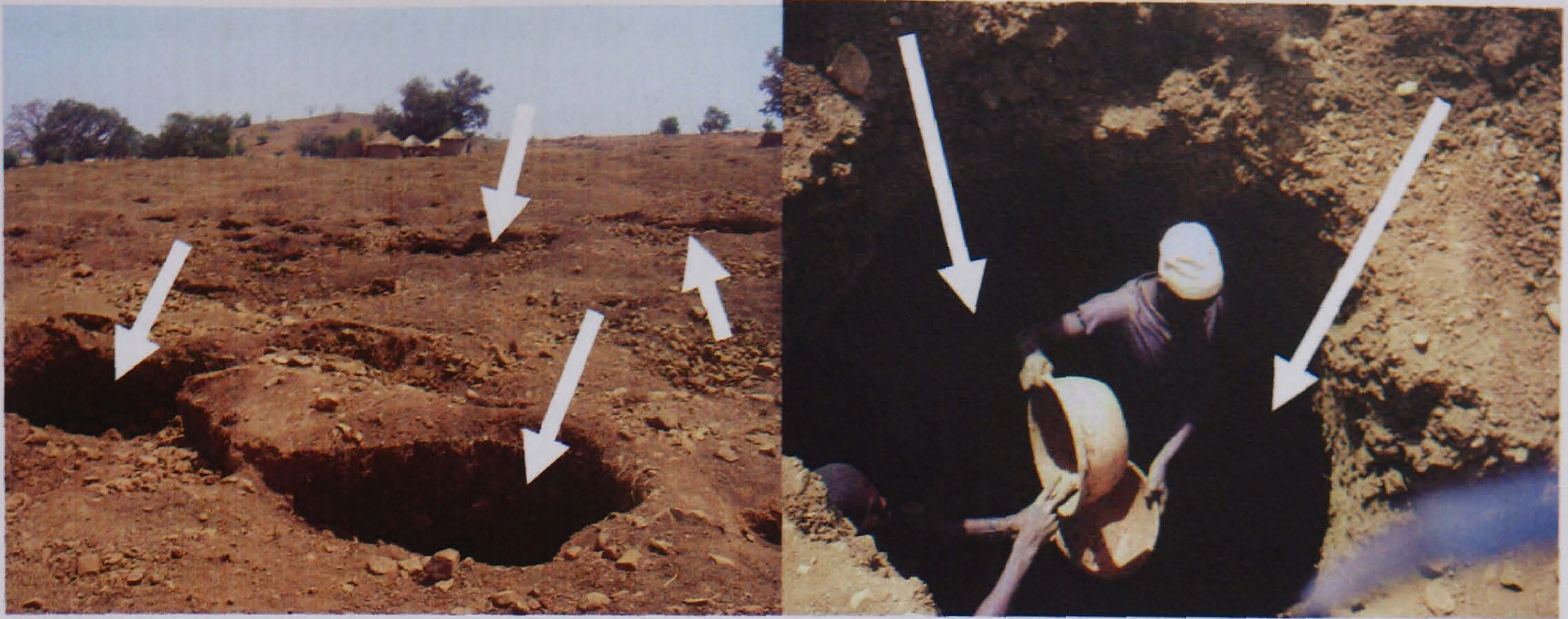


Figure 5.20: Underground mining at Duusi

Source: Fieldwork, 2006

Also evident in Table 5.11 is the small-scale illegal surface mining that covers 258 km² or 17% of the study area. The encroachment of the sites as noted by a few key informants is attributed to the influx of mining workers from the south and the perceived cheap labour in the north. The assertion by Aubynn (1999) that the nature of small-scale surface mining activities tends to impact severely on the natural environment reflected participants' views, as most of them, with the exception of the small-scale miners, saw the activity as exerting much pressure on the environment. Observation made during the GPS coordinates readings and interactions with research participants contradicted the assertion made by Griesbach and Sanders (1998, p.869) that land users, especially miners, unintentionally, degrade the environment from which they make their living, as the opposite is true in the study area where miners indiscriminately and intentionally degrade the environment with the aim of acquiring more wealth (greed and environmental degradation).

Another issue raised during discussions and interviews was the comparative analysis between surface mining and underground mining and their impacts on the environment. Most participants noted that underground mining poses a serious threat to the environment compared to surface mining. Acquah (1992) in his study on mining and environmental impact in Ghana observed otherwise as he concluded in his report that small-scale, illegal surface mining is more threatening to the environment than the underground small-scale mining,

because of the former's reflectivity on the surface, and pollution of water and air. Other authors have also argued that surface mining is more spatially destructive and that the activity produces more waste than underground mining (UNEP, 1993; Ripley, *et al.*, 1996). Aubynn (1999), in his research findings at Wassa West District of western Ghana, concluded that at Tarkwa and Prestea, underground mining is less significant in terms of degradation compared to surface mining where degradation is usually phenomenal and tends to affect large areas. Similar observations were made at Obuasi in the Adansi West District of the Ashanti Region where surface mining have led to a vast area of land derelict (AGC, 1992). Figure 5.21 is a photographic presentation of surface illegal mining site at Nangodi in the Talensi-Nabdam district of the study area.



Figure 5.21: Small-scale surface mining site at Nangodi

Source: Fieldwork, 2006

Another land-use category measured using GPS is the quarrying activity located at Pwalugu, Tongo and Winkogo of the Talensi-Nabdam District. The GPS coordinate readings for the activity suggested 20 km² or 1.3% of the study area. According to the key informant from Lands Commission in Bolgatanga, the activity was revamped by the Government, as part of the structural adjustment program in the early 1990s, to boost employment opportunities in northern Ghana but which has not materialised as most participants see the negative consequences for the environment.

The same explanation was given to sand winning which measured 7.4 km² or 0.5% of the total study area. The GPS survey exercise thus validated participants' perceptions and knowledge of various activities in the study with negative environmental consequences. Figure 5.22 is a photographic presentation of grazing livestock in the study area during the field visit.



Figure 5.22: Cattle grazing at Tongo

Source: Fieldwork, 2006

5.6 Land uses and their interrelationships

Another aspect of literature that needed to be triangulated relates to the complex interplay of various human activities that usually contribute to environmental degradation (Geist and Lambin, 2002). One key informant and some focus group participants noted that there had not been any significant shift from one activity to the other for the 14 year period of study. This was contradicted by other participants based on their views and perceptions. Most of them indicated that small-scale illegal surface mining has become the most recent attractive activity for the youth in the area compared to farming which was, hitherto, the important economic activity in the 1990s. The activity has attracted most of the local youth from the other informal economic sectors such as farming and hunting, sand and stone winning, quarrying, legal small-scale mining, firewood cutters.

Few people have shifted from grazing to the illegal small-scale mining. The reason is attributed to migrant herders from neighbouring Burkina Faso who moves temporally to graze their cattle and therefore does not have any interest in the local activities. This contradicts the general assertion made by Wickens and White (1977) that “nomadic” land use is not isolated from other forms of land-use as nomads usually exchange their produce with local people, own land and employ local people to cultivate for them. There has also been a minimal shift, recently, from the illegal small-scale surface mining to legal small-scale underground mining which, according to the miners’ focus group, is attributed to fear of been caught and prosecuted. Few had shifted to enjoy the benefits given to the legal miners such as free medical attention and subsidies of mining equipments. Other insignificant observed shifts are from farming to sand and stone winning, from sand and stone winning to quarrying activity and from grazing to firewood collection.

The observed movement from one activity to the other during the 14 period of study as triangulated demonstrates how environmental degradation is socially, culturally and economically interpreted through a shift from one activity to another. Nonetheless, it is important to note that such shifts are not permanent (perhaps such was the view of the key informant and those focus group participants who believed there had not been a shift) as it is subject to future socio-economic and political changes in the study area through the intervention of the Government under the district assemblies. However, one cannot down play the cumulative effects of the observed human activities in the study area to have contributed immensely to the degradation of the environment as modelled on the classified satellite images. As echoed by Geist and Lambin (2002), pressures of land-cover type changes are usually linked in complex interrelated structures to cause drastic changes on the natural environment.

5.7 Ranking of land uses according to their relative importance

Ranking exercise was carried out by participants to identify the main activity with severe impact on the natural environment. Figure 5.12 demonstrates the ranking of the various land-uses in the study area in terms of their severity on the physical and social environment. Small-scale mining activity was the first priority by most of the research participants. They observed that the activity not only impact severely on the physical impacts but also on the socio-economic and cultural environment of the study area. Small-scale legal mining was rate second in terms of its severity on the environment by the research participants. This was related to the physical degradation of the environment, death traps and the number of injuries and deaths associated with the activity.

Table 5.12: Ranking of land uses according to their relative importance

Land uses	Order of severity
Bush burning	3
Grazing	4
Small-scale mining, illegal	1
Small-scale mining, legal	2
Sand winning	6
Quarrying	5

Note: 1 (severe); 6 (least severe)

Bush burning was rated third, by research participants, in terms of its severe impacts on the environment, the destruction of farmlands and the reduction of the fertility of the soil. Grazing was rated next to bush burning and was related to the activity of the Fulani herders through the destruction of farm lands. Quarrying and sand mining were the least rated by participants even though their impacts on human health were an issue participant's made mention of.

5.8 Conclusion

In this chapter attempts have been made to examine and analyse the *state of the environment* and *pressures* using some of the techniques of the research methodology. Even though the chapter demonstrated that conventional GIS offers a platform on which different sets of spatially referenced data are assembled, analysed and represented. (Burrough, 1986; Aronoff, 1989; Goodchild and Gopal, 1989; Laurini and Thompson, 1992), there still remained unanswered important spatial issues that needed further clarification or truthing. The integration of local ecological knowledge in the latter part of the chapter put more emphasis on some of the issues raised and added more social issues to the observed environmental changes. The assumption that neither conventional GIS nor local ecological knowledge can stand alone to assess environmental degradation was thus tested to be true in this chapter.

It became evident from the chapter that there have been land-cover changes in the study area for the period of study and this had manifested itself in the decline of savannah woodland, with a total cover of 634 km², over the years with corresponding increase in grasses of various types (208 km²) and built-up and barren environment (392 km²). These changes were due to the existence of activities such as surface mining, underground mining, sand winning, bush burning and quarrying that has taken roots in the study area. The chapter thus demonstrate the importance of the adoption of methodological triangulation in the assessment of the state of the environment and pressures indicators of the DPSIR framework as both the quantitative and qualitative techniques were used to solicit data information. The next chapter is continuation of this chapter as the driving forces, impacts and coping strategies of the observed changes on the environment, some of which were touched on slightly in this chapter are then assessed and evaluated in detail.

Chapter 6

Analysis of GIS based Participatory Assessment Results (II): *Driving Forces, Impacts and Coping Strategies Indicators of DPSIR Framework*

6.1 Introduction

Through the adoption of the proposed assessment methodology it was noted in the previous chapter that the environment of the study area had undergone tremendous spatio-temporal changes over the 14 year period of study which is attributed to mainly human causes. This chapter demonstrates how the research methodology could be utilised to further assess the driving forces, impacts and coping strategies of the observed environmental degradation. The chapter is in three parts. The first part evaluates the perceived driving forces, their complex interplay that is believed to have contributed to environmental degradation in the study area, as well their relative importance. The second part deals with the assessment of the physical and the various social environmental impacts and their relative importance and the third part evaluates and ranks the adapting strategies. The qualitative data collected are systemised in a GIS for environmental database of the study area.

6.2 Driving forces

As reviewed earlier in chapter 2, driving forces are indirect or aspatial natural or human induced forces that cause changes to the natural environment (White, 1976; Durraippah, 1996; McCay and Jentoff, 1998; O'Connor, 1998; MEA, 2003). Key informants interviews and focus group discussions were held to identify the driving forces of the observed environmental degradation in the study area. Participants' views and perceptions were tested

with existing literature and triangulated with secondary data. Responses to the driving forces of the observed environmental changes were noted, not in order of importance, to include the direct causes such as small-scale illegal mining, small-scale legal mining, grazing, bush burning, quarrying and sand winning as presented and analysed in chapter 5 and the natural and indirect causes such as climatic factors, macroeconomic policies, demographic factors, urbanisation, poverty, changing tenure system and community level institutions.

Table 6.1 is a summarized presentation of the responses to driving forces perceived to have contributed to the spatio-temporal changes on the environment in the study area and Figure 6.1 is the perception of the participants concerning the driving forces as represented in a GIS.

Table 6.1: Participants responses to driving forces

Participants	Climate	Macroeconomic polices	Population and migration	Urbanisation	Poverty	Tenure system	Community level Institutions (cultures and beliefs)
Environmental Protection Agency	√	√	√	√		√	√
Mineral Commission	√	√	√	Not sure	√	√	√
Lands Commission	√	√	√	Not sure	Not sure	√	√
Regional House of Chiefs	√	Not sure	√	Not sure	√	√	√
Talensi-Nabdam District Assembly	√	√	√	Not sure	√	√	√
Bolgatanga Municipal Assembly	√	√	√	Not sure	√	√	√
Regional Surveying Department	√	√	√	Not sure	√	√	√
Regional Coordinating Council	√	√	√	Not sure	√	√	√
Concerned Youth Group	√	√	√	Not sure	√	√	√
Women Association	√	√	√	Not sure	√	√	√
Farmers Association	√	Not sure	√	Not sure	√	√	√
Heterogeneous Community Focus Group	√	Not sure	√	Not sure	√	√	√
Heterogeneous Organisation Focus Group	√	Not sure	√	Not sure	√	√	√
Representatives from Pwalugu and Tongo	√	√	√	Not sure	√	√	√
Small-Scale Illegal miners	√	Not sure	Not sure	Not sure	√	Not sure	Not sure
Small-Scale Legal Miners	√	Not sure	Not sure	Not sure	√	Not sure	Not sure

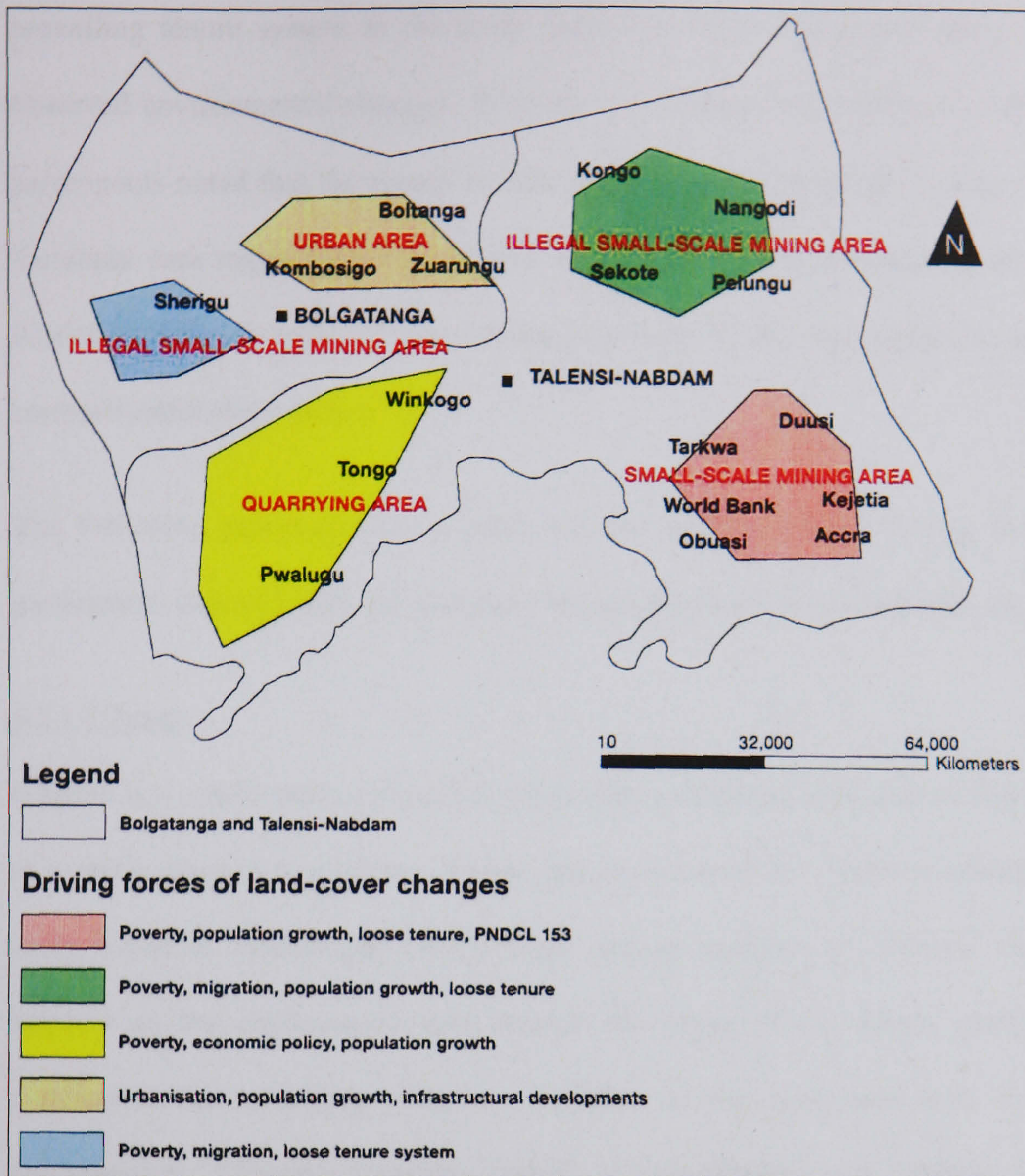


Figure 6.1 Driving forces in GIS

Most participants perceived the prevailing harsh climatic conditions in northern Ghana as a major determinant of the continuous deterioration of the environment. On the issue of economic policies, it was observed that the changing economic policies have, over the years, led to many environmental problems in northern Ghana. It was also discussed that demographic factors cannot be overemphasised when studying environmental degradation in northern Ghana. Almost all of the participants said that the prevailing economic hardships in the country have contributed to the observed environmental degradation in the country and they mentioned the northern Ghana as a poverty endemic zone. The system of land ownership in the three northern regions where the study area is located cannot be isolated when dealing with the indirect causes of environmental degradation. Participants argued about the

prevailing tenure system in the study area and were of the view that it is a cause of the observed environmental changes. With the exception of the small-scale illegal miners, other participants noted that the recent institutional reforms, attitudinal and behavioural changes in the study area might have also played a major part in the degradation of the environment. Participants also found it difficult to relate the benefits of urban expansion in the study area to environmental degradation.

The following paragraphs are a more detailed analysis of the driving forces perceived by participants as tested with literature and triangulated with secondary data sources.

6.2.1 Climate

Climate is a combination of rainfall, temperature, moisture and other meteorological variables at a given place over a period of time and is measured by means, averages and extremes of these variables (Terbough, 1992). Even though analysis of climatic variables and their impacts on the environment falls beyond the scope of this thesis, participants expressed concern on the changing climatic conditions in the study and how it has affected the environment. Climatic variables noted by participants of interest included rainfall, temperature and relative humidity. Participants were of the view that the prevailing climatic conditions in the study area, such erratic rainfall, high temperatures, low relative humidity and frequent flooding in the rainy season, might have played a major role in the degradation of savannah vegetative cover which, according to them do normally succumb to extreme high climatic conditions. Their views support the popular assertion that land-cover dynamics in most arid and semi-arid environment of sub-Saharan Africa are particularly sensitive to spatial and temporal climatic variations and that vegetation conditions are closely linked to physical processes such as evapo-transpiration, precipitation and soil moisture (Jakubaukan, 1999; Boserup, 1996; Constreras-Hermosilla, 2000; Pielke, 2002; Pitman, 2003).

To substantiate their claims concerning the probable climatic influences on the observed land-cover changes in the study area, meteorological data were collected from the Bolgatanga

Meteorological Station over a 14 year period for analysis. The aim was not to reject, completely, issues raised by participants but to observe how such issues correspond to existing data. Figure 6.2 and Appendix 6.1 are graphical and tabular presentations of rainfall distribution (mm), in the study area, for the periods of 1990, 2000 and 2004.

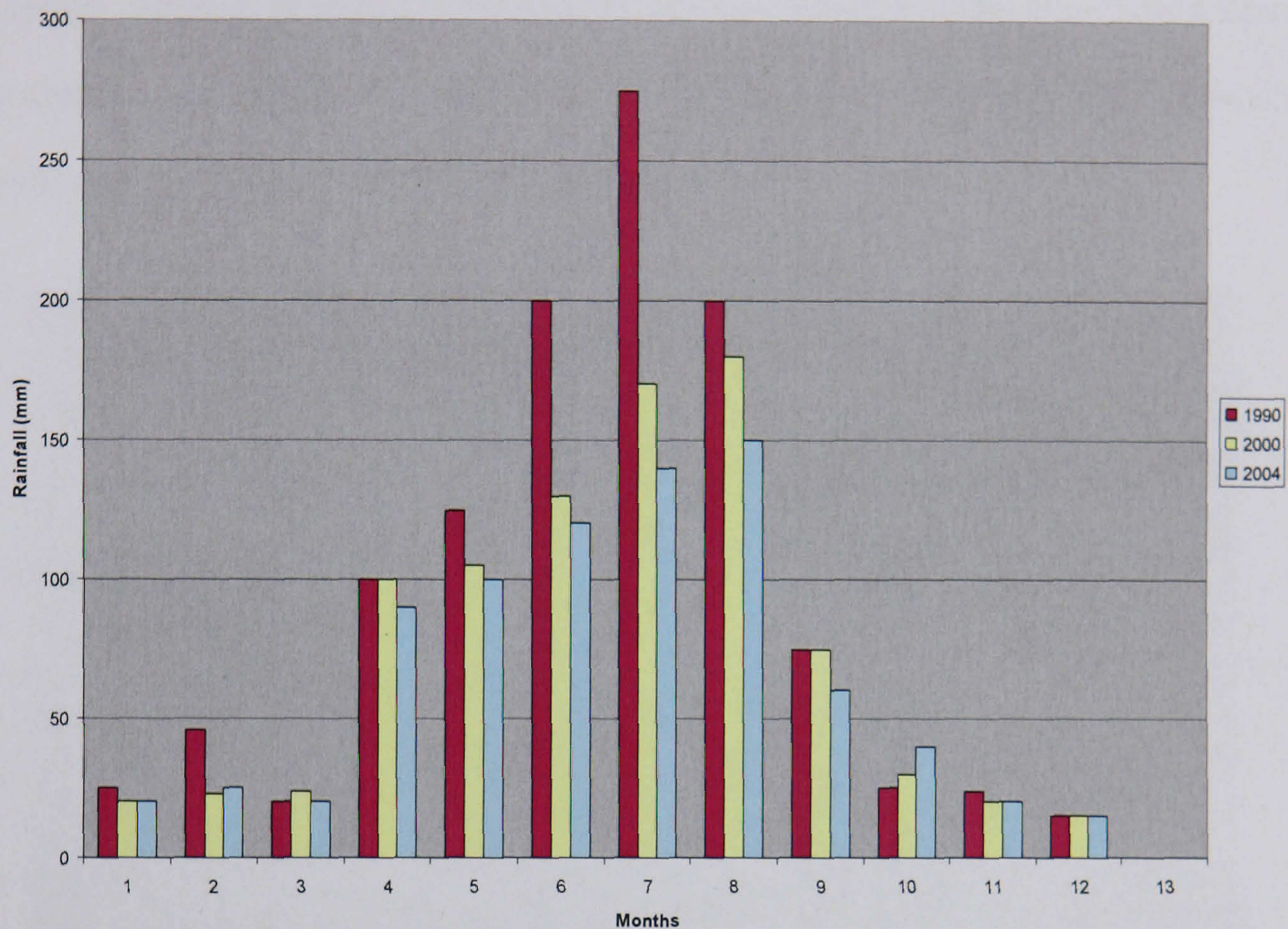


Figure 6.2: Monthly rainfall distribution in the study area for 1990, 2000 and 2004

Source: Meteorological Service, Bolgatanga, Ghana (2003)

Figure 6.2 shows a uni-modal rainfall pattern in the study area for 1990, 2000 and 2004 with maximum rainfall occurring in the months of May to August and long dry season from September to April. Observation of the rainfall pattern seems to suggest that, even though the study area had experienced a declined in rainfall distribution over the years, it is not enough to conclude that the phenomenal changes in the environment can be attributed to that phenomenon without other possible causes. However, one cannot rule out the possible influence of erratic rainfall and vegetative cover as argued by Hulme (2001) and Hote *et al.* (2002) that changes in rainfall pattern, for a considerable period of time, are directly linked to changes in vegetative cover.

Figure 6.3 and Appendix 6.2 are graphical and tabular presentations of temperature figures for 1990, 2000 and 2004. Temperatures regimes have been very high, with very little variations, throughout the observed periods (mean minimum of 32°C and mean maximum of 40°C). Contrary to the inference made by Jakubaukan (1999) and Sternberg *et al.* (2000) that temperature variation is a determinant factor of vegetative cover changes in most savannah environments that cannot be said of the study area where the observed variations are insignificant.

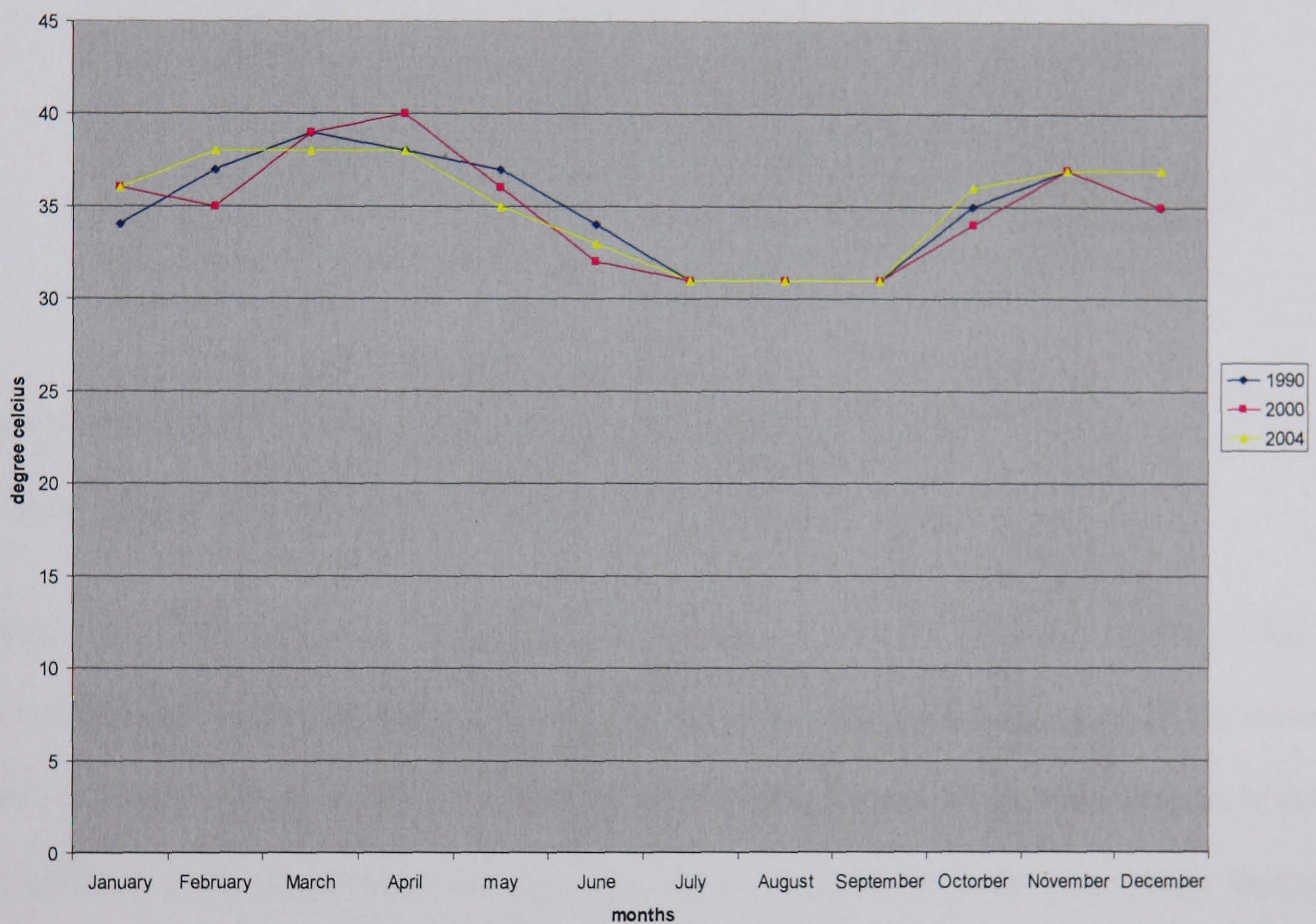


Figure 6.3: Mean monthly temperature in the study area in 1990, 2000 and 2004

Source: Meteorological Service, Bolgatanga, Ghana (2003).

Relative humidity is the measure of the moisture content in the atmosphere and is directly related to temperature and rainfall. As a measure in percentages, low relative humidity is an indication of low atmospheric moisture content and high relative humidity is an expression of high moisture content in the atmosphere. Figure 6.4 and Appendix 6.2 are graphical and tabular representations of monthly relative humidity in 1990, 2000 and 2004.

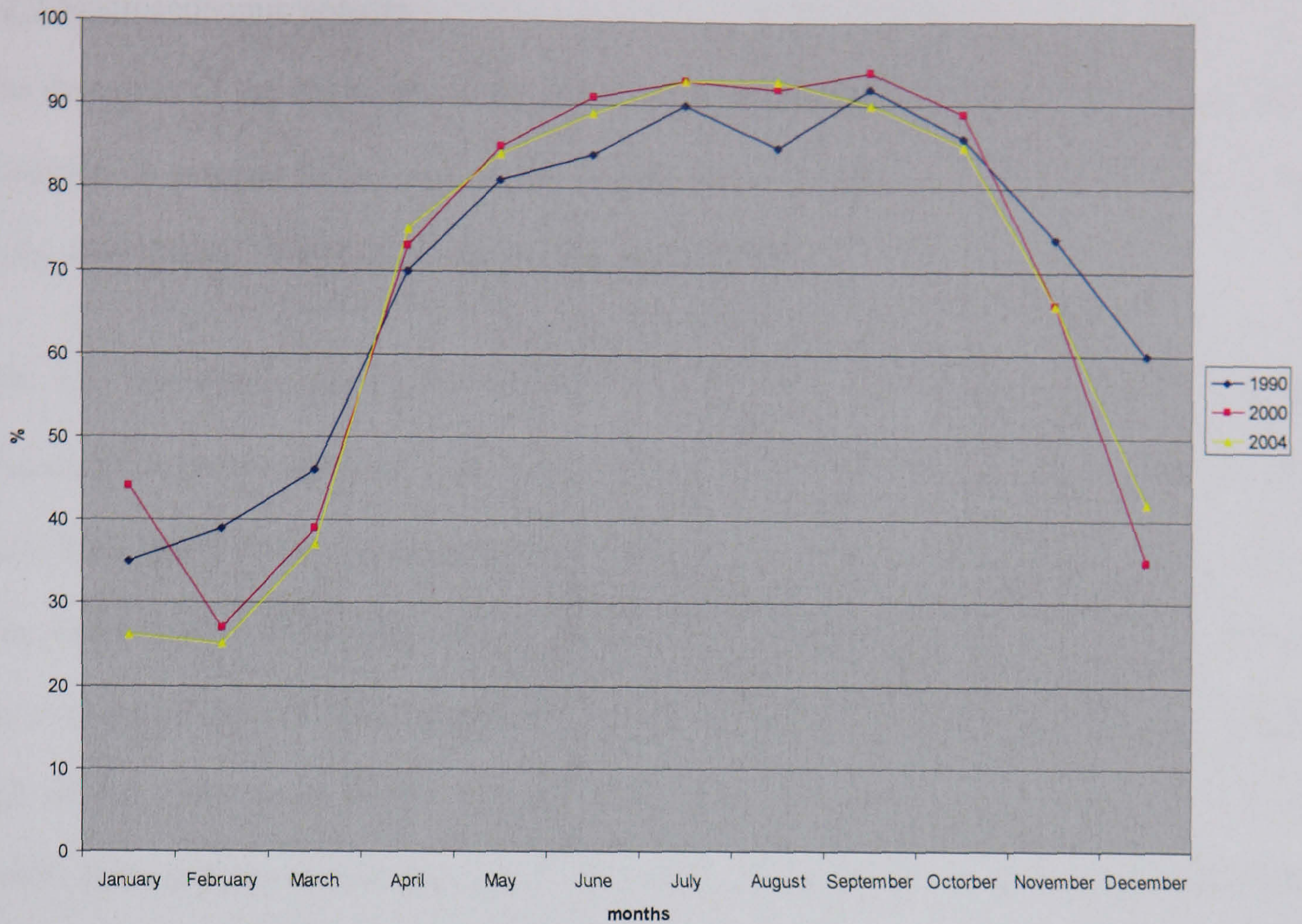


Figure 6.4: Monthly relative humidity in the study area in 1990, 2000 and 2004

Source: Meteorological service, Bolgatanga, Ghana (2003).

Relative humidity had been constantly low during the months of January, February, March, November and December. Like the observed variations of rainfall and temperature, there have also not been sufficient variations in the relative humidity figures for the three periods to have contributed to the phenomenal environmental degradation in the study area. These findings together with participants' responses seem to refute what could have been anticipated by Tucker *et al.* (1991) and Hulme (2001) that climatic variables are major determinant of most land-cover changes in savannah environments.

6.2.2 Macroeconomic policies

The dynamics of the environment are perceived to be dependant on economic policies and a condition of external forces such as the actions of the World Bank and the IMF (Dietz and Rosa, 1994; Reed, 1996; Maler and Munashinghe, 1996).

The key informants interviewed agreed that, despite achievements in boosting up the Ghanaian economy and alleviating poverty, the country's economic transformations in the mid-1980s had a disastrous impact on the natural environment, especially in northern Ghana. The promulgation of the Minerals and Mining Law, 1986 (PNDCL 153) (Appendix 6.3) was given as an example of these measures. As noted by one key informant, prior to the Minerals and Mining Law, local people had been involved in illegal small-scale mining since the 1930s, restricted to a secluded area in the Nangodi environs, with insignificant environmental impacts. However, the national legalisation relating to the small-scale mining industry, attracted many migrants into the area in search of gold and other precious minerals, increasing the environmental impacts of the activity. Most of the participants, the key informants, agreed that the Mining and Mineral Commission of the Ministry of Mines and Forestry did not address their concern and plight, but rather worsened the already fragile environment.

In contrast, most of the target focus groups, with the exception of the small-scale mining focus group disagreed with the notion that government macroeconomic policies had induced environmental problems in the study area. Most of the focus groups participants attributed environmental degradation to internal politics and indifferent attitudes of the district assemblies, the regional coordinating council and the government environmental agencies. The latter were accused of collaborating with some unscrupulous local people and migrants who had taken the law into their own hands and were over-exploiting the natural environment. Even though those sentiments were disputed by the officials from the Mining and Minerals Commission and the district assemblies, the researchers' personal observations and other informal interactions in the study communities revealed that most of the illegal miners are in business with some officials in the region and that most Fulani herdsmen graze

freely in the community lands due to unofficial arrangements with some community leaders and district officials.

These findings on policies for economic transformation follow earlier assertions made by Richardson (1996); Postigi (1996) and Mink (1993) that the initiation and implementation of structural adjustment programmes in most developing countries tends to impact negatively on the environment. This is related to the study area as most of the research participants perceived that the structural adjustment programme of the economic recovery programme in the late 1980s in Ghana, despite its numerous advantages of reshaping the economy, did also, indirectly, contribute to the degradation of the environment in the study area.

6.2.3 Population growth and migration

Almost all the participants perceived the increasing population numbers and density in the area (see Table 6.2) as a key factor of the environmental degradation. However, they differ in their views concerning the underlying causes of population growth in the study area. Most of the key informants attributed population hikes to both rising birth rates and the influx of migrants. In contrast most of the focus group participants attributed population growth only to the influx of migrants, especially from southern Ghana. According to the latter, their communities have been flooded by outsiders who, because of free movement, internal politics and weak tenure systems, have recently come from other areas in the north, from the south and other neighbouring countries to engage in various illegal activities that disregard the fragility of the ecosystem. Most of the key informants interviewed, accepted the problem of the migrant populace but they were convinced that high birth rates (natural increment) are largely responsible for increases in population growth in the study area. One of them commented in the local Akan dialect: “*Yεεmo wo dodo*” meaning “they like giving birth”.

Other key informants also related the population growth issue to practices and traditional beliefs in most of the study communities. One was of the opinion that the current strong traditional cultural beliefs in most of the rural communities in the study area encourage child

birth as children are seen as wealth to the parents, especially to the father as one of the achievements in life is partially measured by the number of wives and children one possesses. In most communities studied, personal observations revealed that it is a taboo to be barren and couples without children are not given any respect and are sometimes treated as outcasts. It was revealed, through the heterogeneous communities' focus group discussions, that the continual increase in population growth in the study area, especially in the Nabte and Talensi communities, is as a result of the practice of early marriage as most parents usually offer their daughters for early marriages.

The focus groups, except for the miners, cited several instances where people who have migrated from the south mining communities, especially from Tarkwa, Prestea, Nsuta and Obuasi, first settled in the regional capital of Bolgatanga and later on moved to the peri-urban, rural communities in search of gold and other precious minerals. Few key informants interviewed raised the issue of permanent return migrants as one of the major contributing factors of population growth and thus environmental degradation in the study area. They commented that after living and working for several years in most mining communities in the south, some miners have returned home with their families and have engaged in small-scale mining to make a living. Others cited temporary returnee farmers who usually migrate to the south (Techiman, Kintampo, Wenchi and Atebubu) during the dry season and return to the north during the rainy season for farming and other extractive activities.

Table 6.2: Population growth and density in the study area

Year	Population growth	Area (km ²)	Population density/km ²
1960	34,275	1509	26.1
1970	95,010	1509	72.4
1984	146,658	1509	111.7
1990	183,800	1509	140.1
2000	229,768	1509	174.0
2010*	303,332	1509	231.0

* Projected population growth and population density for 2010

Source: Population and Housing Census for 2000 of the Ghana Statistical Services (2000)

The Population and Housing Census for 2000 (GSS, 2000) of the Upper East Region estimated the increasing trend of population growth in the study area to be 183,800 in 1990 to 229,768 in 2000 with a projected figure of 303,332 in 2010 (Table 6.2). This trend of population growth, as perceived by most of the research participants has led to increased pressure on land resources for farming, mining and settlement that have all contributed, in one way or the other, to the observed land-cover changes. Population density, calculated as the number of people per square kilometre, was 26.1 in 1960, 140.1 in 1990, and 174.0 in 2000 and estimated to 231.0 in 2010. As argued in Malthusian theory, population growth is seen as direct threat to the environment (Ehrlich and Ehrlich, 1977; De Sherbinin, 1993; Gilbert, 1999).

Boserup (1980) acknowledged that population growth and economic ventures create more demand for natural resources leading to environmental degradation. Geist and Lambin (2001) also asserted that population growth can affect changes in land-cover types through natural increments in terms of the number of people seeking land to cultivate, fuel wood or other economic ventures, labour markets, demand for agricultural and savannah forest products and institutional change. According to them, the larger population, the more intensive the exploitation of the environment by people to satisfy their basic needs for survival as large numbers exert more pressures on the environment through their direct use of the natural resources. The same is particularly true of the study area as most of the research participants perceived that the observed changes on the environment were due to an increase in population growth and scarce natural resources.

Some focus group participants brought up the issue concerning recent migration of Fulani herdsmen who, they commented, usually move to the area in search for greener pastures for their herds. They observed that the current population size and environmental degradation can partly be attributed to the Fulani herdsmen. Basset (1993) observed that the Fulani herdsmen from Burkina Faso and Mali are usually attracted to the study area due to accessibility of market centres and veterinary care that are difficult to come by in their places of origin.

Other participants, mostly focus groups, commented on the migration of small-scale miners who, when faced with the downsizing and closure of their previous mining stations in the south, migrate northward, sometimes with their families, and engage in similar mining operations they are used to in the study area. Other participants cited temporary migrant traders for various petty trading activities (buying and selling). These issues raised by participants were similar to Kane (1995) and Myers (1997) who hypothesised that people are forced to migrate from their original areas to other destinations as a result of economic conditions in their areas of origin.

One of the key informants interviewed gave a contrasting view concerning the south-north migration. According to him, the government's economic policy agenda cannot be realised if people are not encouraged to migrate to the north to help in the building-up of the socio-economic and developmental processes envisaged in the economic recovery programme. Notwithstanding his view, other participants who responded to the migration-environmental degradation nexus felt that, despite the economic advantage of migrant workers, the uncontrolled movements in recent years has contributed to the environmental pressures and have brought about intense degradation of the environment. This is in line with previous studies that have examined the migration-environment nexus and concluded that changes in the environment have mainly occurred due to population increases at destination areas (Amacher *et al.*, 1998; IUCN, 2000).

In response to the nature of migration, most participants noted that migrant mining workers are permanently staying in some of the study communities without any thought of returning to their place of origin. In addition, they cited some small-scale miners who have originated from the south mostly from the Ashanti and the Western region, and have permanently acquired land, through unscrupulous means, for mining activities. Most of the miners interviewed explained that they moved because of depressed social conditions at their place of origin. According to them, moving away from home would somehow earn them respect and social recognition especially when they later return home with capital. Others had migrated in response to recent economic opportunities in the north. Key informants disclosed that the influx of mining workers is partly due to the promulgation and legalisation of the small-scale mining industry that has attracted most migrants to the study area. Most women working in the surface and underground mining sites are wives and concubines of small-scale miners who have migrated to join their partners. Others are merely pay day mining workers and are local women. None of the participants interviewed pointed out the issue of community neglect in their places of origin as a motivation of movement to the north as hypothesised by Nabila (1986) as one major reasons of rural-urban migration.

Participants also made comments on the direction of movements and commuting. Some migrants initially move directly to the mining areas while others initially get settled at Bolgatanga and later move to other areas in search of menial jobs. Movements have also been observed from other parts of the Upper East regions, such as Bawku West, East Mamprusi, West Mamprusi, Bongo and Kasena Nankana to the study area for trading purposes. Others migrate from neighbouring Upper West and Northern Regions but according to participants, such movements are temporary as migrants usually return to their places of origin. It was also observed that some migrants from the south initially settled at Tamale in the northern Region and later migrated to the Upper East Region in search of menial jobs. The same is true of the Fulani herdsmen who migrate seasonally from their places of origin to northern Ghana for pasture.

Participants, mostly focus groups, also discussed the issue of internal migration or commuting especially from the densely populated Bolgatanga community to peripheries of the study area. As most of them observed, such movements are temporary and for petty trading, firewood collection, hunting and farming. The same is not true of the migrant mining workers who, after settling in the Bolgatanga community, later move permanently to the mining communities. This was validated during interactions with the miners' focus groups. It is not the usual case of the migrant small-scale mining workers, who have migrated from the Bolgatanga community and have permanently settled in the mining sites. Reactions from most of the participants revealed that these internal migrants and their activities, apart from the small-scale miners, have minor effects on the natural and social environment as their numbers are few and most of them are farmers.

6.2.4 Poverty

All those involved in farming activities, cattle rearing and other small-scale economic ventures are perceived, by most of the key informants, as poor people in the study area. This, according to key informants, has resulted in the degradation of the environment due to a “*let them do it to survive*” attitude and coupled with the Ghanaian “*culture of silence and hospitality*”. However, they suspect that migrant Fulani herdsmen and small-scale miners do not come to the area because they are poor but with the intention to “*make more money*”. According to them greed, carelessness and lack of environmental awareness, rather than poverty, drives such migrants to engage in various activities, disregarding the natural environment they are dependent on. Most of the focus group participants, especially the local ones, asserted that poverty drives local people, especially youth and women, to take up employment on a “*pay day basis*” to earn some income for living. Many agreed that cases of early marriage and pregnancy, school drop-out, theft and other anti-social behaviours are the results of poverty in the area.

Few key informants related the poverty-environment nexus to economic disparity between northern and southern Ghana. They attributed the prevailing poverty in the north as result of the unequal sharing of the country’s resources to the disadvantaged of the north that has brought about continual exploitation of the natural environment. These sentiments were in line with similar observations made by Forde (1968), Bening (1975), Songsore (1989) and Boateng *et al.* (1992) that the underdevelopment of the north is not only due to the physical environment or lack of resources but to the inequitable distribution of the national wealth that has created untold poverty among the people and has allowed them to cultivate or work on marginal lands for survival.

Even though participants held the general view that poverty is the prime factor of environmental degradation, discussions with the miners’ focus groups brought in other views. Many of them held the notion that they are not poor but rather, as young men who want to lead more decent lives, have decided to go in for lucrative business, thus contrasting with the

earlier hypothesis that the small-scale mining is the hope for the poor, unemployed and poorly educated people of society (McMillian, 1995; Heemskerk, 2001). It was observed during the interactions with the miners' focus groups that most of them are bread winners and had no alternative but to work hard to feed their dependants.

However, mounting evidence suggests that poverty has been one of the driving forces that have led many young people into small-scale mining. The nature and mode of operations of the small-scale mining in the study area prove how poor the miners are. Interactions with the miners in the mining communities revealed the poor working conditions and the crude methods of extraction of gold. Most of the miners use simple, unhygienic tools to go about their activity which are sometimes a threat to the environment. As noted by Hilson (2001) the most common equipment used in many small-scale mining activities are basic hand tools such as picks, axes, sluice boxes and shovels, Honda water pumps, explosives and washing plants. The explanations are that most of the miners cannot afford acquiring appropriate machines for their daily operations that are also environmental friendly. Figure 6.5 show how mining is done, using simple tools, in one of the mining communities visited during field work.

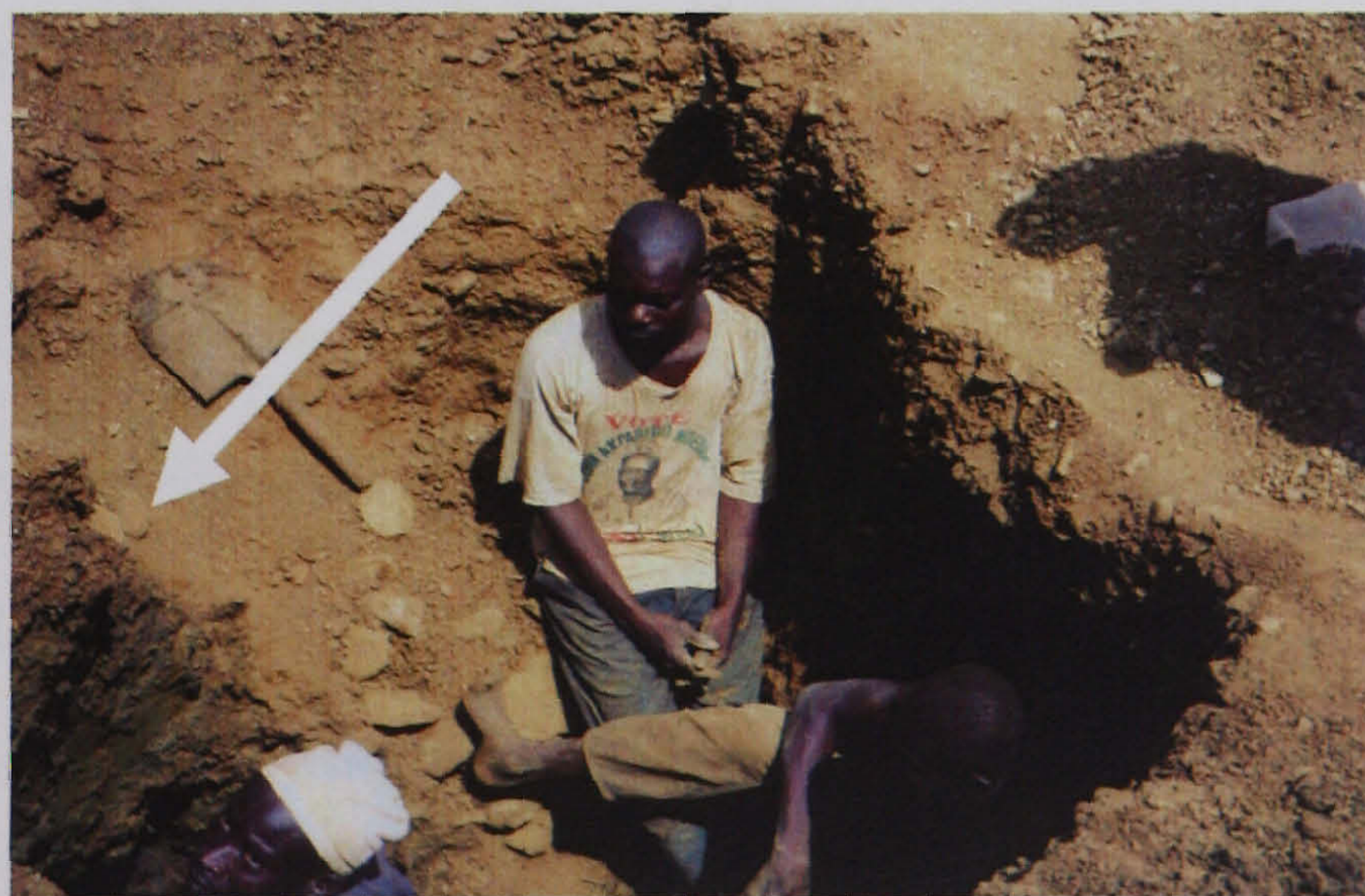


Figure 6.5 Small-scale mining at Sherigu

Source: Fieldwork, 2006

Notwithstanding the negative implications of human activities on the environment the impression created by many in the area is that the exploitation of the environment through small-scale mining and other extractive activities is the surest way of reducing poverty and improving standards of living. Another perception gathered during interactions with research participants was that poverty has been the most direct force of environmental degradation in the study area. One key informant noted: “*those poor people in most of the communities are careless about protecting the environment*”. These findings concerning what is pertaining in the study communities on the poverty-environment nexus is in line with Leach and Mearns (1995) who had argued that poverty is linked with other social factors to bring about environment degradation.

6.2.5 Land tenure

Land tenure refers to the way in which rights to land are obtained and distributed among people (Acquaye and Murphy, 1973; Kasanga, 1988). Land tenure in Ghana, especially in the north, is predominantly communal ownership (Benneh, 1976; Bakang and Garforth, 1998) with the power of trustee entrusted to the spiritual leader (Acquaye and Murphy, 1973). Contrary to misconception, those spiritual leaders are not owners of any land but merely the “protectors” for the benefits of land both now and the future generations (Acquaye and Murphy, 1973). In accordance with the Frafras and the Nabtes (indigenous tribes of the study area), customary practices of absolute entitlement cannot be claimed since land is communally owned and therefore every member enjoys the right of ownership through the approval and “*blessing*” from the spiritual leader (Kasanga, 1988; Hammond, 2000). Outsiders are also entitled to land, temporarily, for economic activity after negotiations with the spiritual leader under laid down terms and conditions (Kasanga, 1988).

Most participants observed the complexity of land ownership in most of the study communities, even for family members. According to them there exist various land acquisition systems that are contrary to the normal community ownership where land is acquired by virtue of one being a member of a landowning community. As one participant

commented, there exist many unscrupulous land acquisitions by individuals who have direct links with the spiritual leaders. Such observations were seen as untrue during interactions with the community leaders in one of the focus group discussions. As noted, there are laid down procedures for the acquisition of land titles with no changes during the last decade. As one elder commented “*we cannot change what our ancestors have laid down for our welfare, it is abomination to do that*”.

Key informants from the Lands Commission and Surveying Departments noted that despite the social value of land in the society, its acquisition and use has contributed to environmental degradation and subsequently created many intra- and inter-community conflicts. They cited instances of misunderstandings between traditional leaders and state agencies, especially when land is acquired for economic and infrastructural developments. Most traditional leaders interviewed, were of the opinion that, more often than not, government interferes in their tenure issues without passing through the customary procedures. This, according to the key informant from the Land Commission, is as a result of false interpretation by the current land-use policy where traditional authorities are entitled to 78% of the total land area under their jurisdiction with the remaining 22% in the hands of the state government for infrastructural activities.

It was observed that the recent tension between the Government and customary landowners was about the legitimate right to transfer land ownership to small-scale mining operators under the Mining and Mineral law (PNDCL 153) which implies that the occupier of any land has the authority to exploit such land for mining purposes and can use his or her discretion as to how best to conserve its natural resources. This is where many conflicts exist as community members feel that their land tenure security is threatened by the Government through the miners' presence.

Most focus group participants, with the exception of the miners, complained about the enforced and poorly compensated acquisition of land by the state government for economic and infrastructural purposes that usually lead to environmental degradation. They blamed the government agencies' inability to control the influx of illegal miners and their mining operations that have contributed to the observed environmental degradation. According to them, the gold extracted by the illegal miners is sold to the precious mineral commission under the Mining and Mineral law (PNDCL 153) without royalties paid to the communities where such gold were extracted. One focus group participant made the following comments. "*It seems the very future of our natural heritage is been compromised for a quest for a better life for others. That should not be the case*".

Most of the illegal small-scale miners interviewed indicated that regardless of community members perceptions they are not outsiders and that as Ghanaians they have the right to indulge in any economic activity of their choice anywhere in their country. They reiterated that the community leaders and the district assemblies are all aware of their presence in the community and the activities they are embarking on. The sentiments of the miners were acknowledged by the other focus group participants but, there again, criticised the mining and mineral policy that failed to outline conditions for mining to prevent or reduce environmental degradation. Most of the focus participants were suspicious of the miners as they found it difficult to read their intentions in the various communities. One of the focus participants said. "*They always play hide and seek with us*".

Other tenure concerns raised by the participants from the farmers association, the concern youth group, representatives from Pwalugu, from the women's association and the small-scale miners was the threat to the people, the property and the environment by the Fulani herdsmen who periodically migrate to the area. According to them, the Fulani herdsmen had been degrading the environment, burning down residences, thatch houses and farms and destroying water bodies and other state property. They complained about their possession of fire arms and their stealing of property and local cows. They attributed the free entrance of the Fulani

herdsmen to the communities to the failure of the district assemblies to tighten up security on the borders to check inflow of the herdsmen and to enforce regulations on the movement of such herdsmen into Ghana or to institute an appropriate form of taxation as many of the herdsmen are usually free from taxation in their home. Community leaders were also blamed for harbouring and encouraging the entry of the herdsmen.

On the issue of the tenure legality of the sand and stone winning in areas such as Nangodi, Tongo and Kongo, participants of the women's focus group were of the opinion that the activity is mostly carried on by peasant women in the society, mostly widows, who, through tradition, have no title to the land. This has led to the illegality of the activity and the resulting environmental impacts. They noted that the marginalisation of women in the society in terms of resource allocation should be looked at if the degradation of the environment is to be prevented or reduced.

6.2.6 Community level institutions

As already reviewed in chapter 2, community level institutions surround, connect and manage communities and usually influence community norms, values, beliefs and aspirations embedded in the culture or community way of life with its significance in establishing rules on land ownership and environmental management. The assertions made by Tuan, (1986), Ellen and Fukui (1995), Appiah-Opoku, (1997) and Rival, (2001) that environmental problems are usually shaped by community level institutions through different belief systems, religious, political ideologies and cultural knowledge seem not to be different from what is pertaining in the study area as observed by most research participants as they are continually and dynamically updated. Impression has been created that the recent attitudinal and behavioural changes in local tradition and culture in the study area have contributed to environmental degradation.

Most participants commented that the cultural dimension of the study area has been altered in recent years due to the influence of lifestyles of outsiders which have, indirectly, affected the

intrinsic values and respect of the natural environment by the local people. Some focus group participants, i.e. the women, traditional leaders, heterogeneous community focus group and the concern youth group, noted the observed environmental degradation is indirectly a linked to changing morals and values associated with changing lifestyle of the local people, especially the youth.

As observed by focus group participants, land resources are valuable assets believed to be tied to the dead, the living and the unborn in permanent relationships. The obligation of the living is therefore, to honour the ancestral property through preservation and proper maintenance. Discussions with one of the focus groups revealed that in the past some communities have punished offenders caught either cutting or planting of trees as such activities were reserved for nature as the sole propagator of trees. Tree planting, in such communities, mostly in the Talensi-Nabdam district, was regarded as an abomination and the offenders were believed to die immediately when the planted tree started to bear fruits. Such practices, according to participants, were aimed to preserve and conserve the savannah forest.

It was also observed during interviews and focus group interactions that in other communities, of the Talensi-Nabdam district, individuals, were in the past, forbidden to visit certain savannah forest reserves set apart for the traditional gods. According to Benneh *et al.* (1990), and re-emphasised by the community leaders, such practices lead to the conservation and preservation of the savannah forest which has recently changed due to the influx of people of different ethnic backgrounds. These were not accepted by the small-scale miners' focus groups as they view them as things of the past and mere superstitions.

Most of the participants agreed that the recent proliferation of various human activities in the study area, notably indiscriminate grazing, uncontrolled bush burning, indiscriminate firewood cutting, intensive small-scale mining, quarrying, sand and stone winning and environmental unfriendly farming practices are all signs of diminishing community level institutions and lack of environmental awareness, values and ethics as stated by Geist and

Lambin (2002) whose views is that the rate of savannah vegetative cover loss is culturally related.

6.2.7 Urbanisation and infrastructural development

In contrast to the more popular assertion that urban growth is directly linked to environmental degradation (Rees, 1992; Nsiah-Gyabaah, 2004), most participants during interviews and focus group discussions downplayed the possible consequences of urbanisation and current developmental structures on the environment. Their reactions seem to suggest that the recent rate of urbanisation and infrastructure development in the area, even though they have contributed immensely to the depletion of most of the savannah trees and grasses over the period of study, had brought about an improved standard of living, especially in areas such as Bolgatanga, Tongu, Pwalugu and Winkogo. Their comments follow an earlier assertion made by Bryan (1995) and Martin (1998) that the benefits from expansion of cities and urbanisation usually outweigh the negative impacts on the environment. One key informant commented: “*one cannot eat his cake and keep it at the same time*”. Nevertheless, very few key informants and focus group participants regretted that some developmental projects such as construction of roads, rehabilitation and expansion of market facility, settlements expansion etc. were executed without prior thought of their serious impacts on the environment

Discussions with some officials in the Environmental Protection Agency revealed that most of the developmental projects were carried out without the approval of the Agency who usually authorise permits for such projects. The reason given was political as various governments are not willing to lose votes for environmental conservation. In such circumstances, many projects are implemented with less regard to their impacts on the environment.

Two main factors accounted for participants' perception of urbanisation and the observed environmental degradation in the study area. The first is that most participants anticipated that their comments on the possible negative effects of infrastructural projects would lead to redirection of government plans for such developmental activities and are therefore not

prepared to voice any comment to undermine Government efforts in bringing “sanity” to the study area. Secondly most of them found it hard to relate the positive and negative aspects of those development projects in terms of increasing standards of living and environmental impacts. The general conclusion is that whilst participants knew of the negative consequences of such activities on the environment they felt they were an inevitable consequence.

6.3 Driving forces and their interrelationships

Table 6.3 summarises the complex interplay of the driving forces deduced from participants’ views and comments. In the first instance, poverty and other driving forces such as in-migration and population growth were perceived by participants to have acted simultaneously but independently with climatic factors to bring about the observed changes on the environment. As already discussed, poverty tends to influence how and why people move from places of origin to the study area in search of jobs which eventually causes a growth in population of the area.

On the other hand, economic policies, as noted by participants, tend to influence existing land tenure systems through the legalisation of the small-scale mining activities that also influences migration. Such were the views and opinions of most of the participants, especially the Regional House of Chiefs’ key informant and the local focus group.

In other development, poverty was observed to be directly linked to population growth and behavioural changes to bring about the observed changes to the environment. Such was the view of most key informants as they observed that child-bearing, which is seen as future investment, leads to population growth and breeds poverty in the long run. Poverty is also known to be a prime factor of environmental degradation.

Poverty, in-migration, population growth, economic transformation, the tenure system and cultural changes were also observed to act collectively and with climatic changes to influence the nature and characteristics of the environment as observed in the study area. It was deduced

from participants' reactions that all forces come to play to bring about those changes on the environment modelled on the satellite images.

The hypothesis that the uncertainty in environmental system dynamics that arises from ecological and human systems, through various social processes, and interacts in a very complex way to bring about environmental degradation (Geist and Lambin 2002; Carney, 1993), is found to be true in this thesis.

Table 6.3: Driving forces interrelationships

Research participants	(P×I×G)	(E×T×I)	(P×G×C)	(N)	(P×I×G×E×T×C)
Environmental Protection agency				√	√
Mineral Commission				√	√
Lands Commission				√	√
Regional House of Chiefs		√		√	
Talensi-Nabdam District assembly			√	√	
Bolgatanga Municipal assembly			√	√	
Regional Surveying Department				√	√
Regional Coordinating Council				√	√
Concern youth group	√			√	
Women group	√			√	
Farmers association	√			√	
Heterogeneous community focus group		√		√	
Heterogeneous organisation focus group				√	√
Small-scale legal miners	√			√	
Small-scale illegal miners	√			√	
Representatives from Pwalugu/Tongo				√	√

(P×I×G)=Poverty-In-migration-Population growth-environmental degradation nexus; (E×T×I) =Economic transformation-Tenure system-In-migration-Environmental degradation nexus; (P×G×C) =Poverty-Population growth-Attitudinal and behavioural changes-Degradation nexus; (N)=Climate-Environmental degradation nexus and P×I×G×E×T×C=Poverty-In-migration-Population growth-Economic transformation-Tenure system-Cultural changes-Degradation nexus.

6.4 Ranking of driving forces according to their relative importance

The driving forces were ranked by research participants in terms of their importance as shown in Figure. Participants agreed that poverty is the major cause of environmental degradation in the study area. As they observed the poor in most of the communities have no alternative but to work on marginal lands for their livelihood. The next important driving forces observed by participants were population growth, migration macroeconomic policies and climatic variation of the study area. Urbanisation and infrastructural development were rated least by participants as they observed that the positive aspect of urbanisation and infrastructural development outweighs the negative environmental impacts.

Table 6.4: Ranking of driving forces according to their importance

Driving forces	Order of importance
Climate variation	2
Macroeconomic policies	2
Population growth/migration	2
Urbanisation	5
Poverty	1
Prevailing land tenure system	3
Local culture	4

6.5 Environmental impacts

Analysis of the responses from most of the research participants, on the adverse impacts of the observed land-cover changes, were in line with Briassoulis (2000) and Fons-Esteve (2003) who postulated that environmental impacts are seen within the physical and social categories. Table 6.5 is a summary response of impacts of observed changes on the environment and Figure 6.6 is participant map in GIS of the spatial distribution of environmental impacts.

Table 6.5: Participants responses to environmental impacts

Participants	Food scarcity	Poor living standards	Cross cultural tensions	Health risks	Impact on women
Environmental Protection Agency	√	√	√	√	√
Mineral Commission	√	√	√	√	√
Lands Commission	√	√	√	√	√
Regional House of Chiefs	√	√	√	√	√
Talensi-Nabdam District Assembly	√	√	√	√	√
Bolgatanga Municipal Assembly	√	√	√	√	√
Regional Surveying Department	√	√	√	√	√
Regional Coordinating Council	√	√	√	√	√
Concerned Youth Group	√	√	√	√	√
Women Association	√	√	√	√	√
Farmers Association	√	√	√	√	√
Heterogeneous Community Focus Group	√	√	√	√	√
Heterogeneous Organisation Focus Group	√	√	√	√	√
Representatives from Pwalugu and Tongo	√	√	√	√	√
Small-Scale Illegal Miner	Not sure	Not sure	Not sure	Not sure	Not sure
Small-Scale Legal Miners	Not sure	Not sure	Not sure	Not sure	Not sure

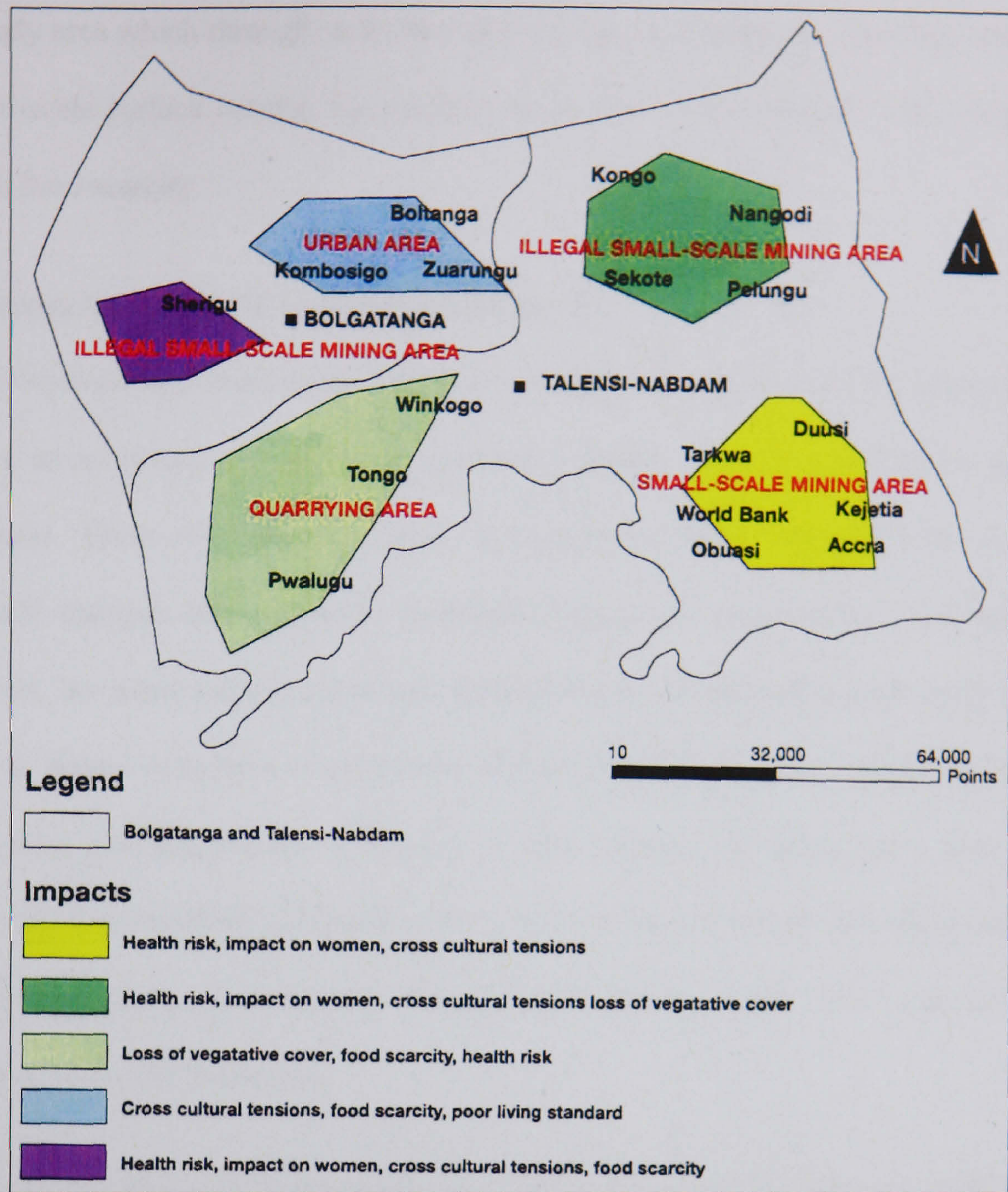


Figure 6.6: Spatial distribution of environmental impacts in GIS

6.5.1 Physical impacts

Participants indicated that considerable areas of savannah vegetative cover in the study area have been cleared to accommodate human activities and other economic and infrastructural developments. These clearings have had significant impacts on the environment which is the main source of livelihood for the rural poor as they provide income and food security. Spatial analysis, from the previous chapter, revealed that the study area has seen a decline of savannah vegetative woodland of 634 km², with corresponding increase in grasses of various types of 208 km² and built-up and barren environment of 392 km² over the 14 years of study.

When probed on the impacts of the observed land-cover changes in the area, research participants were of the view that those observed changes have led to a severe vegetative loss

in the study area which through, activities such as extensive grazing, quarrying, sand winning and small-scale surface mining, has resulted in the loss of soil fertility, a decrease in arable lands and food scarcity.

6.5.2 Socio-economic impacts (high living standard)

On the socio-economic and cultural impacts, most participants pointed out the persistent food shortages, an increased in scarcity of savannah products (firewood collection), hunger and malnutrition. There also observed high out-migration rates, societal costs in terms of behavioural changes and economic hardships among the local people. According to the participants, the observed environmental degradation has threatened food security in the area through an annual reduction in crop yield which has trickled down to higher food prices at both the farm gate and market. According to participants, food prices have, over the years, doubled which is indirectly attributed to the observed environmental and social changes. The perennial food shortages in northern Ghana, as in the case of the study area, have brought about many economic hardships.

Reports from the Regional Statistical Research and Information Directorate of MOFA shows an increase in farm gate prices of items of food in the study area from 1990 to 2004 (Table 6.6) to substantiate the claims put forward by the research participants. As seen in Table 6.6 prices of all the major staple foods in the area show increases. Even though one cannot rule out the influence of market forces as the main factor of the price increases, food shortages as a result of poor yield from a poorer environment appear to be an indirect cause.

Table 6.6: Changes in staple food prices in the study area.

Local staple food	Farm gate prices (in cedis) 1990	Farm gate prices (in cedis) 2004
Red beans	120, 000/50 kg bag	555, 000/50 kg bag
Local rice	250, 000/ 50 kg	520, 000/ 50 kg
Soya beans	170, 000/ 50 kg	320, 000/ 50 kg
Maize	180, 000/ 50 kg bag	85, 000/ 50 kg bag
Groundnut	350, 000/ 50 kg bag	600, 000 /kg bag
Millet	150, 000/ 50 kg bag	250, 000/ 50 kg bag
Sorghum	80, 000/ kg bag	160, 000/50 kg bag
Tuber of yam	2,500/ average tuber of yam	8, 500 /average tuber of yam

Source: Regional Statistical Research and Information Directorate: MOFA (2005).

Key informants and some local focus group participants noted the poor income disparities that had always favoured the rich in the society to the detriment of the poor. In such circumstances, the rich seem not to be affected by the higher standard of living as against the poor who are always hit by the exorbitant high food prices.

The effect of the economic hardship (increase in food prices) has also trickled down to create other social problems such as the drift of the youth of school going age into income generating activities and the increase in child labour especially in the mining and sand winning sectors. Other social issues of importance and noted by participants included high school dropout rates, inadequate housing, youth unemployment, cross-cultural tensions and family disorganisation. These, according to participants, are the result of the observed environmental degradation that has led to changes in the social structures of the various communities in the study area.

It was observed that the social changes that are observed in the study area are not different from other areas in northern Ghana. For example, observations made by Akabzaa and Darimani (2001) in their study of mining and socio-economic implications in a mining community in the western region shows that economic indices such as food prices, accommodation, health and water have recently attracted higher values beyond the reach of the average person and are the indirect cause of environmental degradation.

6.5.3 Cross-cultural tensions

Cross-cultural tensions were observed to be another problem in the study area as outsiders move in with different sets of cultural expectations and norms. Most key informants, community leaders and the women's and the youth groups mentioned several social problems such as prostitution, early teenage pregnancy, early school drop-outs, drunkenness, violence, theft and robbery that have recently taken root in the area, some of which were not known or even mentioned in the early 1990s. According to them these, anti-social behaviours are unavoidable impacts of a migrant population and the income they derive from the small-scale mining activities. Drug addiction was not mentioned by participants thus contradicting Akabzaa and Darmani's (2001) assertion that drugs such as marijuana are mostly consumed in mining communities.

Other anti-social human behaviour observed by participants included health issues, partner separations, violence and theft. Apparently, migrant youth, who find it hard to work, out of laziness, resort to criminal activities such as theft to make their living. Participants noted that this behaviour is prevalent in the mining communities as concerns have been raised by the local people to the district assemblies for their intervention. There were no available data to substantiate such claims although informal discussions with the district assemblies tended to confirm them.

Participants pointed out that those anti-social issues are not new in the area, has become more complicated and have taken different perspectives as a result of migrant workers and the eagerness to make more money out of scarce resources. As commented by one participant,

“the recent economic transformation, poverty and the associated environmental degradation in the north has triggered massive cultural tensions from different cultural backgrounds”.

This is particularly true in the study area.

6.5.4 Health risks

Insights into opinions on health risks associated with the observed environmental degradation were sought by requesting participants’ responses on a number of issues relating to common diseases perceived to have resulted from environmental degradation. Diseases viewed to be indirectly associated with the observed environmental changes activities are infectious respiratory diseases (common among those living in the environs of the quarrying factory in Pwalugu and sand and stone winning at Kongo), skin diseases (common among small-scale illegal surface miners who use mercury to wash gold ore), outbreaks of malaria, typhoid and cholera (exacerbated by water-trapped in the deep trenches of the small-scale underground mines). Table 6.7 and Appendix 6.4 show the rate of incidence of prevalence diseases in the study area perceived to be indirectly related to environmental degradation.

Table 6.7: Prevalence common diseases in the area (1990, 2000, and 2004)

Common diseases	1990 and % by population	2000 and % by population	2004 and % by population
Malaria	16,635 (9%)	71,207 (30.9%)	74,697 (29.4%)
Respiratory infection	4,356 (2.4%)	8,520 (3.7%)	8,760 (3.5%)
Skin diseases	1,677 (0.9%)	4,764 (2.1%)	7,551 (2.9%)
Tuberculosis	133(0.07%)	118 (0.05%)	142 (0.05%)

Source: Regional Bio-Stats Office, Bolgatanga.

There is an increasing trend of reported cases of malaria from 16,636 representing 9% of the population in the 1990 to 74,697. representing 29.4% of the population in 2004. The incidence of reported cases of respiratory tract infections has also increased from 4,356. representing 2.4% of the population in 1990 to 8,760, representing 3.5% of the population in

2004. Reported cases of skin diseases also increased from 1,677, representing 0.9% of the population during the 1990 to 7,551, representing 2.9% of the population in 2004 and tuberculosis with an increase from 133, representing 0.07% of the population in 1990 to 143, representing 0.05% of the population in 2004.

Most of the research participants, especially those in the heterogeneous community focus group, commented that the small-scale legal underground mining is partially responsible for the increase in malaria incident in the study area. According to them, the nature and operations of the underground mining activities promote modifications of the land-cover that favour malaria vector development. The activities create water trapping trenches, divert watercourses and promote bodies of stagnant water especially during the rainy season that have been instrumental in the spread of malarial vectors; anopheles mosquito egg development.

Respiratory infection, through constant inhaling of dust particles, was also found to be more pronounced in areas such as Kongo, Pwalugu, Tongo, Winkogo and Nangodi where sand and stone winning, quarrying and small-scale illegal mining activities are common. Figure 6.7 illustrates the spatial distribution of the identified diseases in GIS.

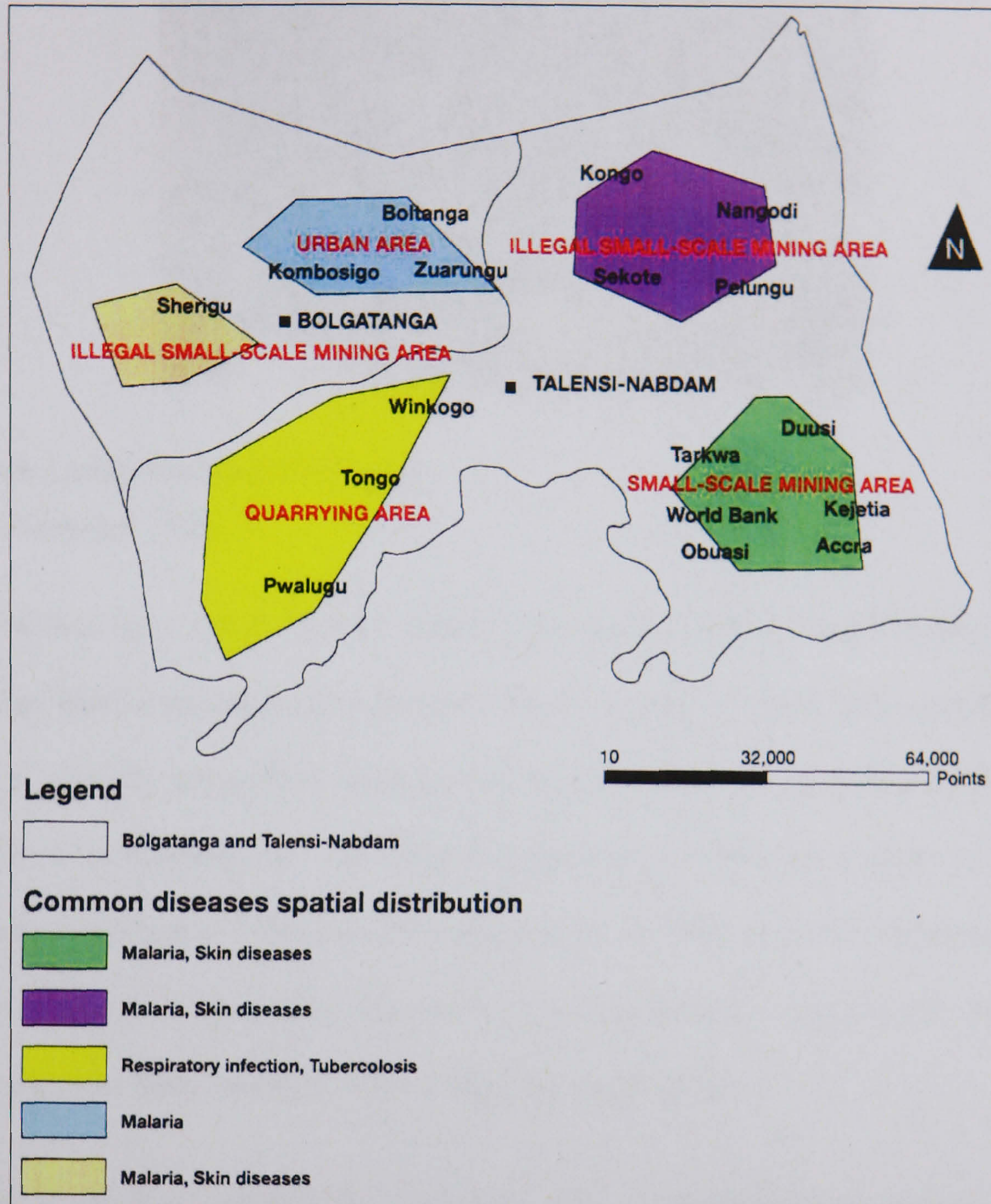


Figure 6.7: Spatial distribution of prevalent diseases in GIS

Skin diseases which were also observed to be common in the study area especially in the mining communities were the result of the crude use of mercury in the washing and processing of gold ore (see Figure 6.8). Most of the research participants, with the exception of the miners, attributed the high incidence of skin diseases to the nature and operations of small-scale mining activities.



Figure 6.8: Gold processing at Nangodi

Source: Fieldwork, 2006

Migrant workers have the potential to transfer diseases between the locations they work. The local groups interviewed expressed concerns that the migrant workers have contributed to the increase of sexually transmitted diseases (STDs) and diarrhoea. According to the statistics obtained from the Regional Bio-Stat office at Bolgatanga, in 1990, the monthly reported cases of diarrhoea incidence in 1990 was 139 as against 245 in 2004. Sexually transmitted diseases have also assumed an increasing trend in the area, according to participants, even though statistics were not made available to us to substantiate the claims.

There was no evidence, during the interactions with the participants, to suggest that health risks associated with the various human activities were misunderstood, even among the small-scale miners, thus contradicting the earlier assertion made by Barry (1997) and Rawana (2000) that small-scale miners are unaware of the health implications of their activities. During discussion, a small-scale illegal miner at Nangodi had this to say: *“the operation is risky in terms of health and my plans are to return home to rest and undertake medical treatment”*. Another small-scale illegal miner commented: *“Your health is always more important, that is why one should not stay here for far too long”*. These comments thus suggest the pre-knowledge of the health implication of the small-scale mining by miners in the study community.

6.5.5 Impacts on women

6.5.5.1 *Environmental degradation*

A few participants, mostly in the women focus group, noted that the recent degradation of the environment had brought about much stress on local women as most of them are the “*household managers*”. As they observed and noted, the recent loss of savannah vegetative environment has cause women to travel longer distances to get firewood and other farm items which were hitherto very close to them. The easiness of men in the various communities to migrate to other parts of the country from the prevailing harsh environmental conditions was observed not to be the same for most women who, as tradition demands, cannot leave without their husbands. This has compelled them to stay home even though the high environmental conditions are not suitable for any serious economic activities for those women. In such circumstances, women in the society are the direct victim of observed environmental degradation. One woman noted: “*We cannot move anywhere without the consent of our husbands. We are therefore daily faced with the severe pressures of the degraded environment which we have to depend for survival*”.

6.5.5.2 *Extractive activities*

Most of the women in the small-scale illegal mining sites are responsible for using hand-held sieves to sieve ground ore for the mineral processing while others provide water for washing, drinking and processing of gold ore. Some of them assist their male counterparts to pound the aggregate ore for milling while others carry ore materials from the mining locations to the milling and refining centres.

Small-scale sand and stone quarrying in the study area is mostly done by women, especially during the non-farming seasons. Sometimes they are helped by their husbands and sons. Other women, who are not directly involved in the extraction activities, sell cooked food and other goods. Almost all of the women’s focus group participants mentioned the unfair treatment by their male counterparts who usually make them do the hard jobs and take their money after

sales. One of the women in the group discussion commented, " *We have mouth but cannot express ourselves. We always have to obey our male counterparts. That is our tradition and custom. We came to meet it and there is little to be done. Somehow we are used to it*".

Women also gave their protest on compensation and sales earnings that always are given to the husbands and the family heads. Some of the husbands, they commented, abandon their families to go to big towns and return only after the money has been spent.

Direct observation revealed that women comprise about 20% of the total workforce of the underground small-scale mining and about 50% of the small-scale surface mining. Few were, however, gainfully employed in quarrying activities and most were involved in sand and stone winning. Almost all the petty trading and selling of foodstuff was done by women mainly from the southern Ghana who bring these goods to the area, sell them and use the money to buy food items at farm gate price for sale in the south. Figure 6.9 shows some women at Nangodi helping with the small-scale mining activities.



Figure 6.9: Women involvement in small-scale mining at Nangodi

Source: Fieldwork, 2006

6.6 Ranking of impacts according to their relative importance

Ranking exercise to identify the severity of the various impacts on the environment was carried out with the research participants. According to most of them, food scarcity has been the major problem in the study area due to the constant deterioration of the environment. This has resulted in poor standard of living. Health problem was rated third by participants as a result of the increase in the prevalence of malaria and respiratory problems in the study area. Cross-cultural tensions were rated fourth and impacts on women was rated least by research participants, even though the women focus group were opinion that the impacts of the observed changes on the environment has impacted severely on women in many communities of the study area.

Table 6.8: Ranking of impacts according to their importance

Impacts	Severity
Food insecurity	1
Poor standard of living	2
Cross-cultural tensions	4
Health impacts	3
Impact on women	5

Note: 1 (severe); 5 (least severe)

6.7 Coping strategies

As already stated in chapter 2, coping strategies are short-term responses to shocks of environmental degradation usually induced through human activities (Donahue and MacArthur, 1998). Participants were probed using the UNRISD (1994) general headings of strategies for coping with harsh environmental conditions that include (i) reducing consumption pattern; (ii) alternative sources of livelihood; (iii) temporary migration; (iv) collective actions to address the issue; and (v) acculturation through behavioural changes. Participants identified alternative sources of livelihood as the major means of coping with the environmental stress as most seem not to have any idea of how community members have come together to protest against those responsible for the problem or have taken actions to help solve the problem. Table 6.9 and Figure 6.10 are the presentation of participant's responses to coping strategies and spatial distribution in GIS.

Table 6.9: Participants response to coping strategies

Participants	Reducing consumption pattern	Alternative source of livelihood	Migration	Collective action	Acculturation
Environmental Protection Agency	√	√	√	No idea	√
Mineral Commission	√	√	√	No idea	√
Land Commission	√	√	√	√	√
Regional House of Chiefs	√	√	√	√	√
Talensi-Nabdam District Assembly	√	√	√	No idea	√
Bolgatanga Municipal Assembly	√	√	√	No idea	√
Regional Surveying Department	√	√	√	No idea	√
Regional Coordinating Council	√	√	√	√	√
Concerned Youth Group	√	√	√	No idea	√
Women Association	√	√	√	No idea	√
Farmers association	√	√	√	√	√
Heterogeneous Community Focus Group	√	√	√	√	√
Heterogeneous Organisation Focus Group	√	√	√	√	√
Representatives from Pwalugu and Tongo	√	√	√	√	√
Small-Scale Illegal Miners	No idea	√	No idea	No idea	√
Small-scale legal Miners	No idea	√	No idea	No idea	√

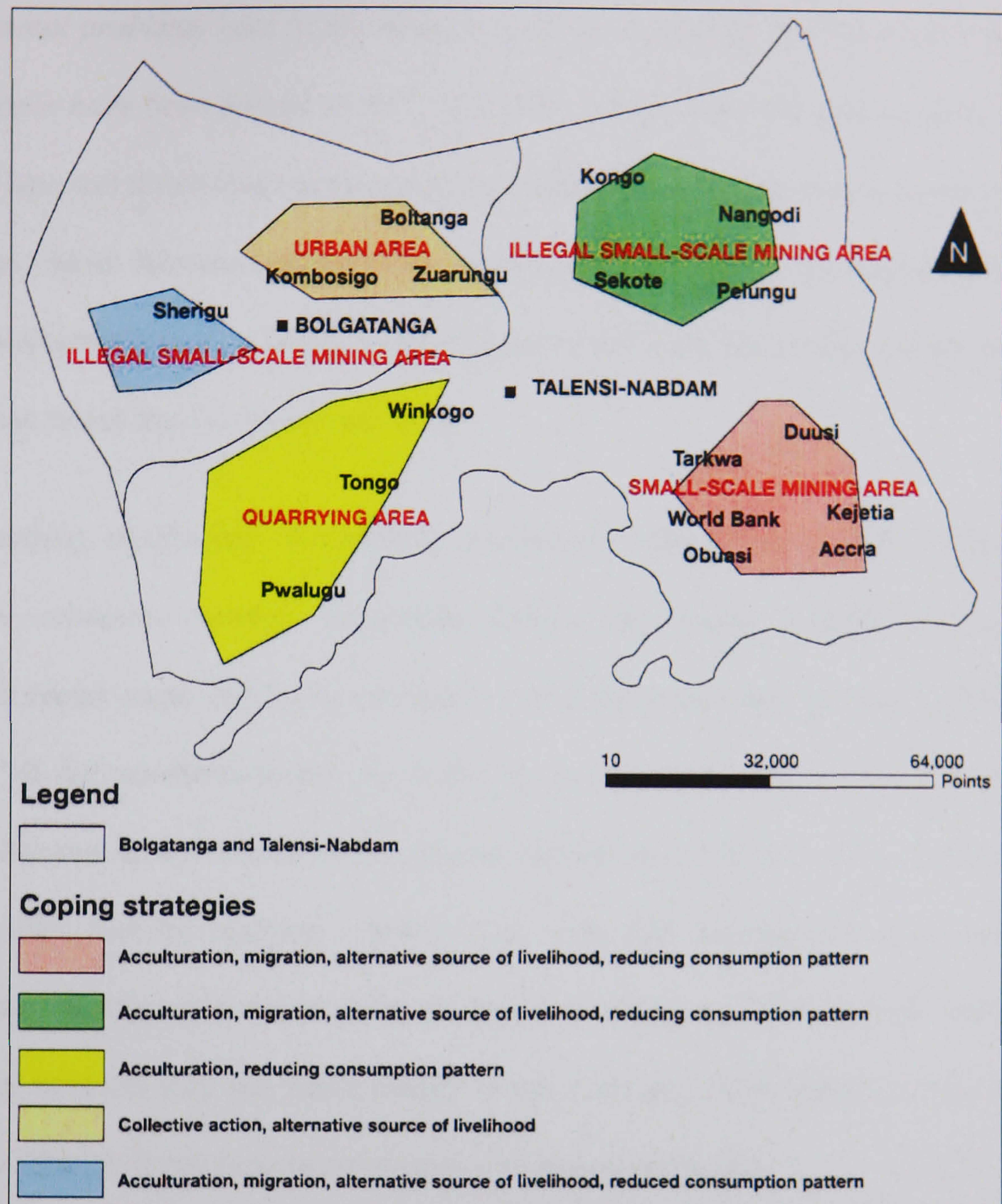


Figure 6.10: Spatial distribution of coping strategies in GIS

On the issue of reduction of consumption patterns as means of coping with the adverse effects of the environmental change, most participants, with the exception of the small-scale miners' focus group, explained that most community members are forced to cut down their feeding habit in order to cope with the unprecedented harsh environmental conditions as observed in the study area. According to one key informant, the situation has been serious in many rural communities where poverty is endemic and local people largely depend on the available natural resources for their livelihood. Nangodi, Kongo, Duusi, Pelungu and Dakutu were areas mostly affected as local people are constantly seen to reduce their consumption pattern

to cope with the harsh environmental condition. A respondent from the representatives from Tongo and Pwalugu focus group commented that: *"The only way to survive the harsh environmental problems here in the north is to cut down our eating habit which the majority of the people have been forced to do"*. However, it was observed that as some community members have cut down consumption pattern to reflect the degraded environment, others, like the miners, have increased theirs. The general opinion among the participants was that migrant workers seem to be living at the expense of the local indigenous people who have no options than to toil hard to make ends meet.

Another coping mechanism observed by participants was the shift from farming to other productive economic ventures, especially small-scale mining. Farming has been greatly affected in recent years due to the decline in soil fertility that has resulted from the constant depletion of the savannah forest. As noted by a participant of the farmers' focus group, *"farming has not been lucrative in the area as one has to spend more time on the farm before good harvests can be realised"*. Some even said that preparations were advanced for abandoning farming to invest in other productive ventures such small-scale mining activity where they believed they can make money in the shortest possible time so as to take care of the family. This shift has been more pronounced among the youth.

On the contrary, a key informant observed that the shift among the youth from farming to other economic ventures is not attributed wholly to the prevailing deteriorating environment but also on economic grounds as it is easier to make economic returns from a mining business compared to farming which the majority of the youth perceived to be boring and an activity for the elderly. The opinion of the key informant seems to suggest that small-scale mining is the hope for the poor, unemployed and poorly educated people who, through this activity, hope to escape complete social marginalisation and also to have a sense of belonging which was also noted by McMillian (1995) and Heemskerk (2001).

Some women in the small-scale mining communities have also taken the advantage of the situation and have resorted to petty trading (selling of foodstuffs and other commodities) as a means of income generation to support their households. One focus group respondent explained that such women were farmers who have decided to indulge in the buying and selling business to raise income to support the family as farming is no longer lucrative. Others are the relatives of the small-scale male miners who buy goods from the south to sell in the north and vice-versa.

It was observed that many local people, unable to face the difficult challenges at home, have migrated south in search of economic fortune. As noted by a key informant, most of them move temporarily especially during the dry season where it becomes difficult to stay in the area, thus supporting the UNRISD's (1994) assertion of temporary migration as a coping mechanism of environmental degradation. Other participants disagreed with the issue of temporary migration as they observed that the recent migrations of able-bodied youths have been permanent and most of them are found mostly in the Ashanti and the Greater Accra Region where they take in menial jobs. As they observed, the assertion of the UNRISD (1994) that movements from places of origin to destinations are usually temporary when one is faced with environmental difficulties is not applicable to the study area as movements have always been permanent. One participant from the farmers' focus group commented how his elder son left home without his knowledge and does not even know, at the time of this interview, where he is now. According to him, most parents are victims of similar situation resulting from the recent harsh environmental problems.

These observations made by participants are similar to earlier studies by Black (1998) and Unruh *et al.* (2004) on environmental refugees, where they stated that environmental degradation has become a cause of such coping mechanisms when affected people no longer gain a secure livelihood in their places of origin and are therefore forced to migrate to other destinations.

Collective actions, through community mobilisation, were observed to be irrelevant in most of the communities to address the environmental problems as noticed from participants' comments. Some participants, however, commented on recent actions by some Nangodi community members concerning the continuous harassment by Fulani herdsmen and illegal small-scale miners but nothing came out positive. The responses suggest that seldom had the affected communities mobilised themselves to help solve the prevailing environmental problems.

The above findings revealed that in most of the communities faced with severe environmental problems, members have adopted seeking support and avoidance mechanisms of coping with the situation. Problem solving mechanisms through collective action, as postulated by Amirkhan (1990), seem not to be evidence in the study area. The findings are in line with Stocking (1998, p.857) that local people often fail to solve their environmental problems as the issues confronting them are usually greater than their powers to change and instead they just learn to cope. It can thus be concluded that most community members, based on the responses from participants, are either apathetic to the severe environmental problems in the area or think that the nature of the problem is beyond their means of preventing or reducing it.

6.8 Ranking of coping strategies according to their relative importance

Ranking exercise was done to identify communities' priorities in terms of coping strategies of the observed changes on the environment. As illustrated in Table 6.10, reduction in consumption pattern was the first priority for all the communities faced with the observed changes on the environment. This is followed by alternative source of livelihood, mostly from farming to mining. Temporal migration and acculturation was a common priority especially in the mining communities where most local people have migrated to the south and where those left behind have adapted to different lifestyle.

Table 6.10: Ranking of the coping strategies according to their relative importance

Coping strategies	Ranking
Reduction in consumption pattern	1
Alternative source of livelihood	2
Temporal migration	4
Collective action	5
Acculturation	3

Note: 1 (most important); 5 (least important)

6.9 Conclusion

In this chapter greater emphasis is placed on the use of the community truthing phase of the assessment methodology to evaluate and assess the driving forces, the impacts and the coping strategies of the observed changes on the environment. Using the assessment methodology, driving forces behind the land-cover changes, for the periods from 1990 to 2004 in the study area, were observed to include factors such as microclimate, macroeconomic transformation, population growth, migration, poverty, land tenure system and traditional and cultural factors. Most of these driving forces, deduced from research participants' observations, have acted in a complex interplay to contribute to the observed changes on the environment. Analysis of the community truthing data further indicated that the impacts associated with the observed land-cover changes included the physical and social impacts, with the physical impacts directly influencing the social impacts. Issues raised by participants concerning the environmental impacts included vegetative loss that has affected the fertility of soils leading to poor agricultural yields, the problem of cultural tensions, impact on the socio-economic development of women in the society, reduction in living standards and high incidence of diseases. Various strategies adopted by the communities to cope with the observed environmental stress include reducing consumption patterns, alternative sources of livelihood, temporal migration, collective action and acculturation through the adaptation to mixed cultures. The general observation was that participants were able to relate their comments and

opinions on the topics under discussions with the aid of the GIS spatial analysis data presented to them despite the fact that most of the issues were aspatial in character. The next chapter is a step further to this chapter as it seeks to evaluate the strength of the proposed assessment methodology through the analysis of participants' responses for a better environment.

Chapter 7

Analysis of GIS based Participatory Assessment Results (III): *Response Indicator of DPSIR Framework*

7.1 Introduction

In the previous two chapters, analysis has focussed on the application of the proposed assessment methodology to assess and evaluate the spatio-temporal state of the environment, the pressures (Chapter 5), driving forces, impacts and community coping strategies (Chapter 6). This chapter is a continuation of the previous two chapters as the proposed assessment methodology is tested again for its strength through the assessment of participants' responses. The purpose of the chapter is twofold: to evaluate local peoples' perceptions of what ought to be done to realise a healthier environment and to evaluate participants' perceptions of the possibility of merging traditional environmental practices and the National Environmental Action Plan of the EPA Act 490 as an alternative solution to the observed environmental problems in the study area. PGIS research has established that local people possess ecological knowledge and, when given the opportunity, are capable of contributing to environmental management of their own environmental problems. This assumption is thus tested in this chapter through the application of the proposed assessment methodology.

7.2 Responses for better environment

Community truthing was conducted with research participants to evaluate environmental management practices and identify local knowledge of alternative strategies that are capable for preventing, reducing, reversing or enticing people to take proper environmental initiatives. To achieve this purpose, participants were presented with six different environmental management scenarios for deliberation. These included (i) business as usual; (ii) driving force reduction; (iii) conservation and preservation practices; (iv) environmental awareness and educational programmes; (v) environmental compensation; and (vi) stricter law enforcement. Most of the suggested responses were related to the study area and based on the interpretation of the classified image maps presented. Responses from participants, summarised in Table 7.1, are presented and analysed in the following subsections.

Table 7.1: Responses for better environment

Participants	Business as usual	Driving force reduction	Conservation and preservation	Environmental awareness and educational programmes	Environmental compensation	Stricter law enforcement
Environmental Protection Agency		√	√	√		√
Mineral Commission		√	√	√	√	√
Lands Commission		√	√	√		√
Regional House of Chiefs		√	√	√	√	√
Talensi-District Assembly			√	√	√	
Bolgatanga Municipal Assembly		√	√	√	√	√
Regional Surveying Department		√	√	√		√
Regional Coordinating Council		√	√	√	√	√
Concerned youth group		√	√	√	√	
Women Association		√	√	√	√	
Farmers Association		√	√	√	√	
Heterogeneous Community Focus group		√	√	√	√	√
Heterogeneous Organisation Focus group		√	√	√	√	√
Representative from Pwalugu and Tongo		√	√	√	√	√
Small-scale illegal miners	√					
Small-scale legal miners	√					

7.2.1 Business as usual

Consistent with what has already been observed on the image maps and with discussions with participants, *the business as usual scenario* refers to a situation where no environmental management practices nor awareness programmes are needed to realise a quality environment based on the assumption that the changes to the environment are severe and irreversible. Respondents were then asked to discuss, to the best of their knowledge and based on the spatio-temporal results of the image maps, whether the *business as usual scenario* is the desired option for the study area. The criteria used were that participants were allowed to answer “yes or no” and with possible explanations. The *business as usual scenario* did not attract many positive responses from the participants as most of them recognised the severity of environmental degradation and felt that something positive should be done either to reduce or prevent further environmental degradation. Their claims follow the more popular *conservatism approach* of the UNRISD (1994) that human activities are detrimental to nature and therefore there is a need to control those activities for a better environment.

The very few participants, who suggested the *business as usual scenario* as the desired option, based their argument on the severity and perceived irreversibility of the already degraded environment, using the 2004 image to substantiate their claims. They noted that it would be unwise for policy makers to initiate programmes and commit resources to an already degraded environment. Such was the view of the small-scale miners. Their reactions were based on three simple reasons: (i) they are outsiders who care little of the indigenous natural resources; (ii) they are there just to accrue capital and later return to their places of origin and (iii) they are afraid that any serious management programmes would affect their activities. The already established assertion that people usually venture into small-scale mining activity because they do not consider the costs and benefits of their activities in a realistic manner (McMillan, 1995; Barry, 1996; Rawana, 2000) seems in this instance to be applicable in the study area.

7.2.2 Driving force reduction

The driving force reduction scenario was consistent with the conservationist, people-centred approach and pricing and accounting-based approach reviewed in chapter 2 where actions are taken to address indirect forces of observed environmental problems. Most of the participants focussed on the driving force option. With divergent views of opinions, participants raised on the following issues: (i) poverty reduction strategies as a means of tackling poverty which were perceived by research participants (see chapter 6) to be indirectly linked to the observed changes in the environment; (ii) intensification of family planning educational schemes and birth control measures with the aim of reducing population growth on the scarce natural resources; (iii) revisiting and possible amendments of government economic and environmental policies, notably, the Mining and Mineral law (PNDCL 153) and the EPA Act 490 of the Environmental Protection Agency; (iv) improving the system of land acquisition from freehold entitlement to complete ownership; (v) active participation of women in decision making processes; (vi) control of influx of migrant workers, especially small-scale miners and Fulani herdsmen; (vii) intensification of anti-bush fire campaigns; and (viii) sensitization of chiefs, community leaders and family heads to lead their communities' needs on issues on environmental conservation practices. Analysis of these responses is presented in the following subsections.

7.2.2.1 Poverty reduction strategies

The environmental benefits of poverty reduction strategy appeared to be clear-cut following the reactions of research participants. Most participants observed that, since poverty is indirectly linked to the observed changes on the environment, tackling it in a holistic manner would lead to an improvement in the quality of the environment within the study area. Based on this assumption, some of the key informants suggested opportunity promotion schemes through economic and social services to benefit the rural poor in most of the Talensi-Nabdam communities of the study area. According to them the marginalised poor in those rural communities do not have any alternative other than to rely on scarce natural resources for

their livelihoods through activities such as sand winning, stone cracking and other poor cultural practices that are usually done by the marginalized poor in society. Other participants were of the view that tackling poverty at the national scale would alter the rate of migrant workers into the study area. And, yet, in another divergent view some participants, mostly key informants, proposed the creation of more environmental friendly jobs targeted to the most deprived rural poor to prevent them from embarking on activities that pose a serious threat to the environment. Some focus group participants were of the view that the recent drift from farming to the small-scale mining sector could be prevented if the Government had initiated programmes to boost local farming through credit facilities, agricultural subsidy schemes, increases in farm gate prices of food commodities, provision of storage facilities in farming communities, improved accessibility from rural communities to market centres for farm product sales and encouragement of the youth to take up farming through appropriate incentive packages.

7.2 2.2 Population control measures

In addition to poverty reduction strategies, most participants were of the view that population growth and environmental degradation are intrinsically linked together (as already observed through the literature in chapter 2 and participants responses in chapter 6) and that any realistic efforts taken to control population growth and movement in the study area would help solve the prevailing environmental problems indirectly. To this end, most participants (mostly key informants and some few focus group participants) agreed that family planning educational programmes, birth control measures and sensitization of the people, especially in the rural and peri-urban areas of Talensi-Nabdam district, to population growth and its socio-economic and environmental implications could, albeit indirectly, help bring a change in the perception of child-birth in the area as sign of individual recognition in the society.

Those few participants who perceived difficulties in embarking upon population growth reduction believed that much would, rather, depend on effective coordination of educational programmes between the local PPAG (Planned Parenthood Association of Ghana), the GSMF

(Ghana Social Marketing Foundation), the PMA (Private Midwives Association), traditional birth attendants and community leaders who are known and recognised in the various communities as past initiatives have failed as a result of the non-involvement of local people, particularly the elders. Despite these suggestions, participants were, however, uncertain about positive results, as in many rural communities, especially in the Talensi-Nabdam district, it is a deeply rooted opinion that child bearing is a sign of fruitfulness and blessings from the traditional gods, as one focus participant puts it: *“abundance of grace await those who obey the traditional gods with more children”*. Few, however, were optimistic that the approach would eventually yield positive results in most of the rural communities.

7.2.2.3 Control of influx of migrant workers

Even though migration was perceived by participants as one of the indirect causes of environmental problems in the area, most of them were not sure about how to tackle it due to the following reasons: (i) the failure of the district assemblies to tighten up security on the borders to check the inflow of the Fulani herdsmen; (ii) the failure of the district assembly to enforce regulations on the movement of cattle and their herdsmen into Ghana; (iii) traditional and opinion leaders who harbour and encourage the entry of outsiders; and (iv) individuals in the communities who own cattle herds which are handled by outsiders on a daily basis.

A few participants who thought of something positive, however, proposed a top-down solution to the problem through the intensification of monitoring procedures by the district assemblies and the Regional Coordinating Council that should be targeted of outsiders and the Fulani herdsmen. One key informant made an important observation that the influx of migrants might be reduced if alternative jobs are created in the areas of origin to serve as a disincentive to move northwards in search of jobs.

7.2.2.4 Macro economic policies

Most participants, with the exception of the key informants from the Mining and Mineral Commission (Bolgatanga), the district assemblies (Bolgatanga and Talensi-Nabdam) and the Regional Coordinating Council, argued that the inconsistency of the content of the Mining and Mineral law (PNDCL, 153) promotes extensive mining activities with little regard for the protection of the environment while the National Environmental Action Plan (NEAP) of the EPA Act 490 is vague about environmental protection principles with no definite methodology for achieving those principles. As noted by a key informant during scheduled interview, *“the content of the NEAP are “merely formal” environmental principles and guidelines formulated to r satisfy some donor agencies who require environmental statements for proposed projects before loans or grants are given”*. Concerned participants noted, with deep interest, the need for a thorough review of the NEAP guidelines and the possible amendment of the Mining and Mineral Law (PNDCL 153) to include bottom-up grassroots participation in the dissemination and implementation of the NEAP agenda and principles. The statutory law in Ghana that stipulates that the state government is the owner of all mineral resources was also suggested by some focus group participants as the cause of the many environmental problems in the country, particularly in the three northern regions. Other focus group participants proposed the non-expansion of the statutory 72 km² land allocation to small-scale underground mining at Duusi and suggested any possible future expansion should be considered in consultation with the Regional Environmental Protection Agency. Some key informants also proposed the extension of the benefits of the PNDCL 153 (legalisation of the small-scale mining) to cover all the mining activities in the districts to accommodate the illegal small-scale miners for monitoring purposes.

7.2.2.5 *Improvement of tenure system*

The concept of “*free for all*” communal title of land in the study area, with nobody taking active responsibility of the management of land resources, was noted by participants to be, indirectly, partially responsible of the observed land-cover changes in the study area. However, methods improving the tenure system in the area to realise a better environment generated conflict among participants. While some participants suggested the absolute supervision of community lands by the state government under the Lands Commission and the District Assemblies, through the adoption of legal procedures for land acquisition and environmental impact assessment, others suggested the absolute supervision by community leaders as previously done in most of the communities in the study area. Those who supported Government supervision pointed out that if the Government is to take up absolute responsibility for land entitlements there should be an immediate amendment of the property rights law to account for conservation and management practices. On the contrary, a focus group participant suggested awareness dissemination as a useful tool in preventing land-use conflicts and litigation that sometimes lead to many social problems and environmental degradation. He based his argument on the fact that most land-use conflicts in the area usually stemmed from the complete lack of free flow of information regarding which land had been acquired, by whom, for whom and for what purpose.

7.2.2.6 *Community level institutions*

As observed during various interactions with research participants, natural resources in the study community are associated with the gods of the land and must therefore be used in accordance with their wishes. Accordingly, tradition requires all users to recognise the intrinsic values of the natural resources for the benefit of current and future generations. Apart from the general regulations, there are specific prohibitions or taboos regarding the use of land, rivers and savannah vegetation. Contravention of the general and specific regulations are usually cause for severe penalties sometimes as severe as death.

According to most of the local focus groups and some key informants, such customary regulations worked well in the past as community members with the fear of their local gods attach much importance to natural resources. However, such traditional environmental management practices are seen as primitive and are not currently promoted by the state government as an effective means of bringing about a change in the environment. It was observed, during interviews and focus group discussions that the merging of traditional environmental practices and contemporary knowledge of environmental practices through the National environmental Action Plan (NEAP) are likely to achieve widespread recognition among local people as that would demonstrate the respect that policy makers have of their traditions and culture. Table 7.2 is a summary of opinions of participants concerning the possible merging of the two management practices.

Table 7.2: Options for desired environmental management practices

Participants	Traditional practices	NEAP
Environmental Protection Agency		√
Mineral Commission	√	√
Lands Commission	√	√
Regional House of Chiefs	√	√
Talensi-Nabdam District Assembly	√	√
Bolgatanga Municipal Assembly	√	√
Regional Surveying Department		√
Regional Coordinating Council		√
Concern Youth Group	√	
Women association	√	√
Farmers Association	√	√
Heterogeneous Community Focus Group	√	
Heterogeneous Organisation Focus Group	√	√
Representative from Pwalugu and Tongo	√	√
Small-Scale Illegal Miners		√
Small-Scale Legal Miners		√

It is important to note that some key informants, notably, EPA, Mining and Mineral Commission, Regional Surveying Department and Regional Coordinating Council and some other focus group participants (small-scale miners) did not favour the sole adoption of traditional environmental management practices as the best alternative for solving the recent environmental problems in the area. According to those key informants, the NEAP seeks, among other things, to coordinate activities of all stakeholders concerned with environmental issues and also serve as the official national guidelines for cooperating with international organizations on environmental matters. Reactions from the small-scale focus group participants were anticipated as they seemed to be comfortable with the existing national environmental action plan that favours the PNDCL 153 of the legislation of the small-scale mining industry contrary to the traditional environmental management practices that seem not to favour outsiders.

In contrast, other participants (Lands Commission, Regional House of Chiefs, Talensi-Nabdam District Assembly, Bolgatanga Municipal Assembly) as well as local focus group participants (women's association, farmers' association, heterogeneous organisation focus group and representatives from Pwalugu and Tongo) were of the view that the present state of the environment, as observed on the classified image maps, could be dealt with through an effective integration of both the traditional environmental practices and the National Environmental Action Plan of the Environmental Protection Agency. They argued that the implementation of NEAP as the sole management practice cannot be effective unless consideration is given to traditional and cultural values. According to them, most past and present environmental policies have failed in their implementation as community values were deliberately ignored.

Other participants, the concern youth group and the heterogeneous community focus group, viewed the adoption of traditional environmental management practices as the best alternative in preventing the continual degradation of the environment. According to them, tradition tends to influence one's way of life and a well cultured community tends to give preference to nature. Their reactions suggest that if environmental awareness programmes are channelled through traditional rulers and community leaders, in most of the communities, the probability of success would be great. As one participant commented, *"it is a fearful thing to fall into the hands of our leaders"*.

7.2.2.7 Urbanisation and infrastructural development

The general consensus among participants was that infrastructural development and urban expansion are positive steps in developing the area despite its negative implications on the environment as already evaluated in the previous chapter. Most participants, however, agreed that it would be impossible to terminate an activity or project because of its environmental implications without considering the social benefits. As some participants noted, the developmental status of Bolgatanga township is comparable to other cities and towns in Ghana (they mentioned Accra and Kumasi), despite the causes of such actions to the

depletion of savannah trees. To this end, participants suggested detailed account of environmental impact assessment and the submission of environmental impact statement for approval be it government or individual initiatives. The EPA, by the other participants, was called to be more proactive in their dealings with such documents for a better environment.

7.2.3 Conservation and preservation practices

Another area of concern noted by participants for the realisation of a better environment was environmental conservation through sustainable utilisation and management of natural resources and preservation of protected areas. The general observation made during interactions with participants was that conservation and preservation programmes have little chance of success unless there is active involvement of all stakeholders in the process of identifying the problems, solutions and what ought to be done to implement various laid down environmental strategies. It was also realized that conservation practices can only be effective in the study area unless efforts are made to identify, develop and promote practices that might benefit the society in the long-run.

Concern among participants was expressed about the way and manner local people, outsiders and state government were depleting the savannah vegetative woodland through various activities at spatial locations identified in chapter 6. As noted among some key informants, in reaction to conservation practices, mobilisation of the affected communities to embark on intensive tree planting exercises was seen as the surest way to improve the quality of the environment. The few others were rather pessimistic about how such practice could be successful in some rural communities where tree planting is seen as disrespectful to the traditional gods, especially in the Nangodi area and its immediate environs. The success of such practices, as noted by key informants, would depend on the sensitization of community members to demystify the importance of a tree planting exercise to the socio-economic development of the area. One of the key informants suggested the inclusion of all stakeholders in the exercise to involve officials from the district assemblies, EPA, regional

coordinating council, Lands Commission and other environment-related agencies. It was realised, during discussions with some research participants, that such an initiative is not new in the study area, only that it usually does not attract full participation of the district assemblies, environmental related agencies and community leaders.

Most local focus groups were of the view that the success of tree planting exercises could be realised under the supervision of the local NGOs and suggested that they should work hand in hand with government environment-related agencies. Focus participants agreed with the key informants on the issue of customary prohibition of tree planting in most of the communities and proposed intensive educational programmes to bring awareness to the people about the need to plant trees. On the maintenance and preservation of protected areas such as the Ankwai East, Gambaga Scarp, Red and White Volta West and Red and White Volta East, some focus participants, especially the concern youth group, women's association and the heterogeneous organisation focus group, suggested the recruitment of local savannah forest guards, to prevent the entry into the protected areas by unscrupulous people for mining and other destructive activities.

7.2.4 Environmental awareness and education programmes

Issues that arose concerning environmental awareness and educational programmes were not different from what has been documented in NEAP. However, most participants, especially key informants, felt that environmental awareness and educational programmes should be intensified in the study area with the aim of educating the general public on the importance of preserving the natural environment. In a more optimistic mood, participants noted that such educational and awareness programmes should take into consideration the full participation of all stakeholders in the area and the content of such programmes should be aimed at developing educational programmes that will help to conserve the savannah resources and prevent its further depletion. Participants mentioned a number of ways for how this can be achieved.

1. *Recognition of community and traditional leaders in environmental awareness programmes.* It was the view of most of the research participants, especially the farmers' focus group, women's focus group, and concern youth focus group, that reaching out to those community leaders can assist, in various ways, to facilitate the implementation of environmental conservation programmes. It was proposed that such an initiative should take into consideration easily accessible educational materials in terms of local language and graphical presentation.
2. *Environmental information dissemination through the local media.* The broadcast media, (URA Radio FM station of Upper East Region) was also seen, by some of local focus participants, as a powerful means of educating the public on environmental matters. In order to perform this role effectively, research participants suggested timing such educational programs to catch the audience of most listeners. They also proposed the use of English language translated into the local dialects (Nabte and Grune). A member of the concern youth focus group suggested that the programme should be interactive where the public would be allowed to phone in to make contributions or asked questions. It was proposed by research participants that such an initiative should play host to the Environmental Protection Agency with support from the Regional Coordinating Council and the District Assemblies.
3. *Targeting important personalities.* The idea of targeting key important figures for environmental awareness creation was suggested by a few participants (Environmental Protection Agency and lands Commission key informants). Important personalities such as the Upper East Regional Minister, District Chief Executives, Regional Police Commanders, Regional Parliamentarians and head teachers of Government-assisted secondary schools should be involved in educating the general public on matters on environmental conservation. The well-known footballer legend Abedi Pele, who is from the Upper East Region

(Paga), was mentioned by the environmental Protection Agency key informant, to be involved in environmental awareness programmes in the study area.

4. *Focusing environmental awareness campaigns for specific sectors* through the involvement of various organisations in the area in environmental protection. According to participants, such initiatives can create a sense of respect and stewardship towards the natural environment and provide a forum for new ideas and greater participation of the communities concerned. Participants, who proposed this also, suggested that local NGOs should be proactive in the dissemination of environmental issues in their programmes through raising public awareness of environment development issues and mobilising people to take actions that might contribute to positive changes to the degraded environment.
5. *Environmental awareness in teaching programmes.* Most participants recommended “mainstreaming” environmental education programmes into primary, senior secondary schools and polytechnics in the study area, as a regular part of the curriculum. According to them, such programmes would tend to increase public environmental awareness and demonstrate a commitment to environmental protection and conservation in the study area. A visit to some of the institutions and informal discussion with the head teachers and principals (Bolgatanga Girls Secondary, Zuarungu Secondary School and Bolgatanga Polytechnic) revealed that such an initiative has already started in most of the schools. Also the University for Development Studies (UDS) (Navrongo), as part of the third trimester community workshop, engaged various communities in the study area on practical issues of environment and development. Notwithstanding these educational developments in the study area, some of the research participants felt that more should be done to promote environmental educational programmes. Some of the key informants suggested annual school awards for best environmental practices, an environmental essay competition

and environmental debates among primary and secondary institutions in the area. The heterogeneous organisation focus group participants suggested periodic visits to environmentally degraded sites in the study area by students and pupils in various institutions, to accustom them with the extent of degradation in the communities.

6. *Environmental education programmes for women and youth.* Some participants suggested extensive mobilisation of the most vulnerable (referring mostly to women) assisting them with adequate financial resources, giving them alternative employment while at the same time emphasizing to them the need to conserve and maintain the natural environment. It was also suggested, by the same focus group participants, that gender issues should be considered at the initiation and implementation of any developmental and infrastructure development and that any such initiative that excludes active participation of women should not be permitted. Other key informants (Environmental Protection Agency and the Lands Commission) who found it difficult to comment on the issue of women and environmental protection, for socio-cultural reasons, suggested remedial measures, through the amendment of the EPA Act 1994 (Act 490), to include active participation of the most vulnerable in society on matters relating to the environment. Concomitant with that is the involvement of women in environmental decision-making processes. On youth involvement in environmental related matters, most of the key informants (Environmental Protection Agency, Mining and Mineral Commission, Lands Commission and Surveying Department) lauded the present Government initiative on national youth employment but suggested such a package should consider its integration with environmental issues whereby training programmes should consider environmental awareness and ethics. When the issue was raised for discussion with the concern youth focus group, most of them suggested that the youth can be mobilised and funding made available for dissemination of

environmental awareness programmes through visits to the communities in the study area. There were, however, not many responses on women's involvement in environmental matters by the key informant from the Regional House of Chiefs and both the legal and illegal small-scale miners' focus group. The reasons might be attributed to the sensitivity of the topic in terms of women's socio-cultural position in the study area and the exploitation of women in the mining sector respectively.

7. *Appointment of advisory committee.* Some participants, mostly key informants, suggested the creation of an all inclusive high powered advisory committee to advise on the detailed formulation of the environmental educational programmes, coordinate all the activities and monitor the outcomes. Participants (mostly local focus group participants), mentioned the inclusion of district assembly officials, representatives of environment-related agencies, special interest groups, such as farmer association, local NGOs, women's association, and concern youth groups. According to the participants, such committees could be formed initially to develop strategies for the awareness programmes and remain in existence to help revise strategies where necessary.

7.2.5 Environmental compensation

Environmental compensation is defined as the provision of positive environmental measures to correct, balance or otherwise that are agreed for the loss of environmental resources (Hornby, 2000). Kuiper (1997) defined it as the creation of new environmental values, which are, somehow, equal to the lost environmental values. According to Kuiper, if the lost environmental values are irreplaceable, compensation that concerns the creation of other environmental values which are as similar as possible becomes necessary. It was found out during the interactions with participants that they shared similar views concerning how affected communities and individuals can be compensated despite the controversy as to who

should bear the full cost. The following were proposed by participants as means of environmental compensation.

1. *Monetary compensation*: This was largely seen, by most participants (mostly the key informants) as the most positive means of showing respect and responding to the needs of affected communities and individuals. Most of the key informants proposed monetary compensation to all affected communities as an alternative means of coping with the environmental problems. Those participants who shared that view mentioned communities such as Nangodi, Duusi, Pelungu, Sekoti, Datuku and Sherigu that need to be compensated. When asked about the procedure for mobilizing adequate funds for such a project, most of the research participants (focus group participants) were of the opinion that the state government, through the district assembly common fund, should bear such responsibility for compensating affected communities and individuals. They argued that it is the Government who directly and indirectly benefits from the activities that degrade the environment. It was later found out from the Regional Coordinating Council that the Government had, over the years, taken many initiatives to compensate affected communities over lands used for various development projects in the study area. A more recent one is reported and pasted on the Ghanaweb site by the Ghana News Agency. Few others (mostly the concern youth group and representatives from Pwalugu and Tongo focus group) proposed “*offenders should pay*” whereby individuals or groups of individuals should pay for cleaning up or restoring degraded land until it no longer poses a serious environmental risk and for restoring the environment “*to how it was before it was damaged*”. They found it difficult to figure out how the state government or other agencies should take the responsibility for offences committed by some group of individuals. They specifically mentioned the small-scale mining activities that have rendered many lands in the Talensi-Nabdam communities’ derelict; nevertheless some responded that Government,

through the district assembly, should come in where an area had been utilized for infrastructural developments. They felt that the government should put in financial resources only when they are responsible for such an act. The rest, mostly in the small-scale miners' focus group, argued on the basis of reverence and the ownership of entitlement. They saw the problem to be purely internal matter and proposed compensation procedures to be initiated and implemented by the communities themselves through their leaders. Their comments were seen as shifting responsibilities to the communities whom they see as responsible for the observed changes to the environment. The general perception was that the research participants saw the need for compensation to affected individuals but were at odds as to who should bear such cost. Nevertheless, most of the participants felt that the state government should take such initiative but with consultation with the community leaders and the district assemblies.

Bolgatanga, June 12, GNA - Government on Tuesday paid a total of 684,750,000 cedis to 10 family heads at Bukere section of Bolgatanga as part-payment for their parcels of land-used for the construction of the Catering Rest House in Bolgatanga Presenting the cheques, the Deputy Upper East Regional Minister, Alhaji Awudu Yiremeah urged the beneficiaries to use the monies judiciously and to refrain from engaging in excessive drinking and marrying many wives. He urged them to use the monies on profitable ventures that would benefit their entire families. "You must not change your lifestyle by drinking bottles of beer instead of your usual pito", the Minister stressed. Alhaji Yiremeah appealed to the beneficiaries to exercise restraint while government processed the rest of their monies for them and urged the Regional Office of the Lands Commission to speed up the process of payment. Payment of compensation to the Bukere land owners was to have taken place on Thursday last week but could not come on because of the absence of some principal witnesses to endorse the claim documents as demanded by law.

Source: Ghana News Agency, Bolgatanga (2007)

2. *Resettlement*: Most participants proposed varied views pertaining to resettlement of affected individuals. While some viewed its socio-cultural implications, others saw it as one of the most effective means of compensating the affected individuals and communities. Those who objected to the scheme argued on the basis of the socio-cultural and political setting of the area, where individual places of residence are determined through ancestral inheritance and therefore become difficult to reallocate. They also mentioned the social cost of leaving their original native land to another unknown setting. As an elderly from one of the communities commented, *"It is better to live and be buried in one's original birthplace than a strange land"*. Some participants, rather, anticipated rehabilitation of community and family houses as a way of compensating affected individuals and families. Those in favour (mostly the key informants) proposed that those living in and around the quarrying site at Pwalugu and Winkogo should be resettled in areas far from the sites but not in a different community for socio-cultural reasons. As explained by some of the key informants (Environmental Protection Agency, Lands Commission and Regional Surveying Department), the nature of the activity of quarrying poses a serious risk to the health of the people living in and around Pwalugu and Winkogo hence their resettlement to areas far from the site but within their place of origin. Their opinions were focused on the fact that if the Government can put up reasonably priced houses in the same vicinity (Pwalugu and Winkogo) but far from the quarrying sites, that might alleviate the many reported cases of respiratory health problems in the districts. Reactions from most of the small-scale miners' focus group seemed not to be in harmony with the other research participants concerning this proposed resettlement scheme. According to them moving people away from their original place of settlement will lead to much economic hardship as individuals may be far away from many economic ventures that are their sources of livelihood. They used their small-

scale mining activity as an example which, according to them, has generated income to many local people through their daily and routine involvement.

7.2.6 Stricter law enforcement

The issue of stricter law enforcement was a conflict among participants, especially the key informants as most of them were rather optimistic that the idea would help address the multitude of environmental problems in the study area. While some key informants advocated law enforcement as a mechanism to reduce impacts and improve the state of the environment in an area that has deteriorated over the years, others were of the view that such measures might not produce any lasting solutions due to the mobility of migrant workers, the perceived difficulty of policing the area, especially the illegal mining sites. They also foresee difficulty in training and recruiting dedicated savannah forest inspectors. Stricter regulations are also not feasible in the area where the EPA is currently understaffed and inadequately equipped with resources to enforce environmental regulations and prosecution of environmental offenders. As observed by one key informant, so long as poverty and other social processes are endemic in the study area, tighter regulations would worsen the situation as illegal miners will move to other hiding sites such as the new operating illegal mining site at Sherigu. Such participants therefore proposed the intensification of educational and awareness programmes instead of enforcing stricter laws.

7.3 Ranking the scenarios according to their relative importance

Most of the key informants opted for the second, third and fourth scenarios as the positive intervention to realise a better environment in the study area. They agreed that if environmental awareness and educational programmes could be intensified that will have direct influence on conservation and preservation practices and driving forces reduction. They considered driving force reduction but were of the view that issues such as population control and migration would be difficult to control hence the importance of environmental awareness and educational programmes as the best option for the realisation of a better environment in the study area. With a few exceptions, most of the focus group participants agreed that a better

environment could be realised if the government, foremost, consider compensation measures in conjunction with environmental awareness and educational programmes and conservation practices. According to them if affected individuals and communities are compensated adequately they would then be able to consider awareness and educational programmes. Figure 7.3 illustrate the ranking of the scenarios according to their importance.

Table 7.3: Ranking of scenarios according to their relative importance

Responses scenarios	Order of importance
(1) Business as usual	6
(2) Driving force reduction	3
(3) Conservation and preservation	2
(4) Environmental awareness and educational programmes	1
(5) Environmental compensation	4
(6) Stricter law enforcement	5

Note: 1 (most important); 6 (least important)

Most of the small-scale miners, however, opted for the business as usual scenario, in view of their satisfaction with the current state of the environment. Their selection attests to the fact that most of them are not originally from the study area but have migrated to meet an immediate economic need and are not concerned about the protection of the natural environment. Table 7.3 shows the ranking of the scenarios by research participants.

7.4 Conclusion

This chapter has relied more on the participatory research aspect of the proposed assessment methodology (even though more references were made to the spatial GIS results) to evaluate participants' views on what they perceived should be done to realise a better environment. Phase 1 of the assessment methodology did not form a major part of the chapter even though participants' comments were mostly linked to the GIS and remote sensing results of Chapter 5. It therefore becomes erroneous to make a hasty conclusion that GIS spatial analysis is not relevant when conducting research on the response indicator of the DPSIR framework. The use of modelled maps prepared participants to think deeply about the spatio-temporal state of the environment that motivated them to make choices and consider what ought to be done for a better environment. Notwithstanding this bias towards the phase II of the assessment methodology, proven results were realised in this chapter as participants deliberated on options for a better environment using the results of the phase I of the assessment methodology. The major finding of the chapter was that despite the strength of each of the discussed environmental management options (with the exception of the business as usual scenario) there were no doubts that a better environment could be realised when those practices are considered simultaneously by policy makers.

Chapter 8

Reflections and Concluding Remarks

8.1 Introduction

This research presents the argument that *GIS based participatory approaches* can effectively be utilised to evaluate and assess environmental degradation under the framework of a modified DPSIR of the European Environmental Agency. In conclusion issues are presented on: (i) the presentation of the overall picture of the content of the thesis; (ii) discussion on the robustness of the proposed assessment methodology; (iii) research participants and their perception on their environment; (iv) potential use of the research findings for environmental policy formulation; (v) lessons learnt through the adoption of the proposed assessment methodology; and (vi) the proposal of possible avenues for future research. Each of these sub-topics is further elaborated in the following sections.

8.2 The overall picture: assessment of environmental degradation in northern Ghana using GIS based participatory approach

This study on “*Assessment of environmental degradation in northern Ghana: GIS based participatory approach*” was conducted in the Bolgatanga and Talensi-Nabdam districts of northern Ghana where the state of the natural environment is perceived to have undergone complex spatio-temporal ecological transformation, through natural, social, economic and cultural processes. The primary aim of the research was to investigate the potential for the integration of local ecological knowledge and scientific GIS techniques to assess the complexity of environmental degradation. To achieve that aim, three related studies were critically reviewed to identify common themes and potential gaps after which the proposed

assessment methodology was designed. The proposed assessment methodology was then structured using two distinctive but complementary techniques and of two phases: (i) use of conventional GIS to assess where degradation has taken place and the nature in terms of the extent and magnitude; and (ii) the use of community truthing (GIS in participatory research approach) to evaluate the causes of such changes, the impacts and coping strategies. The assessment methodology designed was tested for its robustness in the Bolgatanga and Talensi-Nabdam districts of northern Ghana.

For data collection and analysis the study relied on both the primary and secondary sources. The primary data included already geo-rectified 30m resolution remote sensing data images of three different scenes and GPS ground truthing for assessing the accuracy of the classified satellite images. Participatory research (community truthing) data were solicited from the study community with the purpose of enriching the image data in relation to with social issues. This was achieved through semi-structured key informant interviews, group discussions, and direct researcher observation. Figure 8.1 is the summary results of the adoption of the proposed assessment methodology at Bolgatanga and Talensi-Nabdam districts of northern Ghana.

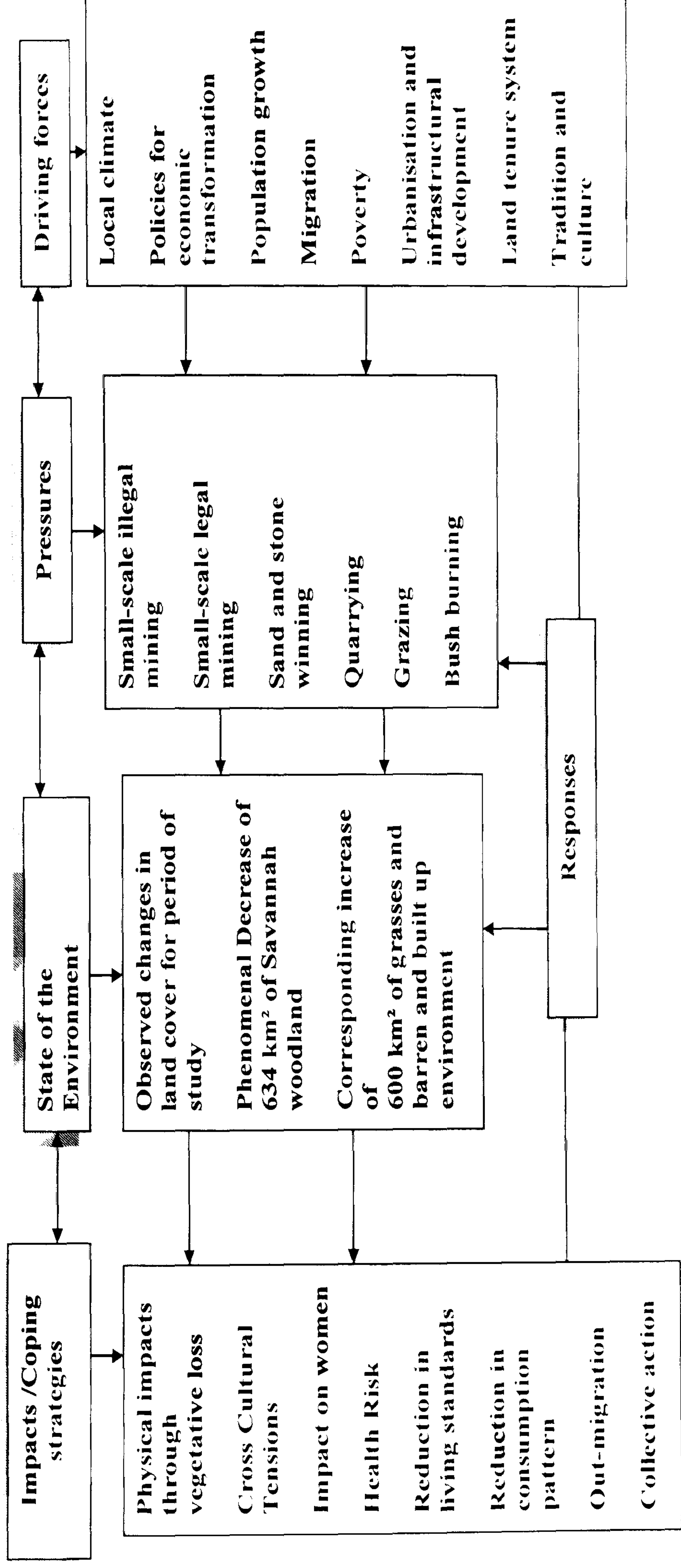


Figure 8.1: Generalised results of study

8.3 Discussions on the robustness of the proposed assessment methodology

The robustness of the assessment methodology is evaluated based on the extent on how the research questions, stated in section 1.4 of chapter 1, are appropriately answered.

Research 1 question was “To what extent is the environment of Bolgatanga and Talensi-Nabdam districts been degraded since 1990, how severe is the degradation in terms of potential rate of recovery and which areas in the two districts are mostly affected?”

In chapter 5, it was demonstrated that conventional GIS, as an assessment tool, offered a platform through which different sets of spatially referenced data were assembled, analysed and represented for understanding of spatio-temporal analysis of land-cover changes in the study area. The adoption of conventional GIS, as part of the assessment methodology, helped to produce important factual information based on what has actually happened to the natural environment of the study area over the 14 year period of study. It became clear in the chapter that there have been phenomenal land-cover changes which have been manifest in the decline of 634 km² savannah vegetative woodland with corresponding increase of 208 km² of dense herb and various grasses and increase of 392 km² built-up and barren environment, all of which symptoms of environmental degradation. The degradation was severe in the Bolgatanga Township, Sherigu, Nangodi, Duusi and Pwalugu where there are many human activities taking place as well as infrastructural developments. Research participants believed in the evidence of ecological regeneration under good environmental management practices.

Through the community truthing exercise, research participants were given the opportunity (relying on PGIS philosophy) to comment on the nature and characteristics of environmental degradation in their area with the aid of image maps. This helped participants to focus attention on issues presented as they rely on the image maps to discuss the nature and causes of environmental degradation in the study area. It was noted that without the provision of classified images and GIS statistics, issues raised by participants would not have truly reflected what is actually happening to the environment. The participatory exercises also helped participants to contribute to the spatial distribution of land-cover type changes in the

study area for the period of study, identify tree types and grass species that have been depleted and the probable causes identify and locate areas of land uses and their contributions to the observed environmental changes. The results obtained demonstrated how the adoption of the proposed assessment methodology helped map out the spatio-temporal changes on the environment of the study area to answer research question 1.

Research question 2 was “What socio-economic and cultural forces usually motivate individuals to take up activities that put pressures on the environment beyond its carrying capacities and how are they interrelated, spatially distributed and ranked in terms of their relative importance?”

Here the question was the identification and locations of various land uses in the study area perceived to have contributed directly to the observed changes to the environment. GPS field exercises and community truthing, as part of the proposed methodology, were used to map out various land uses in the study area. Results obtained through the adoption of the assessment methodology included the following: (i) the existence of small-scale illegal surface mining near Nangodi and Sherigu of spatial extent of 258 km²; (ii) the existence of small-scale legal underground mining near Duusi of spatial extent of 82 km²; (iii) the existence of quarrying and sand wining sites near Pwalugu and Kongo of spatial extent of 27.4 km²; (iv) the lack of spatial extent of grazing, bush burning and cultivation sites were due to the difficulty in defining their boundaries within the study area; and (v) the complex interplay of the various pressures and the dominance of the small-scale illegal mining industry resulting from a shift from the other informal sectors of the local economy in recent years.

As indicated in Figure 8.1, participants pointed out that forces such as harsh climatic conditions, policies for economic transformation, population growth, migration, land tenure system, poverty, urbanisation and infrastructural development and community level institutions were the main social processes that have directly and/or indirectly contributed to the observed changes on the environment. Even though participants commented on the interrelationships of the driving forces, most of them were of the opinion that the observed

changes in the environment in area are due mostly to poverty which is endemic in the three northern regions. The results of part of chapters 5 and 6 thus demonstrate the robustness of the designed methodology for assessing the pressures and driving forces of environmental degradation.

Research question 3 was “What are some of the negative outcomes of the observed environmental degradation in the study area in terms of the physical, social and cultural impacts, how severe are the impacts, how are they spatially distributed, ranked and which groups are mostly affected?”.

Using the Bolgatanga and Talensi-Nabdam districts as case study, phase II of the proposed assessment methodology was used to assess the impacts of the observed land-cover changes and subsequently evaluate the affected communities' coping strategies. Results (Figure 8.1) indicated that the impacts associated with the observed land-cover changes were vegetative loss, cross-cultural tensions, and impact on women, health risk, and reduction in living standard. Spatially, loss of vegetative cover, health risks, impact on women and cross cultural tensions is found within the small-scale mining areas of Duusi, Nangodi and Sherigu. Loss of vegetative cover, food scarcity and health risks are also predominant in the Tongo and Pwalugu areas where they are noted for quarrying and stone cracking activities. In the urban areas of Bolgatanga, Zuarungu and Kombosigo, there are observed problems of cross cultural tensions, food scarcity and poor living standards. According to participants, food scarcity has been the major problem in the study area due to the constant deterioration of the environment. It was observed that women are the ones affected most as tradition demand them to stay home to care for the family as their male counterparts migrate to other places in search of jobs. It is worth noting that, despite the bias towards the participatory research aspect of the designed methodology, results indicated the suitability of the methodology to assess the impacts and coping strategies of an environmentally degraded community such as the Bolgatanga and Talensi-Nabdam districts of northern Ghana.

Research question 4 was: How are the affected communities coping with the observed changes on the environment?"

It was revealed that most community members have adopted several means to cope with the harsh environmental conditions. As commented by participants, reducing consumption pattern, alternative source of livelihood, migration, collective action and acculturation are the identified means through which community members are coping with the environmental stress. Spatially, acculturation, migration, alternative source of livelihood and reducing consumption pattern are more pronounced in the small-scale mining communities (Nangodi, Duusi and Sherigu) while collective action and alternative source of livelihoods are common coping strategies in the urban Bolgatanga area. According to research participants, reduction in consumption pattern is the commonest coping strategy followed by alternative source of employment.

Research question 5 was: What are the possible responses to alter the impacts of stresses on the environment and what are their relative importances?

Notwithstanding the bias towards the participatory research (community truthing) aspect of the proposed assessment methodology, it was realised that local people, when given the opportunity, are able to contribute effectively towards the realisation of a better environment of an environmental degraded area. These were manifested in the results of chapter 7 where participants deliberated most effectively on desired management practices for a better environment and proposed that for the realisation of a better environment decision makers should intensify their efforts in educating the public through various environmental awareness programmes. Most of the participants, especially key informants, opted for environmental awareness, conservation and preservation and driving forces reduction. With a few exception, most of the focus group participants agreed that a better environment could be realised if the government, foremost, consider compensation measures in conjunction with environmental awareness and educational programmes and conservation practices. As they explained further,

if affected individuals and communities are compensated adequately they would then be able to consider awareness and educational programmes.

The above detailed answers to the stated research questions were realised based on the fact that the proposed assessment methodology helped bridge the differences among participants by transforming the independent and abstract thoughts of participants into concrete real issues and has provided the means through which participants can understand issues of environmental problems in their various communities and respond with solutions for a healthier environment. This was possible because the methodology provided a framework within which participants were encouraged to participate in discussions on issues of their environment. We, therefore, conclude that the GIS based participatory approach, designed in this thesis, opened up paths for dealing with important spatial and social issues of relevance to environmental degradation that would not have come into focus if conventional GIS were not integrated with local ecological knowledge.

8.4 Research participants and their perception of their natural environment

This study, among others, demonstrated the value research participants attach to their natural environment. It was revealed, during interviews and focus group discussions, that most of the research participants were quite knowledgeable on matters relating to their immediate environment and prepared to share ideas on the nature and causes of environmental degradation and what ought to be done to realise a better environment. All the key informants and focus group participants who took part in the interviews and discussions appreciated that their environment had, over the years, deteriorated and attributed that not only to the prevailing harsh climatic conditions, but also to various identified social driving forces and human activities that have continuously exerted pressures beyond the carrying capacity of the environment.

An interesting aspect of the findings was that as most of key informants attributed the cause of the observed environmental changes to indirect causes such as economic policies, mining

and mineral policies and migration; most focus group participants attributed the problem to poverty and attitudinal changes. Other inconsistencies observed were the differences in opinions among the key informants concerning the promulgation of the Mining and Mineral law (PNDCL 153). As most of the key informants attributed the influx of migrant workers to the legalisation of the small-scale mining (PNDCL 153), others were of the opinion that the influx has nothing to do with the PNDCL 153 but as a result of current infrastructural development in the region. Most of the focus group participants, with the exception of the small-scale miners, regarded the environment as their own entity and attributed the observed changes on the environment to poverty, attitudinal changes and migration.

8.5 Clues for future users of the assessment methodology

Based on the findings of this research, it is reasonable to recommend that the successful utilisation of the research methodology for environmental degradation assessment should take note of the following during its application in other similar degraded environments.

1. The adoption of methodological triangulation through the integration of conventional GIS and local knowledge to assess areas where degradation has taken place and the causes for the observed degradation. This is important as both conventional GIS and local knowledge have their limitations. As concluded by Stringer and Reed (2007), local knowledge is primarily based on contextual analysis and their social characteristics usually lead to inaccurate accounts of the extent and magnitude of environmental degradation. This highlights the value of a validation process through triangulation of quantitative GIS data with more qualitative approaches to achieve the aim of the study.
2. Restriction to level I of the referenced vegetative classification scheme designed by Agyepong *et al.* (1996), modified from Anderson *et al.* (1976), with the aim of empowering local people to do further classifications and add social meanings to the observed cover type changes.

3. Quantitative assessment of the results of classified images through ground truthing (Moufaddel, 2005; Mas, 1999; Congalton, 1996) before community truthing. The overall accuracy should not be less than 50% to assure oneself of the quality of the satellite images and the distinct characteristics of the land-cover types obtained using the unsupervised classification techniques.
4. The recognition of a sampling procedure that cuts across different social groups and are experts in environmental and social related issues (Cameroon, 2000) (e.g. farmers, women, youth, miners and key informants). It is evident from this study that participants sampled from different social groups helped bridge abstract thoughts into issues of relevance in environmental degradation assessment. This aspect of the research methodology contradicts many PGIS research methodologies where few homogenous individuals are selected for interviews and group discussions.
5. The separation of participants of different socio-cultural backgrounds. This is very useful in geographical settings where socio-cultural barriers prevent bringing people from different social backgrounds to come together for deliberations on issues of relevance.
6. While the commitment of research participants is important for the realisation of good results, winning that commitment initially depends on community entry protocol and the observation of all socio-cultural formalities pertaining to the area to be studied.
7. The recognition of participants' contributions to spatial data. As asserted by Kyem (1998) the successful implementation and application of PGIS research depends upon the commitment of the researcher to use the tool to empower local people through the learning of scientific techniques of GIS participatory mapping. This study deviated from that assertion as participants were not envisaged to learn any scientific techniques but rather to participate in the review of already prepared GIS results through the discussion of social issues.
8. Community truthing exercise should be preceded by detailed explanation of the content of the classified images and topographic maps by the researcher to the participants before

they are allowed to review and comment. This gives assurance to participants that the maps presented to them are actually what have happened to their own environment.

9. The successful outcome of the proposed methodology GIS for environmental degradation assessment must incorporate representations of both facts and subjective judgments. As noted by Kyem (1998) that researchers attempting to introduce GIS into rural and peripheral communities have to take into consideration the representation of value judgements in a technology that draws its strengths from the depiction of empirical facts.

8.6 Clues for policy makers on the use of the research findings

This section elaborates how policy makers can make use the results of the *GIS based participatory approach* for environmental degradation assessment as summarised in Figure

8.1. Potential uses can include the following:

- the GIS statistical results obtained from this study can be used to substantiate claims of the current threat of environmental degradation in the study area and use that to formulate plans and policies for achieving a healthier environment;
- the information gathered can also help decision makers to know the socio-cultural implications of environmental problems and take more holistic steps in solving them;
- the responses from participants, concerning possible scenarios for a better environment, can be used to amend the content of NEAP of the Environmental Protection Agency Act 490 which has failed to provide the framework for ensuring better management of environmental resources and for addressing how natural resources are exploited;
- the PNDCL 153 that tends to legalise, unreservedly, the activities of small-scale mining, in the country could be amended based on the findings of this study. The case of illegal small-scale mining in the study area serves as an example of how environmental regulations and laws, regardless of how good they are on paper, fail to stop mining degradation and can leave communities more vulnerable than before;
- the findings of the study will help policy makers to come to the realisation that a healthier environment cannot be achieved without adequate involvement of local

people who are agents and sufferers of environmental problems. This is important as environmental protection depends not only on government policies and regulations but the people who live in the environment, depend on natural resources for sustenance and expect benefits from it;

- in formulating environmental policies, decision makers should not completely discard traditional environmental management practices but should see how such practices could be effectively utilised with scientific management practices to realise a greener environment;
- the support of cross-communication processes within government departments and environment-related agencies to ensure that environmental legislation be streamlined rather than maintaining sectoral categories, would reduce the potential for contradictory environmental management processes as in the case of the study area; and
- the findings also demystify the preconceived notion that local people are not knowledgeable on issues pertaining to their natural environment. The results of the thesis thus expose how knowledgeable local people are on issues of the environment and the need to tap such resources for policy formulation.

8.7 Shortcomings and recommendation for future research

Even as this thesis aimed at developing a general methodology for assessing environmental degradation using the DPSIR framework, which has so far been achieved, there still remain aspects for future research.

One of the core aims of PGIS is the gathering of dissimilar views through an interactive setting (community forum) to help identify areas of potential consensus and contentions between communities members while at the same time retaining the uniqueness of each participant's perspectives (Abbot *et al.*, 1998; Craig *et al.*, 2002). This was an issue that came out during questions time at one of my conference presentation (participatory GIS section of

RGS-IBG in London, 2006). As hard as it was to incorporate that into the research methodology, it became impossible to test its robustness in the study area. This was due to the socio-cultural and political settings of the area that makes it difficult to gather together people from different socio-cultural backgrounds for deliberations. Despite the fact it did not significantly affect the results of this thesis, it is recommended that future use of the research methodology should, if possible, integrate community forum, as part of the participatory research tools, to deliberate on all issues raised during interviews and discussion to reach consensus.

The research methodology developed and adopted in this thesis was limited to spatial and social processes. What was not considered was the scientific investigation into the toxicological and ecotoxicological processes. However, as environmental degradation assessment transcends the spatial and social processes, the inclusion of toxicological and ecotoxicological processes will highlight the negative effects of environmental degradation on humans. Arguably, if participation is seen as a benchmark for assessing rural environmental problems, as evidence in PGIS philosophy, the question one may ask is what additional PRA tools could be utilized to involve local people in evaluating bio-chemical effects of environmental degradation. A dialogue needs to be established among PGIS researchers as to how best local people could be empowered to contribute to purely scientific issues of environmental degradation. This is a challenge to my critics.

8.8 Concluding remarks

The assessment methodology developed and tested in this thesis highlight the importance of using contextual analysis and scientific evidence to assess environmental degradation. Results explored indicated that by integrating local ecological knowledge and conventional GIS within the framework of DPSIR, detailed understanding of the causes, effects and spatial distribution of environmental degradation could be achieved as well as responses for a healthier environment. This became clear, in this thesis, as the state of the environment was assessed as well as the social processes (driving forces) that motivate individuals to take on activities that exert pressures on the environment beyond its carrying capacity. The approach also evaluated the impacts and coping mechanisms that resulted from the change on the environment. Using the assessment methodology, research participants were able to deliberate extensively on what ought to be done to realise a better environment. This thesis thus demonstrates the importance of “*GIS based participatory approaches*” for assessing environmental degradation which has been tested for its robustness at Bolgatanga and Talensi-Nabdam districts of northern Ghana.

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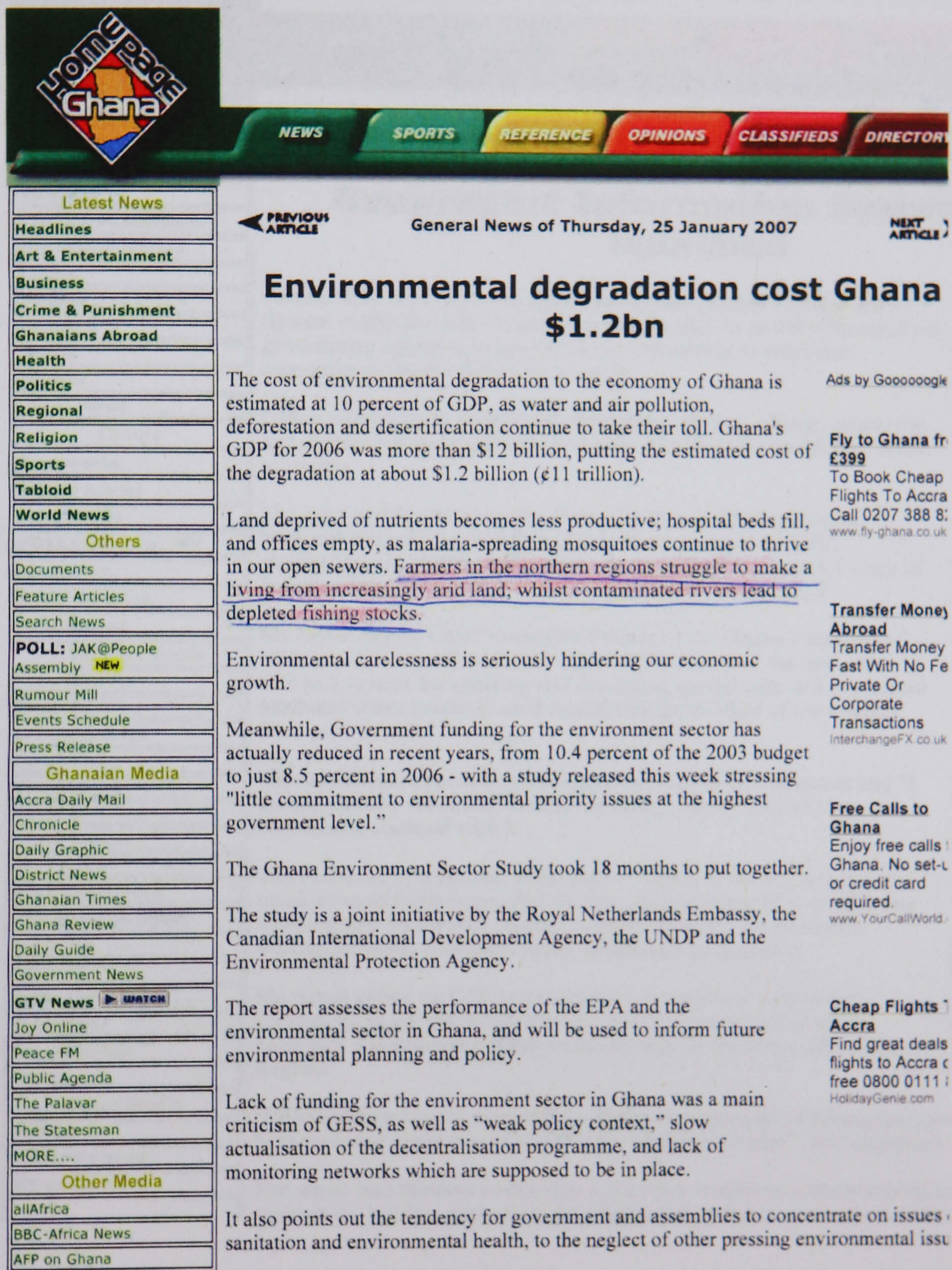
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List of Appendices

Appendix 1.1: Environmental cost to the economy of Ghana

General News of Thursday, 25 January 2007



The screenshot shows a news website interface. At the top left is a logo for 'Ghana' with a map of the country. Below the logo is a navigation bar with buttons for 'NEWS', 'SPORTS', 'REFERENCE', 'OPINIONS', 'CLASSIFIEDS', and 'DIRECTORY'. On the left side, there is a vertical menu with categories like 'Latest News', 'Headlines', 'Art & Entertainment', 'Business', 'Crime & Punishment', 'Ghanaians Abroad', 'Health', 'Politics', 'Regional', 'Religion', 'Sports', 'Tabloid', 'World News', 'Others', 'Documents', 'Feature Articles', 'Search News', 'POLL: JAK@People Assembly NEW', 'Rumour Mill', 'Events Schedule', 'Press Release', 'Ghanaian Media', 'Accra Daily Mail', 'Chronicle', 'Daily Graphic', 'District News', 'Ghanaian Times', 'Ghana Review', 'Daily Guide', 'Government News', 'GTV News WATCH', 'Joy Online', 'Peace FM', 'Public Agenda', 'The Palavar', 'The Statesman', 'MORE...', 'Other Media', 'allAfrica', 'BBC-Africa News', and 'AFP on Ghana'. The main content area displays a news article titled 'Environmental degradation cost Ghana \$1.2bn' dated Thursday, 25 January 2007. The article text discusses the economic impact of environmental degradation, mentioning that it costs 10% of GDP and that the government has reduced funding for the environment sector. To the right of the article, there are several advertisements, including one for flights to Ghana, one for money transfer services, one for free calls to Ghana, and one for cheap flights to Accra.

Environmental degradation cost Ghana \$1.2bn

The cost of environmental degradation to the economy of Ghana is estimated at 10 percent of GDP, as water and air pollution, deforestation and desertification continue to take their toll. Ghana's GDP for 2006 was more than \$12 billion, putting the estimated cost of the degradation at about \$1.2 billion (£11 trillion).

Land deprived of nutrients becomes less productive; hospital beds fill, and offices empty, as malaria-spreading mosquitoes continue to thrive in our open sewers. Farmers in the northern regions struggle to make a living from increasingly arid land; whilst contaminated rivers lead to depleted fishing stocks.

Environmental carelessness is seriously hindering our economic growth.

Meanwhile, Government funding for the environment sector has actually reduced in recent years, from 10.4 percent of the 2003 budget to just 8.5 percent in 2006 - with a study released this week stressing "little commitment to environmental priority issues at the highest government level."

The Ghana Environment Sector Study took 18 months to put together. The study is a joint initiative by the Royal Netherlands Embassy, the Canadian International Development Agency, the UNDP and the Environmental Protection Agency.

The report assesses the performance of the EPA and the environmental sector in Ghana, and will be used to inform future environmental planning and policy.

Lack of funding for the environment sector in Ghana was a main criticism of GESS, as well as "weak policy context," slow actualisation of the decentralisation programme, and lack of monitoring networks which are supposed to be in place.

It also points out the tendency for government and assemblies to concentrate on issues of sanitation and environmental health, to the neglect of other pressing environmental issues.

Ads by Goooooogle

Fly to Ghana from £399
To Book Cheap Flights To Accra
Call 0207 388 8...
www.fly-ghana.co.uk


Transfer Money Abroad
Transfer Money Fast With No Fees
Private Or Corporate Transactions
InterchangeFX.co.uk

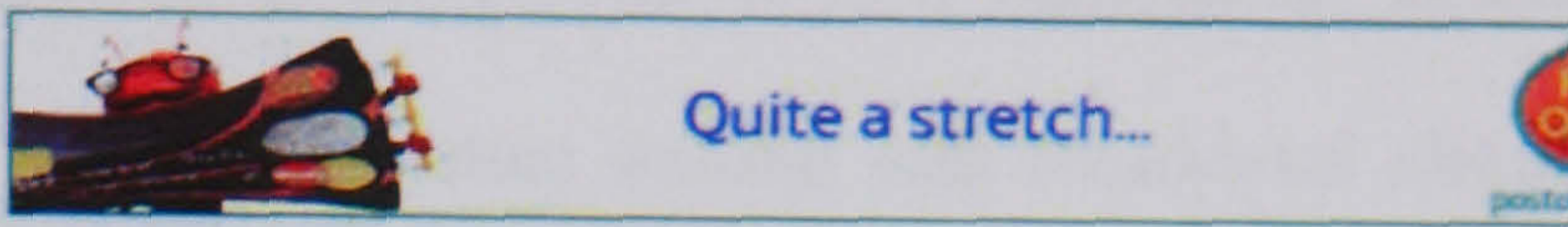
Free Calls to Ghana
Enjoy free calls to Ghana. No set-up or credit card required.
www.YourCallWorld.com

Cheap Flights to Accra
Find great deals on flights to Accra
free 0800 0111...
HolidayGenie.com

Appendix 1.2: GIS in Ghana

Regional News of Wednesday, 15 November 2006





NEWS
SPORTS
REFERENCE
OPINIONS
CLASSIFIEDS

Latest News

Headlines

Art & Entertainment

Business

Crime & Punishment

Ghanaians Abroad

Health

Politics

Regional

Sports

Tabloid

World News

Others

Documents

Feature Articles

Search News

POLL: NPP Govt NEW

Rumour Mill

Events Schedule

Press Release

Ghanaian Media

Accra Daily Mail

Chronicle

Crusading Guide

Daily Graphic

District News

Ghanaian Times

Ghana Review

Daily Guide

Government News

GTV News ▶ WATCH

Joy Online

Peace FM

Public Agenda

The Palavar

The Statesman

MORE....

Other Media

allAfrica

BBC-Africa News

AFP on Ghana

◀ PREVIOUS ARTICLE
Regional News of Wednesday, 15 November 2006

Geographic Information System launched

Accra, Nov. 15, GNA - An international Geographic Information System (GIS) day was launched on Wednesday in Accra with a call on government agencies to use GIS tools effectively to solve the numerous problems facing the country.

GIS is a technology capable of integrating, storing, editing, analyzing and displaying geographically referenced information, which is useful to society.

The day, which was under the theme "Towards the Creation of National Knowledge GIS Database", was organized by GIS stakeholders in collaboration with Ghana-India Kofi Annan Centre of Excellence in Information Communication and Technology.

Ms Joyce Aryee, Chief Executive Officer of the Ghana Chamber of Mines, made the call when she chaired the launch of the day and said GIS as a system for creating and managing spatial data and associated attributes when properly used would change the face of the country from poor to rich.

She said Ghana abounded in rich natural and human resources and "I do not see why we should be experiencing poverty and all the problems associated with it".

The existence of a reliable information system is the key to planning resource mobilization and distribution; management of a country and its resources, its security, border control, banking, construction, mining, housing, communication, health and governance.

Ms Aryee called on GIS practitioners to collaborate with other institutions to use the available resources to maximize the socio-economic development of the nation as well as the West Africa Sub-Region.

"Collaboration is very essential for better management of information and help each and every one of us to know what role to play", she explained.

She urged practitioners to develop a map that would translate planning in agriculture, mining, real estate development and forest resources for better

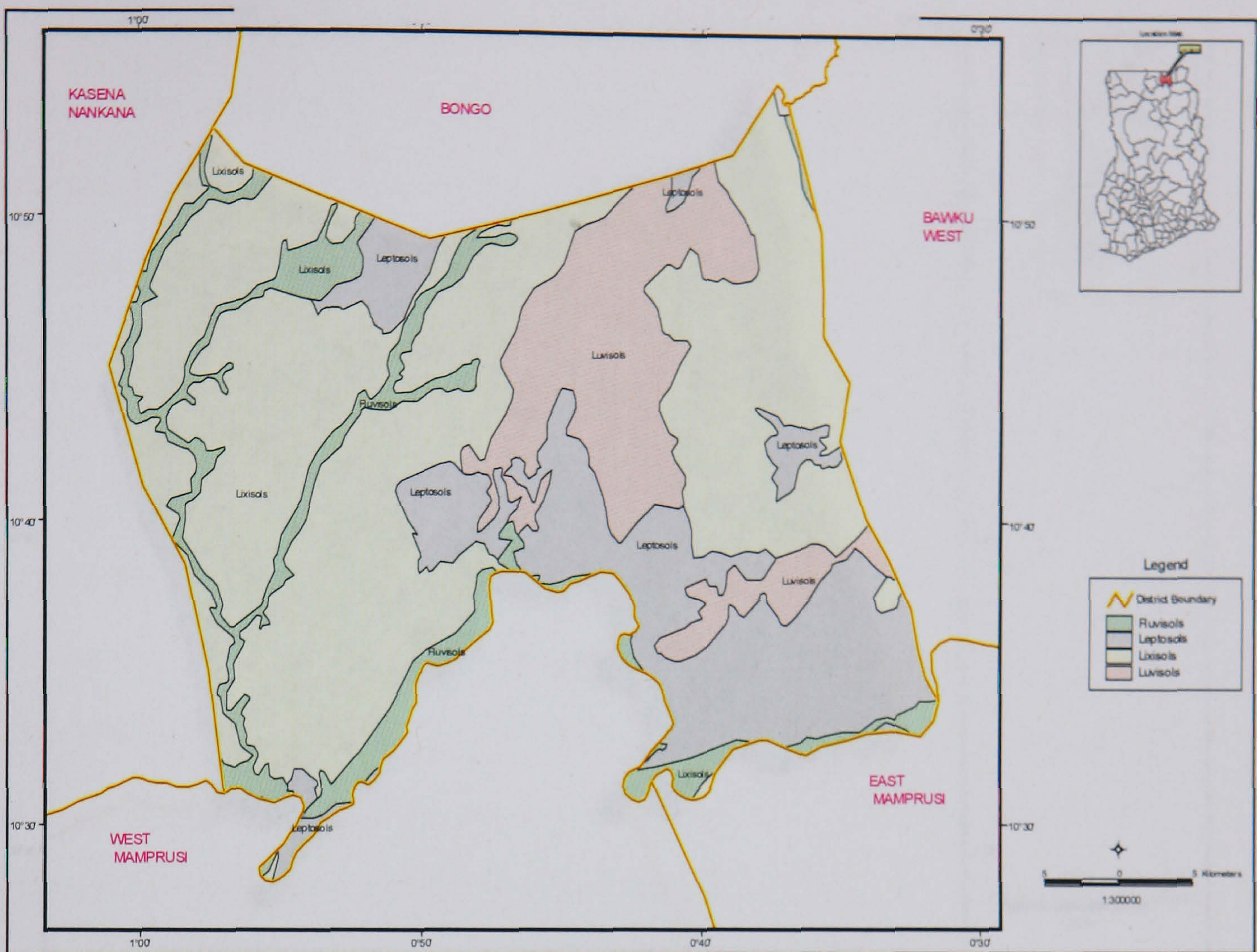
Appendix 3.1: Land-cover classification scheme in Ghana

The land-cover and land-use classification system for Ghana (Agyepong *et al.* 1996) was prepared from that of Anderson *et al.* (1976). It is a hierarchical structure in that it accommodates different levels of information starting with broad-level classes. It has been structured to allow further sub-division into more detailed sub-classes at higher levels. Four levels are recognised with the first two levels corresponding to land-cover categories and the third and fourth levels to land use categories as defined as follows:

LEVELS	DESCRIPTION
Level I	Principal vegetative and non-vegetative Land cover
Level II	Sub-categories of the principal vegetative cover defined in terms of formation characteristics, of canopy closure, tree stand density and dominant life form
Level III	Land-use defined in terms of major environmental management systems
Level IV	Land-use categories defined in terms of products and services

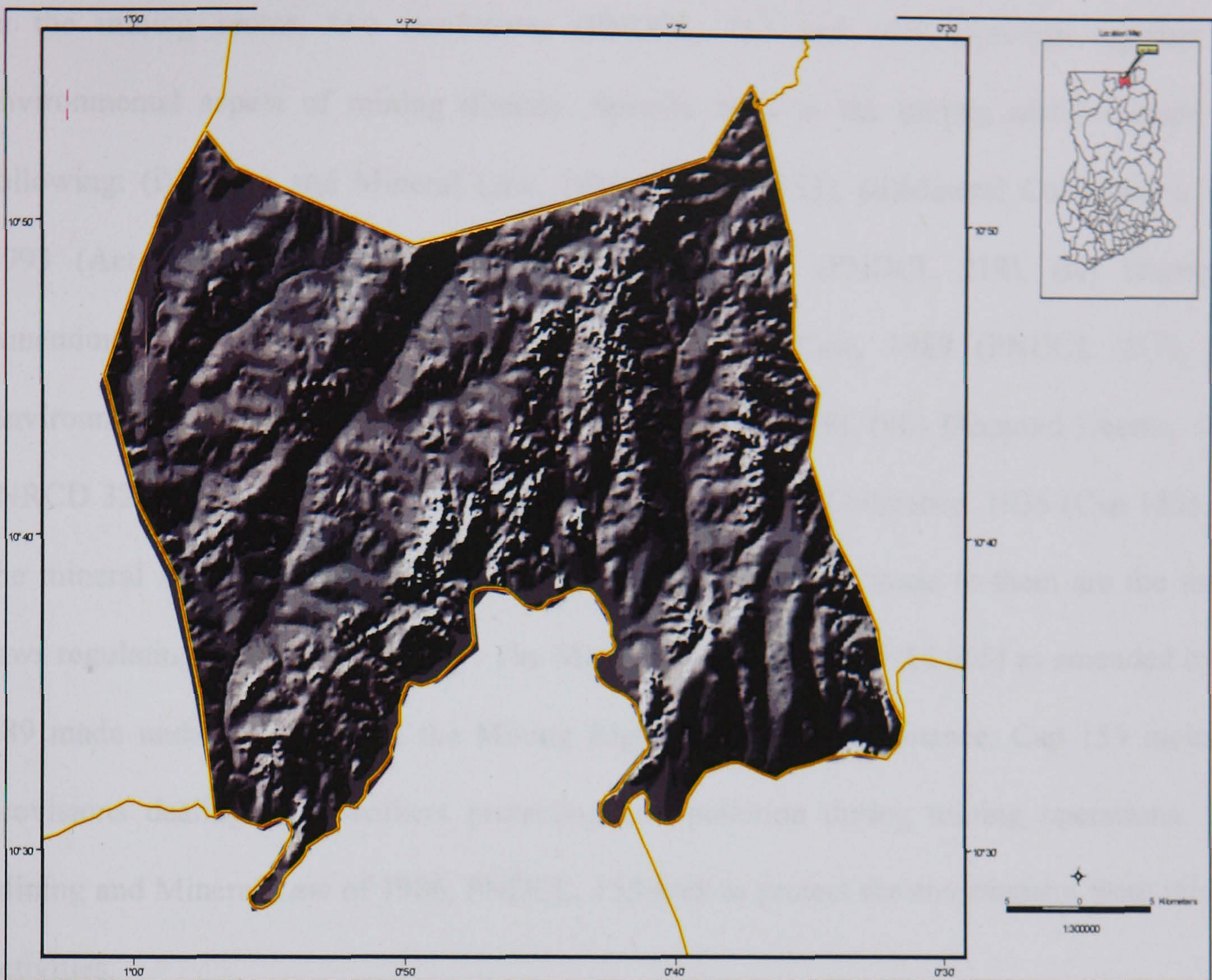
Source: Duadze (2003) cited from Agyepong *et al.* (1996).

Appendix 4.1: Soil map of Bolgatanga, Talensi-Nabdam district



Source: CERSGIS (2005)

Appendix 4.2: Digital Elevation Model map of Bolgatanga and Talensi-Nabdam districts



Source: CERSGIS (2005)

Appendix 4.3: Environmental policy, legislation and implementing institutions in Ghana

In the mining sector, two enactments (PNDCL 153 and 165) currently regulate the environmental aspect of mining directly. Specific laws in the mining sector include the following: (i) Mining and Mineral Law, 1986 (PNDCL 153), (ii) Mineral Commission Act, 1993 (Act 450), (iii) Small-Scale Mining Law, 1989 (PNDCL 218), (iv) Diamonds Amendment Law, 1989 (PNDCL 217), (v) Mercury Law, 1989 (PNDCL 217), (vi) Environmental Protection Council Decree, 1974 (NRCD 239), (vii) Diamond Decree, 1972 (NRCD 32), (viii) Additional Profit Tax, 1985. The Mineral Ordinance, 1936 (Cap 185) and the mineral Act, 1962 (Act 126) and the various amendments made to them are the major laws regulating the mining industry. The Mining Regulation 1970 (LI 665) as amended by LI 689 made under section II of the Mining Rights Regulation Ordinance, Cap 153 included provisions dealing with workers protecting and pollution during mining operations. The Mining and Mineral Law of 1986, PNDCL, 153 seek to protect the environment from mining activities.

Mining and Mineral Law (PNDCL 153 of 1986, section 70 (1) and (3) and 71(1) which stipulate the following:

- (a) The holder of a mineral right shall exercise his rights under this Law subject to such limitations relating to surface rights as the Secretary may prescribe.
- (b) The rights conferred by a mineral right shall be exercised in a manner consistent with the reasonable and proper conduct of the operations concerned, so as to affect as little as possible the interest of any lawful occupier of the land in respect of which such rights are exercised.
- (c) The lawful occupier of any land within an area subject to a mineral right shall retain the right to graze livestock upon or to cultivate the surface of such land in so far as such grazing or cultivation does not interfere with the mineral operations in the area.

(d) The owner or occupier of any land subject to a mineral right may apply to the holder of the right for compensation for any disturbance of the rights of such owner and for any damage done to the surface of the land, buildings, works or improvements or to live stock, crops or trees in the area of such mineral operations.

Environmental Implementing Institutions in Ghana

The Environmental Protection Act 490 transformed the Environmental Protection Council to Environmental Agency (EPA) in 1994 with legal and enforcement roles and the ability to prosecute environmental offenders. The EPA is responsible for ensuring environmental impact assessment of all projects with serious adverse effects on the environment. Other institutions involved in the protection of the environment in Ghana include: Ministry of Lands, Mines and Forestry, Ministry of Food and Agriculture, Ministry of Environment, Science and Rural Development, District Assemblies, Ministry of Energy and the Ministry of Trade and Industry. Many Non-Governmental Organisations (NGOs) are currently registered with the Environmental Protection Agency. The NGOs have formed networks such as NENGO (Network of Environmental Non Governmental Organisation, 1993) and NUENGO (National Union of Environmental NGOs, 1994). Major activities of the NGOs include the following: establishment of agro-forestry, nursery and tree planting, environmental education and communication through seminars and workshops, publishing magazines, pamphlets and hand bills news on the environment, afforestation and wildlife conservation, water, sanitation, health and clean-up campaigns. Green Earth Organisation, Ghana Wildlife Society, Friends of the National Zoo, Friends of the Earth, National Conservation Research Centre, Ghana Heritage Conservation Trust, CARE International, World Vision International, Friends of Animals, Tehnoserve are some leading NGOs in Ghana (Acquah, 1992; EPA, 1995)

Appendix 4.4: Introductory Letter from the School of Geography, University of Leeds



From the Earth and Environment Faculty

University of Leeds
Leeds LS2 9JT

☎ : 0113 343 3344
☎ : 0113 343 3306
mobile : 07901 821418
email: a.t.mcdonald@leeds.ac.uk

Tuesday, January 10, 2006

To Whom It May Concern

The bearer of this letter is **Isaac Agyemang** who is a Doctoral Researcher with the University of Leeds on secondment from the University for Development Studies, Ghana.

Isaac is working on the important topic of:

“The assessment of environmental degradation in Ghana and the use of participatory GIS as a tool in such assessments.”

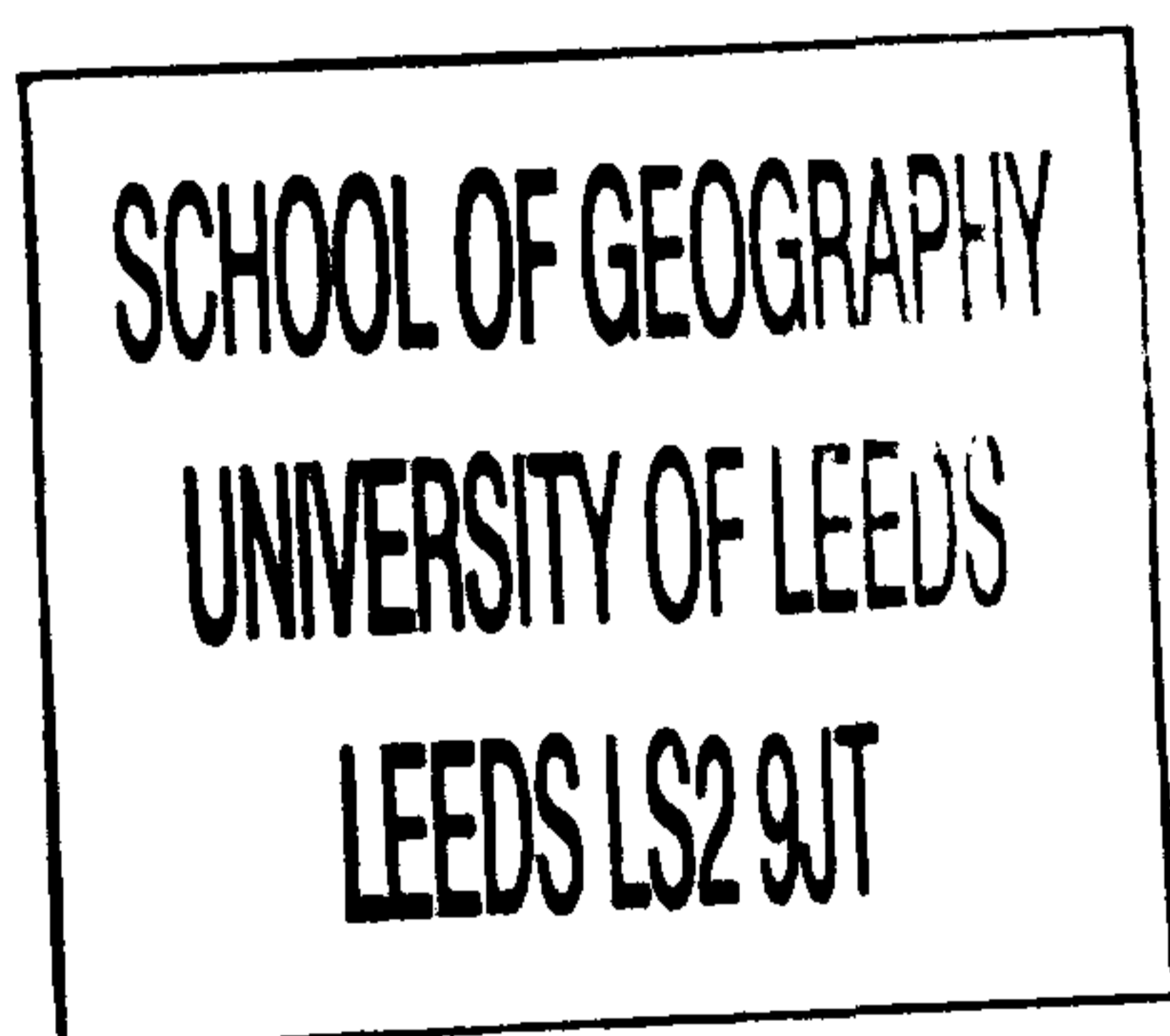
I would be most grateful if you could offer Mr Agyemang such help and support as is required and requested. If you have any queries please feel free to contact me directly by phone or email.

Yours Faithfully,

A handwritten signature in black ink, appearing to read 'Adrian McDonald'.

Professor Adrian McDonald

Direct phone: 44(0) 113 343 3344
Email: a.t.mcdonald@leeds.ac.uk



Professor Adrian McDonald
Professor of Environmental Management

Appendix 4.5: Dates, time and locations of interviews and discussions

Participants	Date of interview	Time of interview	Location of interview
Environmental Protection Agency	26 th February 2006	11.30am-1.00pm	Agency Office
Mineral Commission	27 th February 2006	9.30am-10.30pm	Commission Office
Lands Commission	28 th February 2006	4.30pm-5.30pm	Commission Office
Regional House of Chiefs	2 nd March 2006	8.30am-10.15am	Regional Office
Talensi-Nabdam District	4 th March 2006	9.15am-11.00am	District Assembly
Bolgatanga Municipal Assembly	8 th March 2006	9.30am-11.30am	Municipal Assembly
Regional Surveying Department	11 th March 2006	8.00am-9.00am	Department Office
Regional Coordinating Council	11 th March 2006	2.00pm-3.00pm	Regional Coordinating Council
Concern Youth Group	15 th March 2006	11.00am-12.30pm	Bolgatanga Sand Gardens
Women Association	17 th March 2006	11.30am-12.15pm	BOGIS Bolgatanga
Farmers Association	18 th March, 2006	12.30pm-1.30pm	Zuarungu Secondary School
Heterogeneous Community Focus Group	19 th March 2006	12.30pm-1.30pm	SNNIT House Bolgatanga
Heterogeneous Organisation Focus Group	21 st March 2006	4.15pm-5.30pm	SNNIT House Bolgatanga
Representatives Pwalugu and Tongo	22 nd March 2006	6.00pm-7.15pm	Tongo District Assembly
Small-scale legal miners	24 th March 2006	10.00am-11.20am	Duusi Mining site
Small-scale illegal miners	2006 th March 2006	10.15am-11.30am	Nangodi Mining site

Appendix 4.6: Interviews and Discussions Guide

Key informant/Focus group.....
Date of interview/discussion.....
Number of respondents.....
Location and time of interview.....
Interviewee.....
Mode of recording.....

With reference to the classified image maps:

- What is your view or opinion concerning the nature and extent of environmental degradation in this area? (Probe into the spatio-temporal distribution of land-cover changes and tree and grasses depletion)

.....
.....
.....

- What do you think are major causes of environmental degradation in this area (probe into direct and indirect causes, their relative importance and interrelationships.....)

.....
.....
.....

- What are the effects of the observed degradation on the environment (probe into the physical and social impacts, their interrelationship and relative importance).....

.....
.....
.....

- Which group of people do you think suffer most as a result of the observed environmental degradation? (Probe into gender disparity in the study area)

.....
.....
.....

- Which group of people do you think contribute most to environmental degradation in this area? (Probe into the main agents of environmental degradation in the area)

.....
.....

- How are the affected individuals and communities coping with the stress of environmental degradation? Which of the coping mechanism is usually practice?

.....
.....
.....

- What are the possible interventions to realise a better environment? (consider and deliberate on these scenarios)

- (i) business as usual
- (ii) driving force reduction
- (iii) environmental awareness and educational programmes
- (iv) conservation and preservation practices
- (v) environmental compensation
- (vi) stricter law enforcement

(Probe into the most effective scenario)

- Which way do you think the community as a whole can be encouraged to go into environmental conservation and preservation?

.....
.....
.....

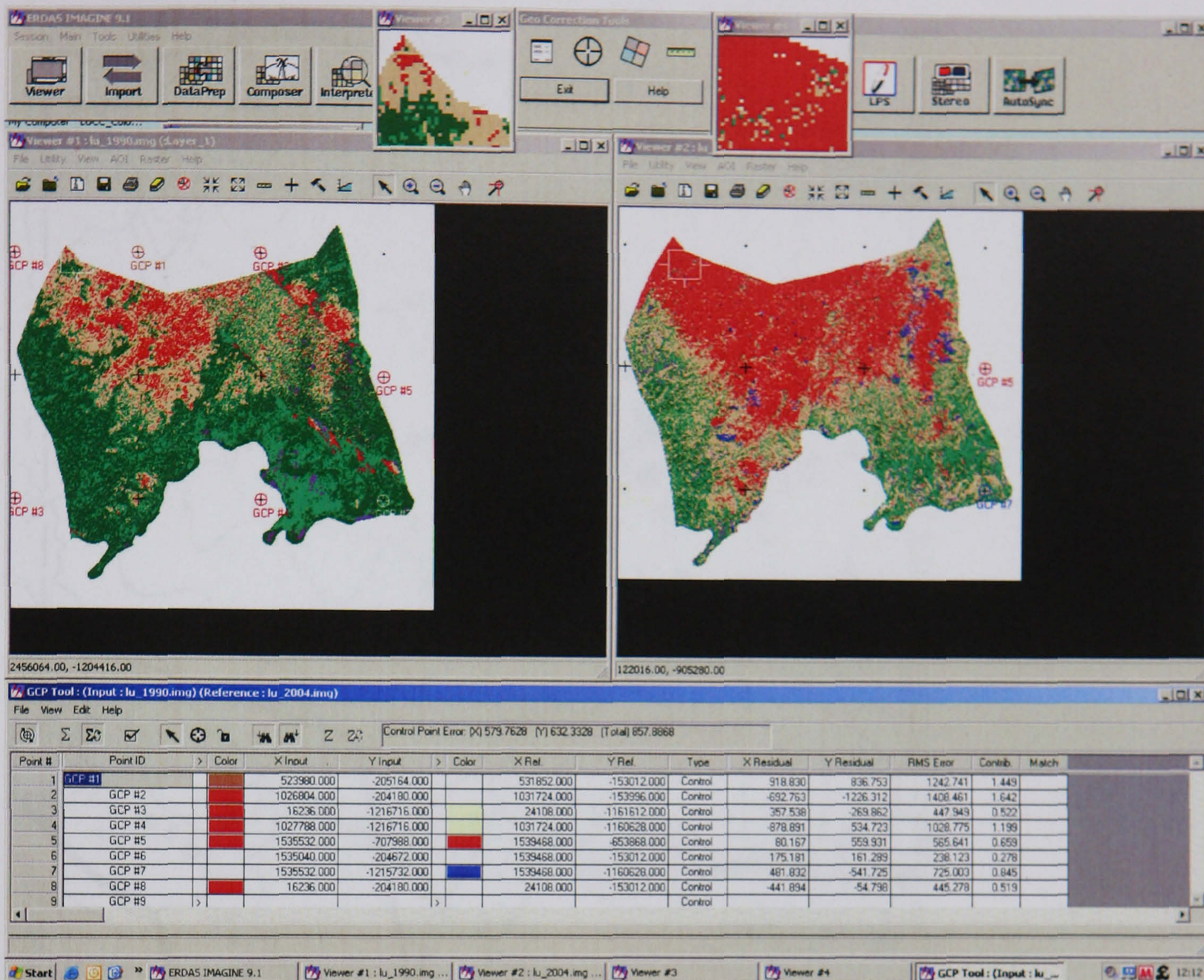
Which category of people in your view, if supported, can contribute most significantly to environmental conservation.....

.....
.....
.....

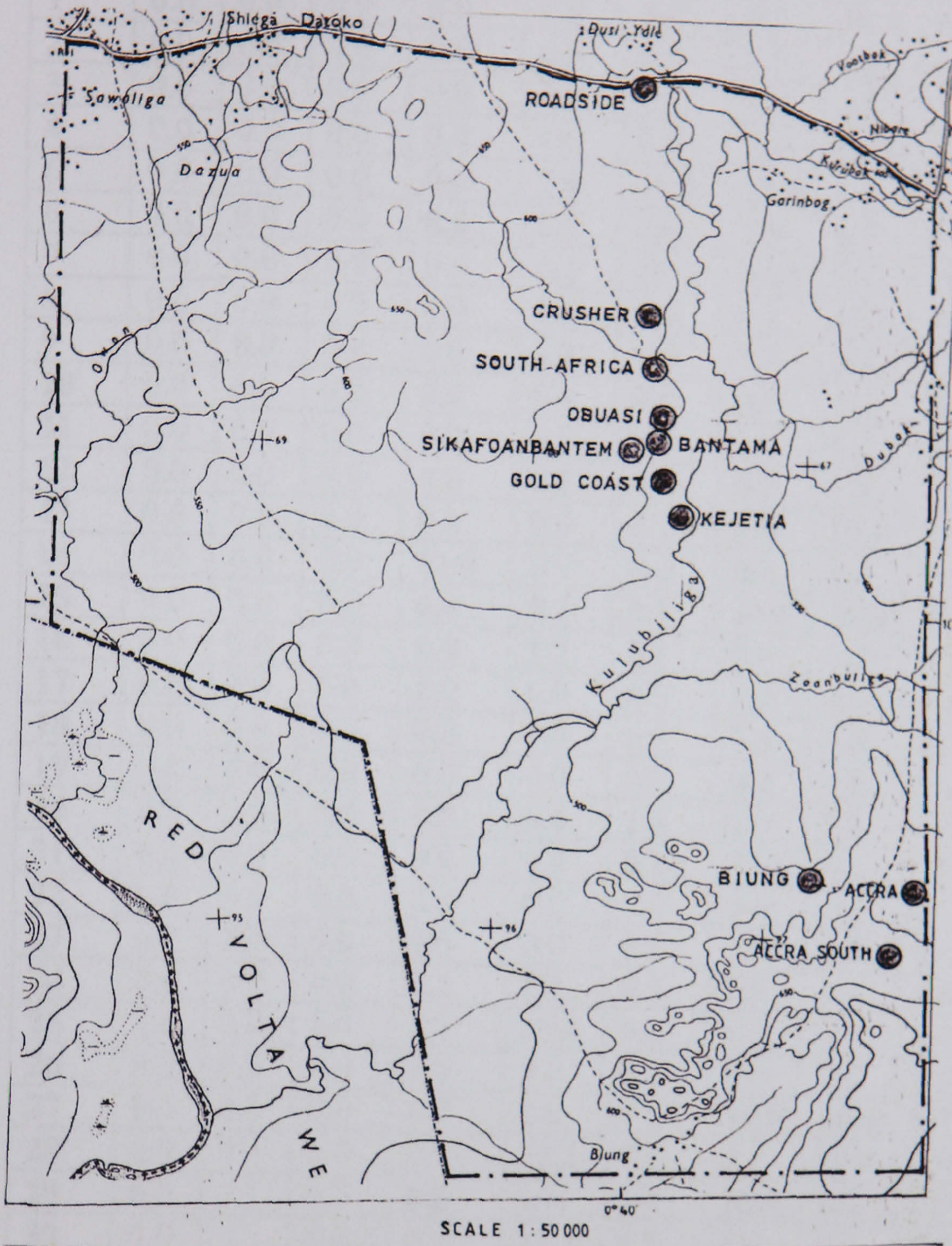
Which way do you think the community as a whole can be encouraged to go into environmental conservation?

.....

Appendix 5.1: Image differencing using ERDAS Imagine



Appendix 5.2: Original Statutory concession small scale mining site at Duusi



Appendix 6.1: Rainfall distribution (mm) for Bolgatanga, Talensi-Nabdam (1990)

Date	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	5.8	0.1	50.4	9.8	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.8	0.0	2.4	0.0	0.0	0.1	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.2	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.5	19.8	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	7.0	10.2	13.4	1.0	0.4	0.0	0.0	0.0
6	0.0	0.0	0.0	8.6	0.0	0.0	2.0	0.1	0.0	0.1	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	13.2	30.0	0.0	18.4	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	18.6	0.6	0.1	15.4	3.2	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	5.2	0.0	2.4	6.8	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.4	37.8	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.2	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.1	0.0	0.1	1.2	0.0	0.0	0.1	0.0
13	0.0	0.0	0.0	0.1	0.0	0.1	4.4	28.4	29.2	0.1	1.0	0.0
14	0.0	0.0	0.0	11.4	0.0	0.0	0.6	0.0	2.2	0.0	0.0	0.0
15	0.0	0.0	0.0	0.4	0.1	0.1	14.6	31.6	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	1.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.4	0.0	0.0	0.0
18	0.0	0.0	0.0	0.2	0.0	0.0	7.8	6.5	0.0	0.1	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.0
20	0.0	0.0	0.0	0.0	6.6	1.6	0.0	1.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.1	52.2	0.0	0.0	0.0	0.0	47.6
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5
23	0.0	0.0	0.0	0.0	0.0	0.1	0.0	6.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.1	1.2	0.1	2.5	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	23.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	14.0	16.8	8.7	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	27.2	0.2	2.2	19.4	0.0	0.0	0.0	0.0
29	0.0		0.0	8.8	0.0	0.0	12.0	6.8	0.0	0.0	0.0	0.0
30	0.0		0.0	0.0	21.4	0.5	0.0	0.0	0.0	0.0	0.8	0.0
31	0.0		0.0		0.8		4.0	0.0		0.0		0.0

Station: Bolgatanga

Number: 1000/027/04

Latitude: 10° 48'N; Longitude: 00°52'W; Altitude: 209.5m

Source: Meteorological Service, Bolgatanga

(2000)

Date	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	24.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	8.7	14.4	39.7	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	23.9	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	14.9	23.6	0.0	0.7	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	15.8	0.0	25.4	0.1	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	5.2	5.8	4.4	11.3	0.0	30.0	0.0	0.0
10	0.0	0.0	0.0	2.2	0.0	10.2	35.4	6.4	0.0	28.3	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	20.1	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	6.5	0.0	0.0
13	0.0	0.0	0.0	4.6	47.6	0.0	23.2	45.8	0.0	0.1	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	19.5	0.0	37.3	0.1	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	18.2	11.5	9.4	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
18	0.0	0.0	0.0	6.8	0.0	54.5	4.7	12.6	0.2	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	1.8	0.0	0.0	15.7	9.9	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	37.3	39.3	0.0	0.1	1.4	0.0	0.0	0.0
21	0.0	0.0	0.0	9.2	4.0	0.0	37.6	0.0	0.0	0.1	0.0	0.0
22	0.0	0.0	0.0	3.8	0.0	10.5	0.1	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	19.8	3.0	0.0	0.0	35.5	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	27.7	1.3	13.2	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	1.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.1	1.3	22.9	0.0	17.8	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.7	13.9	2.2	0.1	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	9.0	0.0	0.0	17.3	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.2	0.0	0.0	0.0	0.0

*Station: Bolgatanga**Number: 1000/027/04**Latitude: 10° 48' N; Longitude: 00° 52' W; Altitude: 209.5m**Source: Meteorological Service, Bolgatanga*

(2004)

Date	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	0.0	0.0	6.3	0.0	0.0	40.8	0.0	0.0	0.1	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.4	57.1	12.1	0.0	0.0	3.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.1	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.1	2.6	0.0	3.3	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	12.3	1.4	13.8	5.7	0.0	0.0	0.0
8	0.0	0.0	0.0	9.6	0.0	1.0	51.1	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	49.5	0.0	4.5	0.0	2.2	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	20.5	0.1	7.3	0.0	10.5	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.4	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.1	0.0	10.1	25.4	0.0	8.7	0.0
14	0.0	0.0	0.0	0.0	8.4	0.0	30.8	0.0	6.2	0.0	0.0	0.0
15	0.0	0.0	0.0	30.0	0.1	0.1	16.2	12.8	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	6.3	0.0	0.0
18	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	5.1	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	27.2	0.0	1.5	0.0	10.5	0.0	0.0	0.0
20	0.0	0.0	0.0	0.6	0.0	1.6	0.0	1.6	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.1	0.0	14.4	0.0	0.5	0.0	0.0
22	0.0	0.0	0.0	20.0	0.0	0.0	2.6	60.3	0.0	0.1	0.0	0.0
23	0.0	0.0	0.0	0.0	0.1	0.1	12.1	1.8	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	14.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.6	26.6	28.5	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	2.5	0.0	2.2	1.1	3.4	3.0	0.0	0.0
27	0.0	0.0	0.0	0.1	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	13.6	0.0	10.0	16.4	0.0	0.0	0.0	0.0
29	0.0		9.9	0.1	0.0	0.1	12.0	0.0	5.9	0.0	0.0	0.0
30	0.0		1.2	0.0	0.0	0.0	3.1	0.9	0.0	0.0	0.8	0.0
31	0.0		0.0		0.0		0.0	0.1		0.0		0.0

*Station: Bolgatanga**Number: 1000/027/04**Latitude: 10° 48'N; Longitude: 00°52'W; Altitude: 209.5m**Source: Meteorological Service, Bolgatanga*

Appendix 6.2: Temperatures (°C) and Relative Humidity for 1990: 2000 and 2004 for the study area

BOLGATANGA
GHANA METEOROLOGICAL SERVICES DEPARTMENT

Values of MONTHLY MEAN RELATIVE HUMIDITY (0600) %

	JAN	FEB.	MAR.	APR	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR
1990	35	39	46	70	81	84	90	85	92	86	74	60	
2000	44	27	39	73	85	91	93	92	94	89	66	35	
2004	26	25	37	75	84	89	93	93	90	85	66	42	

MONTHLY MEAN RELATIVE HUMIDITY (1500) %

1990	18	22	31	40	47	54	64	69	66	44	28	23	
2000	26	14	20	37	49	64	68	72	69	56	28	21	
2004	17	16	24	42	56	61	66	70	66	49	31	21	

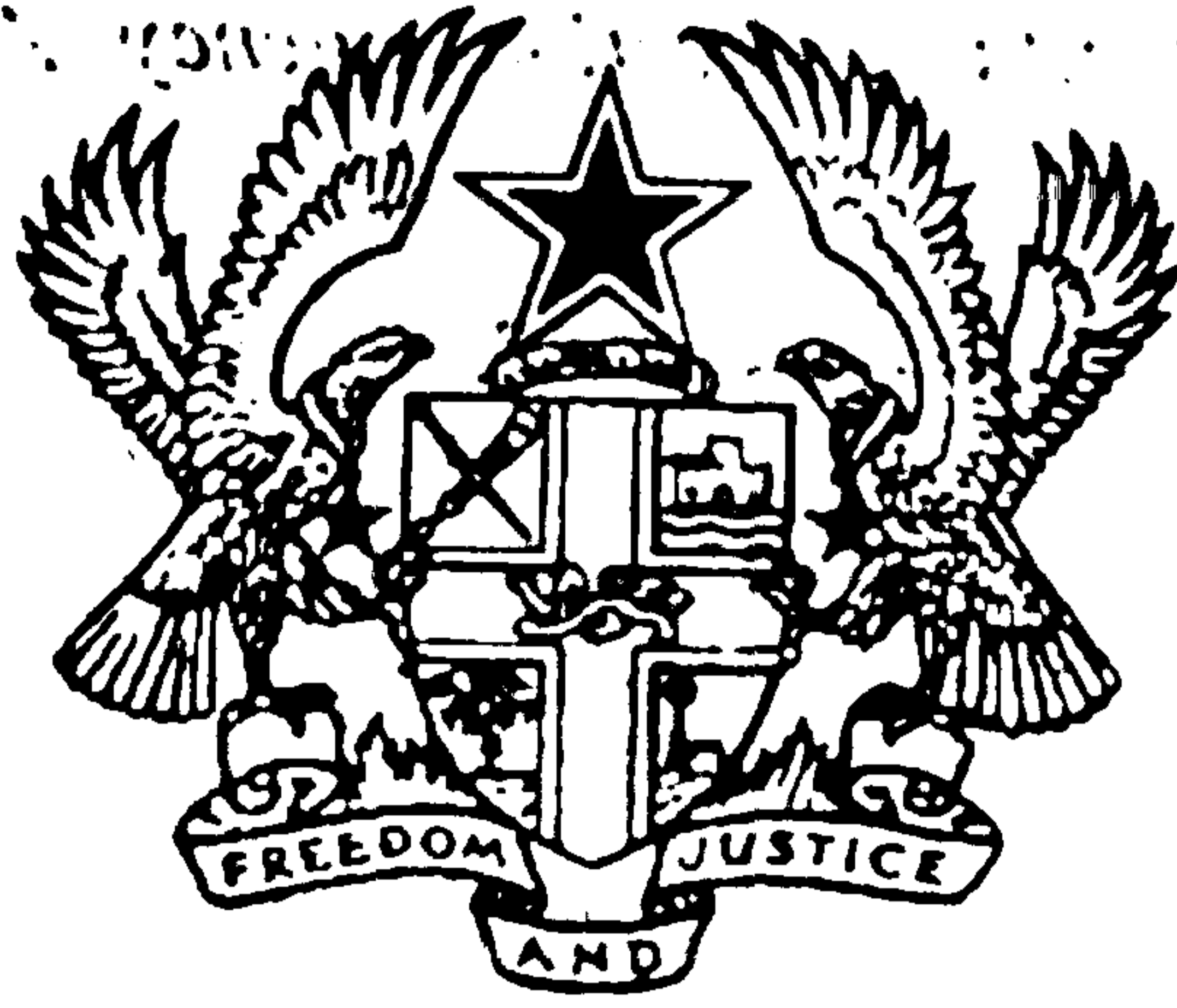
MEAN MAXIMUM TEMP °C *BOLGATANGA*

1990	34.2	36.6	39.0	37.9	36.5	33.5	30.7	31.3	35.4	37.3	35.4		
2000	36.1	35.1	39.0	39.5	35.8	32.2	31.1	30.5	31.1	34.0	37.3	35.2	
2004	36.1	37.7	38.3	37.5	34.6	32.5	31.0	30.9	31.3	35.9	37.1	37.7	

MEAN MINIMUM TEMP °C

1990	20.9	22.2	25.0	26.7	25.4	24.0	23.0	22.9	22.4	23.6	23.4	21.7	
2000	22.3	21.0	25.2	27.2	25.0	23.1	22.7	22.6	22.3	22.8	21.0	19.6	
2004	21.6	23.9	25.7	26.2	25.3	23.0	22.2	22.2	21.8	23.2	22.6	21.9	

FOR: *ISAAC AGYEMANG*



THE FOUR HUNDRED AND NINETIETH

ACT

OF THE PARLIAMENT OF THE REPUBLIC
OF GHANA

ENTITLED

THE ENVIRONMENTAL PROTECTION AGENCY ACT, 1994

AN ACT to provide for the establishment of an Environmental Protection Agency in place of the Environmental Protection Council and for related purposes.

DATE OF ASSENT: *30th December, 1994*

BE IT ENACTED by Parliament as follows—

PART I—ESTABLISHMENT OF THE ENVIRONMENTAL PROTECTION AGENCY

1. (1) There is established by this Act a body to be known as the Environmental Protection Agency referred to in this Act as the "Agency".

Establishment of Agency.

(2) The Agency shall be a body corporate with perpetual succession and a common seal and may sue and be sued in its corporate name.

(3) The Agency shall for the discharge of its functions have power to acquire and hold any movable or immovable property and to enter into any contract or other transaction.

Act 490

Environmental Protection Agency Act, 1994

Functions
of the
Agency.

2. The functions of the Agency are—

- (a) to advise the Minister on the formulation of policies on all aspects of the environment and in particular make recommendations for the protection of the environment;
- (b) to co-ordinate the activities of bodies concerned with the technical or practical aspects of the environment and serve as a channel of communication between such bodies and the Ministry;
- (c) to co-ordinate the activities of such bodies as it considers appropriate for the purposes of controlling the generation, treatment, storage, transportation and disposal of industrial waste;
- (d) to secure in collaboration with such persons as it may determine the control and prevention of discharge of waste into the environment and the protection and improvement of the quality of the environment;
- (e) to collaborate with such foreign and international agencies as the Agency considers necessary for the purposes of this Act;
- (f) to issue environmental permits and pollution abatement notices for controlling the volume, types, constituents and effects of waste discharges, emissions, deposits or other source of pollutants and of substances which are hazardous or potentially dangerous to the quality of the environment or any segment of the environment;
- (g) to issue notice in the form of directives, procedures or warnings to such bodies as it may determine for the purpose of controlling the volume, intensity and quality of noise in the environment; —
- (h) to prescribe standards and guidelines relating to the pollution of air, water, land and other forms of environmental pollution including

- the discharge of wastes and the control of toxic substances;
- (i) to ensure compliance with any laid down environmental impact assessment procedures in the planning and execution of development projects, including compliance in respect of existing projects;
 - (j) to act in liaison and co-operation with government agencies, District Assemblies and other bodies and institutions to control pollution and generally protect the environment;
 - (k) to conduct investigations into environmental issues and advise the Minister thereon;
 - (l) to promote studies, research, surveys and analyses for the improvement and protection of the environment and the maintenance of sound ecological systems in Ghana;
 - (m) to initiate and pursue formal and non-formal education programmes for the creation of public awareness of the environment and its importance to the economic and social life of the country;
 - (n) to promote effective planning in the management of the environment;
 - (o) to develop a comprehensive database on the environment and environmental protection for the information of the public;
 - (p) to conduct seminars and training programmes and gather and publish reports and information relating to the environment;
 - (q) to impose and collect environmental protection levies in accordance with this Act or regulations made under this Act;
 - (r) to co-ordinate with such international agencies as the Agency considers necessary for the purposes of this Act; and
 - (s) to perform any other functions conferred on it under this Act.

Appendix 6.4: Diseases incidence in the study area

Ghana Health Service, UER, Data

FOR ISAAC AGYEMANG

Malaria

	1992	2000		2004			
	Total	Male	Female	Total	Male	Female	Total
Bolga	16635	33,996	37,211	71,207	35,494	39,203	74,697
Bongo	677	4,284	4,415	8,699	7,679	8,302	15,981
KND	12884	15,298	16,750	32,048	14,499	15,260	29,759
Total	30196	53,578	58,376	111,954	57,672	62,765	120,437

Respiratory Infection


	1992	2000		2004			
	Total	Male	Female	Total	Male	Female	Total
Bolga	4356	4,671	3,849	8,520	4,546	4,214	8,760
Bongo	94	508	399	907	800	712	1,512
KND	1334	3,015	3,037	6,052	2,876	2,857	5,733
Total	5784	8,194	7,285	15,479	8,222	7,783	16,005

TB

	1992	2000		2004			
	Total	Male	Female	Total	Male	Female	Total
Bolga	133	70	48	118	66	47	113
Bongo	2	2	1	3	2	2	4
KND	126	8	3	11	1	-	1
Total	261	80	52	132	69	49	118

Skin Diseases

	1992	2000		2004			
	Total	Male	Female	Total	Male	Female	Total
Bolga	1677	2,476	2,288	4,764	3,837	3,714	7,551
Bongo	173	105	112	217	494	461	955
KND	2240	1,677	1,700	3,377	1,816	1,581	3,397
Total	4090	4,258	4,100	8,358	6,147	5,756	11,903


 DELA K. ASAMANY
 REG BIOSTATS OFFICER, UER
 REG. BIOSTATS OFFICER
 M. O. H. BOLGA
 REG. BIOSTATS OFFICER

ATTENTION: DAVID HUGHES
 DR RUTH
 PLEASE DELIVER TO ISAAC
 AGYEMANG

Appendix 6.4: Diseases incidence in the study area

Ghana Health Service, UER, Data

FOR ISAAC AGYEMANG

Malaria

	1992	2000		2004			
	Total	Male	Female	Total	Male	Female	Total
Bolga	16635	33,996	37,211	71,207	35,494	39,203	74,697
Bongo	677	4,284	4,415	8,699	7,679	8,302	15,981
KND	12884	15,298	16,750	32,048	14,499	15,260	29,759
Total	30196	53,578	58,376	111,954	57,672	62,765	120,437

Respiratory Infection


	1992	2000		2004			
	Total	Male	Female	Total	Male	Female	Total
Bolga	4356	4,671	3,849	8,520	4,546	4,214	8,760
Bongo	94	508	399	907	800	712	1,512
KND	1334	3,015	3,037	6,052	2,876	2,857	5,733
Total	5784	8,194	7,285	15,479	8,222	7,783	16,005

TB

	1992	2000		2004			
	Total	Male	Female	Total	Male	Female	Total
Bolga	133	70	48	118	66	47	113
Bongo	2	2	1	3	2	2	4
KND	126	8	3	11	1	-	1
Total	261	80	52	132	69	49	118

Skin Diseases

	1992	2000		2004			
	Total	Male	Female	Total	Male	Female	Total
Bolga	1677	2,476	2,288	4,764	3,837	3,714	7,551
Bongo	173	105	112	217	494	461	955
KND	2240	1,677	1,700	3,377	1,816	1,581	3,397
Total	4090	4,258	4,100	8,358	6,147	5,756	11,903


 DELA K. ASAMANY
 REG BIOSTATS OFFICER, UER
 REG. BIOSTATS OFFICER
 M. O. H. BOLGA
 UER EAST REGION

ATTENTION: DAVID HUGHES
 OR RUTH
 PLEASE DELIVER TO ISAAC
 AGYEMANG