Design and Development of an Integrated Land Management Model in Guyana

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ABSTRACT

Design and Development of an Integrated Land Management Model in Guyana

Mohamed Irfaan Ali

Land management remains a concept, principle, and process yet to be fully understood and practiced worldwide. The different land tenure systems, competition for land use, different economic principles and social norms have made it difficult to have a one-cap-fits-all land management domain at international and regional levels. Even at national levels, competing national developmental goals have led to conflicts in land management principles and processes. This thesis, in an attempt to bring some structure into conflicts in land management, undertook a critical evaluation of land management in Guyana. The evaluation identified horizontal and vertical overlapping jurisdictions that are counterproductive to good of national resource management. To overcome these conflicts, the thesis designed and developed an integrated land management model to ensure that the environmental, economic and social factors in land development are simultaneously considered in a stakeholders' participatory environment. In order to give effect to this model, the thesis used an adaptation of the Spatial Analytic Hierarchy Process in a Multi-criteria Decision Analysis to undertake land use sustainability analysis for housing, agriculture, mining and forestry in Guyana. The results of these analyses demonstrated that the problem of overlapping jurisdictions and competing land use can be resolved through the integration of expert knowledge and Spatial Analytic Hierarchy Process (SAPH) technology. The thesis concluded that sustainable land management goals are attainable in the environment of stakeholders' collaboration and the development and maintenance of a national spatial data infrastructure that ensures unhindered access to current and accurate spatial data on the status and extent on national and anthropogenic resources.

Keywords: Mohamed Irfaan Ali; Guyana; Land Management; Integrated Land Management Model; Multi-Criteria Decision Analysis (MCDA); Spatial Analytic Hierarchy Process (SAHP); Geographic Information System (GIS); Land Suitability Assessment; Low Carbon Development Strategies (LCDS).

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My heartfelt appreciation to my mother Bibi Shariman Ali and father Mohamed Osman Ali who implanted the love for reading and interminable desire for pursuing academic studies. The support and encouragement from my relatives and friends also helped me to persevere, especially during the difficult periods when I encountered significant roadblocks. I, therefore, wish to express thanks to my relatives and friends.

Most importantly, I give thanks and praise to God who made this journey possible.

DEDICATION

This thesis is dedicated to my parents Mohamed Osman Ali and Bibi Shariman Ali for their unconditional love and to my wife Arya Ali and our son Zayd Ali who have both brought tremendous joy and blessings to my life

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LIST OF ABBREVIATIONS

Abbreviation	Full Meaning
ADP	Agriculture Diversification Programme
AHP	Analytic Hierarchy Process
APM	Area Production Mode
AUMA	Alberta Urban Municipalities Association
CBOs	Community-based Organisations
CEWG	Community Engagement Working Group
CHPA	Central Housing and Planning Authority
CI	Conservation International
DMS	Database Management System
DSS	Decision Support System
ELLA	Evidence and Lessons from Latin America
EPA	Environmental Protection Agency
ETZ	Equatorial Trough Zone
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GECAFS	Global Environmental Change and Food Systems
GLSC	Guyana Lands and Surveys Commission
GFC	Guyana Forestry Commission
GGMC	Guyana Geology and Mines Commission
GoG	Government of Guyana
GRDB	Guyana Rice Development Board
GRMEDA	Guyana Rice Millers & Exporters Development Association
GUYSUCO	Guyana Sugar Corporation
GIS	Geographic Information System
GTZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HIPC	Highly Indebted Poor Country
ICT	Information and Communication Technology
IADB	Inter-American Development Bank
IDNDR	International Decade for Natural Disaster Reduction
IFPRI	International Food Policy Research Institute
ILM	Integrated landscape model
ILMM	Integrated Land Management Model
ITCZ	Inter Tropical Convergence Zone
LCDS	Low Carbon Development Strategies
LAS	Land Administration System
LISPs	Low Income Settlement Programs
LPWG	Land Policy Working Group
LUWG	Land Utilization Working Group
M&E	Monitoring and Evaluation
MoHW	Ministry of Housing and Water
MoA	Ministry of Agriculture

CHPA	Central Housing and Planning Authority
MoHCHPA	Ministry of Housing, Central Housing and Planning Authority
MoAA	Ministry of Amerindian Affairs
MCDA	Multi-criteria Decision Analysis
MSPM	Most Suitable Parcel Model
MSE	Micro and Small Enterprises
MDA	Multi-criteria Decision Analysis
MDGs	Millennium Development Goals
NCS	National Competitiveness Strategy
NDC	Neighbourhood Democratic Council
NDS	National Development Strategy
NGOs	Non-Governmental Organisations
NLDLA	National Land Development and Land Allocation
NLMC	National Land Management Council
NSDI	National Spatial Data Infrastructure
PPP	Public and Private Partnerships
PRSP	Poverty Reduction Strategy Papers
RDC	Regional Democratic Council
RPA	Rice Producer Association
SAP	Sugar Action Plan
SAHP	Spatial Analytic Hierarchy Process
SWALIM	Somalia Water and Land Information Management project
SFP	State Forest Permission
SFEP	State Forest Exploratory Permit
SLM	Sustainable Land Management
STDM	Social Tenure Domain Model
SDSS	Spatial Decision Support System
TSA	Timber Sales Agreement
UNECA	Economic Commission for Africa
UNECE	United Nation Economic Commission for Europe
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNEP	United Nations Environment Programme
UNCTAD	United Nations Conference on Trade and Development
USAID	United States Agency for International Development
WLC	Weighted Linear Combination
WCL	Wood Cutting Lease
WCU	World Conservation Union
WG	Working Group
WWF	World Wildlife Fund
WMO	World Meteorological Organization

CHAPTER 1: INTRODUCTION

1.1 Background

Guyana is known to be a country with an expansive landmass and water resources (approximately 83,000 square miles or 215,000 square kilometres). It is located on the Northern Atlantic Coast of South America. The country has an extensive forest cover with significant potential for attracting carbon credit and is extremely rich with mineral resources such as gold, diamond, manganese, and aluminium. Although the facts as mentioned above are known, the country has suffered from a lack of an efficient and effective land management system, which provides the infrastructure for implementing land-related policies and land management strategies, with the ultimate aim of achieving sustainable development in an environmentally friendly manner.

The management, administration, ownership, and control of land resources by numerous agencies or institutions have seen overlapping jurisdictions and functions. This has often resulted in conflicts and challenges as these agencies wrestle to advance their interests. On a larger scale, it has also infringed on the social and economic development mandates of the Government, thereby forcing development initiatives to be placed on hold until the conflicts or concerns are amicably resolved. Notwithstanding, the problem continues to permeate the various agencies and has found itself affecting landowners, administrators, surveyors, and policymakers.

As illustrated in table 1.1, ‘public lands’ are administered by the Guyana Lands and Surveys Commission (GLSC) while the ‘state forest’, ‘state agriculture lands’, ‘mining districts’ and lands identified for housing development are administered by the Guyana Forestry Commission (GFC), the Ministry of Agriculture (MoA), Guyana Geology and Mines Commission (GGMC) and the Ministry of Housing, Central Housing and Planning Authority (MoHCHPA), respectively. Amerindian lands, on the other hand, are administered by the Amerindian Council in collaboration with the Ministry of Amerindian Affairs (MAA), while ‘a complex land tenure system governs private lands'. It is noteworthy that a complex land tenure system governs other lands which include, 'private lands,' protected areas, national parks and administered by private individuals and multiple agencies (Lemel 2001).

Table 1.1: The list of agencies that administer land in Guyana

Agency	Land Administered
Guyana Lands and Surveys Commission	Public Lands
Guyana Forestry Commission	Forestry
Guyana Geology and Mines Commission	Mining
Ministry of Agriculture	Agriculture
Central Housing and Planning Authority	Housing Development
Village Council (Amerindian)	Amerindian Lands
National Parks Commission and IWOKRAMA	National Parks and Protected Areas

Each agency that administers lands does so with the support of specific laws, regulations, and in most instances national as well as sector-specific policies. Unfortunately, most of the laws, regulations and sectoral policies are not compatible. Given the absence of an integrated approach to land management, there are numerous land-related problems. Bishop (1998), for instance, argues that the lack of a national land management framework contributes to issues such as (i) multiple land use conflicts due to the prevalence of overlapping jurisdiction; (ii) environmental degradation and pollution; and (iii) illegal resource utilization. The present disjointed and uncoordinated approach to land management also leads to inefficiency and conflict regarding policy direction and implementation.

These problems are likely to intensify in the future due to the signalled intention by the Government of Guyana to encourage the exploitation of the country's natural resources (such as, gold, diamond, bauxite, manganese, uranium etc.), while simultaneously protecting the environment as envisioned in the Low Carbon Development Strategies (LCDS).

Notwithstanding the implications associated with the absence of a national land use framework as a basis for effective guidance for land development planning, there is a paucity of research that examines land management in Guyana. The most comprehensive study of land administration in Guyana is the study by Bishop (1998) who reviews the institutional and policy environment of land management in Guyana. In particular, the study provides an in-depth review which emphasises land administration locally. Some of the documents reviewed by the author include the: National Development Strategy (NDS), the Land Tenure Policy Report, the Forest Policy Statement, Mining Policy, Eco-tourism Plan, Housing Policy, Environmental Policy, Bio-diversity Strategy, and the Land Use Baseline Report. The study, in an ephemeral way, highlighted some of the adverse consequences of the weak land administration framework but also offered an extensive range of recommendations that may serve to create a national land use policy for sustainable urban and regional planning. Although the assessment of Bishop (1998) was thorough, it did not address the administration of private lands and Amerindian lands.

Lemel (2001), however, partially addresses the shortcomings in the study by Bishop (1998) by focusing on the administration of private lands in Guyana. Using case-study materials obtained from fieldwork conducted during 1997-1998, the author argues that tenure of private lands is subject to pronounced insecurity and disorder despite the implementation of widespread initiatives since 2000. While Lemel (2001) advanced the literature on land administration in Guyana, it failed as well to capture the administration of state lands and Amerindian lands.

More recently, Harvard Law School (2007) indirectly addresses land administration by examining the conflict that results from the occupation of similar land space by Amerindians and small and medium scale mining companies in Guyana. The study reviews the legal and regulatory framework under which these mining companies operate and those which protect the rights of Amerindian communities. It also documents many cases whereby small and medium scale mining companies operated in a manner which was inimical to indigenous people. The study offers numerous solutions to realign the activities of mining companies with the rights and interests of Amerindian communities.

Land management is the process by which the resources of land are put to good effect (Dale and McLaughlin 1999; UN-ECE 1996). Good result, however, can be different things to different land managers or societies as it can be defined as the desired outcomes from use of the land and land resources. The desired effect may be primarily economic, social or environmental. Previously, the land management focus was on economic impacts of land use and land reform programmes concentrated on land development and land titling for economic benefits of activity in the land market. Understanding that land suitable for development was finite, that populations were expanding, and that unrestrained development could not continue indefinitely soon led to more cautious views on management of development and the concept of sustainability (Smyth and Dumanski 1993). While land management can be performed at local or individual levels of land holding, since ecological impacts of land management decisions can have wide-ranging effects (extracting water from a stream for irrigation of crops upstream can reduce access to water lower down the watershed for example), sustainable land management is best practised at larger scales, ideally nationally (Dale and McLaughlin 1999). This statement, therefore, gives the responsibility of performing sustainable land management directly to the state. The state has an obligation to provide good governance on the management of the land under its jurisdiction.

Sustainable land management is the maintaining of equilibrium of economic, social and environmental demands on land and land resources in an environment of responsible governance (Williamson et al. 2010). The equilibrium must be maintained in two dimensions: across the current demands, and over time into the future. Most often this balancing of demand is conceptualized as shown in Figure 1.1 where economic, social and environmental land goals meet at an ideal intersection.

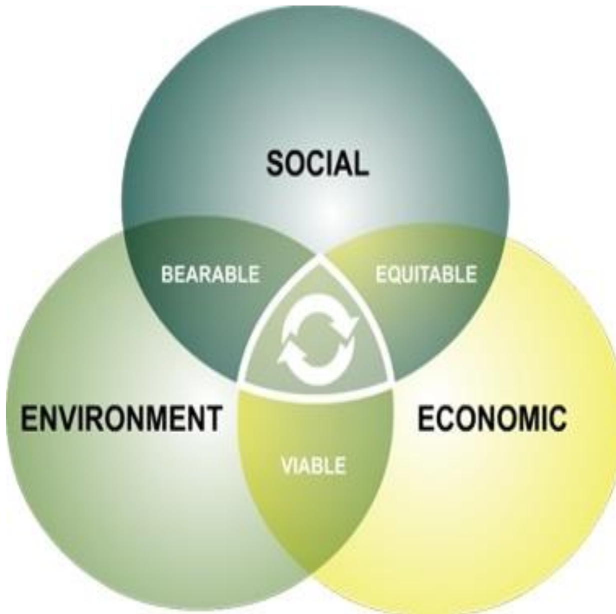

Figure 1.1: An ideal SLM aims to ensure that land uses are bearable, viable, and equitable
Source: Adapted from Williamson et al. (2010)

Sustainable land management is a *knowledge-based procedure* that helps integrate land, water, biodiversity, and environmental management to meet rising human demands while sustaining ecosystem services and livelihoods. SLM is necessary to meet the requirements of a growing population. Improper land management can lead to land degradation and a significant reduction in the productive and service functions (World Bank 2006).

Land management principles that can lead to sustainability particularly in developing countries have been listed as (Williamson et al. 2006; ILC 2004):

- Improving allocation of land and land resources
- Providing equity in access to land for groups living in poverty
- Improving security in land transactions and land use
- Designing sustainable land use arrangements
- Capacity building in land management and land tenure systems

The objectives of SLM are:

a. To harmonize the complementary goals of providing environmental, economic, and social opportunities for the benefit of present and future generations, while maintaining and enhancing the quality of the land (soil, water, and air) resource. (Smyth and Dumanski 1993)

b. To promote human coexistence with nature with a long-term perspective so that the provisioning, regulating, cultural and supporting services of ecosystems are ensured. SLM is an essential prerequisite to sustainable development; progress should be made simultaneously at all levels. In terms of such concerns as food security, poverty alleviation, livelihood improvements, water conflicts, and ecosystem services, SLM is an important local issue that is also a global concern.[1]

[1] WOCAT. https://www.wocat.net/en/slm/sustainable-land-management

The inter-relationships between the components of the land management paradigm that leads to sustainable land management is conceptualised by Enemark (2005) as in figure 1.1. In this structure, the particular country characteristics inherent in the institutional structure can influence the ability of the whole to achieve sustainable land management. Enemark suggests mechanisms for institutions to better address activities so that sustainable land management can occur. These suggestions require institutions that could undertake the following tasks:

- Perform in-country (and, in the case of the OECS countries, intra-regional) gap assessments to determine the specific capacity needs
- Ensure that all investigations and reforms are multi-disciplinary and holistic over all relevant land management institutions
- Establish separation of authorities and responsibilities between national and local land management institutions in the framework of good governance for all rights, restrictions and responsibility management functions
- Encourage capacity building within institutions and educational programmes to be multi-disciplinary including technical, social science and information technology components
- Encourage and support strong professional organisations that promote sound ethics and professionalism that will, in turn, flow into the strengthening of state institutions

- Encourage the development of strong linkages between state, academia, and professional bodies so that research, education and professional growth can continuously upgrade concepts within the whole of the land management paradigm.
- Address capacity building in institutions in all complementary initiatives and donor projects.

According to Burns and Dalrymple (2008), Good governance in an ideal SLM occurs where:

- Land policy is in line with principles of fairness and equity.
- A variety of accepted and socially legitimate rights are legally recognized and can be recorded.
- Land management and associated instruments (zoning and development control plans, conservation plans, etc.) are justified by externalities and undertaken in an efficient, transparent manner.
- Land administration institutions have clear mandates and operate transparently, cost effectively and sustainably.
- Information provided by the land administration system is reliable, sufficient, and accessible at reasonable cost.
- Management, acquisition, and disposal of public land follow clear procedures and is applied transparently.
- Property valuation serves the public and market needs and property taxation is transparent and efficient in support of policy.

- Judicial and non-judicial institutions are accessible with clear mandates and resolve disputes fairly and expeditiously.

The Core Values of an ideal Sustainable Land Management System are:

- Guarantee ownership and security of tenure
- A basis for land and property taxation
- Provide security for credit
- Reduces land dispute
- Monitor and develop land markets
- Protect State Lands
- Facilitate land reforms
- Promote improvement in land and buildings
- Improve urban planning and infrastructure development
- Support environmental management
- Produce statistical data as a base for social and economic development

Attributes of an Ideal Sustainable Land Management System

The attributes of an ideal SLM are:

a. Exist in an environment that has a high level of awareness of SLM and CCA concepts by stakeholders.
b. Exist in a political climate that is sensitive to the roles of SLM/CCA in national development strategies through effective leadership.

c. Supported by land laws and other legislation that address SLM/CCA issues and challenges. Laws are current, implementable, organic (community-driven), and equitable.

d. Supported by clear land policies that promote:

    - Sustainable landuse (land preservation and conservation)
    - Protection of fragile lands
    - Disaster risk mitigation measures
    - Policy monitoring and evaluation
    - provision for policy implementation
    - Clear communication with stakeholders

e. Exist in a supportive institutional environment or arrangement that encourages:

    - Collaborative data collection
    - Coordination of activities
    - Sharing of data and other resources
    - NGO and private sector collaboration

f. Managed by a team of personnel that is skilled and be able to develop proactive local actions to address SLM/CCA challenges.

g. Managed using modern and appropriate technologies in support of efficient data collection, data analysis, data management, and land resources monitoring.

h. Supported by landuse plans and development control measures that are sensitive to dynamic nature of land and climate resources as well as social complexities and realities.
i. Supported by funding regimes that facilitate human capacity enhancement, upgrading of tools, currency of data, and review of policies, laws, and regulations.
j. Exist within land tenure and land registration systems that are transparent, non-discriminatory, secured, and facilitate the expression of rights, responsibilities, and restrictions.
k. Supported by a land information system that is current, comprehensive, and reliable.

Issues in Sustainable Land Management and Urban and Regional Planning

a. Crafting of appropriate institutional framework [multiplicity of agencies, overlapping jurisdictions, stove-pipe approach to management).
b. Management of informal tenure system.
c. Multiplicity of overlapping land-related laws.
d. Currency and adequacy of land policies and land laws.
e. Sustainability of the existing system of land management.
f. Level of competence of available human resources.
g. Level of technological innovations.
h. Completeness and accuracy of records and information.

i. Level of property markets.

j. Adequacy of land tenure and land use management infrastructure to support climate change adaptation.

k. Level of monitoring and evaluation capacity.

In terms of the relationship between SLM and land development, in general, good governance in SLM provides a solid bedrock for sustainable land development strategies. In an environment where the rights, responsibility, and restrictions attached to land tenure are not managed in a coordinated manner, it breeds opportunities for disorderly land development, promotes squatting, little regards for the rights of others, and total contempt for the environment. In other words, good governance in SLM provides transparency, accountability, public participation, and progressive integrated social, economic, and environment development goals: key aims of urban and regional planning.

From the foregoing, it is important to note that SLM is the foundation for effective land use and land development planning. It provides a long-term perspective on a nation stewardship for strategic urban planning. It shapes the design of institutional, technical, and human resources for urban and regional planning, without which urban and regional planning activities will be in a state of turbulence as currently experience in Guyana and other developing countries. It is also to be noted that SLM is the bedrock for effective urban and regional planning, hence is the emphasis of SLM. The intention here is to highlight the role SLM plays in urban and regional planning. The current approach by urban and regional planning practitioners is to focus on physical planning with no regards for land management issues. There have been cases where informal settlements (a product of poor land management) have created tremendous challenges to urban design due to little regards to land management issues.

1.2 Problem Statements

This research is motivated by the following realities of urban and regional planning issues in Guyana in particular and in the Caribbean in general:

- A deficit of competence in land management especially in the public sectors
- Weak governance system in urban and regional planning
- Weak land management infrastructure
- Lack of transparency and accountability on the making of development decisions
- Confusing and overlapping regulatory frameworks
- Complex administrative processes
- Increasing incidence of land grabbing by all sectors of the society
- Little consideration in seeking the optimum land use decisions

1.3 Goal of the Thesis

The goal of this dissertation is to contribute to the development of a framework that encourages sustainable land development planning in support of national economic, social, and environmental goals. A framework that builds relationships between concepts that are usually treated in isolation. A framework that expand the classical concept of land, labour and capital as the three pillars of wealth generation to emerging concept of economic, social, and environmental development as the three pillars for national developments. Economic, social, and environmental goals are achieved through a multi-criteria evaluation of these three goals in every developmental projects by ensuring their conference and fit in a sustainable manner. By not allowing short-term gains to become the overachieving goals as the detriment of long-term gains.

1.4 Aims and Objectives

Notwithstanding the paucity of research that examines land management in the Caribbean in general and in Guyana in particular, this thesis aims is to contribute to learning by seeking solutions to the sporadic nature to land management and urban and regional planning decisions in the Guyana through action research and the use of analytical tools.

The specific objectives of the thesis are as follows:

- To undertake a comprehensive review of the literature concerning land management with the aim of identifying the core management issues with respect to land governance.
- To evaluate the adequacy of the existing framework for land management in Guyana.
- To examine land management models utilized by both developed and developing countries with the aim of designing an integrated land management model.
- To design technology and data-driven integrated land management system that will help overcome the challenges of land management decisions and urban land development; thus, ensuring optimal land use in Guyana.
- To apply the design in critical sectors of land development in Guyana.

1.5 Working Hypotheses

In keeping with the aforementioned, the objectives of the study are guided by three main hypotheses:

- The present land administration framework, processes, and structures, if maintained, will result in continued conflicts and sub-optimal use of Guyana's land resources.
- The current land use practices do not adequately address the issues of sustainable land management which seeks to maximise the

economic and social gains from land use, whilst minimising the negative impacts on the environment.

- A coherent land management model would positively contribute to national development under the Low Carbon Development Strategies (LCDS).

1.6 Research Questions

Towards testing the hypotheses above, the primary research questions are:

a. How do the present land development framework, processes, and structures adopted by the various responsible agencies contribute to and complement the National Development Strategy (NDS)?
b. How would an integrated land management model complement National Development Strategy?
c. How would a coherent integrated land development model contribute to National Development Strategy?

1.7 Scope of the Thesis

This dissertation focuses mainly of national development planning as opposed to site-specific physical land use planning. This means that site specific planning regulations and development standards will not be addressed. The focus is on the general analysis of land suitability and land allocation for various major land uses. The broad issue of overlapping and competing demand for land for economic and social gains as well as environmental preservation and conservation will be addressed using qualitative and quantitative tools and processes in a stakeholder's participatory context.

1.8 Methodology

The research methodology was designed to meet the objectives of the research. The methodology is based on classical action research methods; whereby a real world problem was first identified and fully justified and problem solving technique was developed to address the key challenges in the problem identified through case study, development of models, practical application of the models, and validation of the model. The research commenced, as shown in Figure 1.2, with a review of the existing literature on land administration, land management, and system design technologies as a means of identifying research gaps, refining the research problem, and designing structured solutions to land management.

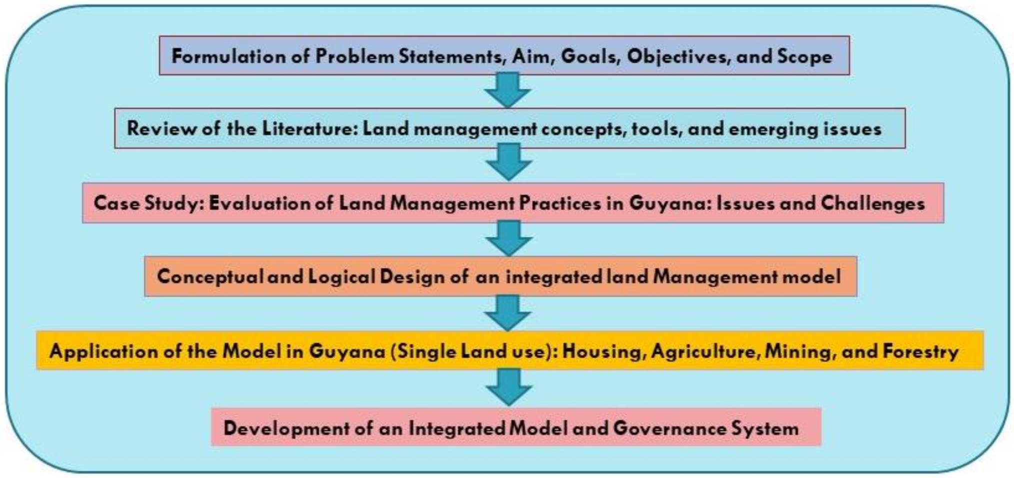

Figure 1.2: Framework for Thesis Methodology

Following the literature review, the design of an integrated land management model was formulated. This model benefited from a GIS-based multi-criteria decision analysis technique and stakeholders' consultation through interviews and workshops.

The model was tested in an area that straddles three administrative regions of Guyana to determine the suitability of lands for agriculture, housing, and mining with the aim to reduce existing and potential land conflicts. The test results were shared with stakeholders who helped in proposing development constraints.

The researcher assessed the validity of the model outputs, then developed a plan for future implementation of the model.

1.9 Organization of the Thesis

The thesis is structured as follows into ten chapters followed by references and appendices:

Chapter 2 critically reviews the literature on land administration for sustainable development. In this regard, academic and other studies concerning land suitability analysis, land use planning, and GIS, etc. have been reviewed. Particular attention was given to integrated land management models utilized by various countries. This is done with the aim of developing an integrated land management model.

Chapter 3 reviews the land management framework in Guyana by: (i) identifying the agencies responsible for land administration in Guyana; (ii) critically reviewing the laws and regulations guiding the operation of the land administration agencies; (iii) evaluating the quantum and tenure characteristics of the lands in Guyana; and (iv) evaluating the approaches to land utilisation and the impact of the existing institutional environment with respect to generating land conflicts in the future.

Chapter 4 presents the general research approach or methodology adopted. In particular, this Chapter describes the analytical framework applied in the study, the research design and data collection and information management techniques. The Chapter also proposed Integrated Land Management Model (ILMM) that caters for the unique needs and aspirations of Guyana and the Caribbean.

Chapters 5, 6, 7, and 8 applies the Spatial Analytic Hierarchy Process (AHP). The technique combines GIS and MDA as a means of determining the optimal land use. In these Chapters, the techniques are used in multiple applications to determine the most suitable sites housing, forestry, mining, and agriculture in Guyana. Each of these four chapters began with problem definition, objective statement, and methodology. They concluded with results, discussion, and conclusion.

Chapter 9 focuses on the implementation of the integrated land management model along with a proposed governance system on dealing with overlapping jurisdiction. The results of these analyses confirmed the principles of sustainable development and how land use conflicts can be avoided by simultaneously considering the environmental, economic and social factors. Chapter 10 contains the conclusions and the recommendations resulting from the experience gained in undertaking this dissertation.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The literature on land management is extensive. This section examines the body of research with specific emphasis on issues such as the definition of land management, conceptual (or theoretical) models on land management, land management and sustainable development, decision support systems or information infrastructure for land management and land policies. The discussion will also cover emerging issues related to land management such as: land banking, land conservation, food security, disaster risk management, decision analysis tools for integrated land use management (e.g. multi-criteria decision analysis and spatial analysis techniques), pro-poor land management (land for poor vulnerable groups), and climate change among others.

2.2 Defining Land Management

Land management involves a comprehensive set of activities, policies, and technologies aimed at determining the utilization of land, as well as all the resources contained therein for achieving various social, economic and environmental objectives. Over the years, numerous formal definitions have been offered for land management; with the more recent definitions emphasizing sustainable development.

Enemark (2007) for instance, defines land management broadly as: "… all activities associated with the management of land and natural resources that are required to achieve sustainable development. The concept of land includes properties and natural resources and thereby encompasses the total natural and built environment" (3). Land management is also broadly defined by Williamson, Enemark, Wallace, and Rajabifard (2010) as: "… the activities associated with the management of land as a resource to achieve social, environmental and economic sustainable development" (453).

Enemark and Parker (2005) define land management thus:

> Land Management is a very complex and interdisciplinary concept that includes a mix of technical, natural, and social sciences. Land management can be described as the processes by which the resources of land are put to good effect. It is about land policies, land rights, property economics, land-use control, regulation, implementation, and development. Land management encompasses all those activities associated with the management of land as an asset and a resource to achieve sustainable development. (4)

Meanwhile, Smyth and Dumanski (1993) define land management as:

> …as a combination of technologies, policies, and activities aimed at integrating socioeconomic principles with environmental concerns in order to maintain and enhance productivity, reduce the level of production risk, and enhance soil's capacity to buffer against degradation processes, protect the potential of natural resources and prevent degradation of soil and water quality, be economically viable, be socially acceptable, and assure community access to the benefits from improved land management. (2)

According to the United Nations, Economic Commission for Europe (UN-ECE 1996) land management may be defined as follows:

> Land management is the process by which the resources of land are put to good effect. It covers all activities concerned with the management of land as a resource both from an environmental and from an economic perspective. It can include farming, mineral extraction, property and estate management, and the physical planning of towns and the countryside. It embraces such matters as property conveyancing, including decisions on mortgages and investment; property assessment and valuation; the development and management of utilities and services; the management of land resources such as forestry, soils, or agriculture; the formation and implementation of land-use policies; environmental impact assessment; and the monitoring of all activities on land that affect the best use of that land. (13)

Further, the World Bank (2006) defines sustainable land management (SML) as:

> a knowledge-based procedure that helps integrate land, water, biodiversity, and environmental management (including input and output externalities) to meet rising food and fiber demands while sustaining ecosystem services and livelihoods. (xiv)

SLM is necessary to meet the requirements of a growing population. Improper land management can lead to land degradation and a significant reduction in the productive and service (biodiversity niches, hydrology, carbon sequestration) functions of watersheds and landscapes. In layman's terms, SLM involves the World Bank (2006):

a. preserving and enhancing the productive capabilities of land in cropped and grazed areas—that is, upland areas, downslope areas, and flat and bottom lands; sustaining productive forest areas and potentially commercial and non-commercial forest reserves; and maintaining the integrity of watersheds for water supply and hydropower generation needs and water conservation zones and the capability of aquifers to serve farm and other productive activities;

b. actions to stop and reverse degradation—or at least to mitigate the adverse effects of earlier misuse—which is increasingly important in the uplands and watersheds, especially those where pressure from the resident population is severe and where the destructive consequences of upland degradation are being felt in far more densely populated areas downstream. (xiv)

While there is no standard definition for land management, all the definitions above regard land management as a set of activities aimed at sustainable development (Enemark 2007; Williamson et al. 2010; Smyth and Dumanski 1993; UN-ECE 1996). The reason for some commonality among the various definitions may be explained by the conceptual models developed to explain land management over the years.

2.3 Conceptual and Theoretical Models of Land Management

Many conceptual models were developed by academics to explain land management. Probably one of the most popular models was proposed by Dale and McLaughlin (1988). This model was subsequently extended by others over the years. Building upon this seminal model, Enemark (2004) proposed a conceptual model which hypothesizes that land management takes the form of a hierarchy whereby land policies form the foundation for land management.

According to Enemark (2004) land policies determine the objectives for land management and are generally contained in the legal and regulatory framework which governs the use of land as a legal, economic and physical object. Within the hierarchy, appropriate cadastral systems provide the basis for effective land administration systems, which involves four core functions, namely, land tenure, land value, land-use and land development. Together, land polices, cadastral systems and land administration systems facilitate land management: Figure 2.1.

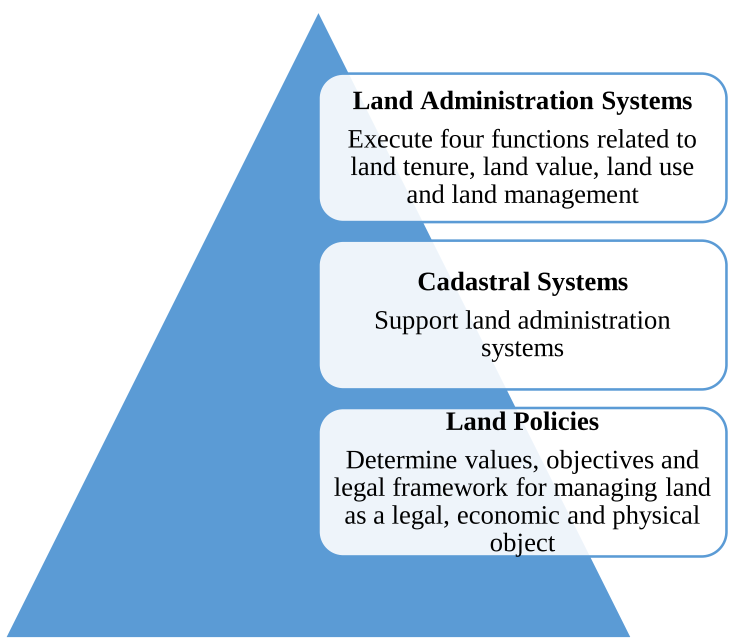

Figure 2.1: Conceptual framework for land management
Source: Enemark (2004, 12)

Based on this conceptual model the author argues that land management is primarily aimed at sustainable development. Enemark (2004) also posits that land management encompasses numerous activities that may be grouped under three broad classifications, namely: (i) land policies; (ii) land use management; and (iii) land information as depicted in the Integrated Land Management Model for Sustainable Development. In this model, land management comprises different types of planning activities (such as regional and spatial planning and construction planning). The planning activities are usually aided by appropriate land information systems and the plans developed from these activities are executed through planning permissions, building permits, and sectoral land permits. According to Enemark (2004), land policies provide the overall framework for all the planning activities and are contained in sectoral land laws, policies and programmes.

Enemark (2004) argues that land management systems may also be viewed from the perspective of the 'land management paradigm' as depicted in figure 2.2. In this alternative conceptual model, land administration is regarded as the operational component of the land management system and seeks to implement land policies with the aid of an integrated land information system. This conceptual framework suggests that land policies are designed to achieve multiple objectives which may change to reflect the needs of society. Some of the specific objectives identified by Enemark (2004) include land tenure, land markets, real property taxation, land use, natural resource, and the environment, land use, land issues related to poor and vulnerable groups (women, minorities and the poor) and land conflict.

In this regard, land policies provide the overall framework for land-use management.

The land information infrastructure, on the other hand, essentially captures and processes cadastral and topographic data on the natural and built-up environment. Within the context of the '*land development paradigm'* sustainable development is the main objective of the land management system and has three dimensions. These are:

a. The social dimension which involves improving the well-being of citizens.

b. The economic dimension which involves optimizing economic returns or gains.

c. The environmental dimension which involves preserving or maintaining the integrity of the environment.

Sustainable development is realized when the various objectives are achieved simultaneously.

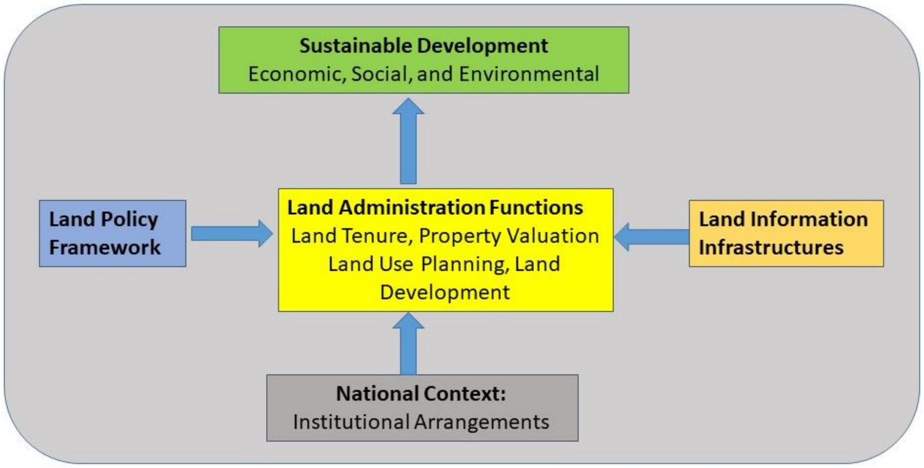

Figure 2.2: Land development paradigm
Source: Enemark (2004, 8)

The '*land development paradigm*' was developed by Enemark (2004) into a 'Global land management perspective'. This is done by expanding the land administration function and illustrating how the various components should interact to develop efficient land markets and land management, which in turn facilitates sustainable development. In this alternative conceptual model, the four land administration functions are supported by an integrated land information infrastructure (or spatial data infrastructure). Further, all activities associated with the land administration function should conform to the existing institutional framework and land policies.

Based on this model, the land administration system is described as a coherent system where the component parts interact with each other. It is built on an integrated land information system where information is shared and easily accessible by all those responsible for performing the four land administration functions. Additionally, the model suggests the need for common policies and processes to facilitate interaction among the four functions.

Enemark et al. (2005) extended the work of Enemark (2004) by incorporating Information and Communication Technology (ICT) into the land development paradigm (figure 2.3). According to the authors, ICT can be employed to facilitate interaction between the land administration infrastructure, professionals and the general public. This, in turn, would allow for the implementation of e-government and e-citizenship. Citizens would be able to access information and actively participate in management activities through ‘e-government’ and ‘e-citizenship’ respectively. According to Enemark et al. (2005), this would improve governance. The study argues that land management should also be driven by a ‘new vision’ which regards land management as a policy imperative. According to Enemark et al. (2005, 52) underpinning the vision are: ‘an holistic approach to LAS, recognition of risk information as a central requirement for land information and management, recognition of the human and governance elements, and facilitation of incremental adoption of the model by countries at transitional stages of economic development.’

Williamson et al. (2010) propose yet another conceptual model that combines the land development paradigm with the ‘vision’ for a spatially enabled land administration system. The authors illustrate how the issues surrounding land in society may be addressed by organizing the land management activities based on six levels of hierarchies: land policy; land management paradigm; land administration system; spatial data infrastructure; cadastre; and land parcel.

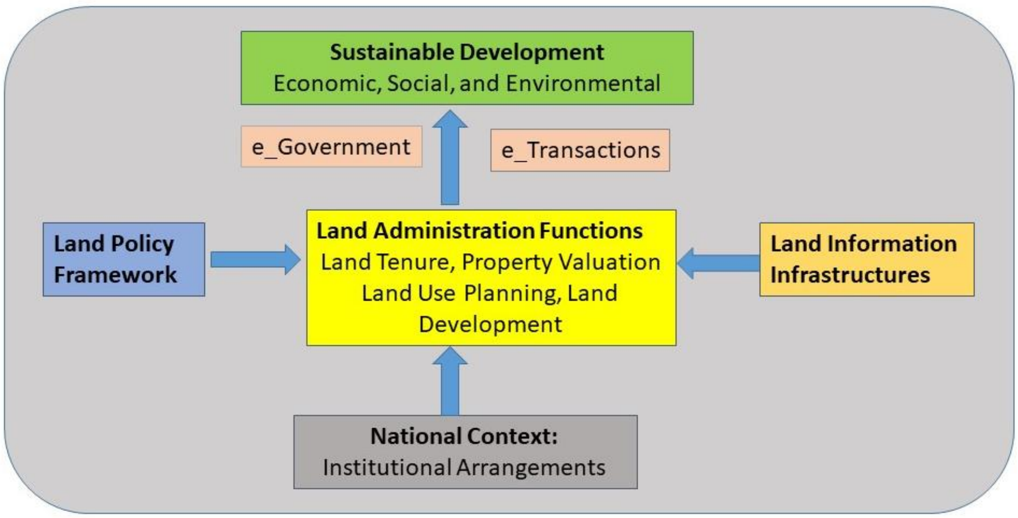

Figure 2.3: Land Development Paradigm with ICT
Source: Enemark (2005, 19)

2.4 Components of Land Management

Notwithstanding the variations in the conceptual models, there are several commonalities among all those discussed earlier. All the models build on the 'land development paradigm' and 'global land management perspective' initially proposed by Enemark (2004). These models also contain common elements such as a land policy framework, land information infrastructure, and land administration systems. Additionally, the models agree that sustainable development is the primary objective of land management.

2.4.1 Land Management and Sustainable Development

As noted earlier, there is a consensus in the literature that sustainable development is the ultimate objective of land management. However, sustainable development is viewed differently by other writers. For instance, Smyth and Dumanski (1993) propose five pillars of sustainable development which include: ecological protection, social acceptability, economic productivity, economic viability, and risk mitigation. The concept of sustainable development has also evolved to encompass issues such as good governance and quality of life (Enemark, Williamson and Wallace 2005; Williamson et al. 2010). According to the literature, sustainable development is only realized when the various aspects of sustainable development are balanced or pursued simultaneously.

2.4.2 Land Policy

Land policies essentially give directions to the aims and objectives for a land management system. It provides the overall framework for land management. Some jurisdictions such as Ghana, have explicit land policies. In other jurisdictions, however, these policies are partially articulated by governments in the form of constitutional provision(s), general laws, as well as sector-specific laws and policies governing land-use and resource management. Enemark (2006), for instance, contends that land policies in

Demark are expressed in the constitution, general laws (such as the Land Registry Act, The Subdivision Act, The Valuation Act, and the Planning Act) and sector-specific laws (such as the Agricultural Holdings Act, the Environmental Protection Act, and the Nature Protection Act). Similarly, van der Molen (2005, 95) argues that the land policy in the Netherlands exists as a '*composition of a myriad of laws, policy decisions and regulations*' rather than an explicit national policy.

The manner in which countries approach the formulation of land policies vary. In some European countries, the parliament crafts land policies. Governments along with high-level bureaucrats are principally responsible for policy formulation and implementation in other countries (Enemark, Williamson and Wallace 2005). Yet other countries, such as Ghana, develop land policies via consultations with all stakeholders (World Bank 2006). Indeed, according to Enemark (2004), land policies may be associated with land tenure, land markets, real property taxation, land use, natural resources and the environment, land conflict and land issues related to poor and vulnerable groups (such as women, minorities and the poor).

2.4.3 Land Administration

Land administration is an extensively researched area. Indeed, the literature on land administration covers a wide range of issues from the definition of land administration to the principles of land administration, practices of land administration in developing and developed countries, land administration and capacity building, land administration reform, theoretical frameworks and models to improve land administration and the link between land administration and development issues.

Based on this definition, Dale and McLaughlin (1999) contend that land administration has a regulatory dimension that relates to land use, a fiscal dimension that deals with land value and a judicial dimension that is linked to a land ownership dimension. Enemark (2004) defines land administration as “recording and disseminating information about tenure value and use of land when implementing land policies. Appropriate land administration systems then provide the basis for sound land management towards economic, social and environmental sustainability” (3).

Dale and McLaughlin (1999) define land management as the “process of regulating land and property development and the use and conservation of the land; the gathering of revenues from the land through sales, leasing, and taxation; and the resolving of conflicts concerning the ownership and use of the land” (163).

Using a similar definition, Ting (2002) argues that the overall aim of land administration is to support sustainable development by minimizing conflicts regarding rights, restrictions, and responsibilities over land. Enemark (2004), on the other hand, defines land administration as systems and processes aimed at establishing efficient land markets and land-use administration. These systems and processes interact to administer land tenure, land value, land use, and land development. Meanwhile, the World Bank (2006) defines land administration as:

> A system implemented by the State to record and manages rights in land. A land administration system may include the following major aspects: a) the management of public land; b) the recording and registration of private rights in land; c) the recording, registration and publicising of the grants or transfers of those rights in land through, for example, sale, gift, encumbrance, subdivision, consolidation, etc; d) the management of the fiscal aspects related to rights in land, including land tax, historical sales data, valuation for a range of purposes including the assessment of fees and taxes, and compensation for State acquisition of private rights in land, etc; and e) the control of the use of land, including land use zoning and support for the development application/approval process. (13-14)

In an effort to emphasize the social dimension of land administration systems Augustinus and Lemmen (2001) propose a Social Tenure Domain Model (STDM). The STDM is a way of making all the social tenures (such as overlapping claims, family and group rights, women's rights, traditional and informal tenures) visible. While examining land administration systems in developed countries, Enemark (2005) calls for the adoption of models that balances sectoral interest with the overall development objective.

These models should be built on appropriate Land Use Data Systems that allows for integrated planning and decision making across sectors. Williamson, Enemark, and Wallace (2006a) build on the previous study by proposing an integrating land administration model which covers all the areas of land administration and driven by a vision aimed at sustainable development. The model allows for e-government through a web-based spatial land management system.

2.4.4 Link between Land Administration and Development Issues

The literature establishes important linkages between the various facets of land administration and several development issues. Feder and Nishio (1998) propose a conceptual framework which illustrates the association between land ownership and farm productivity. Additionally, the study provides empirical evidence which suggests strong positive relationships between land registration/land titling to investment in agricultural activities, output and income of farmers, and access to credit. Feder and Nishio (1998) argue that the land registration system may also have implications for social equity and poverty alleviation. Byamugisha (1999), builds upon the work of Feder and Nishio (1998) by proposing an alternative conceptual framework linking land registration to investment in land, access to credit, transaction efficiency in land markets, labour mobility and efficiency, and the marketability or liquidity of land. The author argues that these linkages serve to explain financial development, aggregate investment, and economic growth.

Similarly, according to Deininger and Binswanger (1999) land administration has important implications for the social and economic status of households since land is the primary means for sustaining investment, wealth accumulation the livelihood of citizens. The authors contend that land regulations and property rights impact on output/income and consequently the economic status of households. These regulations and rights also determine the willingness of households to work and capacity to access credit which in turn impacts on their wellbeing. Meanwhile, Bell (2009) which examines land administration projects in East Asia shows the projects placed varying emphasis on economic and social issues, such as social equity and stability, economic growth, fiscal sustainability, environmental responsibility and sustainability, tenure security and access to land, and the development of land markets. Bell (2009) also claims that the projects are important for achieving the Millennium Development Goals (MDGs) which speak to issues such as poverty alleviation, food security, good governance, conflict avoidance, and social and economic progress.

Further, Williamson et al. (2010) argue that land administration systems provide the platform for supporting governance and rule of law, alleviating poverty, providing security of tenure, supporting land and property taxation, resolving land conflict, managing land resources optimally and developing infrastructure. Together these benefits contribute to the achievement of sustainable development, which has three dimensions, social and economic progress, and environmental sustainability.

2.4.5 Land Tenure and Informal Settlements

Land tenure is primarily viewed as a social relation involving a complex set of rules that govern land use and land ownership. Durand-Lasserve and Selod (2007) in examining urban land tenure formalization in developing countries, deemed land tenure as the rights of individuals and communities to occupy, use, develop, inherit, and to transfer land. The authors examined the links between tenure insecurity and poverty and further consider the potential social and economic effects of land tenure formalization. They highlight that tenure informality may enable quick access to land at a low cost for the poor; however, the drawbacks include the distortion of land use, entrapping informal settlers in poverty, likely to result in tenure insecurity, discourages investment by households and communities in informal settlements, and hinders the provision of urban services and infrastructures.

Land tenure formalization is seen as a process by which informal tenure is integrated into a system recognised by the public authorities to ensure that tenure security can be achieved through administrative recognition or delivery of real property rights. Land tenure formalization also depends on legal, social and political factors which include a constitutional, legal and regulatory framework. Moreover, it includes the political balance of power at central and local government levels, the demand for tenure formalization, the political will and commitment, pressures from the civil society and concerned communities, the perception of the legitimacy of the informal settlement, and the financial and human resources available for implementing tenure formalization at the central and local government levels.

The health of a country's land administration system can be gauged by the level of informal settlements and how this informality affects effective land markets. Good governance and land administration systems are undermined when actions are not taken to stop or prevent illegal activities by others that affect land management such as illegal logging or encroachment on forest reserves or state lands.

2.5 Emerging Issues

In the section below a review of the emerging issues confronting land management are presented.

2.5.1 Land Management and Land Banking

The concept of land banking is relatively new to many developing countries, although similar practices may exist informally and are often unregulated. On the contrary in the developed world, particularly in North America and Europe, formalized land banking is being recognized as an important player in land tenure arrangements; and one that often presents policymakers and legislators with unique challenges. Land banking can, in fact, create a significant impact on land acquisition and the way land is managed, distributed or allocated. It is further argued that the concept of land banking differs significantly in its applicability within or amongst developed and developing countries.

The understanding of land banking may vary from State to State. For instance, land banking in the context of the public sector in developed countries is most often seen as a strategy for dealing with urban renewal, preserving open spaces; and stabilizing property and land values in a particular area (Cleveland State University 2005).

Land banking is also deemed to involve the buying or acquisition of residential and underutilized property, lands and agricultural lands at low prices for the purpose of productive reuse; or to sell to the public at prices above what they are valued (O'Brien et al. 2005; Alexander 2011).

Another view sees land banking as a process of structural acquisition and temporary management of land in rural areas by an impartial State agency, with the purpose to redistribute or lease the land to improve the agricultural structure; or to re-allocate the land for purposes with a general public interest (Damen 2004). Yet again, land banking is defined as the publicly authorized acquisition of land to be held for future use to implement public land policies (Strong 1979). Other definitions see land banking as a mechanism through which urban development is encouraged (Alexander 2005) and instruments for urban renewal (Harrison 2007).

Land banks were thus often created by various levels of governments or non-profit entities to acquire, hold, and manage foreclosed or abandoned properties (Sage Computing Inc. 2009). While, in certain instances, land banks are deemed to be governmental to take ownership of and manage land or properties in the long-term interest of the communities that are affected by abandoned or neglected buildings and properties.

Land banking generally consists of at least three fundamental actions namely: land acquisition, land management, and land development. Efficiency in each of these fundamental areas is critical to successfully achieving land banking objectives. Land banking in developing countries is a concept that is most often associated with accessing land for public purposes such as for housing, managing land markets, used as an instrument for economic growth, and directing land speculation; here land banking may be used as a tool by private investors to speculate on land value as a profit-making endeavour (Harrison 2007). It can further be elaborated that the concept is built on the premise or practice of sourcing, procuring or purchasing land and holding on to it until the value has increased or is considered useful or profitable to sell or release for the purpose of housing, or other development purposes which may include infrastructural development or agricultural development.

Land banking is an essential process in helping to restore productive use of neglected properties. However, it should not be used independently of other methods to ensure effective land management practices. Land banking may not independently resolve conflicts in land management, particularly with the issue of overlapping jurisdiction of State agencies; but it can be considered as one of the solutions to aid in resolving issues surrounding abandoned properties, and aid in the constructive use of lands for the community and national development.

2.5.2 Land Management and Land Conservation

Land conservation consists of methods designed to preserve land, the environment, and its resources in response to the overuse of existing land or ‘already developed’ land in order to ensure continued availability and sustainability for specific purposes. According to Ingerson (2004), land conservation is an increasing priority for rural communities, suburban developments, and cities which are driven by the desire for safe drinking water, pollution-free air, and public amenities such as parks, new initiatives to conserve land and resources.

The definition of conservation, which is more in line with land ethics, speaks to the safeguarding of healthy life-support eco-systems that shape the climate, cleanse the air and water, regulate water flow, recycle essential elements, create and regenerate soil and enable ecosystems to renew themselves (IUCN, UNEP and WWF 1991). Land conservation contributes to the improvements in land use practices (de Brun, 2007). Liniger and Critchley (2008) for instance, add that soil and water conservation techniques contain the potential to transform rural livelihoods and landscapes by mitigating or preventing land degradation.

As mentioned previously, land conservation is crucial to ensuring the sustainability of a specific environment and its resources and plays a critical role in the land management process given the numerous competing interests for land use, such as demand in population growth, urban development, infrastructural expansion, and extractive activities such as mining, deforestation, energy exploration etc. and the effects of climate change. Land conservation has come under some criticism given that the social and institutional dynamics have often been ignored in some land conservation programmes (Brechin et al. 2002). However, today institutional design and social relations are increasingly being recognized as crucial to the effectiveness of conservation initiatives (Ostrom 1991; West et al. 2006).

2.5.3 Land Management and Land Use Planning

Conflicts have constantly arisen to challenge land ownership, land use, and land management and control in many States. Conflicts ranging from the demand of land for housing development, for use in agricultural and infrastructural development, and those allocated to be used for national development, recreational parks, etc. Hence, in order to address these areas of concern, land use planning has been developed as one of many tools and systems used in land management, usage and allocation. Land use planning is undertaken in an environment of competing uses and is dubbed as a balancing act. Land use planning may have various terms which are used interchangeably such as: regional planning, town and country planning, urban planning, or spatial planning. The overarching theme in all the terms suggests that land is used in the most efficient way to achieve economic, social and environmental goals (WMO 2007).

According to Daniele (2001), land use planning is defined as, “the systematic assessment of land and water potential, alternatives for land use and economic and social conditions in order to select and adopt the best land use options. Its purpose is to select and put into practice those land uses that will best meet the needs of the people while safeguarding resources for the future. The driving force in planning is the need for change, improved management or for different patterns of land use dictated by changing circumstances" (4).

Land use planning is described as, "a systematic and iterative procedure carried out in order to create an enabling environment for sustainable development of land resources which meets people's needs and demands" (FAO/UNEP 1999, 14). Land use planning assesses the physical, socio-economic, institutional and legal potential and constraints with respect to the optimal and sustainable use of land resources, and empowers decision-makers on how to allocate those resources (FAO/UNEP 1999).

The Canadian Institute of Planners defines land use planning as "the scientific, aesthetic, and orderly disposition of land, resources, facilities and services with a view to securing the physical, economic and social efficiency, health and well-being of urban and rural communities" (Yang and Qian 2017, 236).

Land use planning is dubbed as "a key municipal function, which includes long-range land use policy, growth management, capital budgeting and regulatory or implementation planning" (AUMA 2007, 3). It generally involves zoning of appropriate types and forms of land uses, as well as infrastructure and open space planning directed at the efficient utilization of land in order to provide benefits to the broader population, the economy, and the environment.

The main objective of land use planning is to organize and prioritize land development activities within a specific territory, while at the same time ensuring the sustainable use of natural resources which is achieved by identifying the right balance between economic, environmental and social goals (ELLA 2007).

Haub (2009) notes that planning is considered to be, "a set of procedures, tools, and instruments which are used to design and make decisions about what is to be done in the future" (4). Land use planning in itself is described as, "a tool used to organize multiple demands for land while minimizing the likelihood of competition and conflict" (ELLA 2007, 1). According to GTZ (2011), land use planning is one of the tools that can help to [address challenges] as it focuses on negotiating future land and resource uses by all relevant stakeholders.

Other key tools have been identified by Blumner (2006) such as zoning, master plans, and land use plans which are generally described as relatively inflexible instruments designed to regulate future development and were developed to protect private interests as well as public welfare. In the process of land-use planning, according to Fox (1988), diagnostic tools using aerial photographs, sketch maps and semi-structured interviewing have been applied to problems of conflict over state forests and lands.

2.5.4 Land Management and Disaster Risk Management

Disasters, often natural or man-made, may threaten peoples' lives, cause significant damage to private and public property and infrastructure, and can disrupt the social and economic activities and livelihoods of many. In fact, disaster is defined as "a serious disruption of the functioning of society, causing widespread human, material or environmental losses which exceed the ability of affected society to cope using only its own resources" (IDNDR 1992, 12). With the occurrence of disasters whether frequent or otherwise, there is a need for Disaster Risk Management which allows for the identification of practical remedies for disaster problems and challenges. Hence, Disaster Risk Management is defined as: "a series of actions - programmes, projects and/or measures, and instruments expressly aimed at reducing disaster risk in endangered regions, and mitigating the extent of disasters" (Gratwa and Bollin 2002, 19).

2.5.5 Land Management and Food Security

Food security has evolved following the urbanization and industrialization era. Prior to this era, its importance had waned and was largely neglected given that its contribution to the development and total economic activity was unrecognized (van Keulen, Kuyvenhoven, and Rubenb 1998). Now, food security has become a significant area of concern following the post-world war era. Many countries have recognized the importance that food production plays in their economic development; and more importantly, that improving food supplies is also essential to enlarge markets to facilitate the production of industrial goods (van Keulen et al. 1998). It is also becoming widely accepted that an increase in agricultural productivity is required to improve rural incomes and maintain the supply of food for urban populations, raw materials for agro-industrial development, and cash-crops for export earnings (van Keulen et al. 1998). According to the UNECA (2004), food security's realization is heavily dependent on the accessibility of household or community to land and tenure security. It is also contingent on them being able to mobilize related resources for food production and distribution. Increasing public and private investment in agriculture have also been recognized by G-20 leaders as crucial to food security and hunger eradication.

The demand for land to expand infrastructural developments to cater to urbanization and growing populations, the need for housing, industrial expansion, communication, transportation, and the development of additional commercial districts, have in earlier years, been treated with more priority than food production and laid more claims to land once used for agriculture and food production. In addition, the effects of land degradation, deforestation, and the clearing and extraction of minerals and other resources have competed with land space for agricultural activities thereby placing much strain on agricultural output and food production.

However, over the years, specifically beginning in the 60s and 70s, the need for a rapid increase in food productivity was realized and deemed to be critical if countries were to maintain their food supply, support the growing demand for food, and provide for the increasing populations. According to Müller et al. (2007), food production has doubled over the past thirty years and tripled in developing countries as a result of research and development and technological progress; however, meeting and sustaining the world's population demands for food are still to be achieved. On the contrary, UNCTAD (2011) has recorded a significant decrease in agricultural investments in many developing countries over the last ten years. According to FAO (2009), in developing countries, there has been a decrease in public spending towards agriculture by approximately 7%. Official Development Assistance has also decreased from 17% in 1979 to 3.5% in 2004.

Figure 2.4 summarizes the connection between land tenure and food security depicting direct land policy opportunities to improve food security. The diagram seeks to capture the concept of allocation of land for agricultural production and income generation; and improved welfare, food security, and nutrition (Maxwell and Wiebe 1998). It also supports the argument that loss of access to land in an agrarian society leads to a reduction in income and access to food (Maxwell and Wiebe 1998).

Figure 2.4: Conventional conceptual links between land and food

2.5.6 Planning for Food Security

The conceptual model called: ‘Planning for Food Security’ developed by Caldwell et al. (2011), intends to portray the factors (environmental, economic, and social factors) that influence policies and strategies which are developed and/or adopted by some countries when planning for agriculture and food security. Categories such as “environmental opportunities and constraints”, “social and economic factors”, and “sustainable development” and “catchment management” (the impact that development will have on water quality and land degradation) are given consideration in this model and depicts their interrelationships or interdependencies.

2.5.7 Land Tenure and Food Security

Maxwell and Wiebe (1998) presented a conceptual model that seeks to explain the dynamic relationship between land tenure and food security. More specifically, the model demonstrated how linkages are created between consumption and investment decisions, endowments, production and exchange decisions, and entitlements – all of which influence or impact the distribution of resources within and among households. Depending on a household's endowments, access to food and commodities will vary significantly and will influence the extent or degree to which sufficient food can be afforded and consumed thereby contributing to the activity and health of the members of the household. Other variables or factors are taken into consideration in this model such as marketing, household resources (land, capital, labour, access to technology and markets), and investment in land or capital; and they all influence or impact decisions to generate household access to food and commodities. The model also speaks to land tenure and food security. This model suggests that institutional reforms or evolutionary changes in land tenure often lead to greater equity, greater productivity, and better conservation practices, all of which will benefit food security.

2.5.8 Food Systems and Food Security

FAO presented a conceptual framework that best encapsulates their definition of food security which states (FAO 2007), “FAO’s vision of a world without hunger is one in which most people are able, by themselves, to obtain the food they need for an active and healthy life, and where social safety nets ensure that those who lack resources still get enough to eat” (14). The framework is said to give operational meaning to this definition as it identifies several important factors that can have a lasting impact on food security. These factors include socio-economic and political conditions, access to food, access to markets, purchasing power, the stability of food supplies, and the resulting food consumption and food utilization of the nation.

Frank et al. (1999) presented a conceptual framework for food security. The framework highlights the relationship between three dimensions of food security, that is, availability of food, access, and food utilization. Similar to the previous conceptual models discussed, this conceptual model suggests that food availability is dependent on domestic food stocks, commercial food imports, food aid, and domestic food production. The model also suggests that food security is also dependent on food supplies at the regional or national level and accessibility to food through availability in the market and other local sources. The model also ties in households’ food production and income generation which collectively contribute to achieving food security objectives. Importantly, it also recognizes the importance of key resources such as human resources, capital resources, community resources and natural resources which speaks to land availability.

2.6 Spatial Decision Support Systems

Spatial Decision Support Systems (SDSS) have been employed in many countries to support sustainable development. Kersten et al. (2000) provide a number of case studies and applications of SDSS to support sustainable land development, water resource management, natural resource conservation, and crop management among other uses. Additionally, Kersten et al. (2000) offer a comprehensive summary of application areas for DSS such as environmental decision-making, environmental impact assessment, water resources management, agriculture, forestry, manufacturing, infrastructure, and medicine. These information systems have also been used to address a variety of problems (structured, semi-structured and unstructured) and support decision-making at the operational, managerial and strategic levels.

Notwithstanding the variation in applications, SDSS generally have an architecture with three common elements, namely, (i) geographic database component; (ii) model component; and (iii) user interface (Sprague 1980).

These components are often described differently. Xiaoli et al. (2009), for instance, describes the three common layers as (i) database server layer, (ii) business service layer; and (iii) user interface layer (for other descriptions of the three common elements see Sprague 1980). The database component usually contains the relevant spatial and attribute data as well as Database Management Systems (Bello-Dambatta 2010).

The Database Management System (DMS) comprises computer programs which allow for the optimal management of data stored in the DSS. On the other hand, the model component provides the modelling functionalities for every level of management (operational, managerial and strategic) and problem type (structured, semi-structured and unstructured). This component is managed by a Model Management System (MMS); which contains computer programs that may be used to build and update models. It is noteworthy, that the MMS allows for the use of a variety of models: linear programming, integer programming, goal programming, and Analytic Hierarchy Process (AHP). Finally, the interface layer provides a range of data operation functionalities and editing features via the DMS and MMS. This module provides a variety of dialogues among which include: graphical user interfaces, menus, direct command languages, and natural language interaction.

Spatial Decision Support Systems (SDSS) are capable of facilitating both individual decision making and group decision-making. Since the proposed ILMM favours group decision-making it will employ an-tier client-server architecture. This type of DSS architecture is extremely useful for group decision-making and information sharing. According to Bello-Dambatta (2010), three types of client-server models exist. These are: (i) static model using HTML, (ii) client-side processing; and (iii) server-side processing using a scripting language. Of the three options, the server-side processing is the most preferred currently.

2.6.1 National Spatial Data Infrastructure

National Spatial Data Infrastructure (NSDI) attracts a multiplicity of definitions. NSDI is described as "the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data" (Clinton 1994, 17671). According to Rajabifard and Williamson (2001) "The Australian and New Zealand Land Information Council (ANZLIC 1998) defines a National SDI as comprising four core components: an institutional framework, technical standards, fundamental datasets, and clearinghouse networks" (3). Gharaibeh et al. (2018) also defined NSDI as "… an umbrella that covers policies (institutional frameworks), standards, organizational procedures and technologies in the usage, management, and production of spatial data" (5067). Based on these definitions a NDSI comprises rules and guidelines (or standards), technologies, institutional framework (or policies) and human resources that provides a unified platform (or national spatial clearing house) which promotes the collection, production, usage, sharing, and management of geospatial data among a variety of stakeholders.

NSDI typically has five main components. These are policies and standards; information technologies; databases and metadata; network of users and data providers; institutional arrangements (McLaughlin and Nichols 1994). One of the most important elements of the NSDI is the national spatial clearinghouse which consists of several servers with digital spatial data (Crompvoets et al. 2004). This clearinghouse allows for the manipulation of spatial data from numerous sources via the internet (*ibid* 2004) and provide a suite of commonly used services (INSPIRE Architecture and Standard Working Group 2002). In a web survey conducted in December 2001, Crompvoets and Bregt (2003) found the steady growth in national clearing houses across the globe between 1994 and 2001. Crompvoets and Bregt (2003) also found that national clearing houses were implemented more in North American, South America, Europe, Southeast Asia and Australia than Africa and the Middle East. Similar evidence was found by Crompvoets et al. (2004). NSDI are built to create a national network linking databases and users and enhancing the accessibility, communication, and use of geographically referenced data (McLaughlin and Nichols 1994).

The benefits that may accrue from developing and implementing NSDI are many. Hu and Li (2017), for instance, argues that it reduces data redundancy and duplication of efforts to collect geospatial data, improves transparency and enhances participation by the public in governmental activities and stimulates the growth of new businesses. Tonchovska et al. (2012) also contends that spatial data infrastructure: “(i) reduce duplication of efforts among governments, (ii) lower costs related to geographic information while making geographic data more accessible, (iii) increase the benefits of using available spatial data, and (iv) establish key partnerships between states, counties, cities, academia, and the private sector” (1).

2.7 GIS and Land Use Suitability Modelling in Planning

2.7.1 GIS in Land Use Planning

Dueker and DeLacy (1990) stated that land development planning can be enhanced if land records are current and modernized. This, in turn, is possible with the application of Geographic Information System (GIS) concepts and techniques. The authors argue that GIS makes land transaction and land development process more efficient and effective when used for site selection and evaluation, property valuation, property conveyance, site planning and developing plans for service development. Innes and Simpson (1993) went on to argue further that it is imperative for planners to understand GIS since it would allow them to play a more meaningful role in developing policies as well as simple analytical maps. However, the authors suggest that changes in the institutional arrangements and responsibilities of planning agencies are necessary if these benefits are to be derived from the use of GIS technology.

Lober (1995) argues that GIS-based techniques offer solutions which are optimal and implementable. However, Lober cautioned that it is essential to have a continuous process that identifies locational criteria, including social and ecological, when using GIS techniques. Meanwhile, Ceccato and Snickars (2000) reason that GIS allows for the straightforward representation of qualitative data as well as provide the basis for the integration of different social groups in the planning process. As such, they argue that the use of GIS ensure access to resources, greater transparency and promote democracy. Klosterman (2013) examined the revolution of information technology and its impact on planning. He contends that planning now revolves around GIS. In this study, the author chronicles trace the evolution of planning as an applied science during the 1960s to planning as an avenue for social interaction and interpersonal communication aimed at achieving collective goals in the United States.

2.7.2 Approaches to Land Use Suitability Models

Land use planners make complex decisions regarding land use planning. These decisions, however, can be simplified with the aid of various land suitability assessment methods. Rabia and Terribile (2013) refer to land suitability assessment as "… the investigation of a certain part of the land's appropriateness to a specific type of land use" (15). According to the authors, the land suitability assessment involves six steps, starting with the collection of data from fieldwork, consultation with stakeholders, and the literature. At this stage, the factors that affect land use are defined. The factors are then rated and weighted. Finally, the computed weights are combined to generate suitability maps.

The extant literature offers an extensive range of land suitability assessment techniques. Each technique has unique strengths and weaknesses. In one of the earliest survey of the literature, Hopkins (1977) compares the various land assessment models such as Gestalt, mathematical combination, and spatial multi-criteria decision analysis among others. Apart from describing the steps for generating suitability maps using each model, Hopkins highlights their limitations and strengths. For instance, Hopkins argues that the Gestalt method allows planners to consider the interdependence of multiple factors but does not provide a rating for various land uses. He also contends that only a few individuals have the capability of using this method while planners often lack knowledge of the study area. The mathematical techniques such as the ordinal combination, which provides for ranking of the various land use factors, are superior to the Gestalt method but involves invalid mathematical operations according to Hopkins. Meanwhile, the non-linear combination method requires the use of unknown functional relationships even though it corrects some of the limitations of the Gestalt technique. It is also noteworthy that the factor combination and cluster analysis technique requires extensive evaluative judgments. The table 2.1 provides a summary of some of the limitations associated with each method. According to Hopkins, the best approach is to use a hierarchical method which combines the linear and non-linear combinations as well as follows the rules of combination method.

Table 2.1: Limitations of land suitability techniques

Methods	Limitations
Gestalt	Very few planners have the ability to use this method. Planners often lack the knowledge of the study area to effectively utilize this technique. Difficult to communicate information to decision makers and scrutinize.
Mathematical combination	
Ordinal combination	The mathematical operation for this technique is invalid. It cannot be used for determining relative suitability based on slope type. It is not effective for generating suitability maps.
Methods	Limitations
Linear combination	It cannot handle the interdependence among the factors and relative suitability for a given land use.
Non-linear combination	The non-linear functions used for this method only apply to specific components of overall suitability rating and not appropriate for generating land use suitability.
Factor combination	Only suitable when a few factors are considered Difficult and time consuming to rate various combinations of the factors considered. The rating of regions relies entirely on the implicit judgment.
Cluster analysis	Requires great care of interpretation and costly. Only appropriate when the expected results are superior to the other methods.

Source: Adapted from Hopkins (1977)

Malczewski and Orgyczak (1996) evaluate other decision rules highlighting their advantages and disadvantages. The study classifies the approaches into three major categories. These are optimizing decision rules, satisficing decision rules, and quasi-satisficing decision rules.

Collins, Steiner, and Rushman (2001) chronicles the evolution of land suitability analysis in the United States over the period of 100 years. According to the authors, during the first phase, land suitability analysis took the form of hand-drawn sieve mapping overlays by landscape architects during the late nineteenth and early twentieth century. This was followed by the birth of the planning literature with the publication of the Town and Country Planning Textbook in 1950 that instigated the discussion on land-use suitability techniques throughout the late 1960s and early 1970s. The third phase of the evolution involved the application of computer technology for land use suitability analysis at University of Pennsylvania, Harvard University and University of Massachusetts created the foundation for Geographic Information Systems (GIS). During the fourth stage, a variety of techniques emerged to supplement the GIS-based land use analysis. Among these included: Boolean logic, fuzzy logic, multiple criteria decision making, multi-criteria evaluation methods. The now popular, Analytic Hierarchy Process (AHP), was developed and extended. Collins, Steiner, and Rushman argue that the fifth stage involves the use of artificial intelligence (AI) to replicate expert knowledge in land-use suitability analysis.

Dujmovic, Tre, and Dragicevic (2009) extended the discussion on land-use suitability assessment method by examining techniques such as simple additive scoring, multi-attribute value technique (MAVT), multi-attribute utility technique (MAUT), analytic hierarchy process (AHP), ordered weighted averaging, outranking methods, and logic scoring of preference (LSP). Based on their evaluation of the various techniques, the authors argue that the method chosen should be contingent on its ability to capture human evaluation logic rather than randomly selected without proper justification. Dujmovic, Tre, and Dragicevic reasoned that the LSP method is the most accurate method and appropriate for land use evaluation, suitability maps, and natural resources planning.

2.8 Summary

In summary, the thesis adopts the United Nations Economic Commission for Europe's (UN-ECE 1996, 13) definition of Land Management as well as the World Bank's (2006, xiv) definition of Sustainable Land Management. These principles influenced Enemark's (2004, 8) land development paradigm with Information and Communication Technologies (ICT) support (Enemark and Parker 2005). The emerging role of land use planning is playing in land management is at the forefront of this thesis. The role is to ensure that land is used in the most efficient way to achieve economic, social, and environmental goals (WMO 2007; FAO/UNEP 1999; and ELLA 2007).

The use of ICT, SDSS, and GIS in support of sustainable land management cannot be over emphasised (Kersten et al. 2000; Dueker and DeLacy 1990; and Lober 1995; Corcato and Snickers 2000; Klosterman, 2013). The Weighted Linear Combination methods of land suitability analysis is selected amongst all other methods.

2.8.1 Justifying the Choice of Using a Weighted Linear Combination

The two general classes of multi-criteria evaluation methods are Boolean overlay operations and the weighted linear combination (WLC) methods (Mokarram and Hojati 2016). According to Malczewski (2002), WLC is one of the most widely used GIS-based decision rule because it is easy to understand, intuitively appealing, and easy to implement within a GIS environment. This method also provides the best site selection because of its flexibility and used in many fields such as ecological science, urban-regional planning, waste management, hydrology and water resource, agriculture, forestry, natural hazards, recreation/tourism, housing/real estate, geological sciences (Al-Hanbali et al. 2011). The critical elements that determines the accuracy of the WLC, are: the assignment of weights to the parameters and GIS procedures used to derive the final output (Micheal and Sailesh 2016).

2.8.2 Assumptions and Limitations of the Weighted Linear Combination

Notwithstanding the popularity of the WLC it is often misapplied because the assumptions underlying the approach is not fully understood and therefore produces questionable results (Malczewski 2002). The implicit assumption of the WLC that its parameters do not vary as a function of geographical space is also unrealistic and therefore render this technique deficient (Malczewski 2011). Other deficiencies of the WLC has been well documented in the literature. For instance, Drobne and Lisec (2009) compares the Weighted Linear Combination (WLC) method and Ordered Weighted Averaging (OWA) method. The authors posit that the WLC has several limitations, including, trade-off (or substitutability), the inappropriateness of the non-linear scaling factors which sometimes are standardized using a blurred process, and suffer from decision risks. They argued that the OWA minimizes the impact of trade-off and decision risks on the results but pointed out that the WLC is advantageous since it allows for the use of different relative weights to each factor in the aggregation process. Eastman (1999) highlighted limitations of the WLC that were similar to those identified by Drobne and Lisec (2009). Eastman, however, argued that fuzzy measures is capable of overcoming some of these deficiencies. The ability of fuzzy measures to address the deficiencies were supported by other studies such as Jaing and Eastman (2000), Comber et al. (2010). The OWA, which utilizes fuzzy aggregation operations is not without deficiencies. Comber et al. (2010) argue that the OWA technique necessitates a thorough understanding of its application by decision makers which may be lacking. This in turn could affect the utility of the OWA in terms of addressing the tradeoff and decision risks. A possible solution to this problem is the AHP, which when combined with sensitivity analysis enhances the reliability of land suitability models (Feizizadeh and Blaschke 2013a, 2013b; Feizizadeh and Blaschke 2014). The reliability of the weights generated from the AHP can be validated with the consistency ratio. More importantly, the weights from the AHP process provides additional benefits among which includes consensus building among stakeholders, the combination of subjective and objective data and decision criteria which addresses inconsistency caused by incomplete judgment and preferences (Benke and Pelizaro 2010). Given the benefits of the AHP it is used in the thesis.

CHAPTER 3: THE CURRENT LAND MANAGEMENT SYSTEM IN GUYANA

3.1 Introduction

This chapter discusses the management of lands in Guyana with the specific aim of highlighting the following:

- The agencies responsible for land management in Guyana.
- The laws and regulations guiding the operation of the land management agencies.
- The quantum and tenure characteristics of the lands in Guyana.
- The manner in which lands are currently being utilised by various land-related agencies.
- Whether there are overlapping jurisdictions that either contribute to land conflicts or have the potential to generate similar conflicts in the future?

The discussion is also aimed at advancing the literature on land management in Guyana by proposing an 'Integrated Land Management Model (ILMM)'. The land model in Guyana is not only designed to address all the problems identified in the study by Bishop (1998) but also to situate the discussion of land management within the Low Carbon Development Strategies (LCDS), a new development paradigm that was adopted by the Government of Guyana recently. The model draws from advances in information technologies and provides an integrated framework for managing, manipulating and disseminating information to the various stakeholders. This is critical for an effective land management framework.

3.2 Physical and Socio-Economic Characteristics of Guyana

Guyana has a total land mass of 83,000 square miles. It is located on the Northern Atlantic Coast of South America. The country has four natural regions, namely, the low coastal belt, the hilly sand and clay region, the interior savannah and the forested highland region. The low coastal belt, which accounts for approximately 6% of the country's total land mass, is rich with alluvial and clayey soil suitable for commercial agriculture activities. Since most of the population resides on the low coastal belt, significant commercial and industrial activities are concentrated in this region. The hilly sand and clay region accounts for approximately 25% of the total land mass of the country and is found immediately after the low coastal belt. This region is rich with sand, clay, loam, and bauxite. It is not surprising that the most important economic activity in the hilly sand and clay region revolves around bauxite mining. The interior savannah comprises grasses, scrub, and low trees ideal for cattle rearing. This natural region accounts for approximately 6% of the total land mass of Guyana. The forested highland region accounts for approximately 63% of Guyana's total land mass and it is extremely rich with minerals, such as gold, diamonds, and manganese and an extensive forest cover with significant potential for attracting carbon credit. According to Bishop (1998), the highland region also has many waterfalls and it is rich in biodiversity, thus making it ideal for the harnessing of hydroelectric power generation and eco-tourism. Table 3.1 shows the size and the dominant economic activities of each natural region.

Figure 3.1: Map of Guyana and its neighbouring countries
Source: https://www.bing.com/images/search?view=detailV2&ccid

Table 3.1: Economic activities in the natural regions of Guyana

Natural Region	**Size (sq. miles)**	**Current Economic Activities**
Low coastal belt	4,980	Agriculture, commercial and industrial activities
Hilly sand and clay region	20,750	Mining (mostly bauxite)
Interior savannah	4,980	Cattle rearing
Forested Highland region	52,290	Mining and logging
Total	**83,000**	

The country is also divided into ten administrative regions with its own administrative or Local Government unit (figure 3.2). The land mass of each region varies in size. The Upper Demerara – Upper Berbice (Region No. 9) is the largest region while Demerara – Mahaica (Region No. 4) is the smallest region. Notwithstanding the size of the latter, over forty-one percent of the population resides in this region. The dominant economic activity of each region is influenced largely by its natural features. For instance, the regions which are predominantly forested highland, such as, Regions 1, 7 and 8, are largely dependent on logging and mining for gold and diamonds. The regions which occupy large portions of the coastal plain, such as Regions 2, 3, 4, 5 and 6, are primarily involved in farming, sugar cane cultivation and coconut cultivation. Regions 9 and 10 which are predominantly interior savannah and hilly sand and clay are involved in cattle rearing and bauxite mining respectively. Table 3.2 and figure 3.2 show the ten administrative regions and the economic activities that dominate each.

Table 3.2: Administrative Regions – size, natural features and main economic activities

Administrative Regions (*Size*)	**Natural Features (*Main Economic Activities*)**
Region 1: Barima – Waini; (*20,399 km^2*)	Predominantly forested highland with *logging and mining for gold and diamonds*
Region 2: Pomeroon – Supenaam; (*6,195 km^2*)	Mostly forested highland and coastal plain; *rice and coconut cultivation, cattle raring, and logging.*
Region 3: Essequibo Islands -West Demerara; (3,755 km^2)	Mostly low coastland and hilly sand and clay region. - *Mainly farming; to a lesser extent cattle rearing and sugar cane and coconut cultivation*.
Region 4: Demerara-Mahaica (2,232 km^2)	Predominantly low coastal plain with a small portion occupying the hilly sand and clay region; *commercial and industrial activities are concentrated in this region. Agriculture activities such as non-traditional farming, sugar and coconut cultivation are also dominant. To a lesser extent, cattle raring is done in this region.*
Region 5: Mahaica – Berbice; (4,190 km^2)	Predominantly low coastal plain. *Rice farming is the main economic activity followed by sugar cane and coconut cultivation and cattle rearing.*
Region 6: East Berbice – Corentyne (36,234 km^2)	Coastal plain and small portions of the intermediate savannah, hilly sand and clay region and forested highland; *rice farming, sugar cane cultivation, and cattle rearing. Logging done on a small scale.*
Region 7: Cuyuni - Mazaruni (47,213 km^2)	Predominantly forested highland and a small portion of the hilly sand and clay region; *Mining for gold and diamonds dominates the economic activity in this region. Has the potential for hydroelectric generation schemes.*
Region 8: Potaro – Siparuni (20,051 km^2)	Predominantly forested highland and a small portion of the hilly sand and clay region. - *Mining for gold and diamonds dominates the economic activity in this region. Has the potential for ecotourism. IWOKRAMA Rainforest partly in this region.*
Region 9: Upper Takutu – Essequibo (57,750 km^2)	Predominantly interior savannah and occupies a portion of the highland region. - *Cattle rearing are the dominant economic activity with mining done on small scales. Has the potential for ecotourism*.
Region 10: Upper Demerara - Upper Berbice (17,040 km^2)	Occupies the largest portion of the hilly sand and clay region. - *Mining of bauxite the main economic activity. It also occupies a portion of IWOKRAM Rainforest.*

Source: Administrative Regions of Guyana, South America http://www.guyanaguide.com/admin_reg.html (accessed February 6th, 2012)

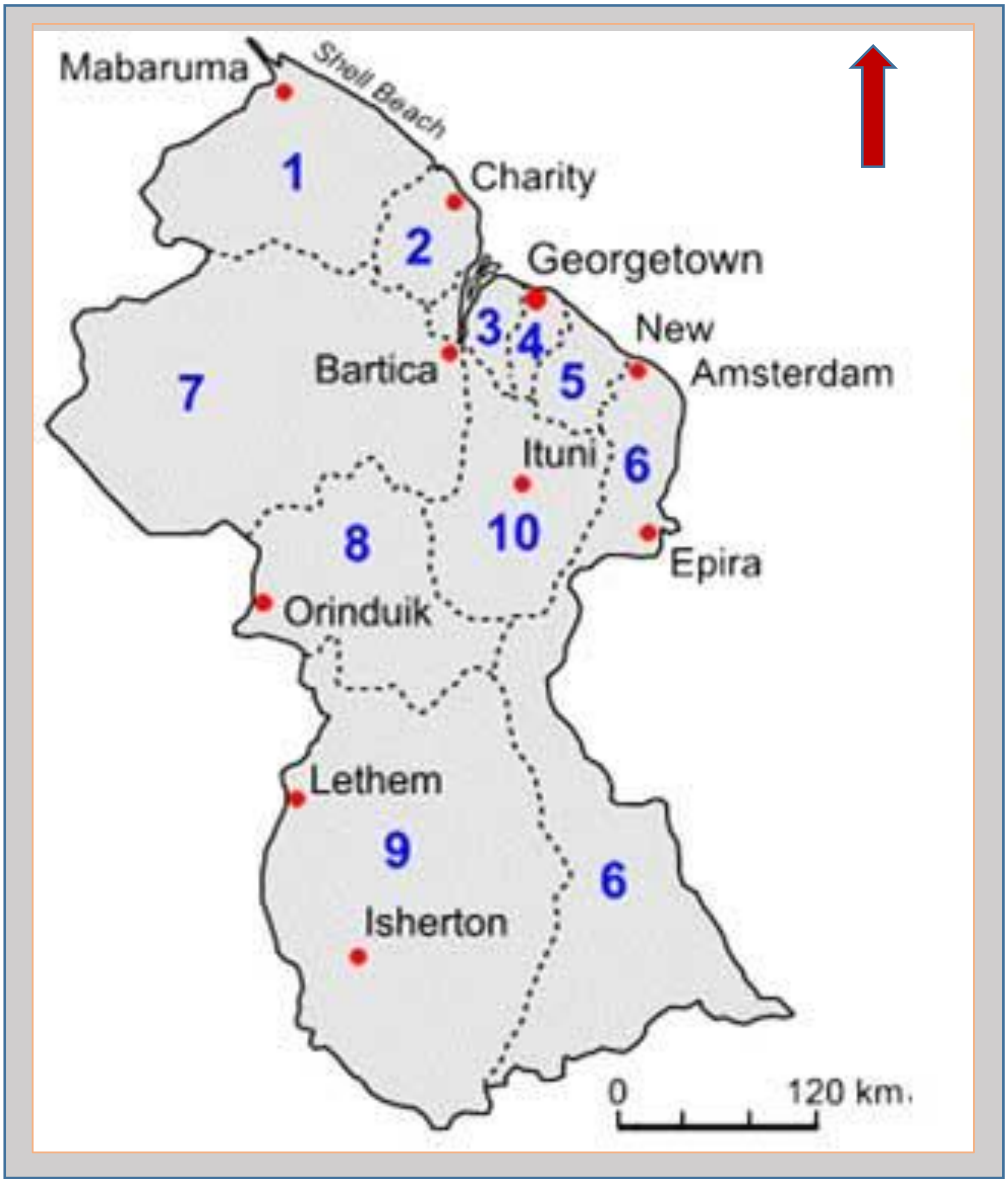

Figure 3.2: Map showing the ten administrative regions of Guyana
Source: https://www.bing.com/images/search?view=detailV2&ccid

3.3 Legal and Regulatory Framework Governing Land Management

The current legal and regulatory framework regarding land management is complex. For instance, state lands are managed primarily by the Guyana Lands and Surveys Commission (GLSC). However, the Guyana Forestry Commission (GFC) and Guyana Geology and Mines Commission (GGMC) have rights over the state forests and mineral resources which are located on all state lands respectively. The Ministry of Housing and Water, Central Housing and Planning Authority (MoHCHPA) and the Ministry of Agriculture are also empowered to administer state lands for housing and agricultural purposes. Amerindian lands, on the other hand, are administered by Village Councils. However, the Ministry of Amerindian Affairs (MoAA) is involved in the extension and demarcation of lands which Amerindian communities and villages apply for over time. Private lands are owned and administered by private individuals, cooperative societies, and the Guyana Sugar Corporation (GUYSUCO) a wholly owned government agency, with the latter being the most significant owner of such lands. For the purpose of land administration, the country’s lands are generally classified as State or public lands, Private lands, and Amerindian lands.

As mentioned in the previous section, numerous agencies administer state lands in Guyana. Each agency is empowered and mandated by specific laws to regulate the acquisition and utilization of lands for various purposes, such as mining, logging, housing development, agricultural uses, etc. Figure 3.3 shows the various agencies which are responsible for land administration and how the agencies utilise lands to achieve sectoral goals which in turn are intended to achieve various national priorities that at the macro level involves balanced and sustainable economic growth and development.

Further, each agency is guided by the following specific regulations and policies governing land management and utilisation.

a) the Guyana Lands and Surveys Commission Act 1999;
b) the State Lands Act 1998, Lands Department Act, 1903;
c) Land Surveyor's Act 1891;
d) the Mining Act 1989 (cap. 65:01);
e) Guyana Geology and Mines Commission Act 1969 (Cap. 65:09);
f) Geological Surveys Act 1918 (Cap. 59:02);
g) Occupational Safety and Health Act 1997 (Cap. 99:10);
h) Environmental Protection Act 1996 (Cap. 20:05);
i) Industries Aid and Encouragement Act 1951 (Cap. 95:01);
j) Forestry Commission Act 1979;
k) The Housing Act 1948;
l) Town and Country Planning Act (Chapter 20:01).

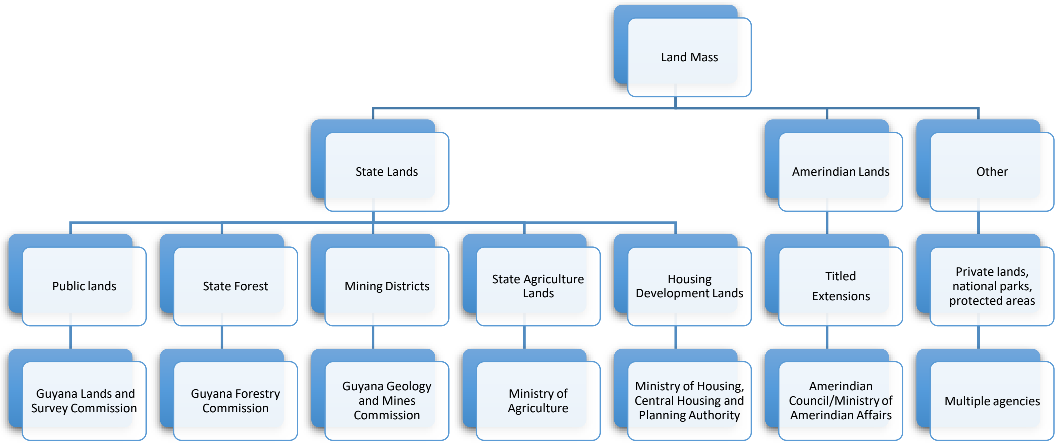

Figure 3.3: Land management agencies in Guyana

3.3.1 Guyana Lands and Surveys Commission

According to Bishop (1998), over seventy percent of the lands in Guyana are controlled by the State – often regarded as 'public lands' (Public lands include all Government and State lands as defined by the Land Department Act and State Lands Act respectively). These lands are administered primarily by the Guyana Lands and Survey Commission (GLSC) which was established in June 1, 2001. This semi-autonomous agency was created through the Guyana Lands and Surveys Commission Act No. 15 of 1999 (also referred to as Chapter 59:01). According to Chapter 59:01, the Commissioner of the Guyana Lands and Surveys Commission (GLSC) is entrusted with the responsibility of managing, regulating and protecting the use of 'public lands'. This involves the issuance of various forms of permissions to utilise state lands, such as, long-term leases, mortgage permissions and transfers and renewal.

According to Chapter 59:01, the Guyana Lands and Surveys Commission (GLSC) is also responsible for the following: (i) monitoring and enforcing the terms and conditions under which public lands are sold or let; (ii) creating and maintaining records of public lands as prescribed by the law; (iii) providing the general public with access to information related to public lands; (iv) liaising with all the agencies involved in the registration and storage of records pertaining to public lands; (v) compiling and maintaining an inventory of all the land resources of Guyana with emphasis on their quality, degree, pattern of utilisation, etc.; (vi) preparing a land use plan for the Country; (vii) initiating studies that are related to or would inform policies on land development projects; and (vii) enforcing all laws related to public lands and land surveys.

Over the years, in order to effectively carry out its functions, the Guyana Lands and Surveys Commission has established offices in the regions with significant public lands. These include Regions 1, 2, 3, 4, 6, 7, 9 and 10. Most of the lands in Regions 5 and 8 are controlled by private individuals as well as the Guyana Forestry Commission (GFC) and Guyana Geology and Mines Commission (GGMC). In addition to those stipulated in Chapter 59:01, the activities of the Guyana Lands and Surveys Commission are guided mainly by the State Lands Act, 1998; Lands Department Act, 1903; and Land Surveyor’s Act, 1891. The core activities of the Commission are executed by four divisions, namely, Land Administration, Surveys Division, Land Information and Mapping, and Corporate Affairs.

3.3.2 Guyana Geology and Mines Commission

The Guyana Geology and Mines Commission (GGMC) was established in 1979 as a semi-autonomous agency to replace the Geological Surveys and Mines Department of the Ministry of Energy and Mines. It is governed by the Geology and Mines Commission Act 1989 (Cap. 65:09). Under Cap. 65:09, the Guyana Geology and Mines Commission has rights over all minerals on state lands and is empowered to grant mining permits as well as concessions to individuals interested in mining. The Act also entrusts the Guyana Geology and Mines Commission with the responsibility of supervising and regulating mineral exploration in accordance with the Mining Act 1989 (Cap. 65:01), Guyana Geology and Mines Commission Act 1969 (Cap. 65:09), Geological Surveys Act 1918 (Cap. 59:02) No. 6 of 1918; Occupational Safety and Health Act 1997 (Cap. 99:10), Environmental Protection Act 1996 (Cap. 20:05), and Industries Aid and Encouragement Act 1951 (Cap. 95:01).

The GGMC has identified a total of six mining districts (figure 3.4): Berbice, Cuyuni, Mazaruni, Northwest, Pataro, and Rupununi Mining Districts. The total land mass of the six mining districts is approximately

45.8 million acres. When the GGMC closed areas (National park (that is, the Kaieteur National Park and Iwokrama Rainforest) and Amerindian lands), are excluded from the total land mass of the six mining districts, this leaves approximately 34.2 million acres available for mining.

Mining is carried out in six Mining Districts: Berbice (District 1), Pataro (District 2), Mazaruni (District 3), Cuyuni (District 4), North West District (District 5), and Rupununi (District 6). Table 3.3 shows the total acreage per mining district as well as the acreage available for mining in each.

Table 3.3: Total acreage per mining district and the quantum of land available for mining

Mining District	Total	GGMC Closed	Amerindian Lands	National Parks	Available for mining
No. 1	8,680,376.3	96,608.7	109,500.0	-	8,474,267.6
No. 2	3,511,109.4	1,002,557.3	230,929.6	189,477.5	2,088,145.0
No. 3	7,780,723.3	347,331.8	1,171,763.0	-	6,261,628.5
No. 4	4,388,713.7	511,053.0	165,258.0	-	3,712,402.7
No. 5	3,873,683.5	871,020.4	663,174.0	47,349.3	2,292,139.7
No. 6	17,607,344.1	86,681.2	4,785,861.8	1,700,186.1	11,034,615.0
TOTAL	45,841,950.3	2,915,252.4	7,126,486.5	1,937,013.0	33,863,198.5

Source: Adapted from Guyana Geology and Mines Commission (2012)

The largest mining district is the Rupununi (District No. 6) which accounts for approximately 38.4% of the total mining area and 32.6% of the total area available for mining. This is followed by Berbice (District No. 1) and Mazaruni (District No. 3). It is noteworthy that all of the mining districts occupy a significant proportion of the state forest.

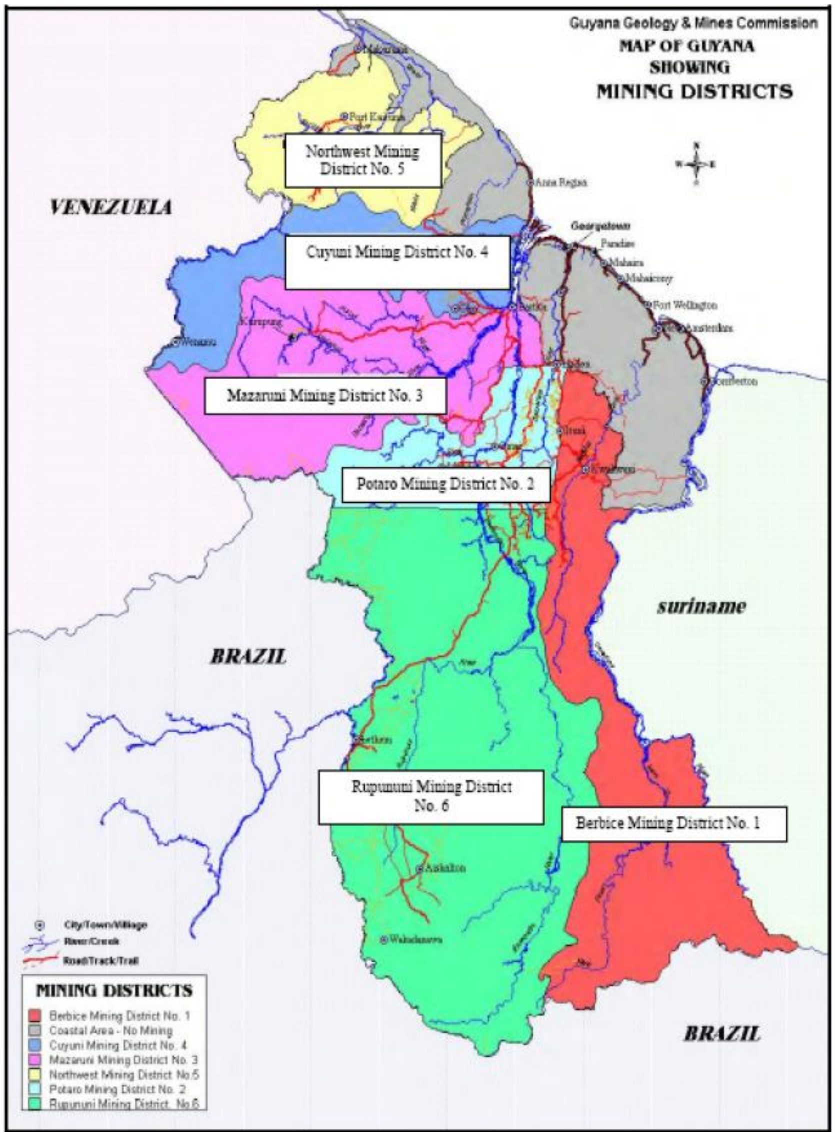

Figure 3.4: The Mining districts in Guyana
Source: Adapted from Guyana Geology and Mines Commission (2012)

Under the Mining Act 1989, the Guyana Geology and Mines Commission (GGMC) is allowed to grant the following: (i) small-scale claims; (ii) medium-scale prospecting and mining permits; (iii) prospecting licences; and (iv) permission for geological and geophysical surveys. Table 3.4 shows the number of claims, licenses, and permits issued by the Guyana

Geology and Mines Commission and the area occupied by mining operations of varying scales during the period 2006-2010. According to table 3.4, the number of mining claims, permits and licenses increased continuously between 2006 and 2010 notwithstanding, the total area utilised for mining has declined from 16.6 hectares in 2008 to 10.2 hectares in 2009.

Table 3.4: Mining claims, licenses, permits and area utilised by mining firms, 2006-2010

	2006	2007	2008	2009	2010
	(hectares)				
Claims (Small Scale)	9,408	10,563	12,582	13,476	…
Prospecting Licences	54	65	107	261	…
Mining Licences	10	10	10	11	…
Prospecting Permits	3,869	3,976	5,413	7,243	…
Mining Permits	270	374	550	646	…
Reconnaissance	8	13	13	21	…
Quarrying Licences	3	4	5	3	…
Petroleum Licences	-	-	-	7	…
Large scale occupancy	…	…	14.0	7.0	…
Small scale occupancy	…	…	2.4	0.2	…
Medium scale occupancy	…	…	0.2	3.0	…
Total	-	-	16.6	10.2	

Source: Adapted from Guyana Geology and Mines Commission (2012)

3.3.3 Guyana Forestry Commission

The Guyana Forestry Commission (GFC) was established in 1979 by the Guyana Forestry Commission Act 1979 as a semi-autonomous agency to administer the State Forest Estate of Guyana. Specifically, according to Section 4(1) of the Guyana Forestry Commission Act 1979, as amended by

Act No. 14 of 1981, the functions of the Forestry Commission include, among other things:

a. to formulate, advise the Government on, and implement the forest policy of the Government as determined by the Government;

b. to be responsible for the management and control of the exploitation of the forests of Guyana so as to ensure an optimum yield of forest produce and the maintenance or improvement of the environment;

c. to determine or assist in determining the location, distribution, volume, quality and most valuable use of the forest resource;

d. to undertake economic studies and prepare plans for the development of forestry and forest industries;

e. to advise on lands that are to be permanently designated as forest reserves for the practice of forestry;

f. to identify, establish, maintain and manage forests, including national parks, wildlife areas, and nature reserves, for the purposes of production, protection of the environment, education, recreation, the provision of amenities, and matters of scientific, historical or special value.

The Guyana Forestry Commission Act 1979 gives the Guyana Forestry Commission rights over all State forests. In addition to the Guyana Forestry Commission Act 1979, the activities of the Guyana Forestry Commission (GFC) are guided by the Low Carbon Development Strategies (LCDS), the

National Forest Policy 2011, the National Forest Plan 2011, the National Competitiveness Strategy (NCS), the Code of Practice for Forest Operations, and the Forests Act 1953, as amended by the Forests Act 2009. Under the Forest Acts (Chapter 67:01), the Guyana Forestry Commission may declare any land as state forests except Amerindian Villages.

Based on the latest estimates, the total forested area was over 70% of the total land mass of which a significant proportion is regarded as state forests under the jurisdiction of the Guyana Forestry Commission (GFC). Guyana has a total land area of approximately 214,970 square kilometres. 163,377 square kilometres of this (76%) is forested. Of this amount, 135,800 square kilometres is classified as State Forest under the jurisdiction of the Guyana Forestry Commission. The remaining forest areas are classified as State Lands, Amerindian lands and private property.

As at the end of June 2011, the Guyana Forestry Commission allocated 51% of the total state forest. Approximately 40.8% of the unallocated state forest was unutilised while the remaining 8.2% set aside as research or reserve areas (figure 3.5). The land allocation ratio by the forestry sector has been relatively unchanged over the last six years.

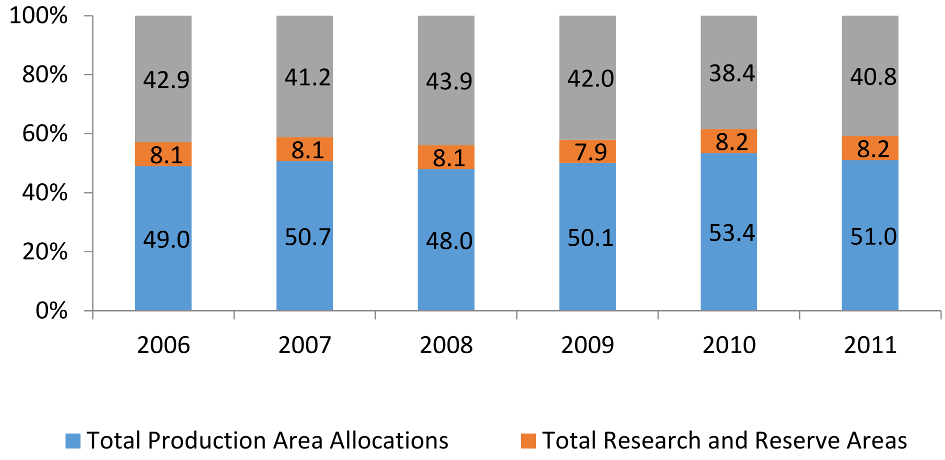

Figure 3.5: Land allocation within the forestry sector for the years 2006-2011
Source: Adapted from Guyana Forestry Commission (GFC) (2011)

Currently, the Guyana Forestry Commission (GFC) operates a three-tier system for allocating state forests. Under this system, there is the Timber Sales Agreement (TSA) that allows for the allocation of large areas of forest for ten to twenty-five years. There is also the Wood Cutting Lease (WCL) and the State Forest Permission (SFP) that grant permission to loggers to exploit the State Forest over the medium-term (that is, three to fifteen years) and on an annual basis, respectively.

Figure 3.6 also provides the categories of tenure between 2006 and 2011. Based on the chart, the greatest proportion of the state forests was allocated under Timber Sales Agreement (TSA), followed by State Forest Permission (SFP), and State Forest Exploratory Permit (SFEP).

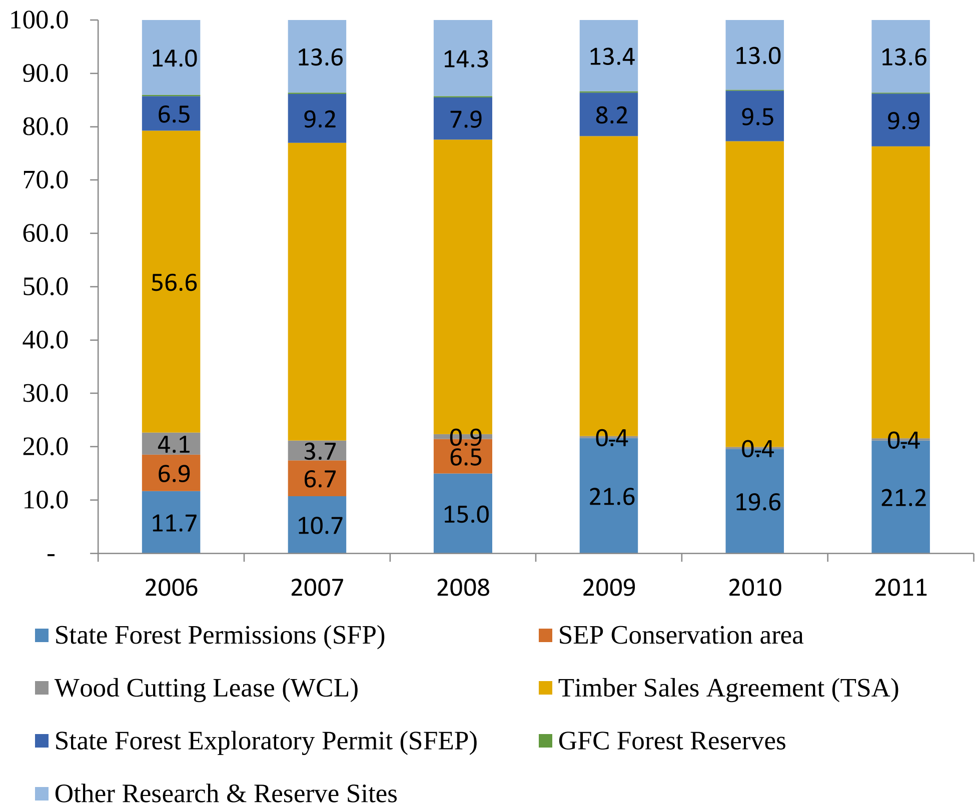

Figure 3.6: Land allocation of the forestry sector (as % of State Forest)
Source: Adapted from Guyana Geology and Mines Commission (GGMC) (2011)

3.3.4 Ministry of Housing and Water, Central Housing and Planning Authority

The Central Housing and Planning Authority was established under the Housing Act 1948 as a corporate body under the Ministry of Housing and Water. The Central Housing and Planning Authority (or Central Authority) is empowered to hold, acquire and utilise lands for housing purposes. Specifically, the Central Authority is empowered to:

- divest Government land to eligible Guyanese for residential purposes
- develop housing schemes and regularise squatter settlements

- facilitate the orderly development of cities, towns, urban and rural centres
- grant security of tenure (transport and certificate of titles to land)
- prepare development plans for urban centres
- collaborate with stakeholders to develop sustainable communities
- provide public goods and services (such as roads, drainage etc.) to new and existing communities

The Central Authority also has the power to declare an unhealthy area as a slum clearance area and may convey completed housing schemes to Local Authorities. Despite the mandate of the Central Authority, the Commissioner of Guyana Lands and Surveys Commission is ultimately responsible for transferring all ‘public lands’ utilised for housing purposes. This is done through the issuance of Certificates of Title.

Over the past two decades, the Ministry of Housing and Water has been proactive in facilitating the Central Authority to aggressively fulfil its mandate. Consequently, the Central Authority acquired and transformed significant state and private lands into new housing schemes throughout the country. It also regularised numerous squatter settlements during this period.

Figure 3.7 shows the quantum of lands utilised for housing development by the Ministry of Housing and Water and the Central Authority between 2004 and January 2012.

Based on this figure, the housing development activities of the Ministry of Housing and Water are highly concentrated in Regions, 2, 3 and 4. These are the most populous regions with significant excess demand for housing units. Given the projected expansion in the population over the next twenty-five to thirty years, there will be a greater need for the development of new settlement schemes in these regions.

3.3.5 Amerindian Council and Ministry of Amerindian Affairs

The Amerindian Act 2006 (Chapter 29:01) sets forth the rights of Amerindians with respect to land tenure. In particular, this Act makes specific provisions for land management, allocation, leasing, titling, demarcation and extension as it relates to Amerindian land claims. The Amerindian Act 2006 sets out the process through which Amerindian villages and communities may apply for an extension of a village and grant for state land, respectively. According to Section 59 of the Amerindian Act 2006, an Amerindian Village may apply to the Minister of Amerindian Affairs for an extension of village land. In addition, based on Section 60 of the Amerindian Act 2009, an Amerindian Community may also apply to the Minister of Amerindian Affairs for a grant of state lands.

Apart from the Amerindian Act 2006, there are other laws which confer on Amerindians the right to land. These laws may be grouped under three broad categories; namely, entitlement laws, procedural laws, and laws providing for limitations. Figure 3.8 provides a list of the various laws governing Amerindian land titling.

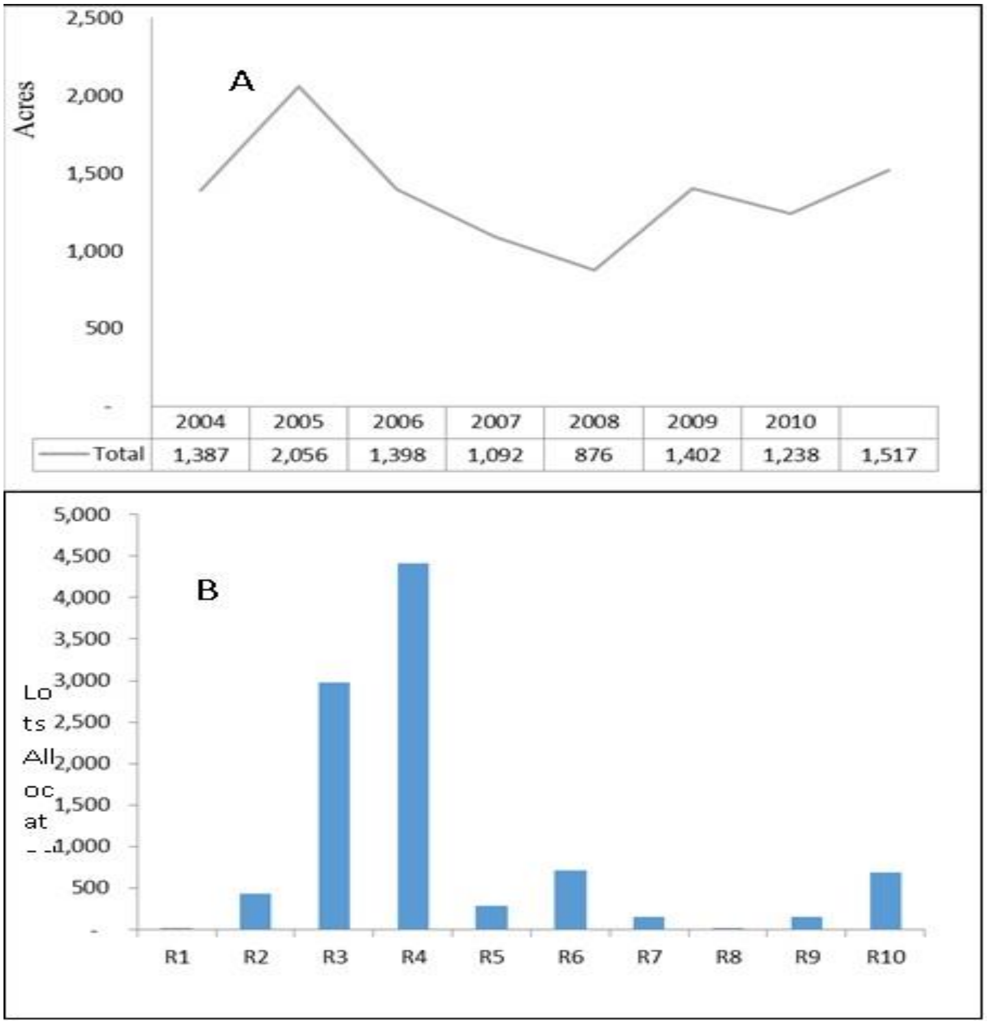

Figure 3.7: Panel A shows the land development profile for 2004-2010 (acres), while Panel B shows housing development by administrative region, 2004 –2012
Source: Adapted from Ministry of Housing and Water, Central Housing and Planning Authority (2013)

Where an application for an extension of a village or grant for state land under the Sections 59 and 60 of the Amerindian Act 2006, the Minister of Amerindian Affairs is required to commence an investigation and make a decision regarding the application for communal land which an Amerindian community has occupied for at least twenty-five years. Notwithstanding this requirement and based on the Act, an Amerindian community may have access to leased land without the approval of the Minister. Further, these communities are allowed to use the communal land for traditional mining, and with the consent of the Village Council, for logging. These activities, however, are subject to the Mining Act 1989 and the Forest Act 2009 and regulations.

While the process of Amerindian land titling may appear to be simply based on the Amerindian Act, it is extremely complex and vague. This may be attributed to several factors. Firstly, there is no consensus among academics and legal practitioners regarding the origins of the entitlement of indigenous peoples to land in Guyana. Secondly, the procedures which existed prior to 2006, differ from what obtained subsequently. For instance, prior to 2006, several Amerindian villages were granted absolute grants of titles to their lands under Section 3 of the State Lands Act Cap. 62:01, and on the basis of the work of the Amerindian Lands Commission, in conjunction with the provisions of the repealed Amerindian Act Cap 29:01. However, since 2006 the procedure followed reflects what is outlined in the Amerindian Act 2006. It should be noted that there is no nexus between the two procedures. As a result, there exist separate and distinct procedures regarding Amerindian land titling.

There are currently ninety-six titled Amerindian villages across the ten administrative regions; of which seventy-seven have been titled and demarcated and nineteen titled but not demarcated. Together, the titled villages occupy approximately 11,501.4 square miles (or 29,788.5 square kilometres). Thirteen villages are also to be titled and expected to occupy approximately 3,075.9 square miles (or 7,966.5 square kilometres). It is noteworthy, that while the Amerindians account for only 9% of the total population, they collectively own 13.9% of Guyana's total land mass. When the extensions are added to the titled Amerindian lands, this increases the share of these lands to approximately 17.6% of the total land mass of the country.

Amerindian lands account for a significant proportion of the total land mass in several administrative regions. As a percent of the total land mass in Regions 2 and 4, the Amerindian titled lands accounts for 27.5% and 28.9%, respectively. The titled Amerindian lands and extensions account for approximately 35% of the total land mass in Region 9 – the largest Administrative region in Guyana. Indeed, when combined the titled Amerindian lands and extensions is larger than Regions 1 and 10. It is also larger than the total land mass of Regions 2, 3, 4 and 5.

Entitlement Laws	Procedural Laws	Laws Providing for Limitations
• Article 149G of the Constitution of the Cooperative Republic of Guyana • The Amerindian Land Commission Act (Cap. 59:03) (Order 43 of 1991) • Section 20A the Amerindian Act (Cap.29:01) • Sections 59 and 60 of the Amerindian Act 2006 • Section 112 of the Mining Act No. 20 of 1989	• Section 3 of the Amerindian Land Commission Act Chapter 59:03 • Sections 61, 63 and 64 of the Amerindian Act No. 6 of 2006 • Section 3 of the State Lands Act Chapter 62:01 • The State Land Regulations • The Guyana Lands and Surveys Commission Act 1999 • The Surveys (Special Provisions) Act Cap 59:04 • The State Grants (President's Signature) Act Cap 62:04 • The Lands Department Act Cap 59:01	• Sections 5 and 6 of the State Lands Act Chapter 62:01 • The State Lands (Amerindian) Regulations • Sections 112 and 113 of the Mining Act No. 20 of 1989 • Section 39 of the Forest Act 2009 • The Forest Act No. 6 of 2009 which was passed by parliament on 22nd January, 2009

Figure 3.8: Laws governing Amerindian land titling

Titling and demarcation of Amerindian lands are facilitated by the Ministry of Amerindian Affairs, in accordance with the Amerindian Act of 2006 and other relevant legislation, including the State Lands Act, the Forestry Act, and the Mining Act.

3.3.6 Private Lands

State lands and Amerindian lands account for approximately 92% of all the lands in Guyana with the remainder classified as private lands. Most of the private lands are concentrated on the coast, thus making such lands ideal for commercial agricultural activities. These lands are owned by GUYSUCO, private individuals, cooperative societies etc. Lemel (2001) classifies the tenure of private lands into the following:

a. Tenant/proprietor estates: these are generally owned by a single family, a few families, co-operative societies or private companies. These estates are mostly concentrated in Regions 2, 3 and 6. There are a few of these estates in Region 4 which account for approximately 20,000 – 21,000 acres.

b. Land co-ops: these are owned by co-ops and their constituent members. In the past, these lands were used primarily for farming activities, but it is not uncommon for same to be distributed to members of the co-ops in small parcels. The land co-ops are scattered across six administrative regions and account for approximately 63,016 acres.

c. Lands development scheme: these are lands developed by the State for farming activities and house lots. Land development schemes account for over 200,000 acres of the best agricultural lands along the coastal plain of six administrative regions.

The estimates of private land holdings are provided in Table 3.5.

Table 3.5: Estimate of Private Lands, 1997-98

Regions	Tenant/proprietor estates (*Acres*)	Land Co-op (*Acres*)	Land Development Schemes (*Acres*)
2	2,000	8,740	18,280
3	2,000	12,676	3,398
4	4,000-5,000	3,160	36,343
5	-	3,838	35,147
6	12,000*	34,602	28,309
Total	20,000 – 21,000	63,016	209,977

Note: The Neighborhood Democratic Council accounts for 10,000 acres.
Source: Adapted from Lemel (2001)

3.3.7 Guyana Sugar Corporation

By far the most significant owner of private lands is the Guyana Sugar Corporation (GUYSUCO). This State Corporation currently owns freehold lands totalling 40,657 acres or 16,460 hectares. It also leases a significant 124,596 acres or 50,444 hectares from the State via licenses, lease, and permission.

These lands are generally under unified management and are not subject to the disputes and conflicts associated with the other categories described by Lemel (2001). Approximately thirty of the total lands controlled by GUYSUCO are "transported" (registered) land property. The corporation leases the remainder from the State, of which thirty-seven percent are held by license, thirty-one percent by lease and only two percent by permission. Most of GUYSUCO's lands are located in Berbice.

It is noteworthy that the corporation has opted to transfer some of its freehold lands to various agencies and individuals over the past two decades. The Ministry of Housing, Central Housing and Planning Authority of the MoHCHPA has benefitted significantly from this move by the corporation. This trend suggests the conversion of prime agricultural lands into residential properties that may have implications on the sugar industry going forward.

3.4 Urban and Regional Planning in Guyana

The Town and Country Planning Act, Chapter 20:01 (hereafter referred to as the T&CP Act) and the Guyana Lands and Surveys Commission Act, Chapter 59:05 (GLSC Act) provides the legal framework for physical planning in Guyana. Following the enactment of the T&CP Act during 1946, the Central Housing and Planning Authority (CH&PA) was established with a technical unit to prepare planning schemes (or physical development plans) at the local and regional levels. The scope of a planning scheme under the Act is as follows:

> A scheme made under this Act with respect to any land, in any urban or rural area, whether there are or are not building thereon, with the general object of controlling the development of the land comprised in the area to which the scheme applies, of securing proper sanitary conditions and conveniences and the co-ordination of roads, and public services, of protecting and extending the amenities and conserving and developing the resources of such area. (8)

The CH&PA is the statutory body incorporated under the provisions of the Housing Act, Chapter 36:20, Laws of Guyana. The physical planning functions of the Authority are executed by the Town and Country Planning Department, in accordance with the T&CP Act, Chapter 20:01, Laws of Guyana.

In 1950, the CH&PA created a planning scheme for the capital city, Georgetown. However, the agency never developed any other plans since then but limited its focus to the preparation of residential sites and offering advice on land use planning. This change in direction by the CH&PA may be attributed to the attention placed on the provision of housing by the government from the fifties to present.

In response to the change, the CH&PA established the Town and Country Planning Department in 1961 with the mandate to delineate the broad regional planning areas under section 15 of the T&CP Act, as well as, prepare design layouts for residential plans. Unfortunately, these plans were developed without any reference to an overall plan to guide the planning activities of the country. Consequently, many problems have arisen. The most significant problem was the creation of plans with limited scope for integrating communities since the plans were prepared without any consideration for existing or future development. Another major problem was the design of development plans with inadequate economic, environmental, and social considerations.

Edinboro (2017) identified the following areas of concern with regards to urban and regional planning practices in Guyana:

a. The laying out and development of adjacent areas without any consideration being given to future integration as a community to the continuity of reserves for main traffic routes or to the proper location of reserves for such engineering services as electricity, water supply, and stormwater drainage.

b. The inadequate or non-provision of sites for public open spaces, educational use, and other essential community facilities.
c. Failure in the design of settlement areas to adequately address the need for safe and fast vehicular movement. The general concern was that in an effort to obtain the largest possible number of saleable plots when developing a new residential area, very little if any thought was given to adequate reservations of land for essential community facilities and road networks. (4)

Recognizing that the approach to spatial planning was deficient, the Government and the United Nations Development Programme (UNDP) embarked on an ambitious project in the 1970s to establish an effective framework for comprehensive and integrated urban and regional planning in Guyana. A major aspect of this project was the creation of development plans for the urban centres. Specifically, the project was aimed at providing: (i) development plans for Linden and Anna Regina, (ii) Zoning plans for various urban and rural areas, and (iii) the outline of a national strategy for physical development. Regrettably, this project failed to deliver on any of its objectives. As a result, the planning practice continued in a piecemeal manner without an overall strategy and plan. In other words, spatial planning has remained stagnant since the 1950s. Additionally, the legislation was never revised for the past seventy years and the authority that was set up to administer the Act continues to focus exclusively on preparing new residential development.

The detriments of the spatial planning practices by the CH&PA is well known and even recognized in one of the most important development strategies the 2001-2010 National Development Strategy (NDS). Indeed, the NDS stated the following with respect to spatial planning:

> Very little urban planning is being undertaken. Whatever planning is being done does neither attempt cohesively to establish goals and objectives at a national level, nor to link their attainment with economic and financial policies. In practice, sectoral strategies have been formulated in isolation, with little attempt being made to integrate them into national strategies, and with little consideration as to how the plans are to be implemented, whether through communities, the private sector, the municipality, or even the government. (248)

Apart from the CHPA, the Guyana Land and Survey Commission (GLSC) has responsibility for preparing land use plans outside municipalities. According to section 4(1)(r) of the GLSC Act, the Guyana Lands and Survey Commission is required to:

> … prepare land use plans for Guyana or any part of Guyana, except any municipality which is subjected to a planning scheme (or interim development control pending the preparation of a planning scheme) under the Town and Country Planning Act.

While the mandate of the Commission is clear, it is noteworthy that there are no provisions in the GLSC Act that set out the procedure for the Commission to prepare and obtain approval for land use plans. This is in stark contrast to the T&CP Act which not only empowers the CHPA to produce land use plans but outlines the procedure the agency should follow. This is further compounded by the limited capacity of the GLSC in the area of land use plans. The absence of any provision that allows for coordination among the various agencies responsible for land use outside the municipalities also constrains the GLSC from effectively preparing these plans.

Policy makers have not only recognized the need for spatial planning but have expressed the need for this activity in the overarching development strategy, the NDS, as follows:

> The formulation and implementation of a National Plan on Land Use, based on present land use patterns and possible opportunities, are critical in this effort. This plan should take into consideration physical, environmental, economic, social, cultural and demographic factors from a Guyanese perspective. The national land use plan will utilise the concept of sustainability, to protect all lands, in this instance agricultural lands, and it will strive to make that concept operational in as many instances as possible. It will take the lead in defining sustainable land use practices. (263)

This notable policy direction, however, lacks infrastructure such as strategies, tools, plans, and human capacity to support its realization. It is the goal of this thesis to contribute to the development of some of this infrastructure.

Edinboro (2017, 6-7) advanced the following key priorities for improving urban and regional planning practices in Guyana:

a. Sub-professional and professional training.
b. The preparation of a national physical development strategy and plans for various urban centres and other defined planning regions.

c. The review and updating of the Town and Country Planning Act.

d. The documentation of clear development planning standards, perhaps in the form of a Planning Standards Manual and regulatory policies to guide day-to-day practice.

e. The adaptation of modernized information system to planning work, such as the use of GIS in planning at the level of the Central Housing and Planning Authority so as to facilitate the easy development of urban indicators and their integration into planning practice and policy formulation.

f. Improving public awareness of planning at all levels of the local government system and in the various communities.

The last two suggestions influence this thesis.

3.5 Issues and Challenges of Land Management in Guyana

Based on the foregoing section, it may be gleaned that multiple agencies have administrative responsibilities and rights over the same lands and there are clear instances of overlapping jurisdiction (table 3.6). This is particularly true with respect to lands administered by the Guyana Lands and Surveys Commission (GLSC), Guyana Forestry Commission (GFC), and Guyana Geology and Mines Commission (GGMC). In some instances, the mining districts and state forests overlap with Amerindian lands. Of recent, there have been disputes over land by other land administration agencies, such as the Ministry of Housing and Water, Central Housing and Planning Authority and various stakeholders. This situation is not surprising given the absence of a national land use framework. It has also contributed to numerous land conflicts over the years. Apart from being costly, the disputes often take many years before they are resolved in the courts. In this section, the study will discuss the issue of overlapping jurisdiction and cite selected examples of land conflicts among different agencies and owners of land in Guyana.

Table 3.6: Summary of lands administered by various agencies

Land Type	Area	Percent of total land mass of Guyana (83,000 sq. ml)
State Lands	58,000 (*sq. miles*)	70 percent
State Forest	52,432 (*sq. miles*)	63 percent
Mining Districts	45.8 (*Mn. acres*)	
State Agricultural lands	200 (*Th. acres*)	
Housing Development Lands		
Amerindian Lands –Titled	11,501 (*sq. miles*)	13.9 percent
Extension	3,076 (*sq. miles*)	3.7 percent
Protected Areas	1.9 (*Mn. acres*)	
Private Lands		
Tenant/proprietor estates	20-21 (*Th. acres*)	
Co-ops lands	63.0 (*Th. Acres*)	
GUYSUCO- Freehold Lease	40.7 (*Th. Acres*)	
	124.6 (*Th. Acres*)	

Note: Th. and Mn. represent thousands and millions

If one is to considered the 3-dimensional space of land resources as depicted in Figure 3.9, a given land parcel may be good for either housing, agriculture or industrial development. With competing interest, this may lead to horizontal overlapping interest. On the other hand a land parcel may be endowed with forest cover on the surface and mineral resources in the surface, thus leading to potential vertical overlapping interest.

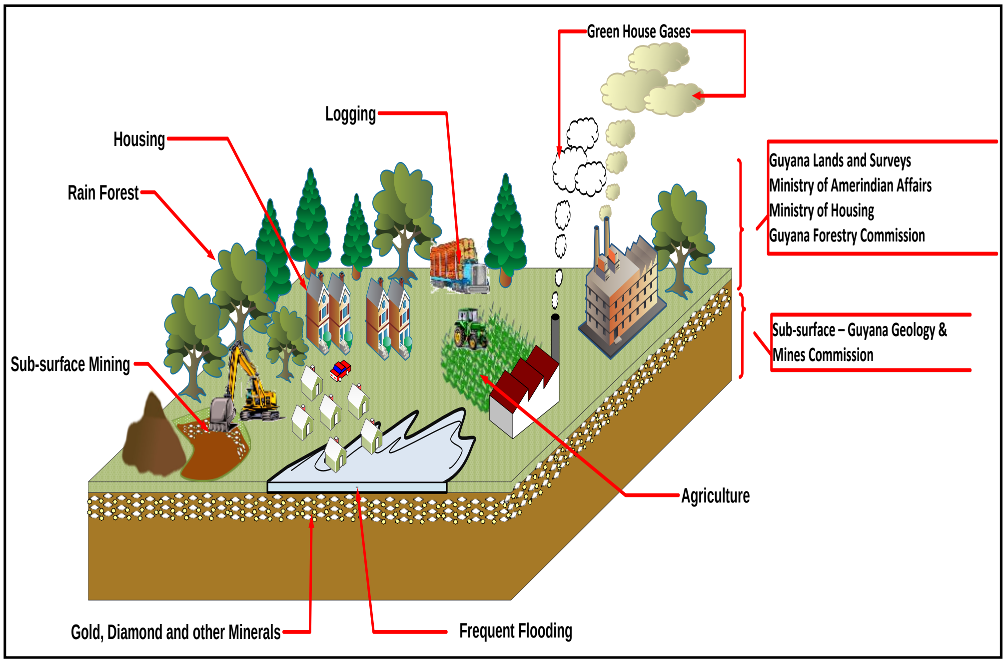

Figure 3.9: Vertical overlapping jurisdiction

3.5.1 Vertical Overlapping Jurisdiction: Conflict between Mining and Forestry

The Guyana Geology and Mines Commission (GGMC) has divided the country into six mining districts, which overlap with areas designated as State forest and public lands by the Guyana Forestry Commission (GFC) and the Guyana Lands and Surveys Commission (GLSC). According to

Bishop (1998), approximately 9.1 million hectares of lands under the purview of the Guyana Geology and Mines Commission (GGMC) are also regarded as State forest. This situation has contributed to several conflicts over the years as a result of poor interagency coordination and the silence of the various legislations on joint use of lands. Indeed, both the Mining Act 1989 and the Forestry Act 2009 allow the Guyana Geology and Mines Commission (GGMC) and the Guyana Forestry Commission (GFC), the authority to grant concessions with exclusive rights for mining and logging, respectively. It is not surprising, therefore, that concessions are granted to miners to carry out their activities in areas which are considered state forest and concessions are granted to loggers to operate in mining districts (Figure 3.10).

> The Guyana Geology and Mines Commission (GGMC) had control over a gold deposit that was located on a Forest Concession held by the Toolsie Persaud Timber Company. The latter filed their objection to mining on their concession based on grounds that such activities were not permissible or legal. Notwithstanding, the Guyana Geology and Mines Commission proceeded with their allocations for mining on the timber company’s concession.

Figure 3.10: The conflict between miners and loggers

3.5.2 Conflict among GLSC, GFC, and GGMC

There are also instances of conflicts among the Guyana Lands and Surveys Commission (GLSC), Guyana Forestry Commission (GFC), and Guyana Geology and Mines Commission (GGMC). In 1969, both corridors on the Soesdyke-Linden Highway were designated as state forest to facilitate agriculture settlement; however, settlements were established without any consultation with the Guyana Forestry Commission. Subsequently, the Guyana Forestry Commission granted concessions to loggers in these areas. At the same time, the Guyana Lands and Surveys Commission had been issuing agriculture leases. This situation resulted in a confrontation with a logger and a farmer in the late 1990's, both armed with title documents. The situation deteriorated to the point where the Guyana Forestry Commission seized the equipment of the farmer and the matter had to be resolved at a Ministerial level. This created significant tension between the agencies.

There are also instances, whereby the Guyana Lands and Surveys Commission consulted the Guyana Forestry Commission to release state forest for agriculture purposes. However, because of the lack of cooperation between these agencies, the former went ahead and issued several leases for agriculture lands without approval from the latter. This has contributed to the overlapping claims by farmers and loggers.

There was a situation where the BARAMA Company cleared a 20-acre farm in the Cuyuni area. The owner of the farm had an agriculture lease from the Guyana Geology and Mines Commission (GGMC) while BARAMA Company was also in possession of a concession from the Guyana Forestry Commission (GFC). The matter was brought before the court.

Large-scale leases were issued under the Intermediate Savannahs Project by the Guyana Lands and Surveys Commission (GLSC). This was done despite the fact that the Intermediate Savannah falls under the purview of the Guyana Forestry Commission (GFC). Since the Intermediate Savannah is a source of high-quality wood which translates into significant monetary benefits for Guyana Forestry Commission it was reluctant to give up the area. This has contributed to numerous instances of conflict between loggers and farmers who were granted permission to occupy the same land space by the Guyana Forestry Commission and the Guyana Lands and Surveys Commission respectively.

Figure 3.11: Selected Cases of Conflict among the GLSC, GGMC, and GFC

The conflict has not been limited to the Guyana Lands and Surveys Commission (GLSC) and the Guyana Forestry Commission (GFC). There were numerous conflicts between the Guyana Lands and Surveys Commission (GLSC) and the Guyana Geology and Mines Commission (GGMC). The mining of silica white sands, for instance, comes directly under the jurisdiction of the Guyana Geology and Mines Commission (GGMC); however, this type of economic activity is prominent on the Soesdyke/Linden highway, which is outside the established mining districts. In fact, this area is considered agriculture lands and, therefore, is under the control of the Guyana Lands and Surveys Commission (GLSC). While the Guyana Lands and Surveys Commission (GLSC) has been reluctant to give up its agriculture lands for mining purposes, the Guyana Geology and Mines Commission (GGMC) encourages this type of economic activity by charging acreage fees and royalties to miners who carry out their activities in this area. Figure 3.12 illustrates the silica white sand that falls outside the mining district.

3.5.3 Conflict between GLSC, MoHW/CHPA

The post-1992 period has witnessed intense conflicts between the Guyana Lands and Surveys Commission (GLSC), the Ministry of Housing and Water (MoHW), and the Central Housing and Planning Authority (CHPA). It should be noted that both agencies are involved in the issuance of lands for residential purposes. However, there is an agreement between the two agencies whereby the Guyana Lands and Surveys Commission issues the leases for these lands while the Ministry of Housing and Water focuses on the developmental aspect of the housing schemes.

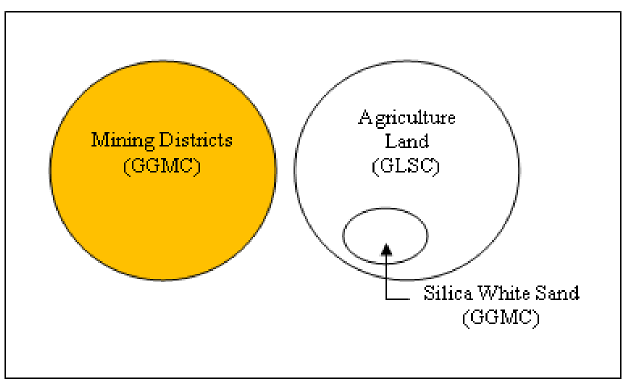

Figure 3.12: Illustrating silica white sand falling outside the mining districts

Notwithstanding the agreement between the MoHW and GLSC, these agencies had numerous conflicts over the years. In recent times, the land conflicts between these agencies have intensified due to the Ministry's quests to develop new settlement schemes, as well as to expand existing ones and regularise squatting in areas designated as agriculture lands. A typical case in point is an area where a farm that existed since 1964 in Essequibo was subdivided into house lots by the Ministry. There was a similar case in Bartica where a housing scheme was developed from land parcels held under leases for over fifty years. Other cases are contained in Table 3.7, which provides a selected sample of conflicts between the Ministry of Housing and Water and Guyana Lands and Surveys Commission (GLSC).

Apart from the land conflicts, it is noteworthy that there are also significant management constraints and difficulties under the existing system. The current system, for instance, requires collaboration among several agencies to deal with simple issues, which often results in unnecessary costs and delays. For a private land developer to have approval for a new settlement project, he is required to submit a plan to the Ministry of Housing and Water, Central Housing and Planning Authority, which then goes to the Neighbourhood Democratic Council. Because of the involvement of multiple agencies, the process can take more than three months.

3.5.4 Factors Responsible for Overlapping Jurisdiction

Based on the foregoing discussion, it is clear that the various bodies responsible for land administration often exercise control over similar land space. In other words, there are many instances of overlapping jurisdictions. This situation may be attributed to several factors including: (i) the sectoral approach to developing the legal and regulatory framework, (ii) the lack of interagency coordination, (iii) inadequate information on lands owned and administered by the various agencies, (iv) the absence of a national Land Use Policy, and (v) the absence of laws that allows for multiple land use.

Table 3.7: Selected Cases of Conflict between MoHWCHPA and GLSC

Name of Area	Acres	Type of Conflict	Nature of Conflict	Cost of Conflict
Region 3 Block 8 Pln. Zeelugt & Tuschen	250	Cattle Farming and Housing Development	The Ministry of Agriculture permitted farmers to rear animals on land owned by CHPA that was identified for housing development. The farmers were compensated.	(1) 1500 residential lots CANNOT be developed. (2) No pasture for 350 cows.
Parfaite Harmonie	400	Rice Farmers blocking drainage canal; Housing area being affected.	Rice Farmers blocking drainage canal. Housing area being affected.	(1) 4,500 residential lots being affected with drainage.
Leonora	10	National Trust and Housing Development	National Trust and the preservation of chimney and gantry of abandoned sugar estate resulting in reduction of residential housing development	(1) 50 residential lots CANNOT be developed. (2) Preservation of Chimney and gantry.

Table 3.7 (continued)

Name of Area	Acres	Type of Conflict	Nature of Conflict	Cost of Conflict
Region 4 Eccles	400	Landfill and Housing Development	Buffer for Landfill reduced housing development	(1) 2,400 residential lots CANNOT be developed. (2) Ideal location for light industrial development.
Hope Dochfour	10	Relief of East Demerara Conservancy and Housing Development	NDIA Outlet canal from East Demerara Conservancy passing through Hope Dochfour housing scheme	(1) Approximately 50 developed residential lots abandoned. (2) Re-routing of relief canal
Hope South (Adjacent to Enmore Estate)	10	Farming and Housing Development	Cash crop (pepper) farming restricted housing development	(1) 60 residential lots CANNOT be development. (2) No land 10 farmers.

Source: Adapted from Ministry of Housing and Water, Central Housing and Planning Authority (2012)

Legal and Regulatory Gaps

The sectoral approach is often blamed for the prevalence of overlapping jurisdictions and the associated land conflicts (Bishop 1998). Based on the many conflicting legislation, it appears as though the laws were crafted to satisfy the needs of each agency with little or no regard given to the collective needs of all the stakeholders responsible for land administration.

Despite the long history of costly land conflicts, there has been little or no coordination among the various land administration bodies. Several factors contribute to this situation. Firstly, the existing laws and regulations are silent on interagency coordination. Secondly, and equally important is the fact that sectoral interests usually dominate the agenda of the various agencies. This may be due to the efforts of each agency to defend its ‘turf’ and to outshine other agencies with responsibility for administering lands locally.

Inadequate Information on Land Use

While information is probably the single most crucial component of an effective land administration system, there are severe deficiencies in this area because of the fragmentation in the land administration process. Firstly, the agencies which administer lands in Guyana do not maintain adequate records of the land parcels under their purview. Moreover, there is limited information sharing among the agencies. As a result, the various land administration agencies are often unaware of all the land parcels they own, especially those with overlapping jurisdictions. This situation contributes to a prevalence of land conflicts that result from multiple agencies issuing or using the same lands.

Inadequate Monitoring Mechanism

The lack of information is compounded by the inadequate monitoring and enforcement by the various agencies. Indeed, very often the agencies are not aware of what is taking place with their lands because they fail to monitor the lands under their purview effectively. This is evident from instances of claim jumping and illegal activities by the various agencies. Apart from minimising the incidence of land conflicts, an effective monitoring and enforcement mechanism would serve to prevent unlawful activities.

The absence of a national Land Use Framework in Guyana usually results in each agency pursuing its own sectoral goals rather than adopting strategies that may serve the national interest more effectively. Indeed, given the current dispensation, it appears as though the interest of each agency often takes priority over the national interest.

The Absence of Legislation that allows for Multiple Land Use

No legislation provides for multiple land use. Given the likelihood of an agency losing revenue by permitting other agencies to utilise the lands that it owns and administers, this situation is not surprising. Consequently, most agencies appear to be opposed to any effort aimed at developing legislation that facilitates multiple land use.

3.6 Conclusions

This chapter of the study examined the legal and regulatory environment governing land management in Guyana. In particular, it reviewed the laws, regulations, and agencies which administer land locally. For this study, land in Guyana is placed into three broad categories, namely, State Lands, Amerindian Lands, and Others. The study revealed that state lands account for over seventy percent of the total land mass of the country and is managed by the Guyana Lands and Surveys Commission (GLSC). However, the mineral resources and areas designated as state forest on state lands are under the control of the Guyana Geology and Mines Commission (GGMC) and the Guyana Forestry Commission (GFC), respectively. Finally, Amerindian lands currently account for approximately 13.9% of the country's total land mass and the remainder being private lands and protected areas.

In Guyana, under the current dispensation, several agencies are responsible for managing the same land space which often results in land conflicts. In many instances, these conflicts end in lengthy court battles that are extremely costly. Given the signalled intention of policymakers to accelerate the utilisation of the country's natural resources which are concentrated in overlapping boundaries, the potential for similar conflicts is enormous. To address this problem, the chapter proposed an Integrated Land Management Model (ILMM). This model will discussed in greater detail in the chapter 4.

CHAPTER 4: CONCEPTUAL DESIGN OF A LAND MANAGEMENT MODEL AND SELECTION OF STUDY AREA IN GUYANA

4.1 Rationale for a Model

From the preceding Chapter, it can be concluded that the current land management system in Guyana is fragmented. The ‘silo’ effect characterizes land use decisions. Each agency makes decisions based exclusively on their sectoral goals, policies, laws, and regulations with little or no reference to national land development goals and objectives. This problem emanates from the various development paradigms (especially the National Development Strategy, NDS) as well as the legal and regulatory framework which encourages each land-related agency to focus on its often narrow sectoral mandates. Based on the current land management activities, each agency is required to make decisions along a vertical continuum that emanates from a particular national development paradigm and concludes with the implementation and review of sectoral projects. This ‘silo type’ decision-making is due to the absence of a National Land Use Policy and implementation framework that allows for horizontal integration across the sectors with capabilities for dealing with cross-cutting issues like social, economic, and environmental development.

Other deficiencies plague the current land management system. For instance, at the level of each agency, land management decisions are made on a project-by-project basis rather than within established frameworks which consider broad landscape-level issues. This problem is compounded by the fact that all the land use activities (such as logging, mining, agriculture, housing, etc.) are considered in isolation rather than collectively as national developmental issues. As a consequence, the capacity of the eco-system to accommodate several land management activities sequentially or simultaneously is often not incorporated into land use decisions. Put differently, land use decisions at the agency level tend to ignore overall land use patterns across spatial and temporal scales. Furthermore, data sharing protocol is informal and based on individual request to each agency as depicted in Figure 4.1.

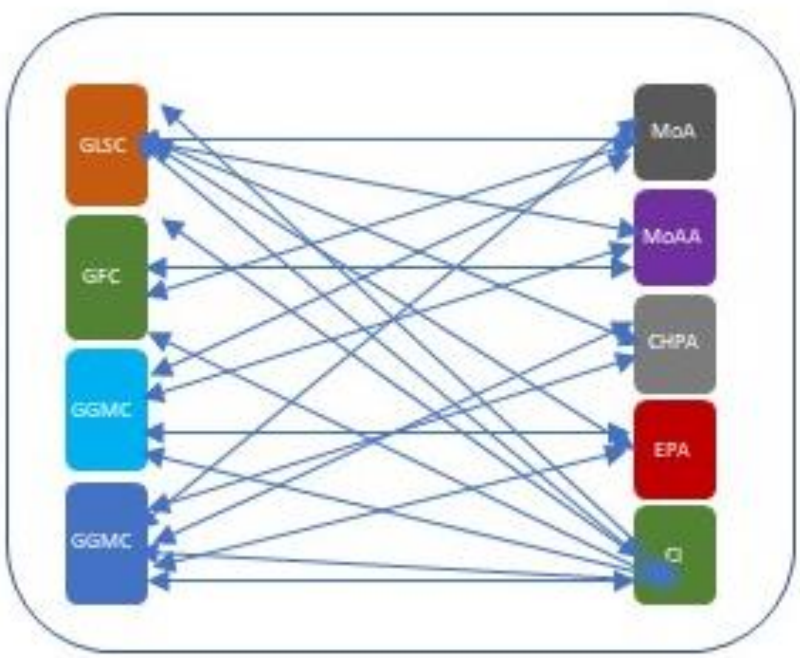

Figure 4.1: Schematic of the current data sharing protocol amongst land agencies

While social, environmental and economic considerations drive the land use decisions, there is the absence of a comprehensive monitoring and evaluation framework with clearly defined objectives which are measurable and time-bound. For instance, there are no clearly defined objectives that speak to the rate at which the country's land resources should be exploited based on the carrying capacity of the environment. This places the country at risk of exploiting its land resources in an unsustainable manner. It also results in the country not fully realizing the potential benefits of environmental goods and services provided by the eco-system. Consequently, it is not only difficult to manage the cumulative effect of multiple land use activities but equally difficult to determine whether that eco-system is capable of withstanding the cumulative impacts of these activities. In other words, there is no way to ascertain if the various land use activities are environmentally sustainable.

The current land management framework does not allow all stakeholders to participate equitably in the decision-making process. The general public, as well as local communities and vulnerable groups (such as indigenous communities, women, and the poor), are seldom given an equal opportunity to participate in this process. Additionally, local organs such as Regional Democratic Councils (RDC) and Neighbourhood Democratic Councils (NDC) are often not involved in the planning and decision-making processes at the policy level. These local agencies only participate at the operational level of land management.

Given the foregoing, the question, therefore, is ‘how can all of the competing land uses be managed on an integrated framework to ensure that Guyana’s land resources are administered to support sustainable development?’ The answer rests in the design and establishment of an Integrated Land Management Model (ILMM) that provides a systematic framework to land management and takes into consideration the needs of all the competing forces. The design of this model will be guided by the theoretical and good practices discussed in Chapter 2. It will offer a perspective on land management that is unique and exploratory.

4.2 The Design Parameters for an Integrated Land Management Model

The ILMM seeks to incorporate participatory decision-making aimed at creating opportunities to establish coordination and collaboration among the various land administration agencies. It also offers the single platform to engage and foster the participation of other stakeholders (e.g., local communities, at-risk groups, local authorities, etc.). It is aimed at enhancing transparency and governance to meet local and international priorities such as the sustainable economic growth, social development, environmental protection and Millennium Development Goals (MDGs) among others. It also aims to provide the prospects for overcoming the deficiencies highlighted earlier such as the ‘silo effect,’ incremental decision making, and exclusion of the capacity of the environment to accommodate the cumulative effect of multiple land uses. It is envisaged that the model will contribute to sustainable development, improvement in the governance and greater efficiencies in land management, equitable allocation of land, and clearly defined oversight roles among the respective agencies. Different user groups/stakeholders can influence strategies for land use, development, and management that can benefit all stakeholders in the long term. Specifically, the ILMM is guided by the following design parameters:

Promoting integrated decision-making - the model allows for both vertical and horizontal integration of decision-making within and amongst land management institutions as well as promote unhindered data sharing using NSDI as depicted in Figure 4.2.

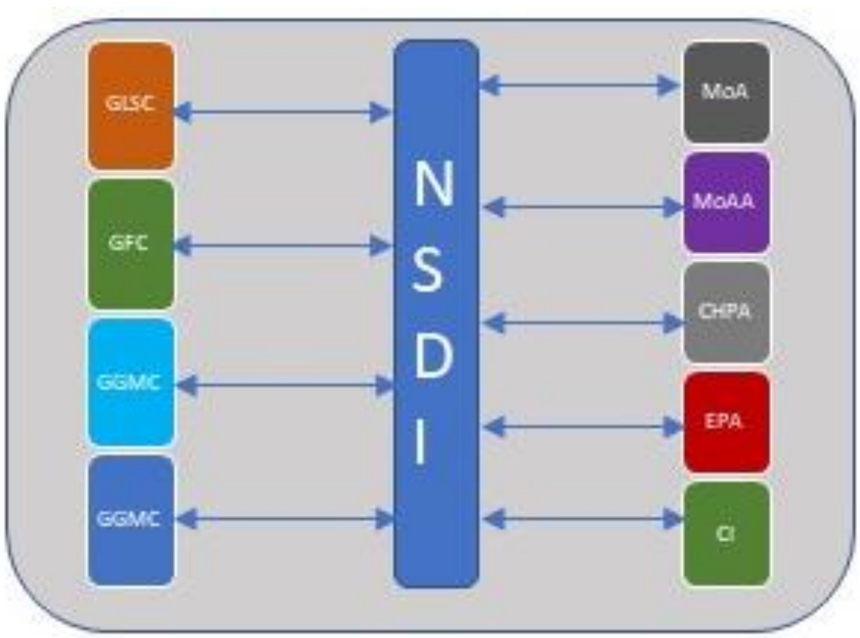

Figure 4.2: Schematic of the proposed data sharing protocol using NSDI

Promoting good governance and transparency through inclusivity – land management decisions will be guided by the collective wisdom of all the stakeholders, including, Cabinet, private sector (landowners, resource developers and other private land users), vulnerable groups (women, youths, and indigenous people), land use and management experts, community leaders and individual citizens who may be affected directly and indirectly by land use decisions.

Promoting effective monitoring and evaluation of land use activities - the model supports comprehensive tracking of all land use activities based on clearly defined thresholds/targets that do not exceed the natural capacity of the ecosystem to sustain same.

Promoting ecological or environmental sustainability of all land use activities - the model encourages the evaluation of the cumulative impact of all land use activities over time and space to avoid environmental degradation. In this regard, land management will not be limited to the effects of individual projects, but instead focus on the total environmental impact of all land use activities on the entire landscape.

4.3 The Components of the proposed Integrated Land Management Model

The model has five modules. These are:

a. Module I: Contextualising national land resources management
b. Module II: Development of land management tools: policies and strategies
c. Module III: Development of Multi-criteria problem solving systems
d. Module IV: Development of monitoring and evaluation systems
e. Module V: Development of correctional systems

The elements of each module will be presented below.

Module I: Contextualising national land resources management

This module seeks to identify the different uses for the country's land resources (table 4.1) and is influenced by endogenous (internal or controllable) factors as well as exogenous factors (external or uncontrollable). Some of the possible uses (both current and future) include shelter (or housing), mineral extraction, timber extraction, agriculture, infrastructure, conservation/eco-services, energy, and indigenous rights. It is noteworthy that the various uses are intended to support sustainable national development; which is the principal goal of an Integrated Land Management Model (ILMM). In other words, all land uses should be determined within the context of achieving social development, economic development, and environmental protection simultaneously. These broader goals may be further disaggregated into specific objectives such as: optimizing economic returns/gains from land use activities (mineral extraction, timber extraction, farming or agriculture, etc.); improving the wellbeing of citizens especially at-risk groups (indigenous people, women, youths, victims of land conflict); and preserving or maintaining the integrity of the environment.

The competing land use requirements for national development are: Food production, Social and economic infrastructure, Energy and shelter, Forestry, Minerals exploitation, Environmental management, Indigenous land rights, Climate change, and Natural hazards.

As noted earlier, two factors influence land uses. These are endogenous and exogenous factors as shown in figures 4.3 and 4.4. The endogenous factors refer to those factors that are within the control of local policymakers that may have implications for land use. These include the overarching development paradigm pursued by the Government and delineated in national strategies (for example, the Low Carbon Development Strategy (LCDS), National Development Strategy (NDS), National Competitiveness Strategy (NCS) and Poverty Reduction Strategy), Sectoral Policies and Strategies (Forestry Policy, Housing Policy, Mining Policy), Land Use Policies and Land Use Plans. For example, if the overarching development strategy requires that more lands be treated as protected areas, this would translate into more land being set aside to provide eco-services. Consequently, fewer land parcels will be available for other uses such as housing, agriculture, mining, timber extraction, etc. This, in turn, would have implications for social and economic development, as it may result in the reduction of output from the other land use sectors, loss of tax revenue, lower investment and employment. The domestic factors include other issues that may drive land uses in a country, such as internal land conflicts, protection of indigenous people's rights (land demarcation), demographic changes that may necessitate new housing developments, and conservation or ecological protection.

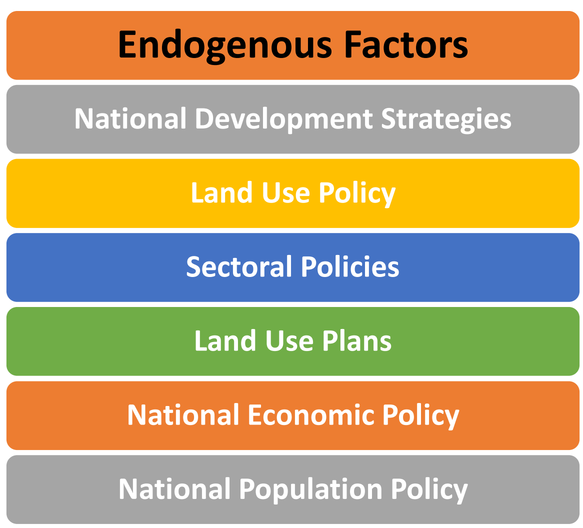

Figure 4.3: The endogenous factors that influence land resources management

The exogenous forces shown in figure 4.3, are factors which influence land use but are outside the control of local policymakers or those involved in land management. The impact of climate change is one such factor which may dictate if certain land parcels should be used for agricultural purposes due to the threat of flooding; even though the land may be extremely fertile and therefore suitable for this type of economic activity. Natural hazards such as earthquakes may also influence decisions regarding the identification of land for housing purposes. Other exogenous factors include global issues such as food security, energy security, global priorities (MDGs), international boundary disputes, and global efforts to tackle climate change. For example, in an effort to combat climate change, the Governments of Guyana and Norway entered into a bilateral agreement to trade credit instrument whereby the former enjoy economic benefits from maintaining the country's standing forest.

This agreement is part of the global effort to address climate change whereby Guyana agrees to maintain its standing forest so that the world may benefit from the ecological services it provides instead of harnessing same for economic gains through various economic activities (such as mineral extraction, timber extraction, and agricultural activities). Guyana faces the risk of conflicts based on unresolved territorial disputes with two of its continental neighbours, that is, Suriname and Venezuela. A few years ago, a major investment project, the Beal Aerospace project, had to be jettisoned because its neighbour, Venezuela, laid claim on the land identified for the project. A similar dispute between Guyana and Venezuela also prevented the country from pursuing the construction of a hydroelectric power plant. Meanwhile, there is a longstanding maritime dispute between Guyana and Suriname that has discouraged investment in oil and gas exploration in the "New River Triangle." These border disputes even though influences land use decisions they are, however, outside the control of those involved in land management in Guyana.

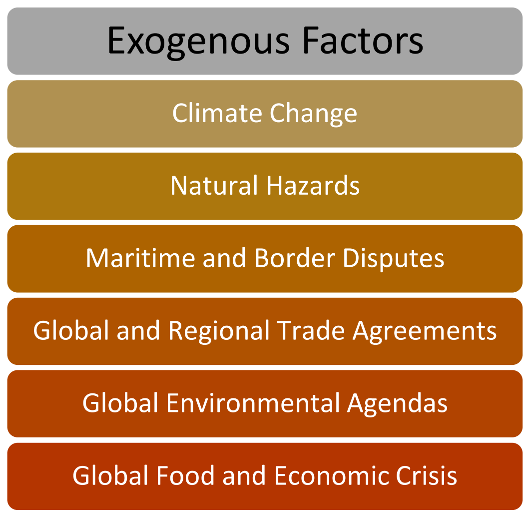

Figure 4.4: The exogenous factors that influence land resources management

The knowledge of how the endogenous and exogenous factors affect competing land use requirements will help in developing land policies and strategies that will foster sustainable land use (figure 4.5).

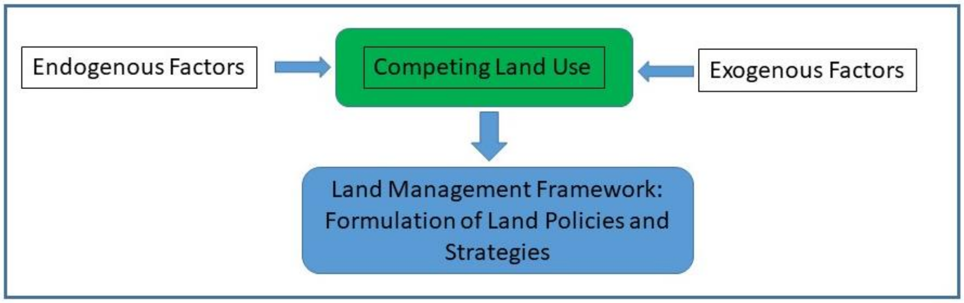

Figure 4.5: Module 1: Contextualising national land resources management

Module II: Land Management Framework

The second module of the model is the development of an integrated land management framework. The module is configured to give effect to the outputs of Module I through the design of policies, strategies, and activities that address current and potential challenges to land management. Within this module, all the land-related agencies pursue their sectoral agenda with due consideration and regard for the impact of their plans on all other land-related agencies: moving from a competitive mode of operations to more complimentary and collaborative mode of operations. However, all land management decisions will now be made via an integrated land management system that is intended to overcome the challenges highlighted earlier. The system will also address typical as well as emerging land management issues, such as land conflict, sub-optimal land use, environmental degradation, etc.

Figure 4.6 provides a conceptual illustration of an integrated land management model in Guyana. Each branch of the tree represents a land administration agency which has a specified sectoral mandate depicted by the leaves. For example, the Guyana Geology and Mines Commission (GGMC) which is depicted by a branch is shown as being responsible for sub-surface mining, gold and diamond extraction, bauxite and other mineral extraction. The Guyana Lands and Surveys Commission, also represented by another branch, is responsible for all state-lands. Like the leaves which facilitate the survival and development of the tree by capturing sunlight and carbon dioxide, the effective fulfilment of the mandate of each agency is essential for the overall development of the country. In the same manner that growth in the branches is critical for the leaves to capture light, it is important that each agency is supported by sectoral laws, regulations, and policies to ensure the effective fulfilment of its statutory mandate. In other words, the expansion of each sector, which is analogous to growth in the tree branches, is necessary for overall growth and development. The trunk, which supports the branches of the tree, ensure continuous growth of each branch and raise the leaves above ground level. It also transports water and nutrients from the roots of the plant and redistributes the foods produced by the leaves. In the same way, the trunk supports the branches; the land management framework is expected to assist the land use agencies collectively, to improve the overall development of the country.

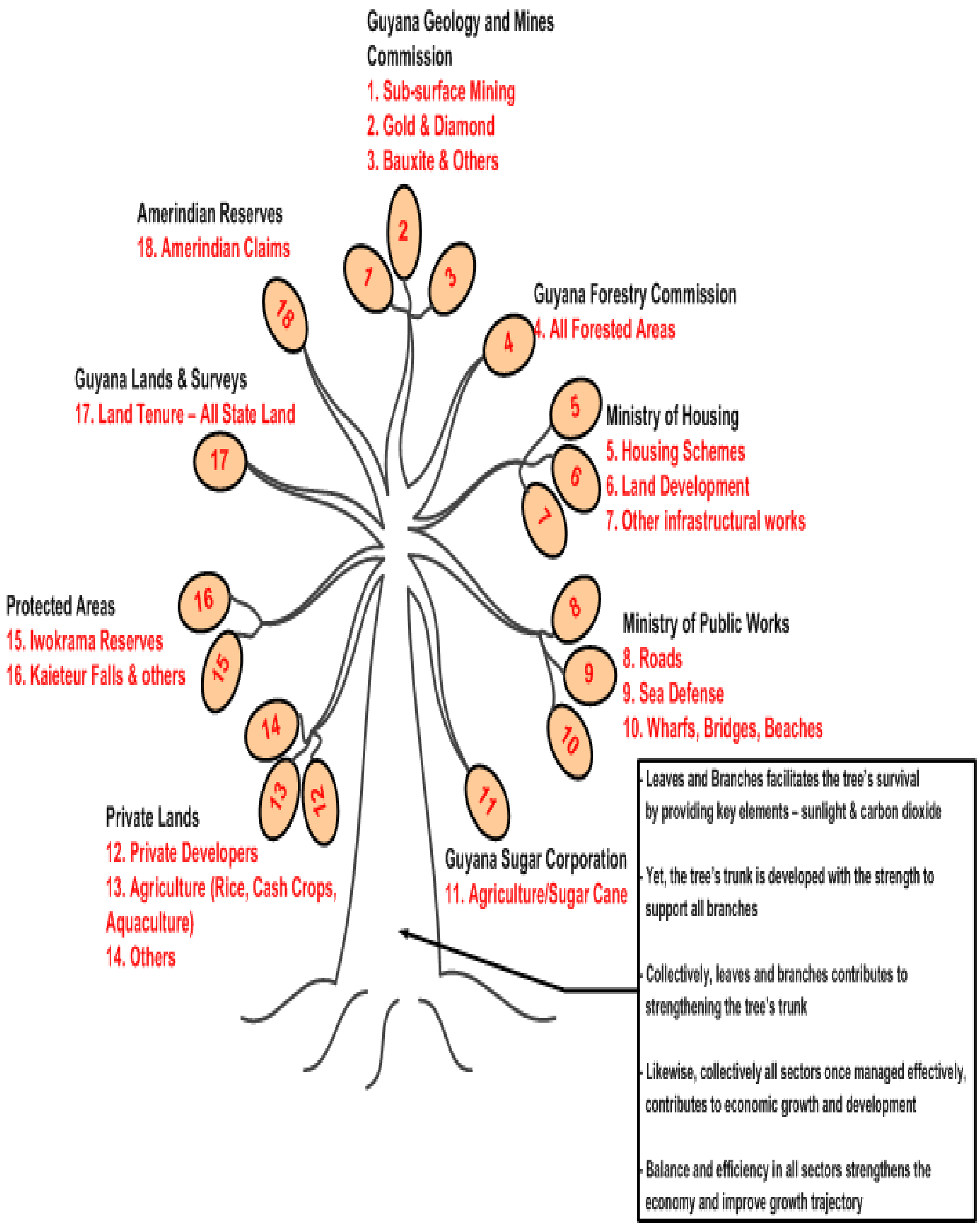

Figure 4.6: Conceptual illustration of land management framework in Guyana

The land management framework of the model is governed by a National Land Management Council (NLMC) and supported by four core elements as shown in figure 4.7: land policy and land use policy sub-system, deliberative and consultative mechanisms, land management operational system and a National Spatial Data Infrastructure (NSDI). This module aims to facilitate both vertical and horizontal integrated using a menu of policies and strategic tools to integrate decision making.

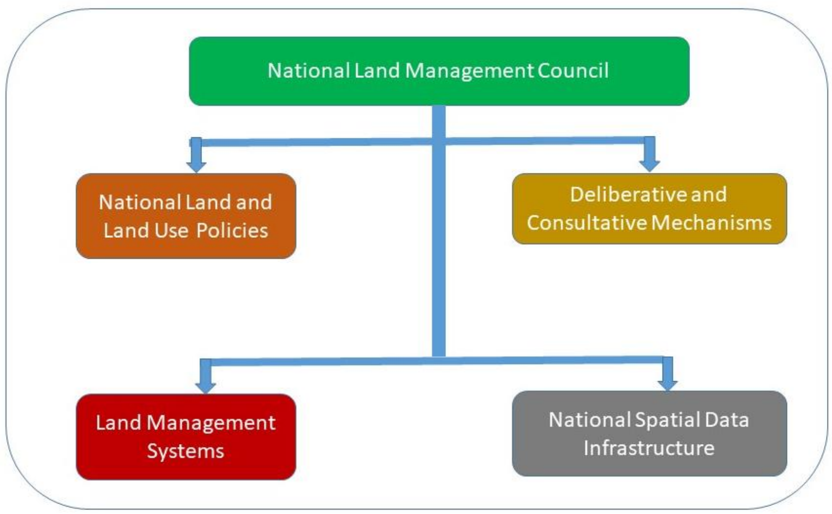

Figure 4.7: Module II-Conceptual illustration of land management framework

In the proposed model, vertical decision-making will be maintained with each agency being allowed to make decisions along sectoral lines based on sectoral strategies and programmes. However, these sectoral decisions will now be guided by overarching National Land and Land Use Policies that promote sustainable development. To ensure the entire landscape is considered and the country's land resources are utilized optimally, all land use decisions will be made within the context of landscape level plans and land use plans respectively. As such, the 'tools' for decision-making will include a national land use policy, land use plans and landscape-level plans, sectoral policies and strategies, and legislation to guide the four land administration functions (that is, land tenure, land value, land use, and land development).

The framework has two-tiers. The first tier is the NLMC. It comprises of high-level Ministers with responsibilities for significant land use sectors, key development partners and representatives' local communities and at-risk groups (women and indigenous groups) and individual citizens. This umbrella land management body will serve several purposes. Firstly, it will ensure that the decisions made by each agency incorporate the concerns and aspirations of other agencies. Secondly, it will help to encourage consensus-based choices whereby involving key stakeholders in the decision-making process. Thirdly, any conflict among the various land administration agencies may be addressed by the NLMC.

The second tier, on the other hand, comprises of all the land administration agencies. They will continue to exercise sectoral operational controls. Under the ILMM, the various agencies will be required to manage land within their sectors in a manner which considers the cumulative effects as well as the aspiration of all stakeholders, including other land use sectors, local authorities, individual citizens, etc. Each agency will be also be required to provide joint oversight over the land mass rather than limiting its focus on sector-specific projects.

The land management framework of the model will contain a Decision Support System (DSS) that provides a common platform for integrated decision-making in a collaborative environment. The NSDI will enable the NLMC and its technical committees as well as the various land-related agencies to examine the cumulative effects of land use activities on the entire landscape with the aid of the Decision Support System will be developed. The information system will also contain measurable targets that capture the ideal future state of the entire landscape given various land use activities. Figure 4.8 depicts the first and second modules of the integrated land management model. It is noteworthy that the first module which contextualizes land use needs influences the land management module.

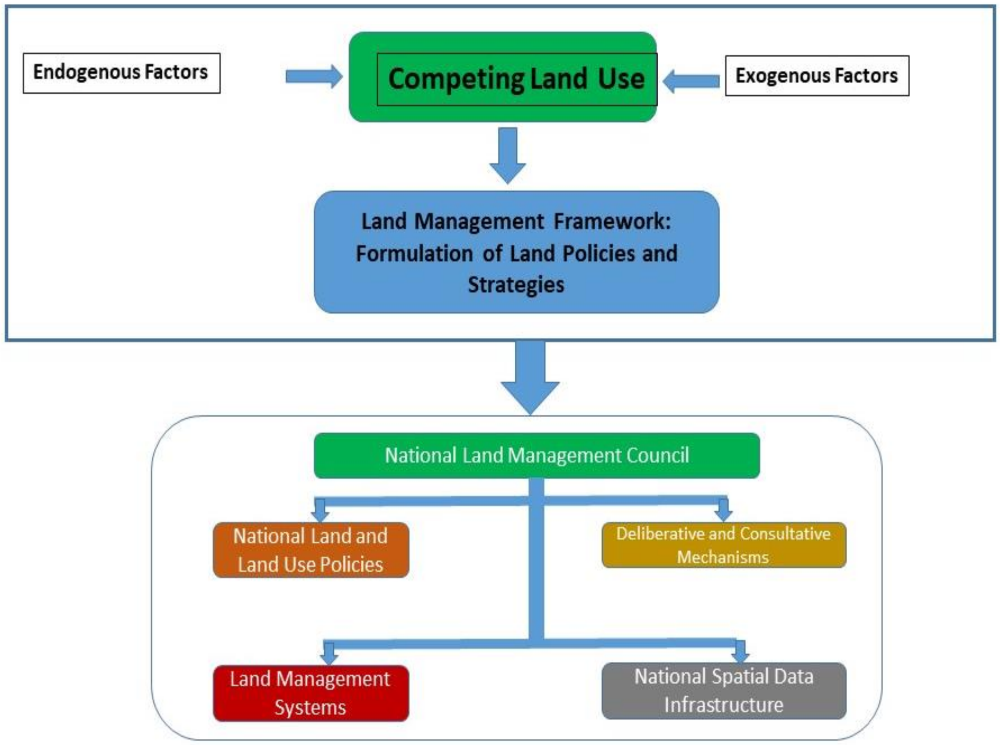

Figure 4.8: Combining modules I and II

Module III: Multi-criteria Problem Solving and Implementation System

The third module of the ILMM contains a problem solving and operational framework that allows for integrated land management. It includes an appropriate participatory multi-criteria decision-making tool which is based on GIS. While there are numerous such tools, this study applies the Spatial Analytic Hierarchy Process (SAHP). Implementation of this tool involves the performance of several activities systematically as captured in figure 4.9.

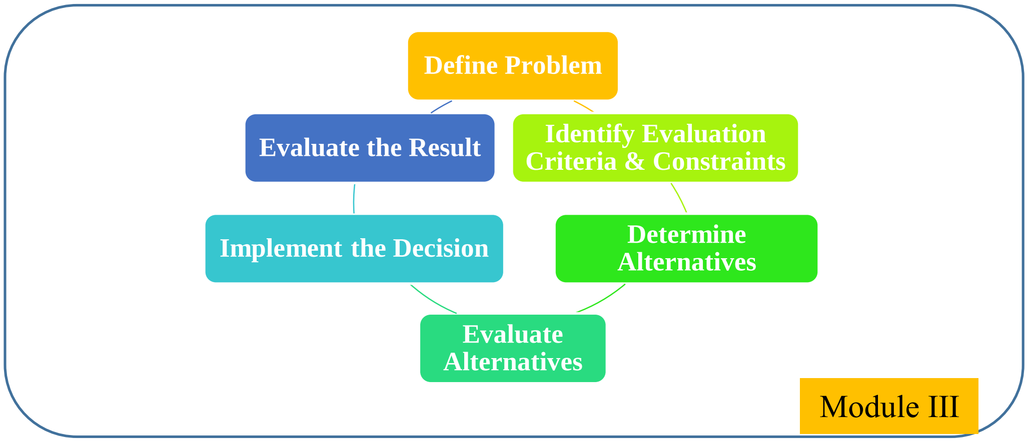

Figure 4.9: Systematic problem solving approach

The operational integrated land management module will be implemented using tools such as:

Land Use Policy - in order to encourage integrated land use planning, an explicit Land Use Policy should be developed as guiding principles that guide all land management decisions. This policy will be developed to capture the collective aspirations of all stakeholders. Since sustainable land development is the ultimate goal of the model, the Land Use Policy will be designed to promote economic growth, social justice, equality, and environmental preservation.

Sectoral Policies and Laws – the sectoral policies and legislation will be maintained to facilitate vertical decision-making. However, they will be refined to encourage adaptive and horizontal decision-making explicitly. In particular, these policies and laws will be improved to ensure that all land use decisions consider the aspirations of society, policymakers, and other sectors. The policies will also establish landscape level objectives which are time bound and mandate monitoring and evaluation. The former is intended to ensure that land use activities are not carried out in a manner that is harmful to the environment. The latter, on the other hand, would allow for sectoral performance to be closely monitored and where necessary, prompt actions or adjustments are made to correct deviations from prescribed objectives and cope with new dynamics in the environment. The laws will also be amended to facilitate and enforce coordination among the various land use agencies by establishing the National Land Management Steering Committee.

Land Use Plans – national and regional land use plans will be a critical element of the implementation framework to facilitate landscape level planning and management. Currently, there is a draft National Land Use Plan and a Regional Land Use Plan for Region VI in Guyana. These plans were developed with the input from the community and institutional stakeholders. As such, the existing land use plans reflect the aspirations of all the key stakeholders. To a large extent, the process established for engaging the stakeholders was not only inclusive but transparent.

Spatial Decision Support System (SDSS) that support integrated sustainable land management. The SDSS, which is one of the most critical tools for

Module III of the model, incorporates information from all the land administration agencies and facilitate coordination and collaboration among the key stakeholders. In other words, the SDSS should provide a common platform for all the land use agencies to make integrated decisions and foster stakeholders' participation, transparency, and cost-effective land management. This module of the model will also serve to avoid land conflict using cost-effective solutions that would not impair social and economic development.

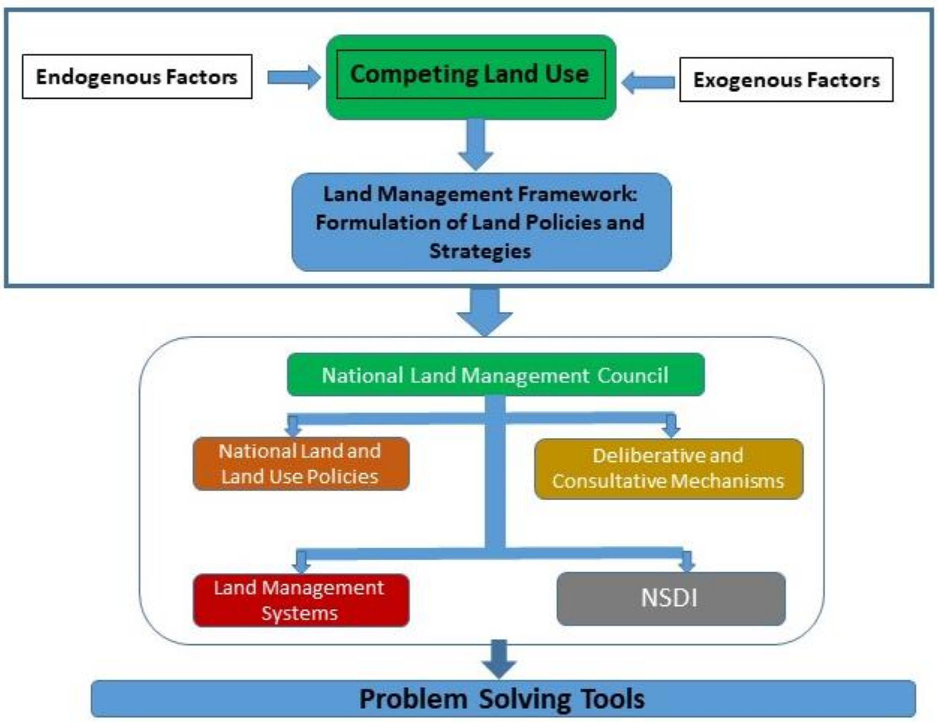

Figure 4.10: Integration the Policy and Operational Modules: I, II, and III

Module IV: Monitoring and Evaluation (M&E) Framework

In general, very little attention is directed at monitoring and evaluation of land management policies and activities not only in Guyana but throughout the Caribbean. Module IV (figure 4.11) of the model, therefore, proposes a monitoring and evaluation framework that allows for monitoring of land management activities, which in turn is intended to ensure that the country's land resources are utilized optimally based on thresholds established for the country. In particular, the monitoring and evaluation framework will:

- scan the environment to identify new internal and external factors that may have important implications for land management at various levels (national level, regional level and the level of each land use sector);
- review the role of all the key stakeholders to ensure they are well positioned to cope with existing and emerging challenges related to land management; and
- evaluate the land management framework (policies, laws, land administration system and information infrastructure system) to determine its adequacy.

This module is essential for identifying any deviations from established land policy targets so that corrective action may be taken as quickly as possible. It would also ensure that the land management framework is responsive to new land management issues.

The established thresholds are the most critical component of the monitoring and evaluation system. The thresholds generally reflect the societal values and scientific knowledge and may, therefore, change over time due to the evolution of scientific knowledge and societal values. While there are existing thresholds for timber extraction in Guyana, similar thresholds are absent concerning other land uses, such as gold extraction, farming, housing, etc.

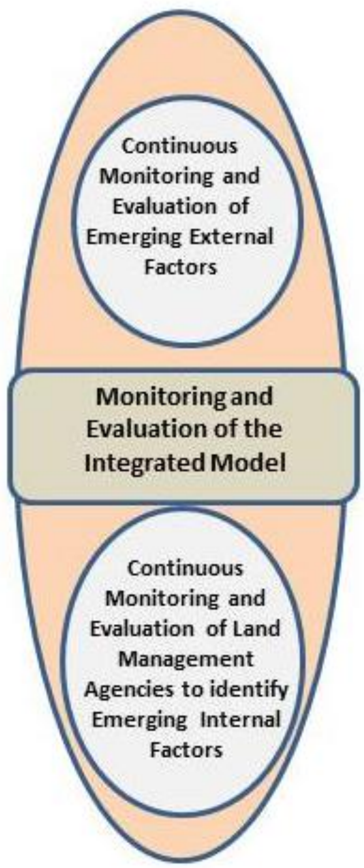

Figure 4.11: Module IV: Monitoring and evaluation framework

Monitoring and evaluation parameters such as current land ownership structure; ranges of land parcel sizes; optimal land use bands; list of restrictions and their relevance should be developed to guide the revision of land policy and operational guidelines.

Figure 4.12 shows the monitoring and evaluation framework combined with the first three modules.

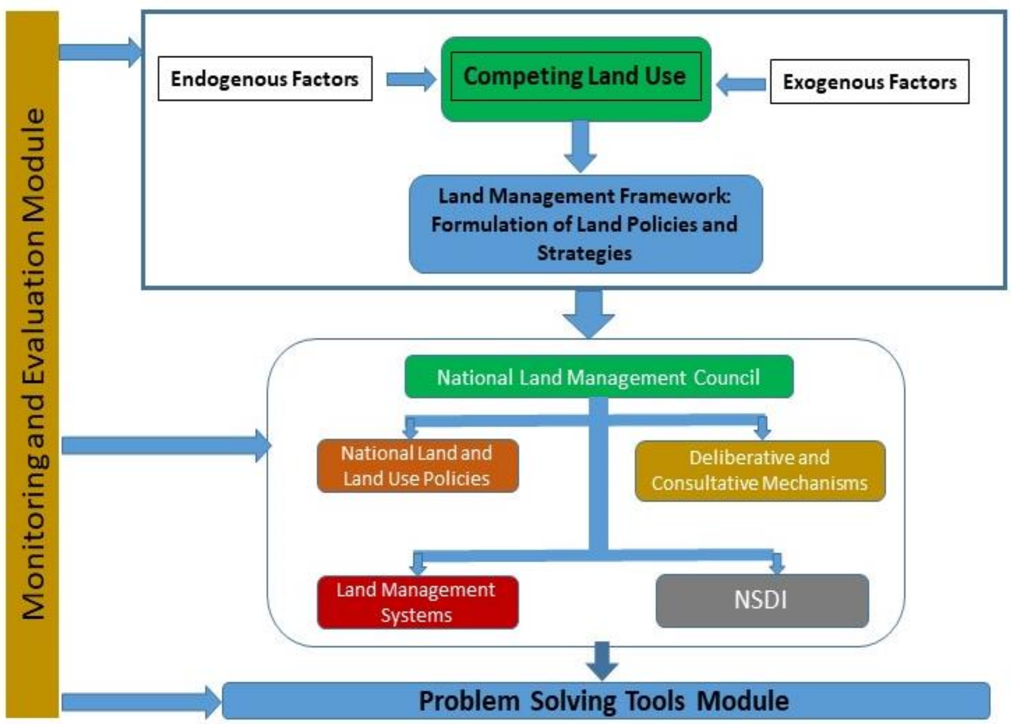

Figure 4.12: Integrating monitoring and evaluation framework with modules I, II, and III

Module V: Correctional Node

Where deficiencies are detected in the land management framework, the correctional node of the model is designed to correct the same (figure 4.13). It is done through a consultative approach among all the key stakeholders and may result in:

(i) Legislative review and reform;

(ii) Institutional strengthening through the provision of adequate human, financial and technical resources; and

(iii) Development and promulgation of new land policies, regulations;

(iv) Enforcement of new policies and regulations;

(v) Review of the oversight role of government and other stakeholders.

This correctional node should encourage participatory decision-making and enhance cross-sectoral linkages.

Figure 4.13: Module V: Components of the correctional nodes

Land conflicts are estimated to cost billions of dollars in losses to national GDP. The node will propose how to manage land use conflicts with cost-effective solutions that would not hamper the economic value of the land. Its goal is to create greater efficiency in land management and equitable distribution of land. It will define oversight roles among the respective agencies.

The correctional node is supported by an extensive range of support services including staff recruitment, training, and development; administration and organisational planning; information technology, networking, and technical support services; procurement – good and services. All of these activities should fall under one umbrella organisational structure that brings together the land administration, management, and use.

The full Integrated Land Management Model is illustrated in figure 4.14.

Based on the foregoing, the ILMM can be regarded as an integrated five modular systems for sustainable land management with the capacity to manage land allocation, land use, and process monitoring in the context of social, economic and environmental objectives of a country. Additionally, the ILMM seeks to promote cross-sectoral linkages, and coordinated land use management and control, resulting in a conflict-free environment, to manage land use and to ensure that such a system is sustainable.

4.4 Conceptual Design of Multi-Criteria Decision Support Tool for the ILMM

The thesis applies the Spatial Analytical Hierarchy Process (SAHP) with the goal of improving decision-making within the ILMM. The Multi-Criteria Decision Analysis (MCDA) technique which uses biophysical data from Geographical Information Systems (GIS) is used to perform land suitability analyses in four key land use sectors in Guyana. This section begins with a brief discussion of GIS and MCDA. It continues with a review of the SAHP technique and describes the procedure that is followed in applying these tools to address land administration issues in Guyana.

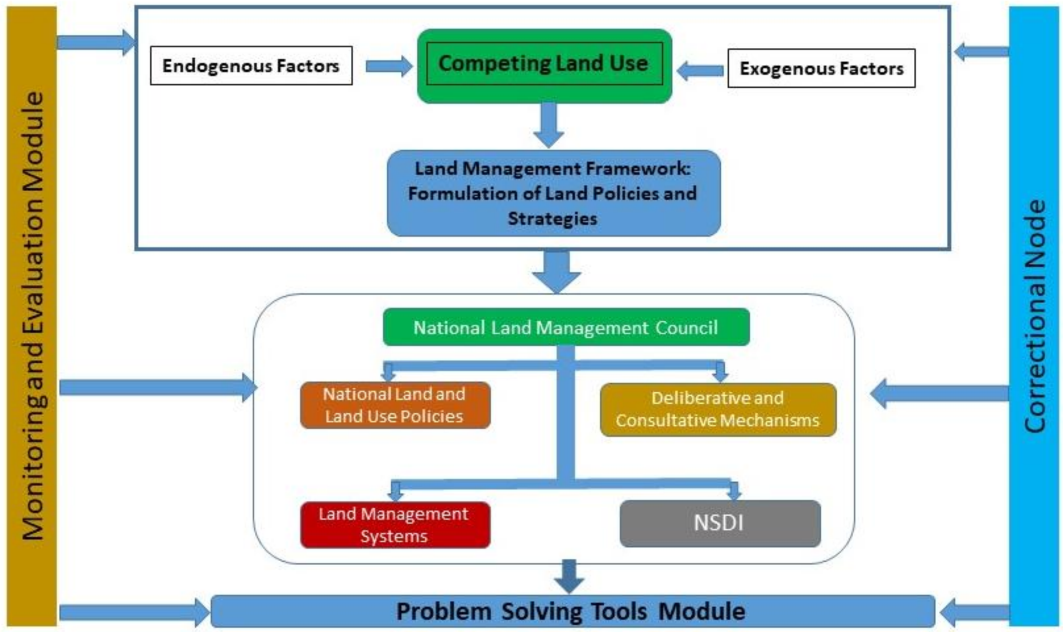

Figure 4.14: The Integrated Land Management Model (ILMM)

4.4.1 GIS and Multi-Criteria Decision Analysis

GIS-based Multi-Criteria Decision Analysis has significant potential in land resources planning and management. However, this powerful approach to solving overlapping spatial problems has not been fully exploited (Nyeko 2012). This thesis attempts to extend the literature by using SAHP within land management framework.

Over the years, literature has provided several definitions for Geographical Information Systems (GISs). The earlier definitions of GIS were limited to the technological facets of the system while more recent definitions focused on problem-solving capabilities of GIS as it relates to spatial problems. For instance, Malczewski (1999) defined GIS as "… A system which contains a set of procedures that facilitate the data input, data storage, data manipulation, and analysis and data output for both spatial and attribute data to support decision-making activities." (16).

More recently, Nyeko (2012) defined GIS as: "… a computer-based system that offers a convenient and powerful platform for performing land suitability analysis and allocation." (341). Based on the preceding definitions, GIS can, therefore, be defined as a decision-support information system which captures, stores, manipulates and generates geographical data that may be useful for solving land use problems.

Multi-criteria Decision Analysis (MCDA), on the other hand, refers to a range of tools which may be used to find the optimal solution to problems that involve several competing objectives. These tools have been combined with GIS over the years to determine the location of numerous land use projects, such as hospitals, solid waste landfill sites, wells, housing schemes, and agricultural projects, etc. They have also been applied to land use management and planning problems but in a limited way Nyeko 2012). According to Malczewski (1999), Multi-criteria Decision Analysis based on GIS may be viewed as a process that utilizes geographical maps (input maps) to generate output maps, (that is, rating and ranking maps) which allows for optimal land use decisions.

The GIS/MCDA problem-solving exercise starts with the identification of the problem and concludes with recommendations regarding optimal land use alternatives. According to Malczewski (1999), the exercise may be divided into three phases, namely, the intelligence design phase, the design phase, and the choice phase (figure 4.13). During the intelligence phase, GISs is combined with formal modelling techniques to identify weaknesses in the existing land management framework (or define the problem). The GISs are then utilised to gather, process and perform exploratory analysis of data during the second phase. The design phase, on the other hand, involves the use of multi-criteria decision analysis (or formal analytical techniques) to develop a solution set of spatial decision alternatives. Finally, during the choice phase, the decision-makers employ both GISs and MCDA to evaluate and rank the various options obtained from the design phase. Each stage of the process may be further sub-divided into a sequence of activities as illustrated in figure 4.15. It is noteworthy that the series of actions may vary (Malczewski, 1999). The sequence of events may determine whether the decision-making process is categorised as the 'alternative-focused approach' or 'value-focused approach' Keeney (1992).

4.4.2 Framework for Spatial Multi-Criteria Decision Analysis

Solving a spatial multi-criteria decision analysis problem involves performing a series of 8 activities in systematic steps. Figure 4.15 shows the sequence of steps that is adopted. A discussion of each step along with an explanation regarding how each will be implemented is provided below.

4.4.2.1 Step 1: Problem Identification

Identification of the problem is the starting point of the exercise. It involves an assessment of the existing system to determine whether optimal decision/criterion outcome(s) are produced. If the current system is deficient, this will represent a problem. In the context of the land administration literature, an optimal system is one which delivers sustainable development in a systematic and coherent manner. According to Williamson et al. (2010), sustainable development has three (3) dimensions, namely, economic, environmental and social.

As highlighted in Chapter 3, the existing land use framework in Guyana is disjointed and contributes to numerous conflicts and problems. Moreover, the current land use framework is not capable of ensuring sustainable development in an environmentally friendly manner. Given the renewed focus on 'sustainable development' as promulgated in the country's new development paradigm (that is, the Low Carbon Development and the Green Economy Strategies), the existing land management framework may be regarded as inadequate in meeting the national Green Economy agendas. Once the problems have been defined, it will become necessary that a set of evaluation criteria and/or a set of constraints be developed for the assessment of the problem. These will trigger Steps 2A and/or Step 2B depending of the nature of the problem.

4.4.2.2 Step 2: Establish Evaluation Criteria and Constraints

The second step of the problem-solving exercise involves establishing the evaluation criteria and constraints. Evaluation Criteria include the goal (or set of goals) that the various stakeholders set out to achieve, based on the physical and other features of land (or attributes) under their control. The evaluation constraints, on the other hand, are all the factors that may prevent the stakeholders from achieving the objectives established. In the context of MCDA based on GIS, the attributes and constraints are usually captured by attribute maps (or thematic maps or data layers) and constraint maps respectively. It is important to note that attribute maps and constraint maps are not available for the entire country. As such, the analysis is restricted to those areas where data are available. If the pathway of Step 2A was followed, Step 2B becomes necessary if the evaluation criteria have constraints that need to be addressed. Otherwise, one may proceed to Step four instead of Step three.

The evaluation criteria and constraints may be determined by reviewing the relevant literature but may be supplemented by interviewing key stakeholders, experts and informants. In this study, both techniques are employed to establish the evaluation criteria and constraints. Given the emphasis on 'sustainable development' in the thesis, the United Nations Guidelines on indicators of sustainable development (United Nations 2007) are observed when establishing the objectives of the stakeholders. The UN guideline identifies three primary objectives for sustainable development. These are: (i) economic objectives; (ii) ecological objectives; and (iii) social objectives. For the thesis, the various objectives are defined as follows:

- *Economic objectives*: maximising revenue from mining, logging, housing, agricultural activities, energy etc.;
- *Ecological objectives*: minimising environmental damage from erosion, pollution and de-forestation;
- *Social objectives*: maximising social gain by preserving cultural diversity, spiritual and religious values, knowledge systems, educational values, aesthetic values, social relations, cultural heritage, recreation and eco-tourism.

The *constraints* include but are not limited to the following:

- maximum potential of soil;
- population supporting capacity;
- climatic resources to produce food and energy;
- availability of technology;
- internal and external market conditions; and
- minimising production costs.

Appendix A provides a detailed list with the specific objectives, criteria and constraints along with associated biophysical parameters for determining land suitability. On completion of Step 2B, a set of alternatives should be considered in Step three.

4.4.2.3 Step 3: Determine alternatives

Once the evaluation criteria and constraints are clearly defined, the next step in the process involves the determination of feasible options and the assignment of a decision variable to each. The variables may be deterministic, probabilistic, or linguistic (Malczewski 1999). For this study, the following alternatives are considered for land use: agriculture (farming), mining, housing, and forestry (logging). Each option is reviewed at the agency level (that is, where the experts from each land management agency determine the best use for land parcels) and national level (that is, where all the land management agencies collectively identify possible land use alternatives).

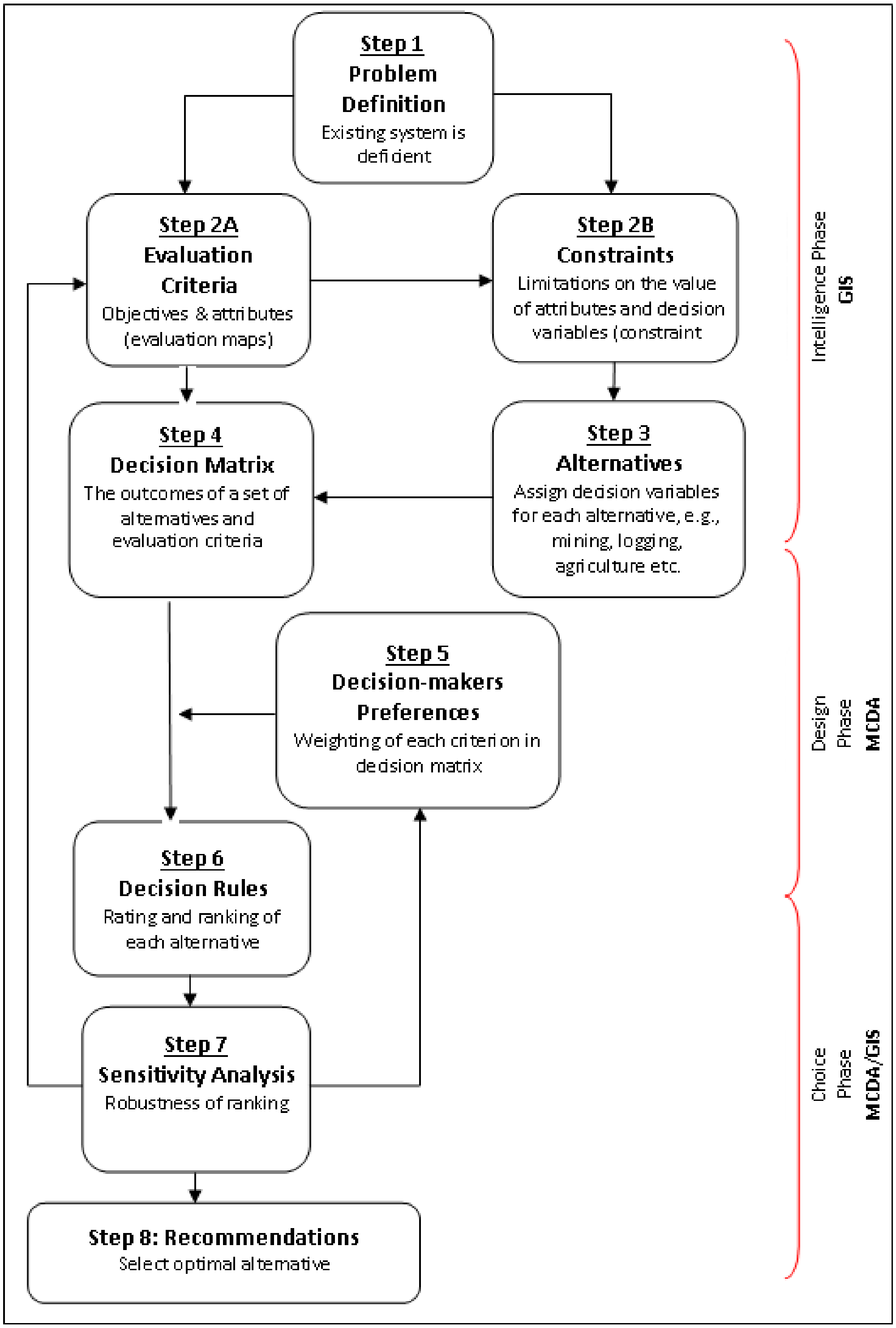

Figure 4.15: Framework for spatial multi-criteria decision analysis
Source: Adapted from Malczewski (1999)

4.4.2.4 Step 4: Decision Matrix

The evaluation criteria from step two are combined with the feasible alternatives from step three to formulate a decision matrix. In essence, the matrix provides a composite score (or decision outcome) for each alternative based on input data and the decision-makers' preferences. The rows of the matrix reflect all the feasible options, while the columns capture either the attributes (that is, features of the land under consideration) or objectives (that is, economic, ecological and social goals). Thus, the matrix may show either the alternative-attribute relationships or objective-alternative relationships (table 4.1 and table 4.2). The alternatives in table 4.1 reflect all the feasible options that are determined by each agency. For example, the Ministry of Agriculture may decide that the lands under its control are suitable for various competing agriculture activities such as rice cultivation, sugar cane cultivation, cash crops, etc. The alternatives in table 4.2, on the other hand, reflect the various uses for lands determined by all the agencies which may extend beyond agricultural activities, such as housing, mining, logging, tourism, eco-services.

The cells of both matrices represent the decision outcomes for a set of alternatives and evaluation criteria. In this thesis, both matrices are employed. On completion of Step four, one proceeds to Step six (and not Step five) decision rules (rating and ranking of alternatives).

Table 4.1: Decision matrix of multi-attribute decision model

	Attribute 1	Attribute 2	Attribute 3	….	Attribute q
Alternative 1: Rice cultivation	$Outcome_{11}$	$Outcome_{12}$	$Outcome_{13}$	….	$Outcome_{1q}$
Alternative 2: Sugar cane cultivation	$Outcome_{21}$	$Outcome_{22}$	$Outcome_{23}$	….	$Outcome_{2q}$
Alternative 3: Cash crop (fruits, vegetables ,etc.)	$Outcome_{21}$	$Outcome_{22}$	$Outcome_{23}$	….	$Outcome_{2q}$
….	….	….	….	….	….
Alternative m	$Outcome_{m1}$	$Outcome_{m2}$	$Outcome_{m3}$	….	$Outcome_{mq}$

Note: Based on Malczewski (1999)

Table 4.2: Decision matrix of multi-objective decision model

	Objective 1	Objective 2	Objective 3	….	Objective q
Alternative 1: Agriculture	$Outcome_{11}$	$Outcome_{12}$	$Outcome_{13}$	….	$Outcome_{1q}$
Alternative 2: Mining	$Outcome_{21}$	$Outcome_{22}$	$Outcome_{23}$	….	$Outcome_{2q}$
Alternative 3: Forestry	$Outcome_{21}$	$Outcome_{22}$	$Outcome_{23}$	….	$Outcome_{2q}$
Alternative 4: Housing	$Outcome_{21}$	$Outcome_{22}$	$Outcome_{23}$	….	$Outcome_{2q}$
Alternative 5: Eco-system services	$Outcome_{21}$	$Outcome_{22}$	$Outcome_{23}$	….	$Outcome_{2q}$
….	….	….	….	….	….
Alternative m	$Outcome_{m1}$	$Outcome_{m2}$	$Outcome_{m3}$	….	$Outcome_{mq}$

Note: Based on Malczewski (1999)

4.4.2.5 Step 5: The Decision-Makers' Preferences

Step five is triggered to introduce the preferences of the stakeholders into the problem-solving exercise as reflected by the relative importance (or weight) assigned to each evaluation criterion. This is done to test the robustness of the ranking after sensitivity analysis in Step seven. The weights can be combined and incorporated into a larger decision matrix that has several components, namely, goal, decision-makers, evaluation criteria, decision alternatives, outcomes, weights and the state of the environment.

The goal refers to the overarching goal that all the stakeholders' attempts to achieve collectively. In the case of this study, the ultimate goal is to ensure that the country's resources are harnessed to promote financial and social development in an environmentally friendly manner based on the Low Carbon Development Strategies (LCDs).

Decision-makers are those agencies involved in administering lands. These include Guyana Lands and Surveys Commission (GLSC), Guyana Forestry Commission (GFC), Guyana Geology and Mines Commission (GGMC), Ministry of Agriculture (MoA), Central Housing and Planning Authority (CHPA), Amerindian Councils/Ministry of Amerindian Affairs (MoAA), GUYSUCO, etc. Each agency is empowered and mandated by specific laws to regulate the acquisition and use of land resources in a sustainable manner.

Evaluation criteria refer to the objectives and attributes that determine the manner in which the decision-makers employ land resources. The evaluation criteria may be established from reviewing the literature and by conducting surveys which target key stakeholders and experts. Objectives are the specific goal (or set of specific economic, ecological and social goals) that each stakeholder attempts to achieve. For example, the objective may be the improvement in forest management or maximising the financial returns from mining while preserving the environment. Attributes, on the other hand, refer to the physical and other features that influence the uses of lands. For example, soil type (clay, sandy clay soil, sandy loams, and loams), elevation, geology, vegetation, hydrology, recreational attributes, etc.

Decision alternatives refer to the various uses for lands, such as the provision of shelter, to protect the environment and for economic benefits (for example, mining, logging, and agriculture, eco-services, tourism etc.).

Outcomes refer to the economic and other benefits/loss from utilising lands in a particular manner. For example, when land is used for mining, this may produce positive results such as export revenue, royalties, employment etc. However, these benefits may come at the expense of destroying the environment or foregoing the benefits from employing the lands for other purposes, such as logging, maintaining the forest cover, etc.

Weights refer to the importance of each criterion relative to the other criteria. The literature recommends a variety of techniques for deriving the weight for each criterion. According to Malczewski (1999), these include the ranking methods, rating methods, the pairwise comparison method, trade-off analysis method, and the multiple comparison techniques. Each technique has its strengths and weaknesses. However, the thesis employs the pairwise comparison method that was developed by Saaty (1980), within the context of the Analytical Hierarchy Process (AHP). With this technique, each stakeholder would be required to undertake a pairwise comparison of each evaluation criteria, with respect to the overall objective using a continuous nine-point rating scale; with one signifying equal importance and nine signifying extreme importance. The results are recorded in the pairwise matrix and then normalised to derive the criterion weights.

The pairwise comparison of each land use alternative, relative to each criterion, will also be done by each stakeholder and recorded in a pairwise matrix using the same nine-point rating scale. The pairwise comparison matrix is also normalized to derive the weight for each alternative.

State of environment refers to the uncontrollable factors within the decision environment. These may include factors such as the impact of climate change, natural hazards, global economy and trade, global security, institutional arrangements, existing policies and regulations, human, financial and technical resources, and political strategy among other things.

4.4.2.6 Step 6: Decision Rules

The various alternatives in MCDA problems can be assessed based on several decision rules. In particular, these rules help to determine the most optimal alternative. According to Malczewski (1999), the decision rules may be divided into two broad categories, namely, multi-attribute rules and multi-objectives decision rules. The former includes the: i) simple additive weighting method; ii) value/utility function approach; iii) analytical hierarchy process; iv) ideal point methods; v) concordance methods; and vi) fuzzy aggregation operation. The multi-objective decision rules, on the other hand include, i) value/utility function methods; ii) goal programming; iii) interactive programming; iv) compromise programming; and iv) data envelopment analysis.

This research employs the Spatial Analytical Hierarchy Process (SAHP), that is, a Multi-Criteria Decision Analysis (MCDA) based on Geographical Information Systems (GIS) as seen in figure 4.16. The Analytical Hierarchy Process (AHP) was developed by Saaty (1980). This decision rule technique involves the implementation of three steps that incorporate the following principles (Malczewski 1999):

- Decomposition principle;
- Comparative judgment principle; and
- Synthesis principle

A. Decomposing the Problem

The first step of the AHP involves decomposing the problem into a hierarchy, with the overarching goal being placed at the apex and the specific sub-objectives (criterion) and associated alternatives at the lower level of the hierarchy.

B. Comparative Judgment Principle

The second step involves the determination of the relative importance of each sub-objective (criterion) and alternative using a pairwise analysis of each sub-objective (criterion) with respect to the overall goal. The pairwise comparison is based on a nine-point rating scale developed by Saaty (1980); with one signifying 'equal importance' and nine signifying 'extreme importance.' During this step of the exercise, a set of comparison matrices are constructed for each level of the hierarchy. These matrices are normalized and the eigenvalues computed using equations 4.1, 4.2, and 4.3 to determine the weight (or relative importance) of each sub-objective (criterion) and alternative.

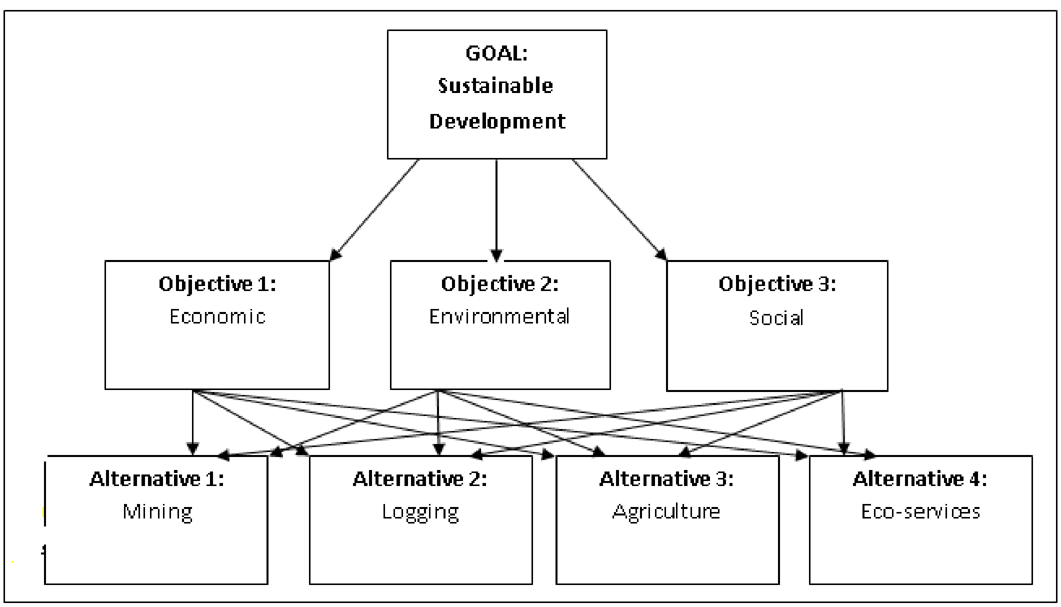

Figure 4.16: Hierarchical structure of multi-criteria decision analysis (MCDA)

$$\lambda_{*} = \sum_{i=1}^{n} X_{i,j} W_{i,j} \qquad (4.1)$$

The reliability of the computed weights is assessed using Inconsistency Ratio (CR) and random Inconsistency Indices (RI) developed by Saaty (1980). If the CR is smaller than or equal to 0.1, the weights are regarded as robust. However, if the CR is larger than 0.1 the weights are considered unacceptable and the pairwise comparison should be revised. The equations used to compute CI and CR are provided below.

$$CI = \frac{\lambda - n}{n-1} \qquad 4.2$$

$$CR = \frac{CI}{RI} \qquad 4.3$$

C. Synthesis Principle

The final step of the AHP involves the determination of the overall score of each alternative and ranking of same using a series of multiplications aimed at determining the overall score of each alternative and the subsequent ranking of same to identify the most feasible option. The overall score for each alternative is computed using Equation 4.4.

$$R_i = \sum_k w_k r_{i,k} \qquad 4.4$$

Equations 4.4 essentially aggregates the weights associated with a particular alternative at the various stages of the hierarchical structure to derive its overall score (R_i). The scores are then ranked and the optimal alternative selected.

Spatial AHP employs the three principles described above. Specifically, it: decomposes the problem into a hierarchy with a goal, sub-objectives and competing land use alternatives; (ii) generate weights for various sub-objectives and alternatives based on pairwise analysis: and (iii) synthesizing the weights from the previous step by using a Weighted Linear Combination (WLC) operation.

The spatial AHP technique, however, is unique as it utilizes Geographic Information System (GIS) and Multi-Criteria Decision Analysis (MCDA) in the process. In this regard, the spatial AHP technique takes '*land suitability measures*' from attribute and constraint maps generated by the GIS and employ MCDA to generate '*ranking maps*' (or land suitability maps). Specifically, this technique uses land suitability measures from the aforementioned maps and applies a Weighted Linear Combination (WLC) operation, which multiplies cell values from standardized criterion maps by the corresponding criterion weights, to derive weighted standardised criterion maps. The values in the weighted standardised maps are then aggregated to form rating maps (or land suitability maps) which are subsequently used to determine optimal land use (figure 4.18). The Weighted

Linear Combination (WCL) model is described in equation 4.5 (Nyeko 2012, 342) as follows:

$$S_k = \sum w_{k,i} x_{k,i} \qquad 4.5$$

where, S_k is the suitability index for pixel/cell k; $x_{k,i}$ is the value criteria i for pixel k and $w_{k,i}$ is the factor weight. The factor weights $w_{k,1}$, $w_{k,2}$; …, $w_{k,n}$ reflective of the relative importance of each criterion for a given pixel.

Figure 4.18 provides a schematic representation of the spatial AHP/MCDA model. Based on this figure, the ultimate aim, in the context of the thesis, is to maximise the economic and social gains while simultaneously protecting the environment.

4.4.2.7 Step 7: Sensitivity analysis

Given the paucity of relevant data as well as the quality of data related to land use and management in Guyana, it is important that the potential error in the analysis be addressed in the multi-criteria decision. The study employs several statistical tools, as well as, sensitivity analysis to deal with possible output errors. These errors may be caused by errors in the input data, criterion value measurements, weighting (or preference) and/or rating (Malczewski 1999).

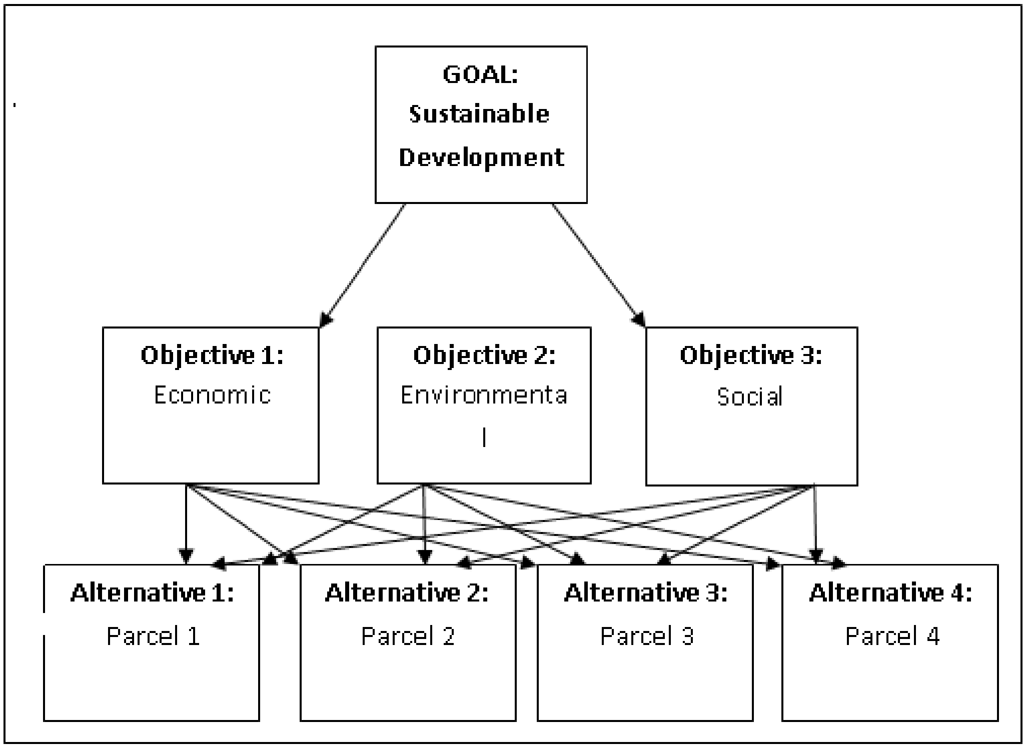

Figure 4.17: The hierarchical structure of multi-criteria decision analysis (MCDA) indicating goal, objectives and alternatives

To overcome errors in the criterion maps the thesis employs the Kappa statistics. Additionally, it applies sensitivity analysis of criterion weights and criterion (attribute) values to determine the robustness of the output results.

4.4.2.8 Step 8: Recommendation

The final stage involves selecting the optimal solution from Steps six and seven. According to Malczewski (1999), recommendations from spatial problems are best communicated using rating and ranking maps in a GIS environment as shown in figures 4.18 and 4.19.

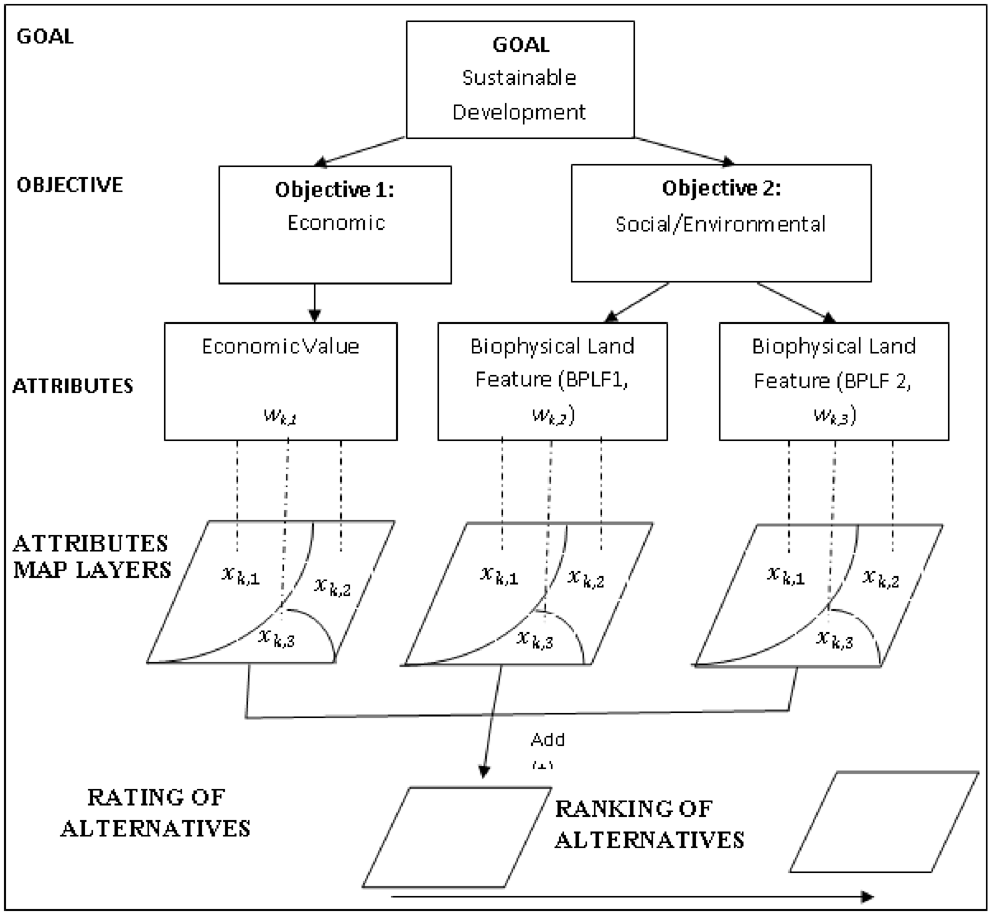

Figure 4.18: Spatial analytical hierarchy process (AHP)
Source: Malczewski (1999, 219)

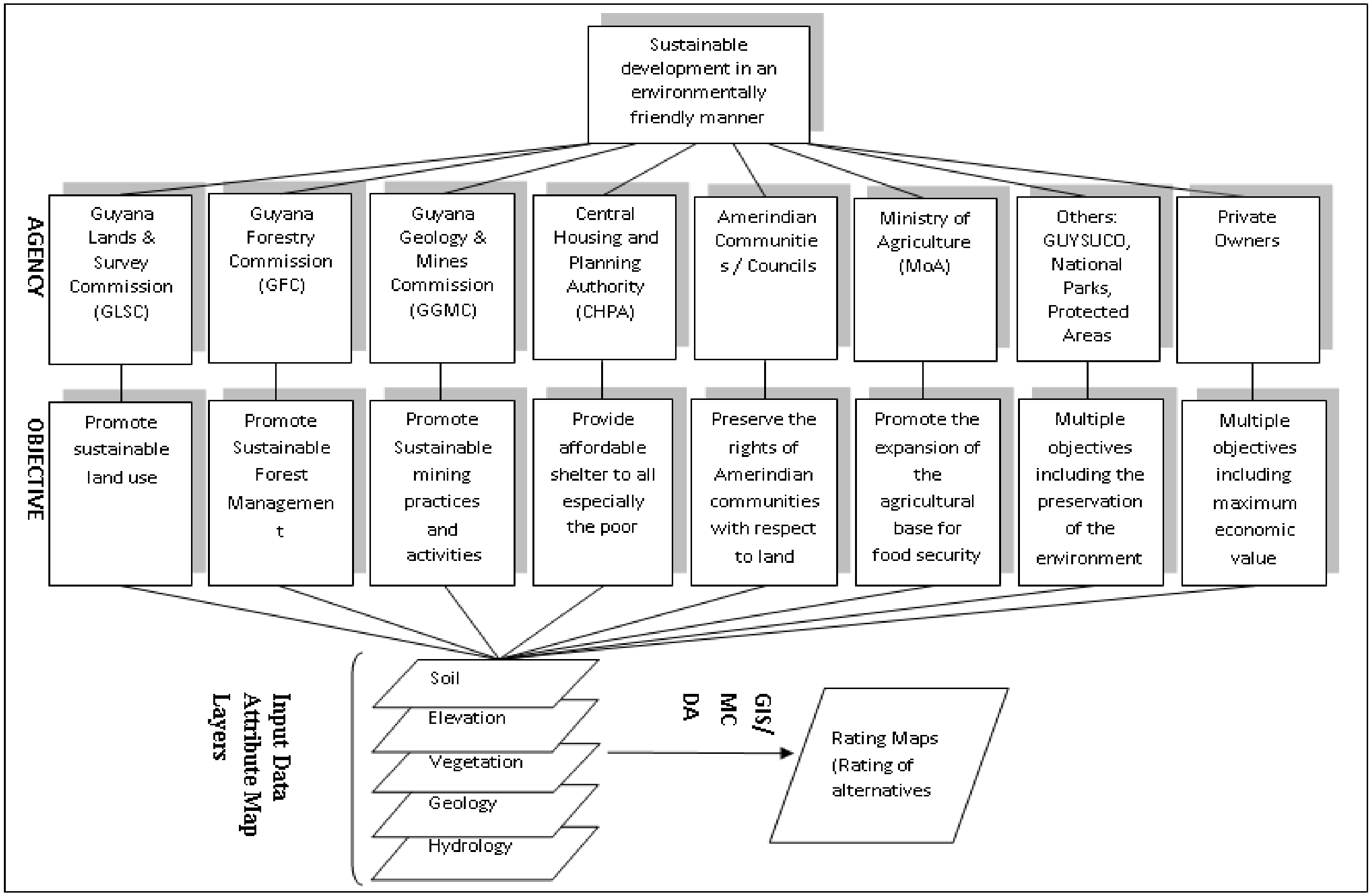

Figure 4.19: Land suitability analysis mode

4.5 Application of the Model and Selection of the Study Areas

This section begins with the rationale for the selection of the study area and then present the geophysical, environmental, and socio-economic characteristics of the study area. The GIS-ready thematic layers that were compiled from different sources in readiness for the spatial planning models were also presented.

4.5.1 Selection of the Study Areas

The study area straddles three administrative regions in Guyana: Region 3 (Essequibo Islands-West Demerara), Region 10 (Upper Demerara - Upper Berbice), and Region 7 (Cuyuni – Mazaruni). The study area was selected for four reasons. Firstly, the study area has been identified as the new growth region of Guyana in line with the national strategic plan with the proposed upgrade of Bartica as a new township and later the second city of Guyana. Secondly, the study area typifies a cluster of abundant natural resources that Guyana in noted for and its development will provide the cushion for the possible fragility of the soon to be oil and gas economy. It is characterized by an extensive range of economic/land use activities, including mineral extraction, logging, housing, and commercial agriculture. In Region three, commercial and subsistence agriculture is the dominant industrial/land use activity while mining and logging characterize Regions ten and seven. Within the study area, there is also enormous potential for hydropower and tourism; which now feature as important economic/land use activities in the country's LCDS.

Thirdly, the GLSC undertook a Baseline Study for the study area in 2002 (GLSC 2002). This study was intended to provide a general framework for land use across the country. While the Plan casually highlighted the possibility of land conflict, it did not provide a framework for addressing the same. Further, the land use plan did not offer any suggestion on how the available land in the study area may be used for different economic and social activities. In this regard, this study may serve to advance the national effort to promote sustainable land use planning, since it offers an analytical decision-making technique to complement the baseline study. Fourthly, the area has a rich set of GIS-ready databases that allows the research to focus on spatial planning modelling as opposed to GIS database development.

For the empirical exercise, both quantitative and qualitative data will be employed. Several sampling techniques may be utilized to gather geographical input data including random, systematic and stratified sampling (Malezewski 1999). While each method has it owns strengths and weaknesses, the systematic sampling technique is appropriate given the paucity of geographical data in Guyana and the effectiveness of this sampling technique when there is limited data. As a consequence, the analysis is restricted to the regions or areas for which geographical data is available.

The geographical data were sourced from several agencies: The GLSC, GFC, GGMC, MoA, CHPA, GUYSUCO, CI, IWOKRAMA and National Parks Commission. The qualitative data, on the other hand, were collected via interviews with experts who have practical experience in land management, especially as it relates to sustainable development. In this regard, formal workshops were organised with experts from the various land management agencies.

4.5.2 Physical Characteristics of the Study Area

General features and location: The study area consists of sections of Regions three, seven and ten which approximates 4,800 square kilometres (km^2) or 1,853.3 square miles (mi^2). Since the area forms part of the Coastal Plain of Guyana it is generally flat and low-lying. Like most of coastal regions of Guyana, the weather and climate of the study area are influenced primarily by seasonal shifts of the Equatorial Trough Zone (ETZ) and its associated rain-band called the Inter Tropical Convergence Zone (ITCZ). As a consequence, the weather is characterised by two wet seasons and two dry seasons. The wet seasons normally last from April to July and October to December. The two dry seasons fall outside these periods. The daily temperatures in the area range between 19^0C to 32^0C; with the lowest temperature occurring during the January-March period while the highest temperature occurs during the September-November period. Rainfall in the area is generally high and ranges between 2,200 - 2,300 mm. Figure 4.20 shows the location of the study area complied with topographic maps of Guyana at a topographic scale of 1:500,000 scale.

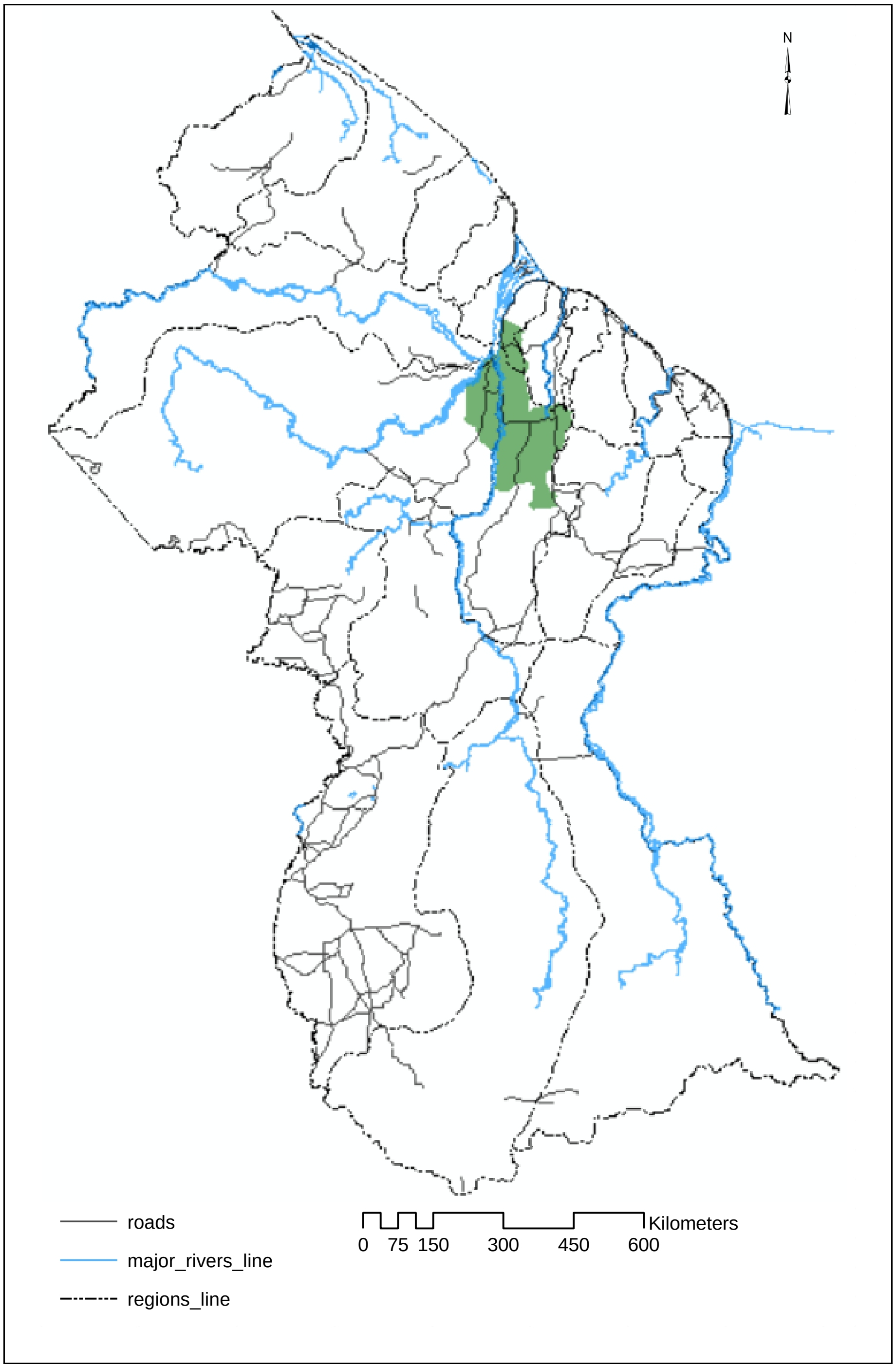

Figure 4.20: Location of study area

Base map of study area: Figure 4.21 shows the base map of the study area that was compiled with topographic maps of Guyana at a scale of 1:50,000. Region ten accounts for the largest share of the study area (sixty-eight percent). This is followed by Region seven and Region three which accounts for twenty-two percent and ten percent of the study area respectively.

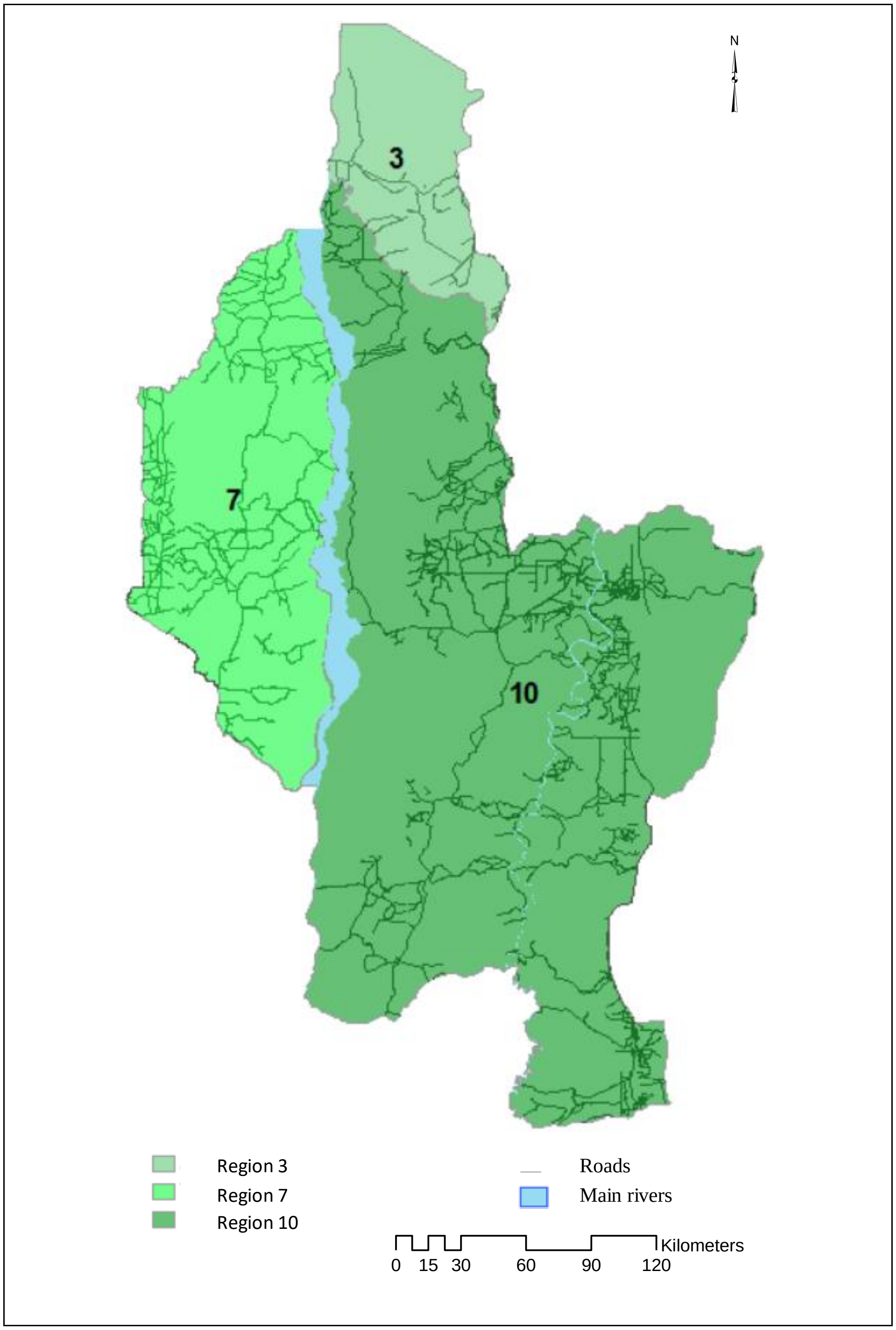

Figure 4.21: Base Map of Study Area

Human settlement and archaeological and/or spiritual sites: There are no archaeological and/or spiritual sites within the planning area. However, there is one historical site, Kyk-over-al. There is also twenty-four settlement area; of which Linden and Bartica are regarded as 'organized settlements' and the others 'disorganized or 'ad-hoc' settlements. Table 4.3 shows the names of the settlements and their population while figure 4.22 shows the spatial distribution of the settlements.

Table 4.3: List of settlements in the study area and their population

Settlement	Population
Rockstone	200
Bartica	6,909
Makouria	101
Akyma	69
Three Friends	129
Coomacka Lands	366
Old England	260
Lucky Spot	37
Mahaicabili	77
Sebaru	5
Lanaballi	250
St Mary's	94
Monkey Jump	44
Kumaka	34
Wineperu	156
Anarika	220
MacKenzie	22,492
Wismar	3,340
Christianburg	2,732
Malali	34
Agatash	185
Ituni	1,000
Mobilissa	101
Teperu	30

Source: Adapted from Participatory Rural Appraisal (PRA) and Population Census (1991)

It is noteworthy that the settlement areas are all equipped with various social facilities, such as schools, churches, police stations, health centres, hospital and community centres. These facilities are intended to satisfy the community needs.

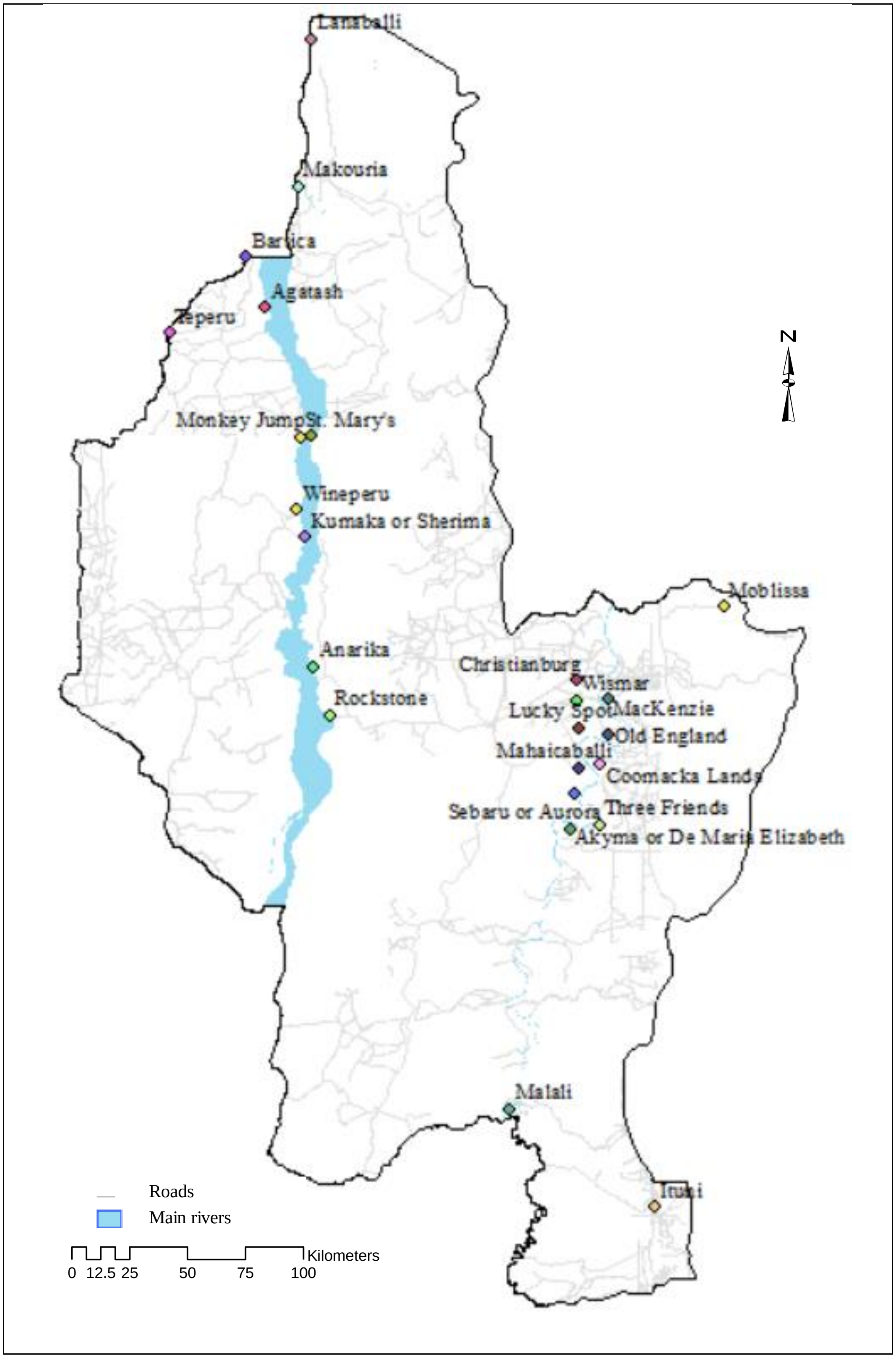

Figure 4.22: Human settlements in the study area

Water bodies: within the study area there are seven rivers, namely, Big Winiperu River, Anarika River, Arakwa River, Arampa River, Arawai River, Arawakai River, Makuba River, Arisauru River and Aritak River. The study area also has numerous creeks, lakes and ponds. Figure 4.23 shows the water bodies in the study area with topographic maps of Guyana at a scale of 1:50000.

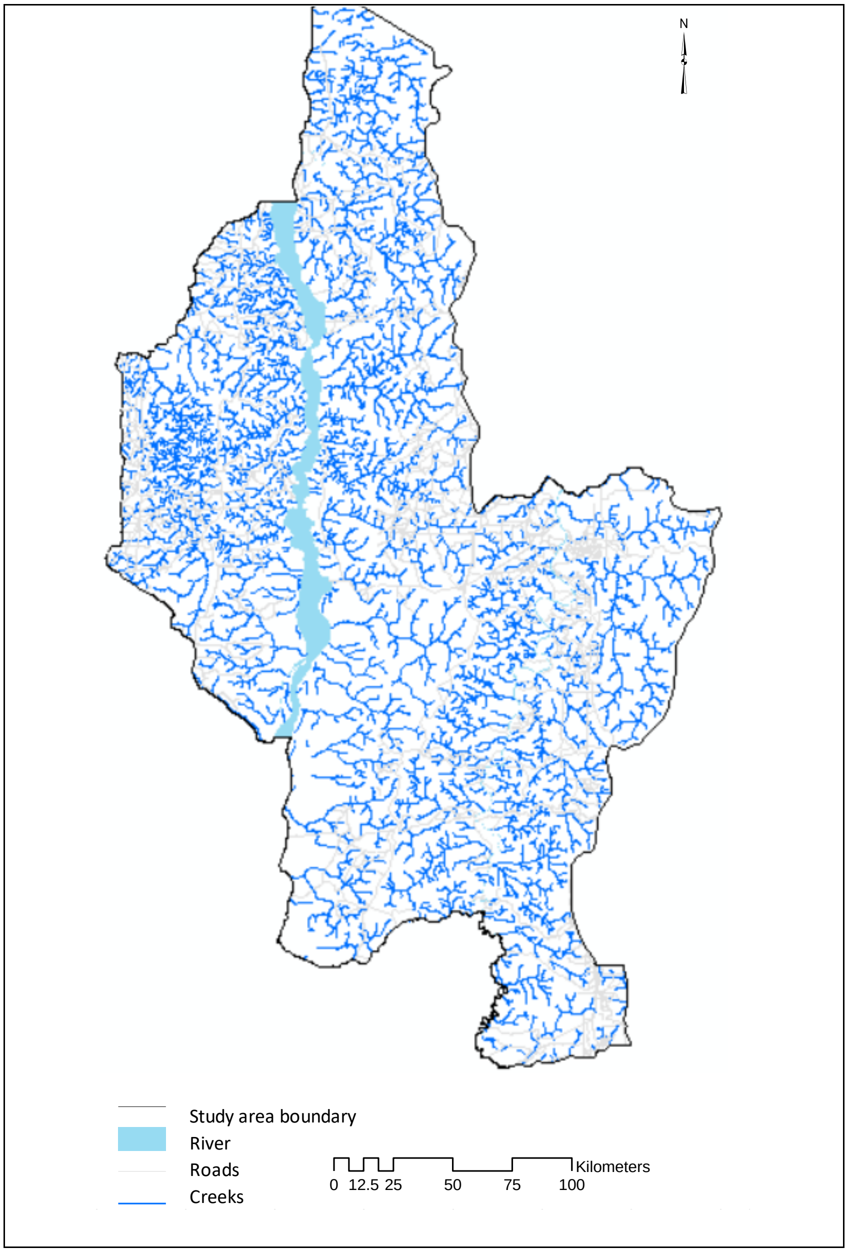

Figure 4.23: Water bodies map

Land Cover and Vegetation: the planning area comprises forest, grassland/Savannah, and human settlements and farms (figure 4.24). The most significant portion of the study area contains forest; classified as mixed forest, wallaba/associated forest and swamp/marsh forest (figure 4.25: Vegetation Map). The land cover and vegetation maps were compiled with 1:50,000 topographic maps, Landstat TM Data 1:100,000 (1992), and Field Verification 2001.

Forest capability: for logging or timber extraction the forest has also been classified as: forest that can be utilized for sustainable commercial utilization (production forest), forest that should set aside for preserving the natural or cultural heritage of Guyana (protection forest) and forest that can be utilized for mining, agriculture, roads and industrial schemes and could be transferred to other land use agencies (conversion forest). It is noteworthy that a significant portion of the production forest contains timber with either great commercial importance or moderate commercial importance. A sizeable portion of the study area also contains timber with low and no commercial importance (figure 4.26: Forest Capability Map). The Forest Capability Map was compiled with 1:50,000 stock sheets from the GFC.

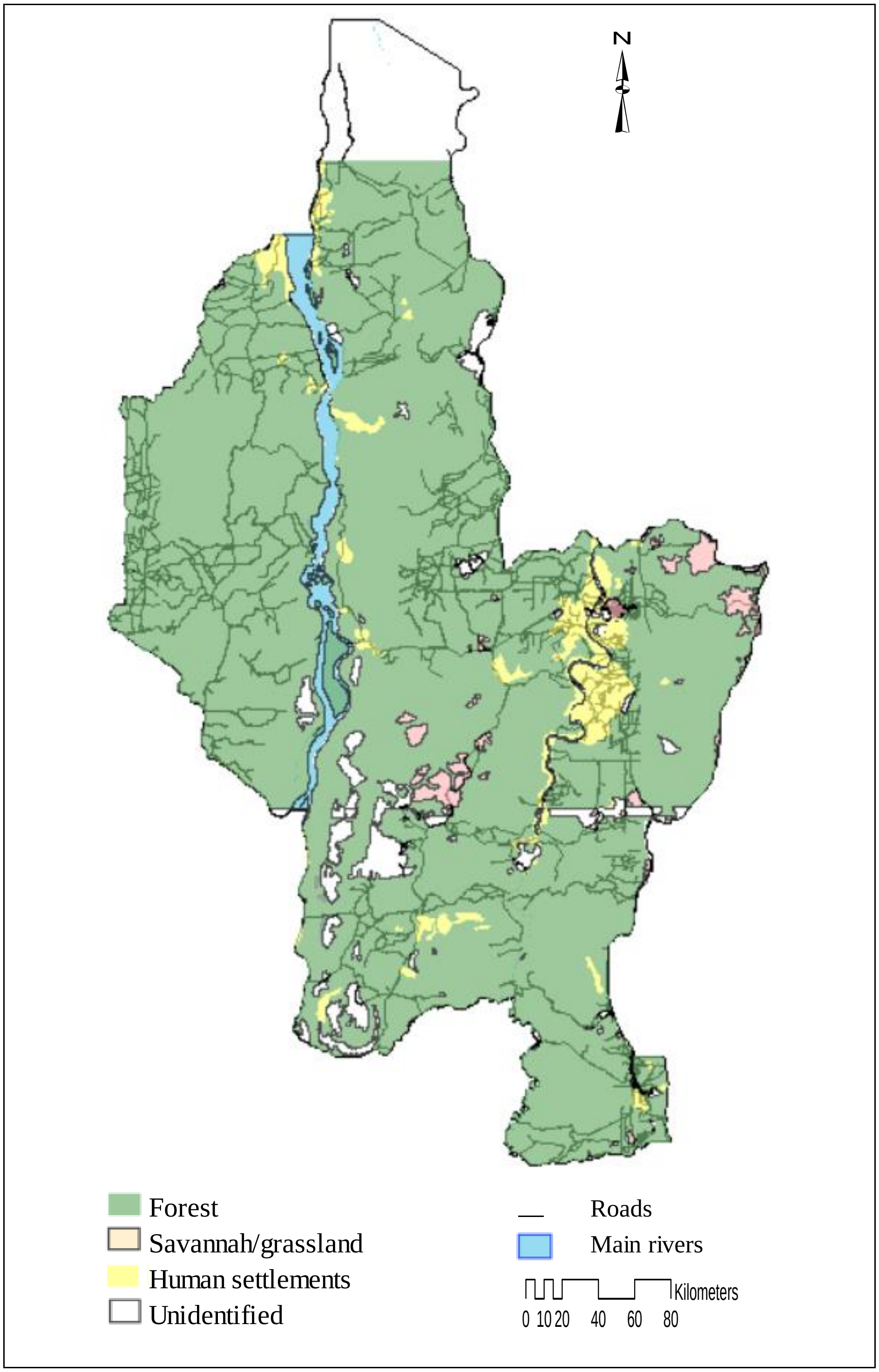

Figure 4.24: Land cover map

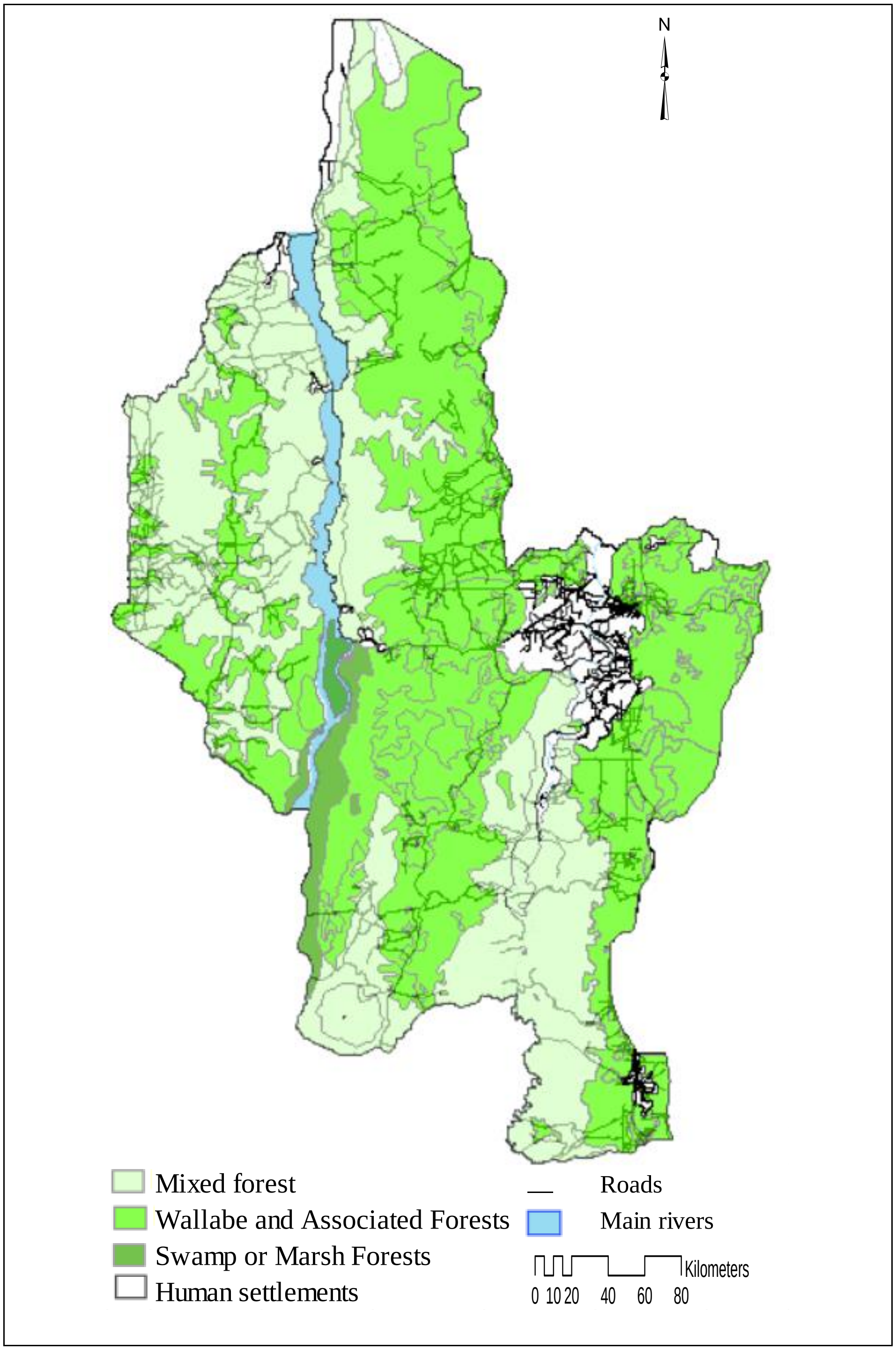

Figure 4.25: Vegetation map

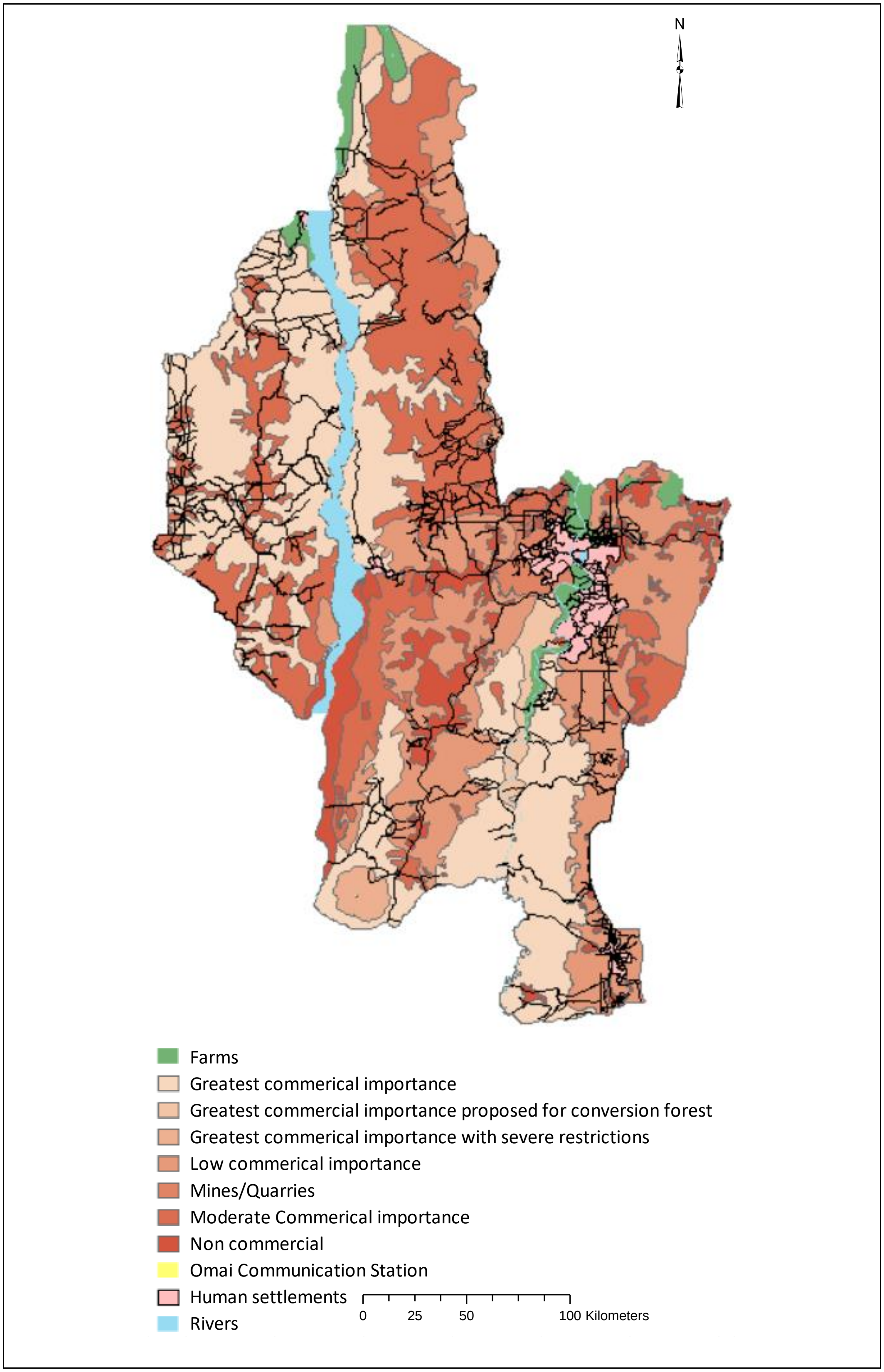

Figure 4.26: Forest capability map

Land Tenure: The largest portion (approximately seventy-three percent) of the planning area is State Forest Land, which may be leased out by the GFC as Timber Sales Agreements (TSA), State Forest Permission (SFPs) and Wood Cutting Leases. State Forest Permissions (SFPs) are given for areas smaller than 20,000 acres and only valid for one year; Wood Cutting Leases (WCLs) are granted for areas between 20,000 and 60,000 acres and valid for three to ten years; Timber Sales Agreements (TSAs) are granted for more than 60,000 acres and valid for twenty to twenty-five years. Figures 4.24 and 4.25 shows the land cover and vegetation of the study area.

Approximately five percent of the study area (240 km^2) was assigned by the Guyana Lands and Survey Commission (GLSC) as agricultural leases which are valid for twenty-five years. Figure 4.27 depicts the agricultural leases granted by the GLSC in the study area. Meanwhile, the Guyana Geology and Mines Commission also exercise jurisdiction over the planning area has granted leases for small, medium and large-scale mining and quarry operations. There is one area closed to mining in the study area. Figure 4.27 shows the areas leased out as well as closed mining areas.

Lithology: the study area contains four lithological units. These are: Migmatites and Granitoid (ideal for stone quarrying operations), Greenstone Belt (suitable for gold mining) and Gabbro (that may facilitate bauxite mining. Based on the Figure below, the largest portion of the study area is occupied by Migmatites and Granatoid followed by Greenstone Belt and Gabbro. Figure 4.28 shows the lithological units in the study area and was compiled with topographic maps at a scale of 1:50,000 from the Guyana Geology and Mines Commission (GGMC).

Soil types: there are six different soil types with varying fertility levels in the study area. Figure 4.29 shows the various soil types and was compiled with 1:500,000 scale Soil Map of Guyana. The most fertile soil types are Al (Low Humic and Alluvial Soil) and At (Low Humic Gley Soils). The least fertile soil types are Qr (Regosols, White Quartz (sand phase) and Ground Water Podzols) and Ry (Red-Yellow Latosols and Regosols). The soil types with moderate fertility are As (Red-Yellow Latosols and Red-Yellow Podolic) and Rb (Reddish-Brown Lateritic Soils). The soil within the study area also varies based on the extent to which it can be drained. When the drainability of the land is combined with the fertility level and other limitations, three broad categories of land are present in the study area. These are Class I-II (good to moderate agricultural land), Class III (poor agricultural land) and Class IV (non-agricultural land). Figure 4.30 shows the capability of the soil in the study area.

Infrastructure (major roads and minor roads): the primary transportation system in the study area comprises major roads as well as numerous minor roads and trails. There are eight major roads of varying lengths. These include Bartica-Potaro Road, Ituni Road, Kwakwani Road, Linden – Rockstone Road, Sand Hill – Makouria Road, Soesdyke – Linden Highway, and Wismar – Rockstone Road. The area also has over five hundred minor roads and trails connected directly or indirectly to the major roads. Figures 4.32 and 4.33 delineate the major roads and minor roads respectively. Topographic maps at a scale of 1:50,000 were used to compile the data.

Social infrastructure: The study area has an extensive array of social facilities, including: schools (18), health centres hospitals (12), police stations (6), markets (12), sport grounds (11), community centres (8), airfields (7), places of worship (12) as well as power stations (7) and water stations (6). See figures 4.34, 4.35, 4.36 and 4.37.

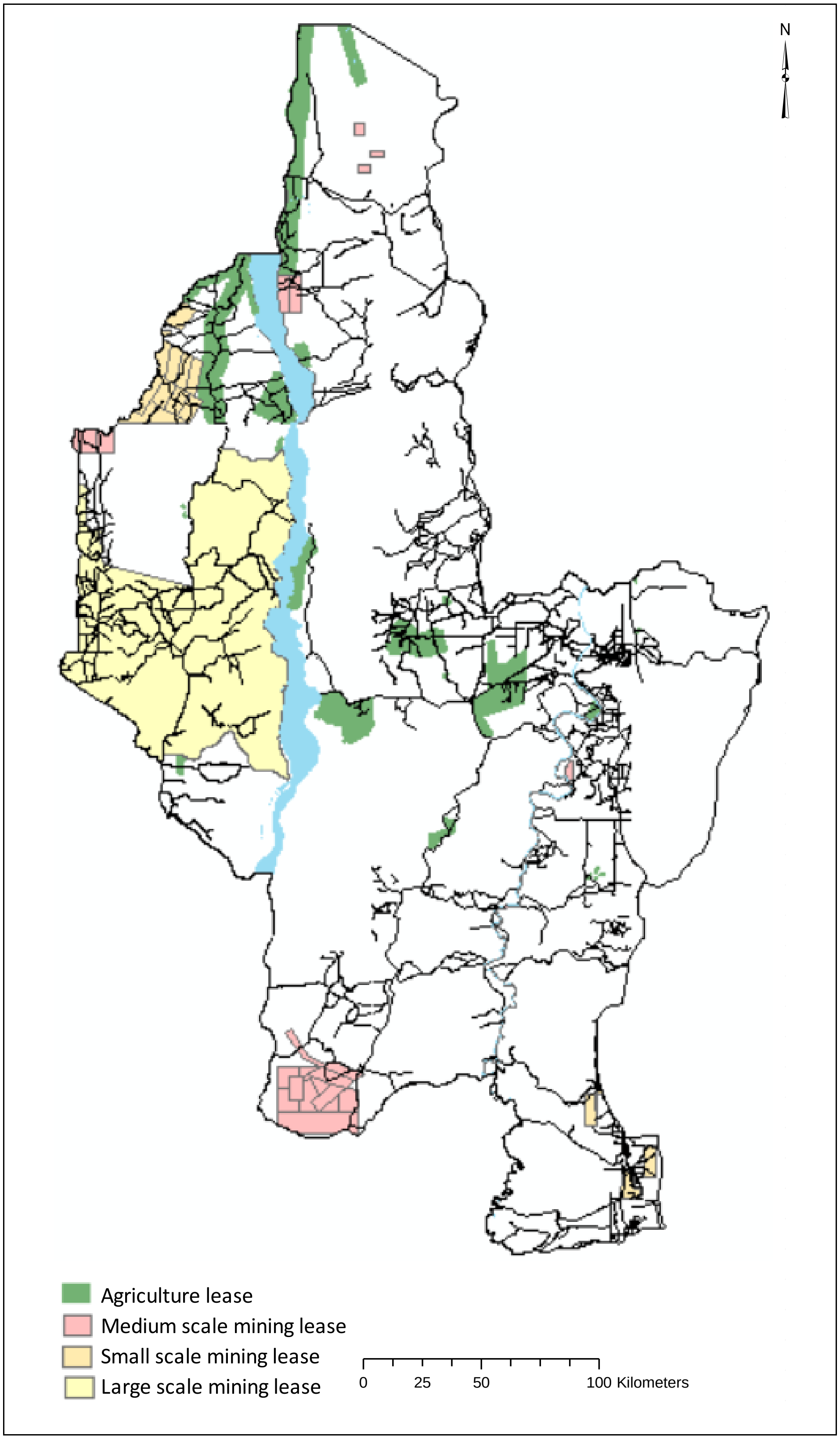

Figure 4.27: Land tenure arrangement

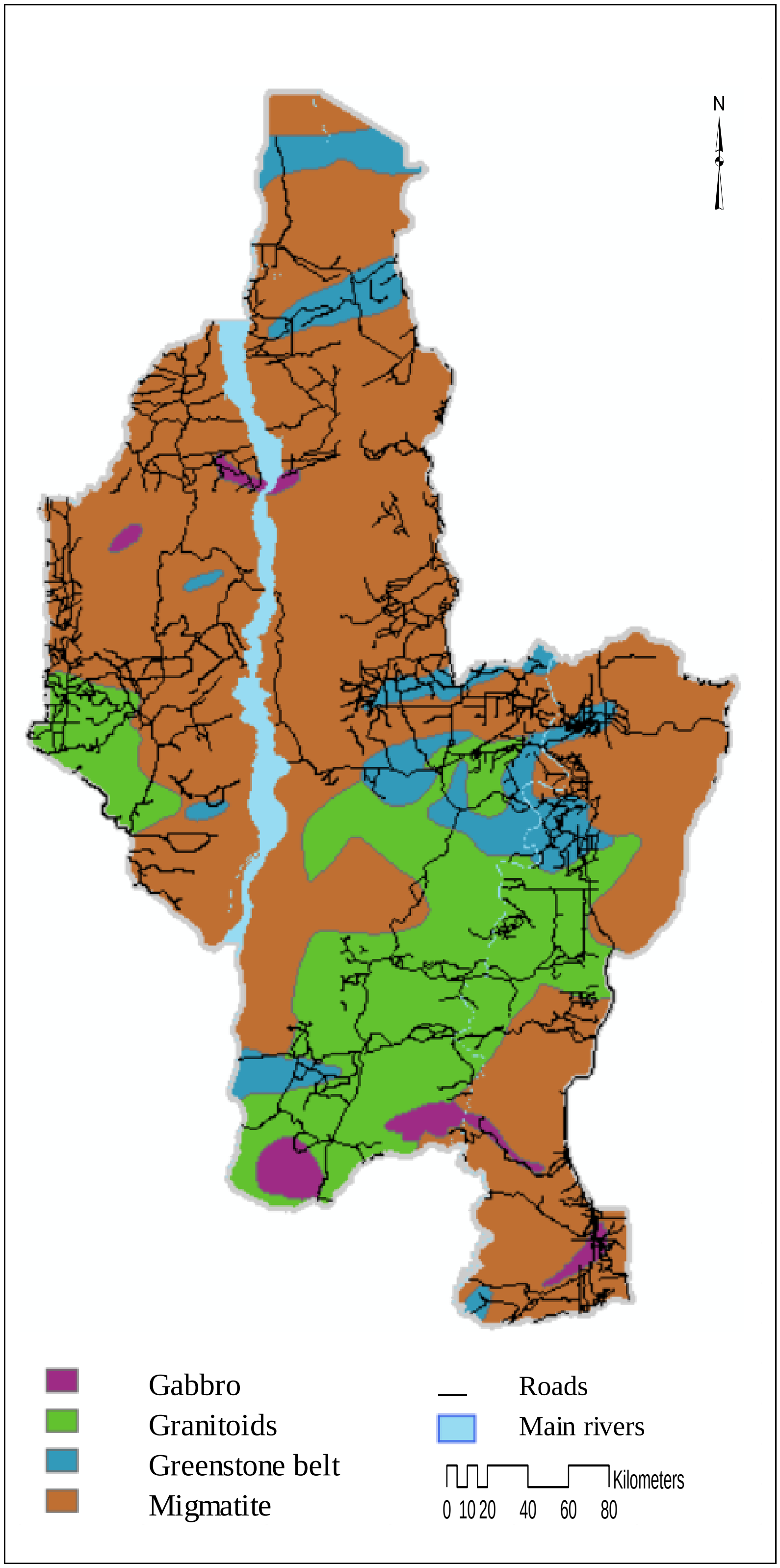

Figure 4.28: Lithology

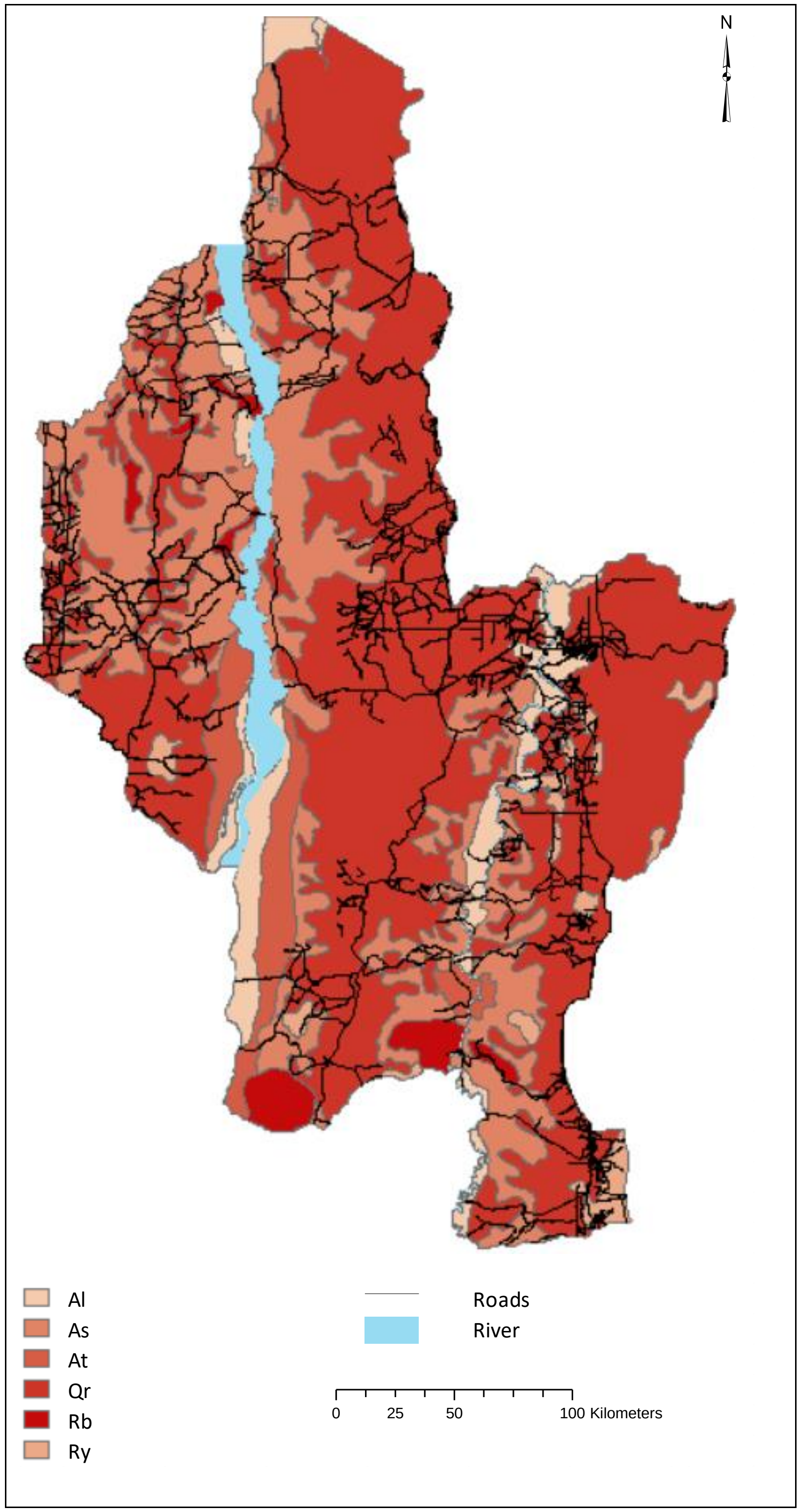

Figure 4.29: Soil types

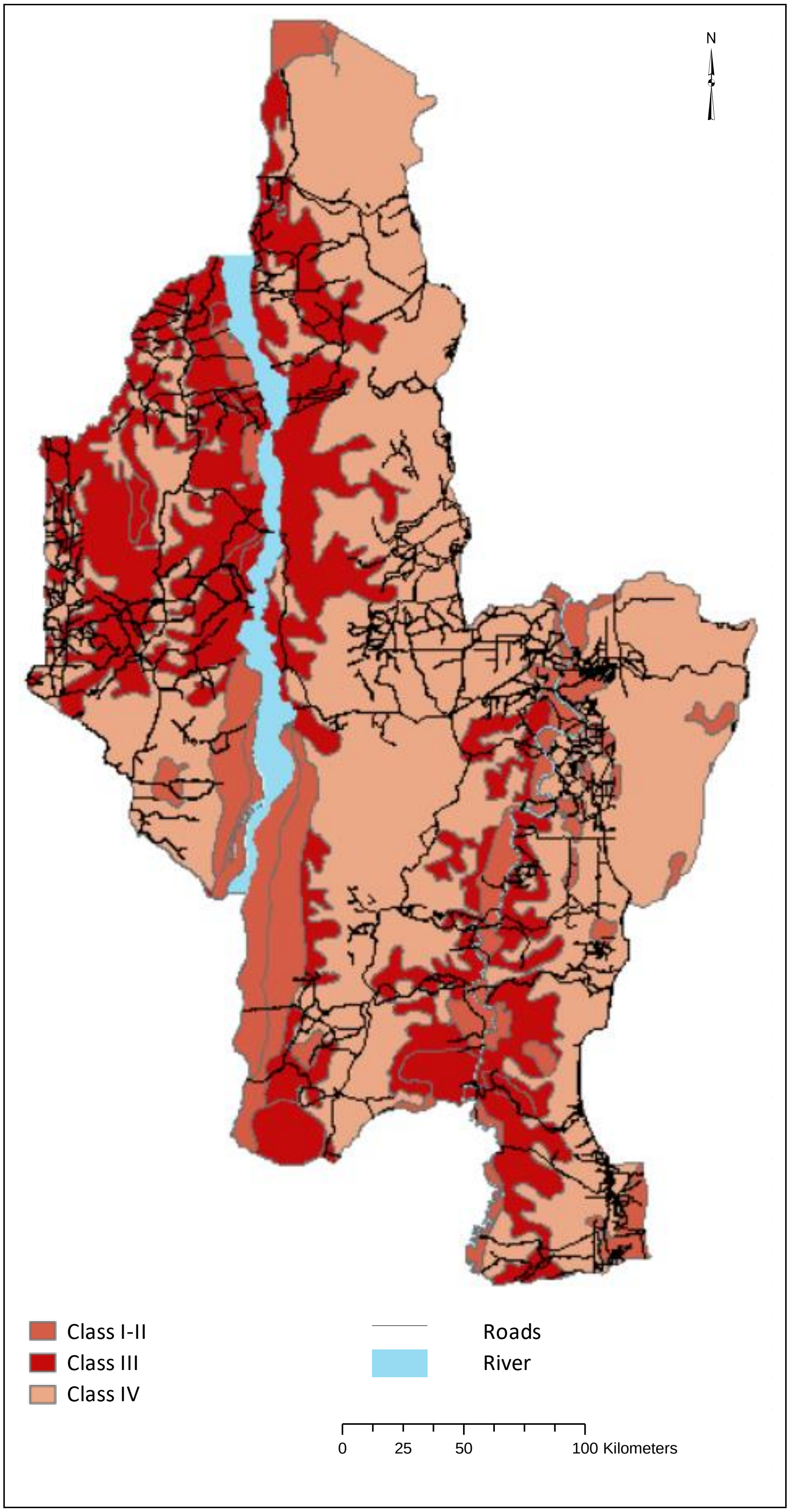

Figure 4.30: Soil capability

Elevation: the study area consists of four landform units, namely, Alluvial, Highland, Hills, and Isolated Mountains. The slopes of these units ranged from less than 1% to 22%. Figure 4.29 shows the elevation map of the study area.

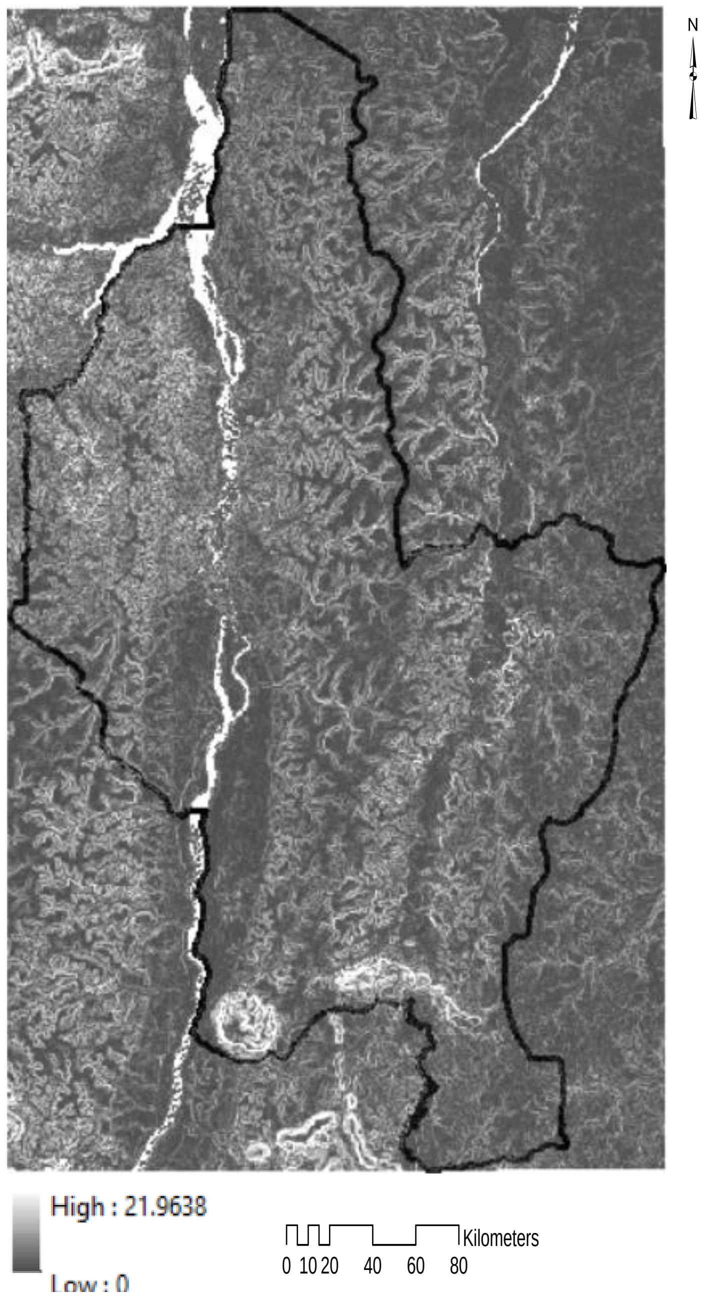

Figure 4.31: Elevation map

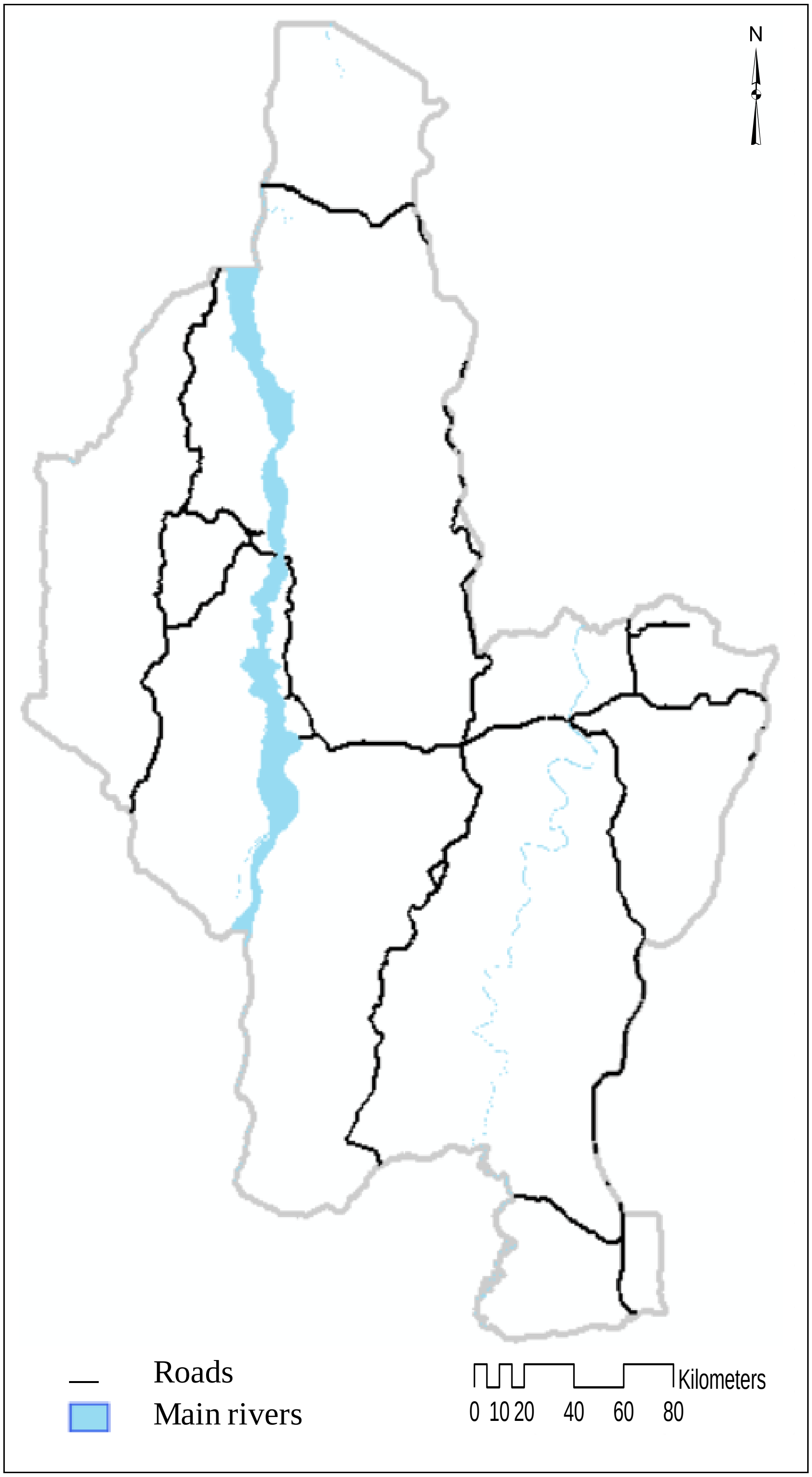

Figure 4.32: Major roads

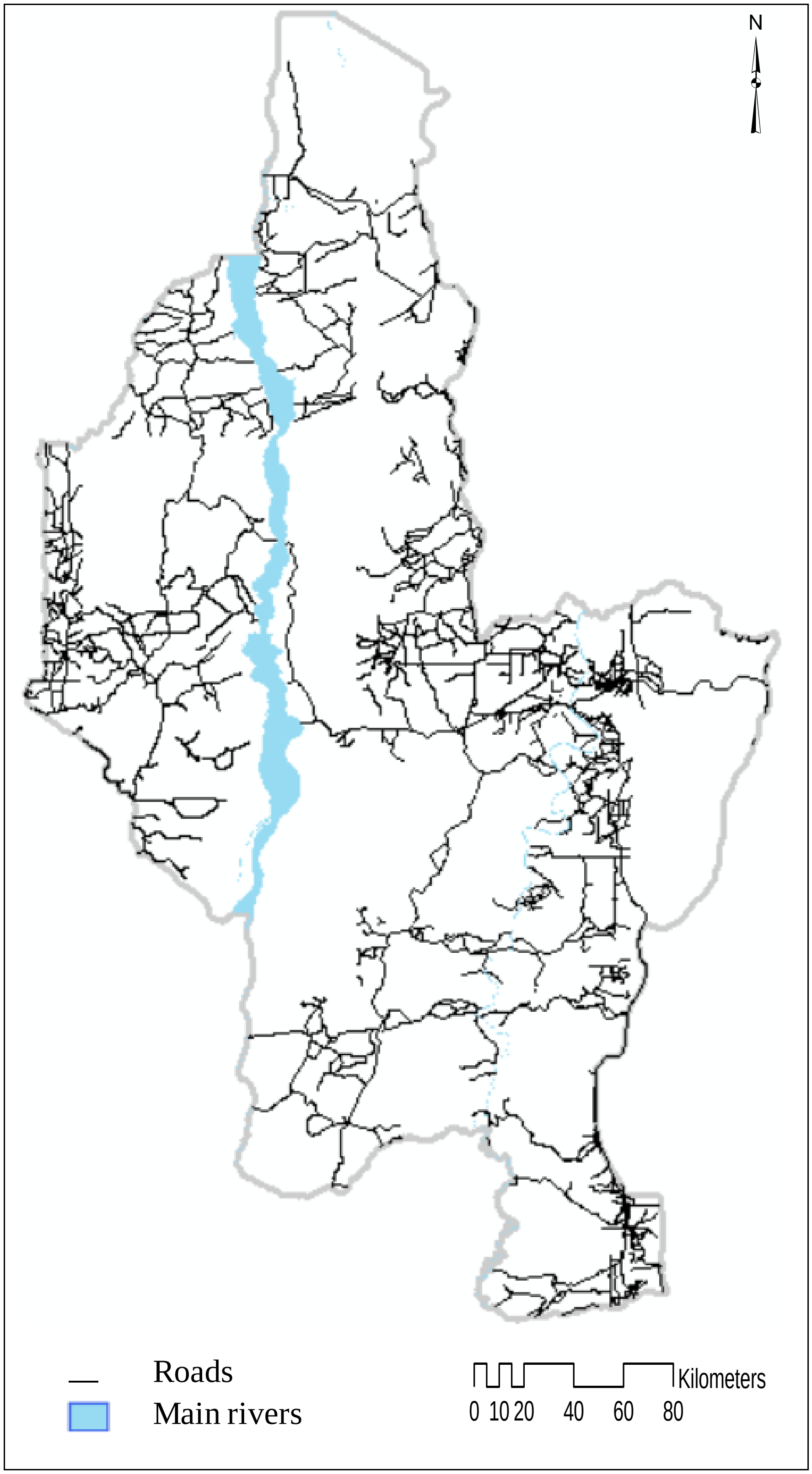

Figure 4.33: Minor roads

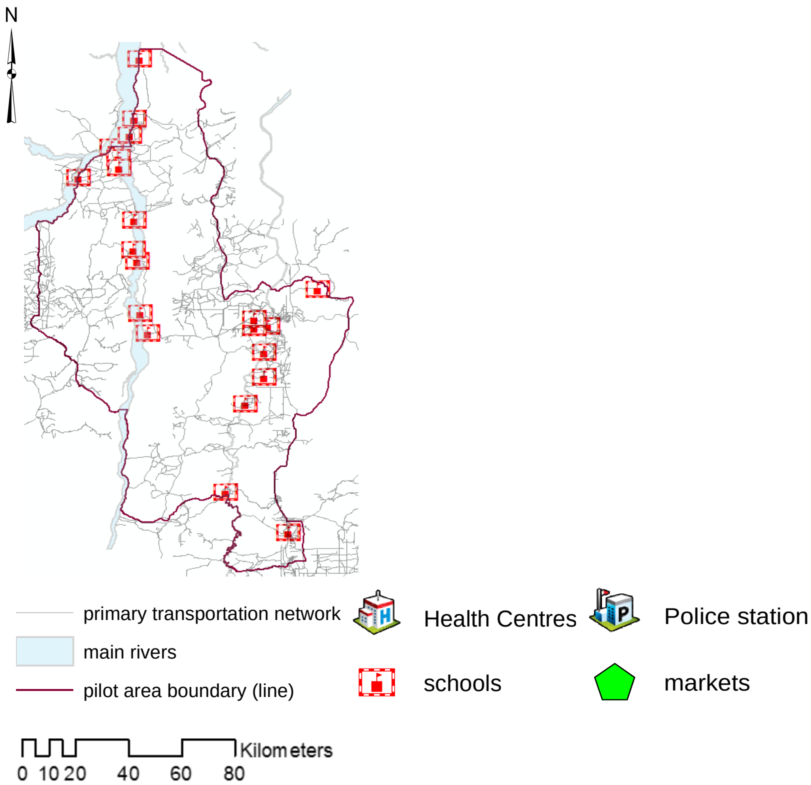

Figure 4.34: Schools

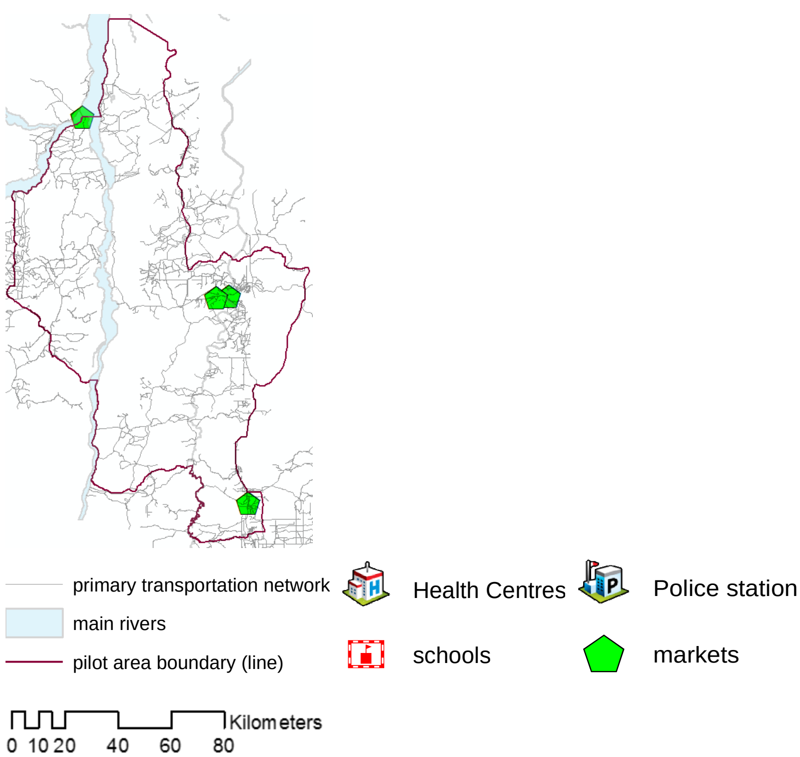

Figure 4.35: Markets

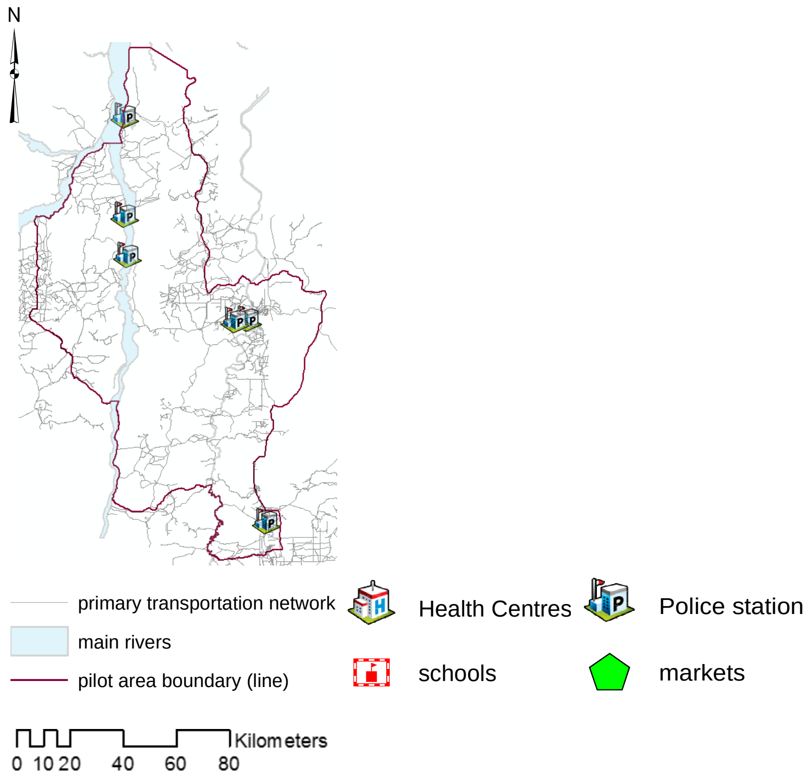

Figure 4.36 Police station

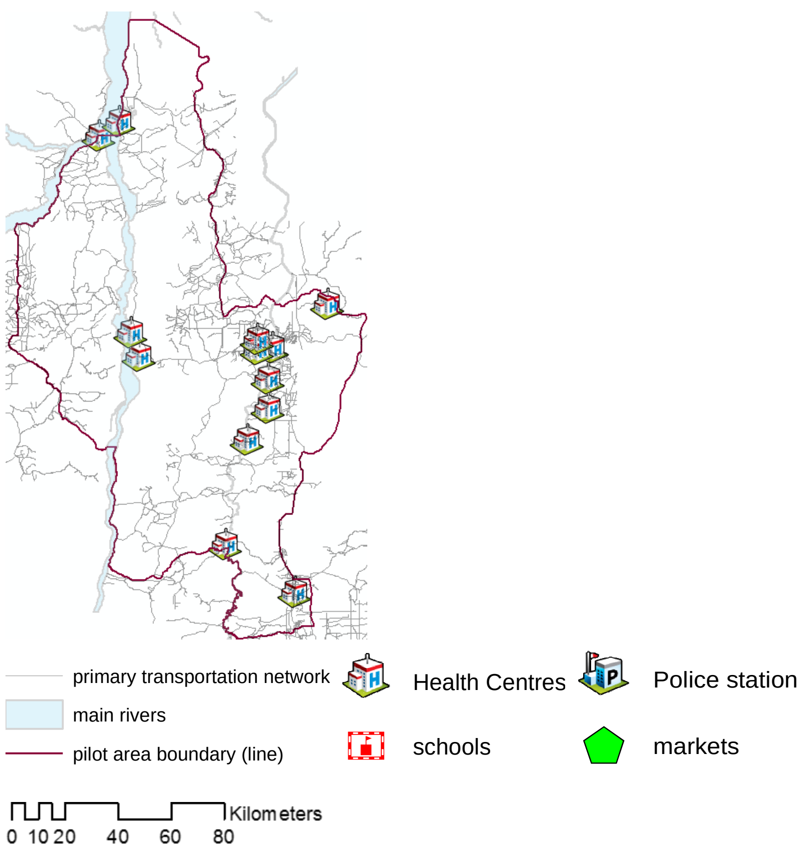

Figure 4.37: Health facilities

Hydropower potential: there are three sites in the study area with hydropower potential. The first is Ikuribisi, which is located in the Ikuribisi River and has a catchment area of 315 km^2. The second site is Tiger Hill which is located in the Demerara River. The catchment area for this site is approximately 534 km^2. The third site is Big Barabara which is situated in the Barabara River. The catchment area of streams for this site approximates 37 km^2 (figure 4.38).

Tourism sites: the study area has five existing tourist sites, two heritage sites (Waterwheel in Linden and Century Old Church), two potential sites in Rockstone and Ituni and a protected area reserved for research, that is, the Moraballi Reserve and Buffer. The data types and sources are shown in table 4.4.

Table 4.4: Data type and sources

Data type	Sources
GIS Data (thematic maps)	a. Guyana Lands and Surveys Commission (GLSC) b. Guyana Forestry Commission (GFC) c. Guyana Geology and Mines Commission (GGMC) d. Ministry of Agriculture (MoA) e. Central Housing and Planning Authority (CHPA) f. Guyana Sugar Corporation (GUYSUCO) g. Conservation International (CI) h. IWOKRAMA and National Park Commission.
Qualitative data	i. Interview of experts j. Literature survey

The modified SAHP will be applied for land use suitability analysis at the study areas for each of the following key land use in Guyana: housing site development, agricultural production, mining exploration, and forestry production. The processes, input data required, and the results are presented in the next four

Chapters. For each analysis, the environmental, economic, and social factors will be considered in an integrated manner to minimize the effect of overlapping jurisdiction discussed in Chapter 3.

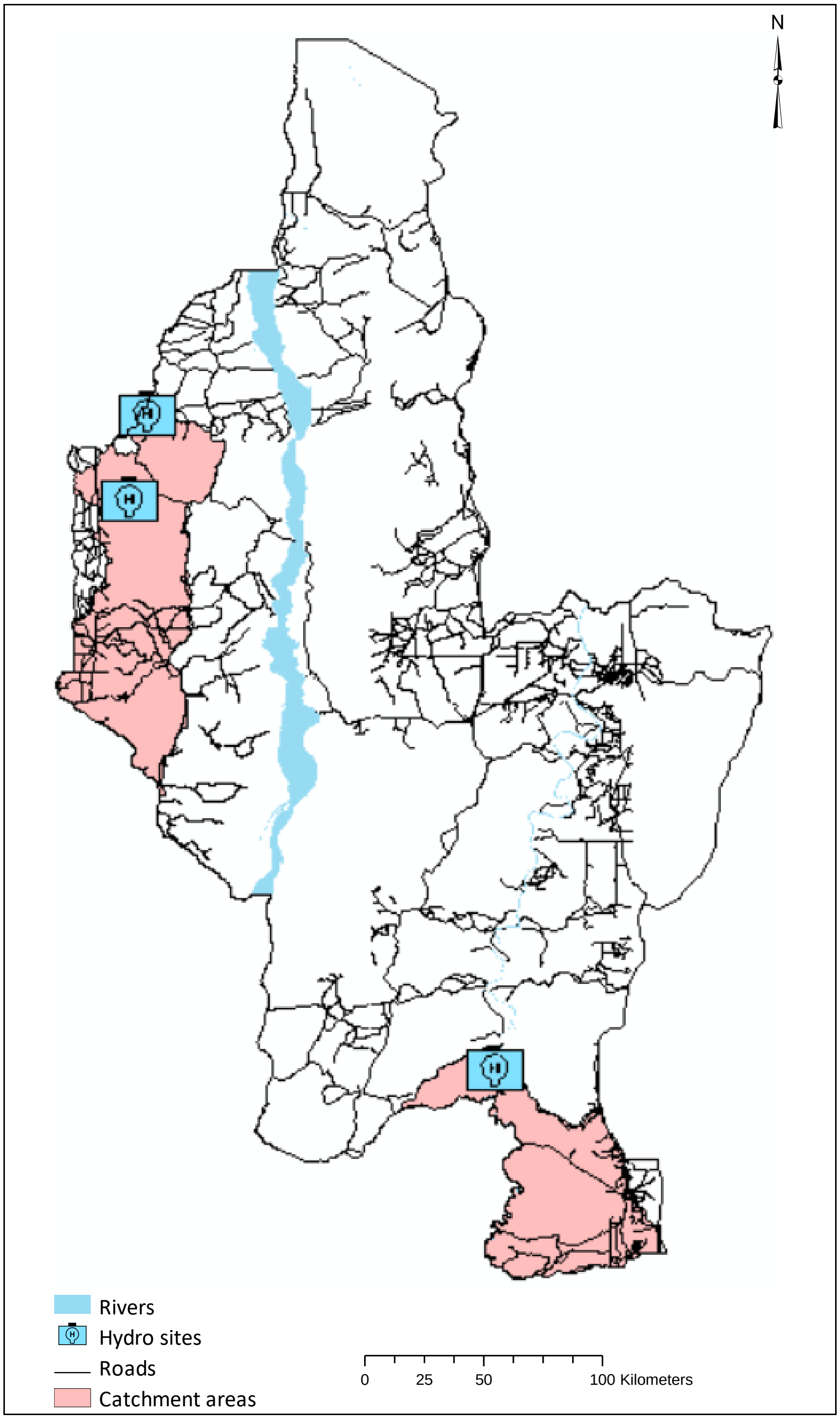

Figure 4.38: Hydropower sites and catchment areas

CHAPTER 5: APPLICATION OF THE SAHP TO HOUSING SUITABILITY ANALYSIS

5.1 Problem Definition

The recent discovery of oil and gas in Guyana and the government effort to improve the social and economic well-being of its citizens are fuelling the demand for housing lots in particular and the development of new residential schemes in general. Flooding in urban areas, shift from wooding buildings that are prone to fire hazard and the need to upgrade current housing conditions are the driving forces behind the increase in housing demand. It is not uncommon for young adults 18-25 years old yearning to own their own house and making this a priority over tertiary education. The current low level of supply of new housing units and the prohibitively high price demanded by private suppliers have propelled the government to make the provision of housing units one of its development goals.

The challenge in the fulfilment of this goal is the strategic identification of the most suitable sites for housing developments that promote the social and economic development of its population and the minimization of informal settlement.

5.2 Objective of the Housing Suitability Model

The primary objective of the application is to identify land parcels most suitable for housing developments that would serve to maximise the economic and social gains from this type of activity, while simultaneously protecting the environment.

To achieve this objective, the land parcel would have to satisfy the following developmental cost constraints:

i. it should be located within close proximity to existing water trunks supply
ii. it should be easily accessible by roads
iii. it should not be costly to acquire and develop

Further, the land parcels identified should be subject to the following minimum constraints:

i. it should be unoccupied
ii. not more suitable for other types of socio-economic activities, such as agriculture, logging, mining
iii. it should not be suitable for providing eco-services
iv. it should not be situated on a sensitive hydrogeological land
v. it should not be situated too close to water bodies
vi. should not be prone to flooding
vii. should not be situated close to hazardous zones

5.3 General Methodology

The application will employ a Multi-Criteria Decision Analysis (MCDA) and Spatial Analytic Hierarchy Process (SAHP), depicted in figure 5.1. This involves the implementation of three steps that incorporated the following principles: decomposition principle; comparative judgment principle; and synthesis principle as explained in Chapter 4 and Section 4.3.2.

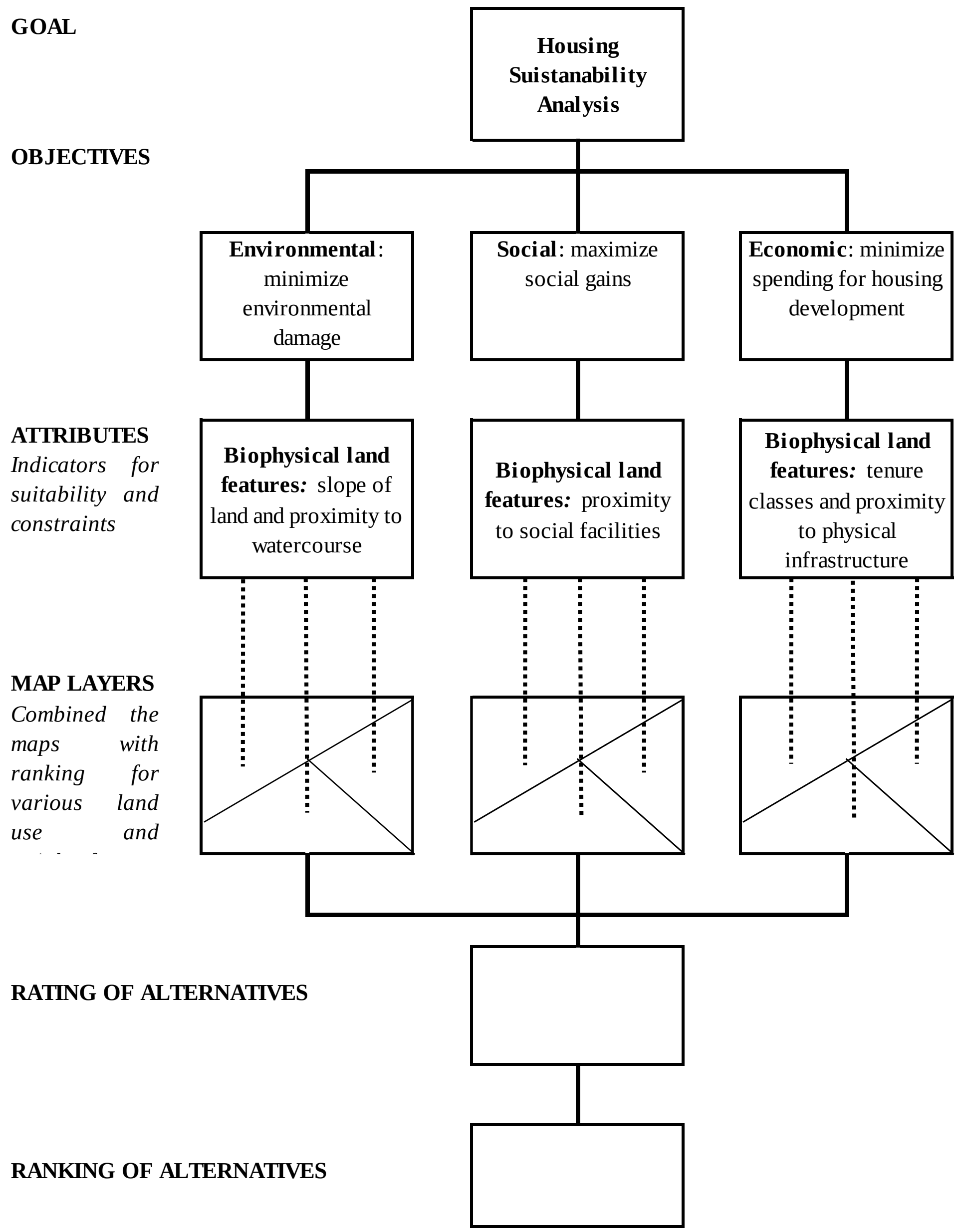

Figure 5.1: Spatial analytic hierarchy process (AHP)

5.4 Specific Suitability Modelling Procedure

The specific suitability modelling procedure followed is delineated in figure 5.2. A vital aspect of this procedure is the involvement of key experts and stakeholder. The procedure began with the identification and selection of key experts and key stakeholders relevant to the specific land use. These stakeholders are then invited to a knowledge sharing and consultation workshops.

At the workshop, the principles and concepts of MCDA and SAHP are shared to prepare them for the task of identifying, quantifying, ranking, and weighting of factors or criteria for determining the most suitable land for housing or settlement development. This interactive workshop is meant to elicit views and concerns such that the most suitable land for housing development are identified and quantifies. The workshop concluded with a pair-wise evaluation of the various criteria using a questionnaire (see Appendix B). During the pair-wise comparison, the participants were asked to note the rationale for assigning a particular score for each criterion. The workshop was supplemented with interviews with the experts for clarification on issues that were not covered adequately in the workshop.

Based on the agreed factors, an MCDA/SAHP model was developed to evaluate the factors. The weights were calculated based on equations 4.1, 4.2, and 4.3 and standardised maps were generated in accordance with the Weighted Linear Combination (WLC) model, that is, equations 4.4 and 4.5.

The results of this initial evaluation were then shared with the same stakeholders in a second workshop to solicit feedback. The feedback received were used to modify the MCDA/SAHP model to generate the final land suitability models.

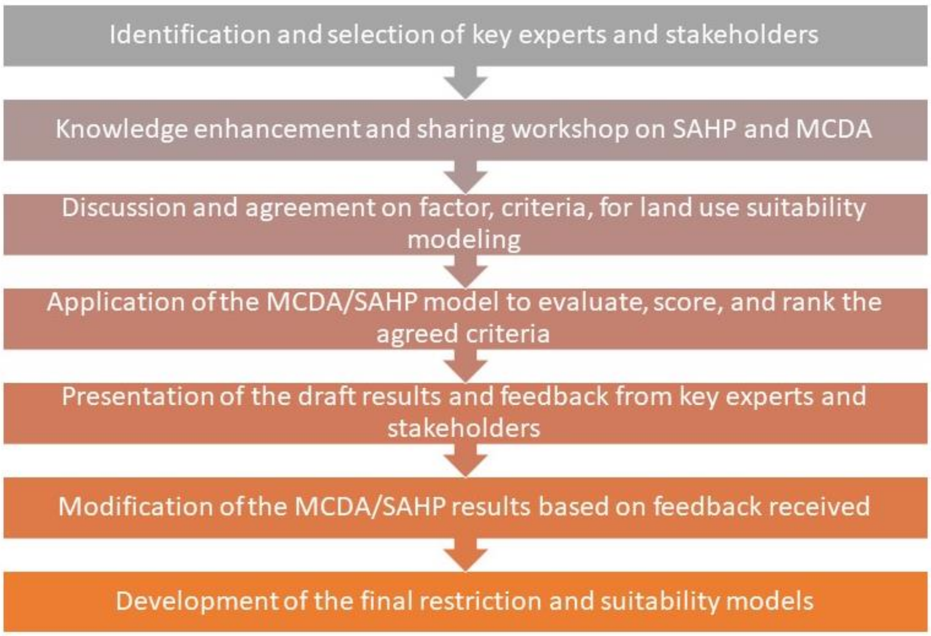

Figure 5.2: Land use suitability procedure

Two primary reasons motivated the application of the approach mentioned above. Firstly, there was a paucity of empirical information for land suitability analysis locally. Secondly, the CHPA employed numerous experts with extensive, knowledge and experience in the establishment of new settlement schemes or expansion of existing schemes. Thus, the approach is ideal in these circumstances since it facilitates decision-making in the absence of adequate information. The opinions of experts were solicited via formal workshops and interviews. During these exercises, the experts were required to determine the relative importance of each indicator through the AHP procedure.

5.5 Criteria Selection and Description

During the workshop, thirty-four criteria were initially identified for housing suitability, but these were later reduced to sixteen after extensive consultation and discussion at the workshop. These criteria were grouped into three categories, namely, environmental, economic and social factors. Most of the requirements were those prescribed in the Inter-American Development Bank's Low-Income Settlement II Project Operating Regulations (IADB 2009) which provided clear guidelines on site selection for the development and expansion of housing schemes.

5.5.1 Environmental Factors

Environmental factors refer to those criteria which are aimed at protecting the environment from damage while simultaneously preventing the establishment of housing schemes in areas where environmental hazards are high. The environmental factors were placed under two broad categories, namely, mandatory criteria and non-mandatory criteria. The former includes those which are expressly set out as mandatory requirements for site selection in the 2009 Operating Regulations of Low-Income Settlement Programmes. The latter, on the other hand, include site selection criteria not specified in the IDB's 2009 Low-Income Settlement II Project Operating Regulations but are considered necessary by the experts working with the CHPA when conducting housing suitability analysis. It is noteworthy that some of the criteria identified by the experts of the CHPA were also suggested by Al-Shalabi et al. (2006), which is a recent study that employs GIS-based-MCDA to determine the suitability of land for housing purposes. The suitability and ranking of environmental factors are shown in table 5.1.

Natural Hazard: Wetland

This criterion is mandatory (IADB 2009) and requires that a new or lateral expansion of an existing housing scheme should not be located on wetlands to avoid natural hazards such as floods. Wetlands are generally identified based on the presence of hydric soils, hydrophytic vegetation, and wetland hydrology. This requirement is intended to protect wildlife habitats as well as sustain aquatic diversity and its relationship to surrounding natural areas through nutrient retention and productivity exportation, among other things. In this study, an area was assigned a score between one and five based on its proximity to wetlands as presented in table 5.1.

Pollution of Surface Water

Acceptable proximity to surface water is a mandatory criterion (IADB 2009) and intended to avoid the pollution of these water bodies. In essence, this criterion restricts the establishment of a new settlement area or lateral expansion of an existing housing scheme, within a certain distance from significant surface water bodies, which includes lakes and rivers. The CHPA has adopted the buffer distance of twenty meters as prescribed by the Code of Practice for Timber Harvesting

(Guyana Forestry Commission 2002). The scores assigned to this criterion were linked to the buffer distances as shown in table 5.1.

Hydrogeological Risk

Acceptable proximity to sensitive hydrogeological environments is a mandatory criterion (IADB 2009) to avoid the risk of groundwater pollution. It restricts the establishment of a new settlement area or lateral expansion of an existing housing scheme in a sensitive hydrogeological environment. This refers to a gravel pit excavated into or above a water table aquifer, areas underlain by a sole source aquifer or other sensitive aquifers, and designated wellhead protection area. This criterion was assigned a score between one and five as shown in table 5.1.

Aircraft Hazard

Acceptable proximity to airports is an important criterion intended to restrict aircraft hazard. This criterion limits the establishment of a new settlement area or lateral expansion of an existing housing scheme, within three kilometres from any airport runway used by turbojet or piston-type aircraft. This requirement is for safety reasons and not mandatory. The study employed a five-point ranking system, whereby the suitability of an area for housing purposes was considered more significant when it was further away from airports. In particular, an area was scored between one and five as presented in table 5.1.

Destruction of Historical or Cultural Sites

This criterion restricts the establishment of a new settlement area or lateral expansion of an existing housing scheme, in an area with significant historical or cultural values. This requirement is intended to preserve the historical and cultural heritage of the country generally, and domiciled communities more specifically. A five-point rating scale was employed to determine the suitability of an area based on this criterion as shown in table 5.1. It is noteworthy that this criterion is not a mandatory selection criterion. However, the CHPA consider it in all its site selection programs.

Ecological Risk

Acceptable proximity to critical habitat is a mandatory criterion that restricts the establishment of a new settlement area, or lateral expansion of an existing housing scheme in critical habitats, defined as areas where threatened or endangered species of fauna and flora exist. A five-point rating scale was employed to determine the suitability of land parcels based on the critical habitat criterion as in table 5.1.

Natural Hazard - Geological Fault Areas

Acceptable proximity to geological fault areas is a non-mandatory criterion that restricts the establishment of a new settlement area or lateral expansion of an existing housing scheme within 500 metres from a fault area. The study employed a five-point rating system, whereby the suitability of an area based on this criterion for housing purposes is more excellent when it is further away from a fault area. In particular, land parcels are scored between one and five as shown in table 5.1. This criterion is not mandatory but is applied by the Central Housing and Planning Authority (CHPA) in land suitability analysis.

Landslide Hazard

Acceptable proximity from unstable area/landslides is a non-mandatory criterion which restricts the establishment of a new settlement area or lateral expansion of an existing housing scheme in an unstable area, that is, an area which is subject to landslides. A five-point rating scale was employed to determine the suitability of land parcels based on this criterion as shown in table 5.1.

Flood Risk

Acceptable proximity from flood-prone areas is a mandatory environmental criterion which restricts the establishment of a new settlement area or lateral expansion of an existing housing scheme in an area that is subject to flooding. This requirement is vital given the flood risks faced by coastal communities. A five-point rating scale was employed to determine the suitability of an area based on this criterion as shown in table 5.1.

Industrial Hazard Zones

Acceptable proximity from hazard zones is a mandatory evaluation criterion which restricts the establishment of a new settlement area or lateral expansion of an existing housing scheme within 500 meters of a sanitary landfill, high power tension line, high pressure natural gas transmission lines, sewage treatment plants, sites with hazardous materials, buried or spilled hazardous waste, operating oil wells, and mine shafts. Furthermore, areas with significant amounts of residual soil contamination should not be used to develop or expand housing schemes. A five-point ranking system was employed, whereby the suitability of an area for housing purposes is more excellent when it is further away from an area with high environmental impact risks. The scores assigned based on various buffer distances are shown in table 5.1.

Adequate Size and Configuration

Adequate size and configuration is a non-mandatory evaluation criterion require the land identified for the new or expanded scheme, to have sufficient space to accommodate between 900 and 1,200 house lots. Since approximately eight house lots are developed per acre, a new or extended scheme requires about 150 acres. Furthermore, the size of the new or extended scheme should be adequate to allow for the construction of roads that would accommodate large vehicles such as fire tenders, solid waste removal trucks, and school buses, etc. The study employed a five-point rating system whereby the larger land parcels are considered more suitable for housing purposes. The scores assigned to this criterion based on various buffer distances are shown in table 5.1.

Deforestation

The stakeholders indicated that there are five broad land cover classes employed to classify land uses in Guyana. These are abandoned lands, pasturelands, cropped lands, lands occupied by natural vegetation, and forest. These lands are owned either publicly or by private individuals. The most suitable parcels for new housing developments are those which fall under the classification of public unoccupied land with minimal vegetation. A five-point rating scale was employed to determine the suitability of an area based on this criterion as shown in table 5.1.

Soil Erosion

The experts and stakeholder at the workshop regard land surface with slopes greater than fifteen degrees as prone to erosion or landslides, due to increased pressure or disruption of natural vegetation. These risks are higher where the soil is loose. As such, the CHPA generally utilizes land with a slope less than fifteen degrees to minimize soil erosion. A five-point rating scale was employed to determine the suitability of an area based on this criterion as shown in table 5.1.

Summary

The summary of the environmental factors and the classification scheme for each is provided in table 5.1.

Table 5.1: Summary of environmental factors and suitability ranking

Housing Suitability Factors	Classification schemes	Ranking Scheme	Ranked Values
Natural hazard (Proximity to wetland in metre) *	0-19	Not suitable	1
	20-39	Marginally suitable	2
	40-59	Moderately suitable	3
	60-79	Highly suitable	4
	> 80	Very highly suitable	5
Pollution of surface water (Proximity surface water in metre) *	0-19	Not suitable	1
	21-39	Marginally suitable	2
	40-59	Moderately suitable	3
	60-79	Highly suitable	4
	> 80	Very highly suitable	5
Hydrogeological risk (proximity to sensitive hydrogeologic environments in metre)*	0-19	Not suitable	1
	20-39	Marginally suitable	2
	40-59	Moderately suitable	3
	60-79	Highly suitable	4
	> 80	Very highly suitable	5
Aircraft hazard (proximity to airport in kilometre)	0-3	Not suitable	1
	4-6	Marginally suitable	2
	7-9	Moderately suitable	3
	10-12	Highly suitable	4
	> 12	Very highly suitable	5
Destruction of historical or cultural sites (proximity to historical/cultural sites in metre)	0-19	Not suitable	1
	20-39	Marginally suitable	2
	40-59	Moderately suitable	3
	60-79	Highly suitable	4
	> 80	Very highly suitable	5

Table 5.1 (continued)

Housing Suitability Factors	Classification schemes	Ranking Scheme	Ranked Values
Ecological risk (proximity to critical habitat in metre)*	0-19	Not suitable	1
	20-39	Marginally suitable	2
	40-59	Moderately suitable	3
	60-79	Highly suitable	4
	> 80	Very highly suitable	5
Natural hazard: geological fault areas (proximity to geological fault areas in metre)	0-500	Not suitable	1
	101-600	Marginally suitable	2
	601-700	Moderately suitable	3
	701-800	Highly suitable	4
	> 800	Very highly suitable	5
Landslide risk (proximity to unstable area/landslides in metres)	0-19	Not suitable	1
	20-39	Marginally suitable	2
	40-59	Moderately suitable	3
	60-79	Highly suitable	4
	> 80	Very highly suitable	5
Flood risk (proximity to flood prone areas in metres)*	0-19	Not suitable	1
	20-39	Marginally suitable	2
	40-59	Moderately suitable	3
	60-79	Highly suitable	4
	> 80	Very highly suitable	5
Adequate size/configuration (Size in acres)	≤ 112.5	Not suitable	1
	≤ 125	Marginally suitable	2
	≤ 137.5	Moderately suitable	3
	≤ 150	Highly suitable	4
	>150	Very highly suitable	5
Soil erosion (slope of land surface in degrees)	0-5	Very highly suitable	1
	6-15	Highly suitable	2
	16-27	Moderately suitable	3
	28-48	Marginally suitable	4
	>48	Not suitable	5

Table 5.1 (continued)

Housing Suitability Factors	Classification schemes	Ranking Scheme	Ranked Values
Deforestation	Abandoned land	Very highly suitable	1
	Pasture	Highly suitable	2
	Cropped land	Moderately suitable	3
	Natural vegetation	Marginally suitable	4
	Forest	Not suitable	5
Industrial hazard zone (proximity distance in kilometres)	>12	Very highly suitable	1
	10-12	Highly suitable	2
	7-9	Moderately suitable	3
	4-6	Marginally suitable	4
	0-3	Not suitable	5

* represents mandatory requirements

5.5.2 Economic Factors

Economic factors are related to the cost of acquiring and developing land for housing purposes. In other words, these criteria include the price of land and the cost of developing physical and social infrastructure for new or expanded settlement schemes. The primary aim of these criteria is to minimise the fiscal pressures of the Government's housing drive. Though these criteria are not mandatory, they are essential. In fact, policymakers at the highest level, such as Cabinet, consider them. The economic factors suitability and ranking are shown in table 5.2.

Land Acquisition cost

Land acquisition cost – this criterion requires that the land cost should not exceed $5 million per acre. Generally, the price of land is strongly linked to the land tenure classes with 'public lands' being the least costly and private transported lands being the most expensive. Public lands are usually available at a cost below $2 million per acre. Private transported lands, on the other hand, very often exceed the $5 million limit. Consequently, the Central Housing and Planning Authority (CHPA) targets public lands and rarely acquires private transported lands to develop housing settlements. In terms of suitability, a five-point rating scale based on tenure classes was utilised as shown in table 5.2.

Table 5.2: Ranking of economic factors based on tenure classes

Housing Suitability Factors	Classification schemes	Ranking Scheme	Ranked Values
Land Tenure	Public Land	Very Highly Suitable	5
	Public Neighborhood Democratic Council	Highly Suitable	4
	Public Co-operative	Moderately Suitable	3
	GUYSUCO	Marginally Suitable	2
	Private Land	Not Suitable	1

5.5.3 Social Factors

Social factors are related to the adequacy of physical and social infrastructure in the area selected for housing development. It is noteworthy that some of the criteria are mandatory while others are not. The ultimate aim of these criteria is to ensure that the residents in new settlement areas have access to essential social services, which in turn are indispensable if the housing programmes are to achieve the national and international priorities that seek to reduce poverty in Guyana. A summary of the social factors suitability and ranking are shown in table 5.3.

Adequacy of key physical infrastructure

Adequacy of key physical infrastructure – this is a mandatory criterion which requires that the new or expanded scheme be located within a one-mile radius from critical infrastructures such as paved roads, trunk water mains, and drainage networks to ensures access to roads, water, electricity, and drainage. In this regard, a five-point ranking system was employed to determine the suitability of land based on this criterion as shown in table 5.3.

Adequacy of key social infrastructure

Adequacy of key social infrastructure – this not a mandatory criterion but it requires that the new or expanded scheme be located within a five mile radius from essential social institutions such as school, health centre (or hospital), and police station. Suitability and ranking of social factors are shown in table 5.3. This requirement is intended to preserve the social wellbeing of the residents by ensuring they have access to consumer goods as well as education, healthcare, and security services. The further away the land is from these social facilities, the lower would be its suitability for housing purposes. In this regard, a five-point rating scale is used for determining housing suitability as shown in table 5.3.

Summary

Table 5.3 shows a summary of the social factors and the ranking scheme for each criterion.

Table 5.3: Ranking of social factors

Housing Suitability Factors	Weights	Classification Schemes	Ranking Schemes	Ranked Value
Adequacy of key physical infrastructure* (*Proximity in Miles*)	0.5	>2	Not suitable	1
		2	Marginally suitable	2
		1 ½	Moderately suitable	3
		1	Highly suitable	4
		< ½	Very highly suitable	5
Adequacy of key social infrastructure (*Proximity in Miles*)	0.5	>6	Not suitable	1
		6	Marginally suitable	2
		5 ½	Moderately suitable	3
		5	Highly suitable	4
		<5	Very highly suitable	5

* represents mandatory requirements

5.6 Weighting of the Criteria using the SAHP

The criteria as mentioned above were utilised to construct a hierarchy for determining the suitability of a site for housing purposes. The overarching goal, that is, the most suitable parcel of land for housing development is placed at the apex. This is followed by three broad sub-objectives, namely, environmental, economic and social which are broken down further into specific criterion as shown in figure 5.3. The sixteen criteria described above are used for the computation process.

The relative weight of each criterion was obtained by following the pairwise comparison procedure developed by Saaty (1980). For this exercise, the nine-point rating scale was utilised, with one signifying ‘equal importance’ and nine signifying ‘extreme importance.’ During this phase of the activity, the experts/specialists of the Central Housing and Planning Authority (CHPA) were asked to fill out a questionnaire (see Appendix B). The data from the questionnaire were inputted into a set of comparison matrices that mirror the hierarchy in Figure 5.3. In this regard, a comparison matrix was constructed for each level of the hierarchy.

Based on the agreed factors, an MCDA/SAHP model was developed to evaluate the factors. The weights were computed by normalizing the matrices and extracting the eigenvalues. The weights were calculated using equations 4.1, 4.2, and 4.3 and standardized maps were generated using the Weighted Linear Combination (WLC) model based on equations 4.4 and 4.5.

The results are discussed and shown in figures 5.4, 5.5, 5.6, 5.7 and 5.8.

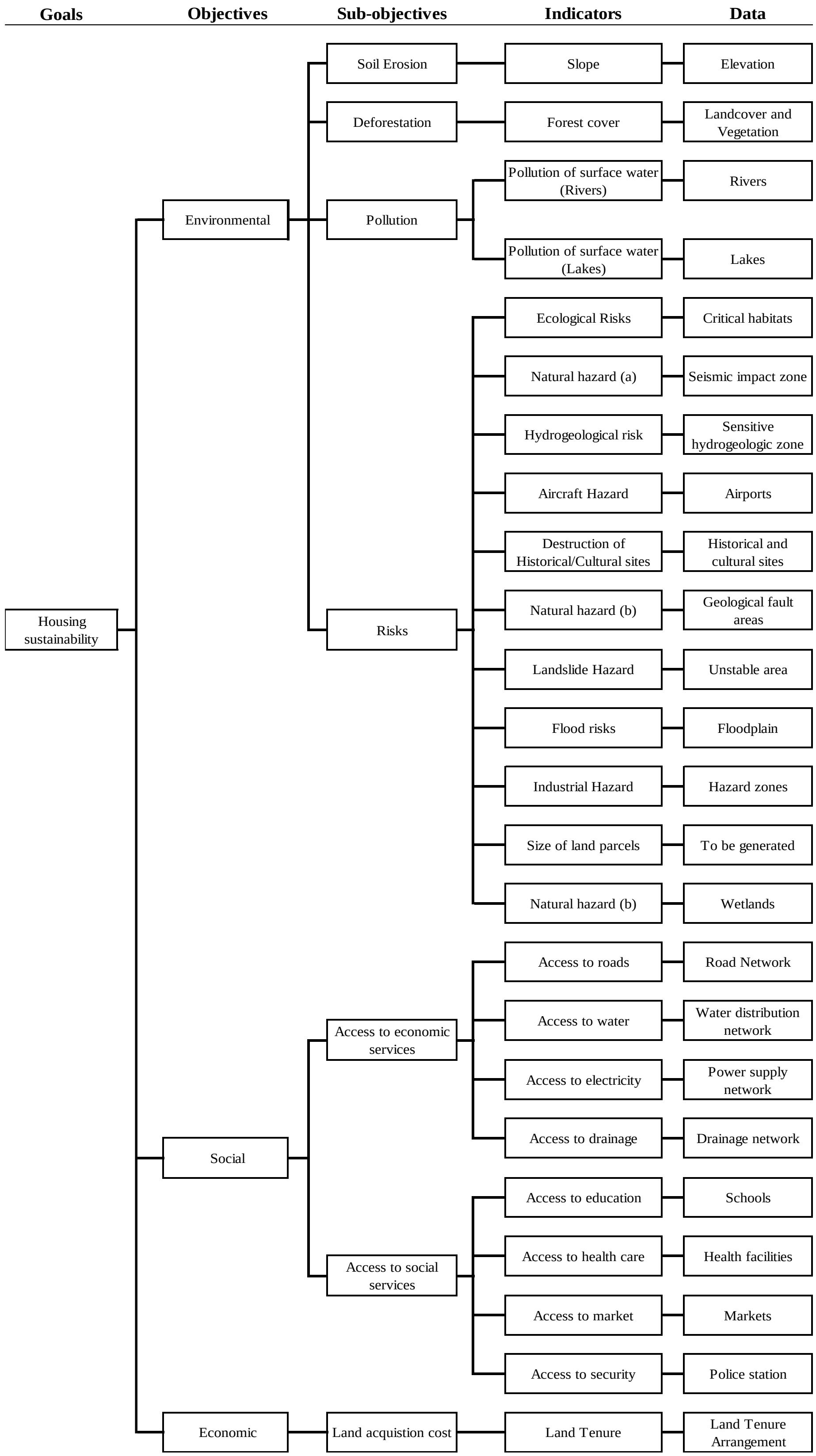

Figure 5.3: Hierarchy model for housing suitability model

5.7 Ranking of Criteria Using Stakeholders' Consultation

The three significant components of land suitability analysis, namely, environmental, economic and social factors, were ranked regarding their relative importance regarding housing suitability, by key experts/specialists at the CHPA. The results from the workshop revealed that environmental factors were of primary importance followed by the economic and social factors (figure 5.4).

The participants of the workshop explained that the high ranking of environmental factors was due to the prominence attached to it in the IDB's Low-Income Settlement II Project Operating Regulations (2009), which guides the CHPA in land suitability analysis. These regulations explicitly mandate compliance with several environmental factors when selecting a particular site for housing development.

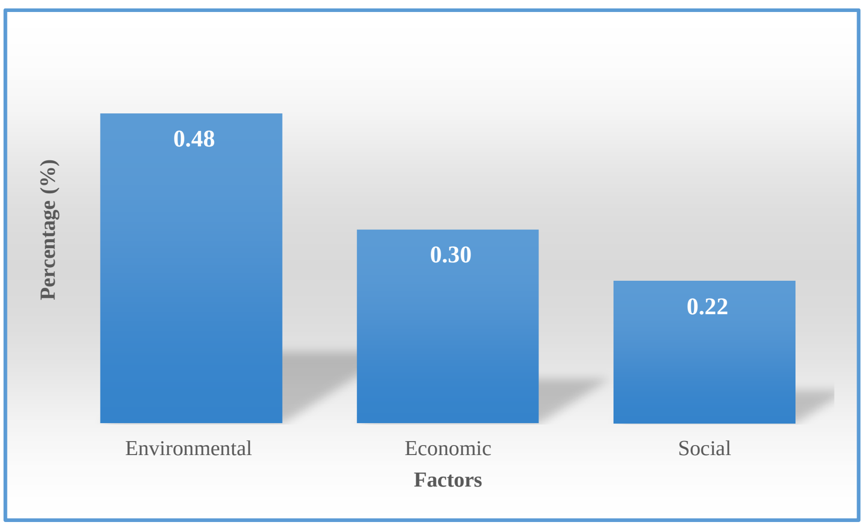

Figure 5.4: Weights for major indicators of land suitability analysis

5.7.1 Environmental Factors

At the workshop, the participants scored each environmental factor almost equally. This is not surprising given the fact that all the environmental factors are regarded as mandatory for the selection of new sites for housing purposes as adumbrated in the Operation Regulations of Low-Income Settlement Programmes (LISPs). Indeed, there were marginal differences between the rankings of each environmental factor viz-a-viz the others. Figure 5.5 shows the relative weights attached to each factor by the participants of the workshop.

Based on figure 5.4, natural hazard (c): wetlands, airport hazard, ecological risks, and surface water pollution: rivers attracted the highest weights. The participants indicated that these factors are ranked relatively high since they are mandatory requirements (IADB 2009). The also offered the following explanation for the ranking of some of these criteria:

i. Natural hazard (c): wetlands – apart from the fact that this criterion is mandatory it is costly and risky for potential homeowners to use such lands for housing purposes.

ii. Pollution of surface water – the IDB's Low-Income Settlement II Project Operating Regulations (2009) sets out specific guidelines to minimise any adverse environmental and social impact of any new settlement scheme, including surface and groundwater pollution. Thus, even where these adverse environmental impacts are minimal, there are mandatory mitigation strategies that serve to reduce the risk of polluting surface and groundwater.

iii. Ecological risks – the CHPA is required to work closely with the Environmental Protection Agency (EPA) and other agencies with oversight responsibilities for protected areas (such as IWOKRAMA, Conservation International and the National Parks Commission) to ensure that critical habitats are preserved. Moreover, it is also a requirement for the adoption of mitigation measures to protect natural habitats, during the construction and operation phases of all housing development programmes.

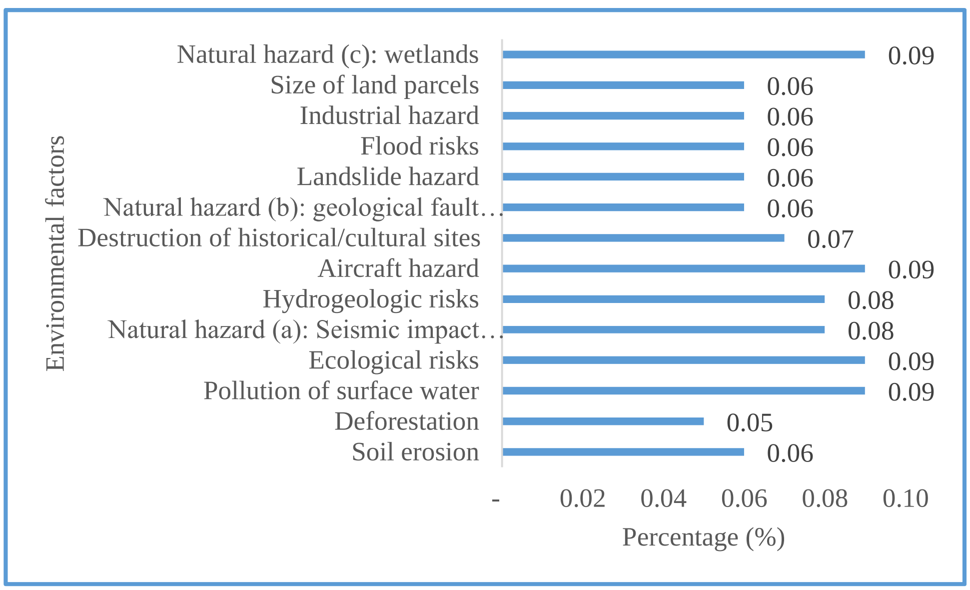

Figure 5.5: Relative weights of environmental factors

According to the workshop participants, these factors were ranked marginally less critical due to the following factors:

i. Hydrogeological risk – though important, seismic impact zones are ranked slightly lower than wetlands and distance from airports, since the aquifers are generally deep and protected by clay with a thickness that ranges from nineteen metres to 120 metres. Thus, hydrogeological risks are relatively lower.

ii. Flood risk - The IDB's Low-Income Settlement II Project Operating Regulations (2009) specifically prescribe the provision of adequate physical infrastructure including drainage, to minimise potential flooding. Thus, while most of the settlement schemes are sited on the Low Coastal Plain, which is prone to flooding, these mandatory requirements serve to minimise the risk of establishing settlement schemes on floodplains.

iii. Landslide risk – most of the housing development is concentrated on the Low Coastal Plain since housing demand is higher on the coastland and the cost of developing new settlement schemes or expanding an existing scheme is less costly along the coast, which is flat and not subject to landslides. Thus, there was marginally lower ranking for these criteria when compared to wetlands and distance from airports.

iv. Land size was ranked marginally less important than wetlands and distance from airport given the availability of lands.

v. Deforestation: the participants indicated that notwithstanding the absence of a National Land Use Policy, the Ministry of Housing and Water has a policy of targeting abandoned lands, which falls outside the forested areas. Thus, the risk of deforestation is low.

Weighting of types of surface water pollution

With respect to surface water, rivers were ranked above lakes (figure 5.6). The participants explained that the relative weight of the former was higher when compared to the latter because most settlement developments are concentrated on the coast where the demand for housing is great but within proximity to rivers. Consequently, the risk of polluting rivers was greater. They also indicated that rivers represent a significant flood risk given the rise in sea level, which warranted a higher weight relative to lake.

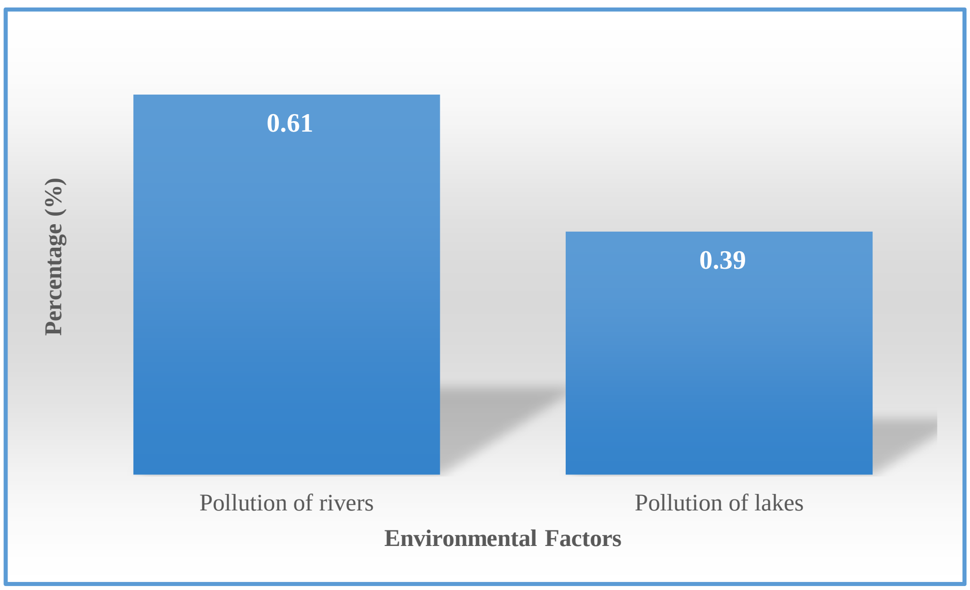

Figure 5.6: Relative weights of surface water and landscape criteria

5.7.2 Economic Factors

The participants of the workshop explained that the acquisition cost for land is the sole economic factor considered when developing new settlement schemes. They also pointed out the direct relationship between acquisition cost and land tenure arrangement.

5.7.3 Social Factors

At the workshop, the participants ranked the adequacy of physical factors and social infrastructure equally. They indicated that these facilities are regarded as equally important for maintaining the wellbeing of potential homeowners.

With respect to physical infrastructure, the participants of the workshop deemed road networks as paramount followed by adequate drainage networks, then water distribution and power distribution networks (figure 5.7). The weights attached to the various criteria were consistent with the importance associated with these factors in the IDB's Low-Income Settlement II Project Operating Regulations (IADB 2009). It is important to note that the participants of the workshop pointed out that access to adequate road networks and water distribution networks were mandatory requirements.

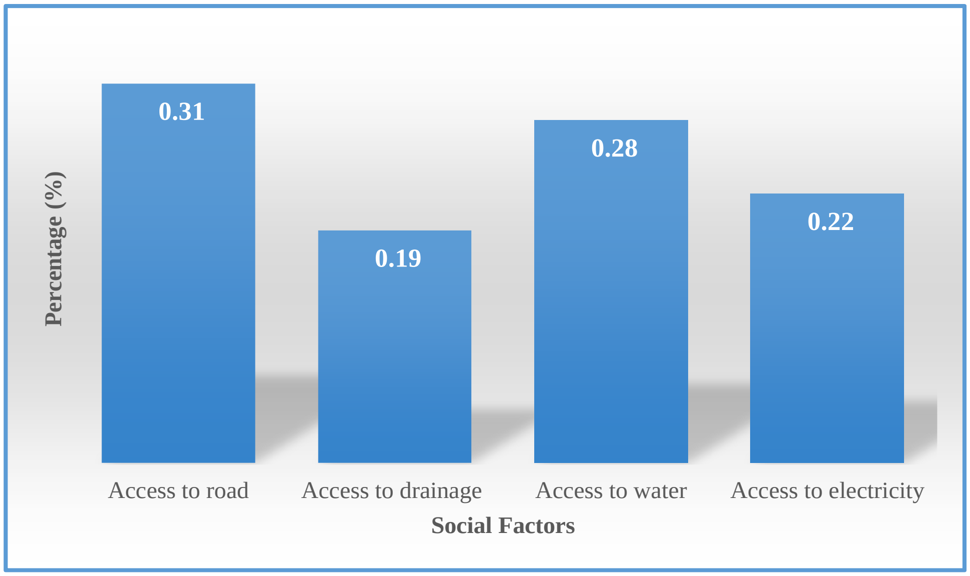

Figure 5.7: Relative weights of physical infrastructure criteria

Concerning social infrastructure, access to health centres was ranked highest, followed by the police station, schools, and markets (figure 5.8). At the workshop, the participants indicated that access to social facilities was not a mandatory condition for establishing a new settlement scheme; however, the IDB's Low-Income Settlement II Project Operating Regulations (IADB 2009) requires that the CHPA coordinate with other agencies to ensure that social facilities are available to residents in new settlement schemes. Notwithstanding the requirement of availability of social services, the key stakeholders responsible for land suitability analysis gave greater preference to areas with access to schools, markets, police stations, and health centres. They explained that the construction of schools and markets could be incorporated easier into the development cost of a new settlement scheme when compared to health centres and police stations. As a result, they opined that greater weight should be given to health centres and police stations.

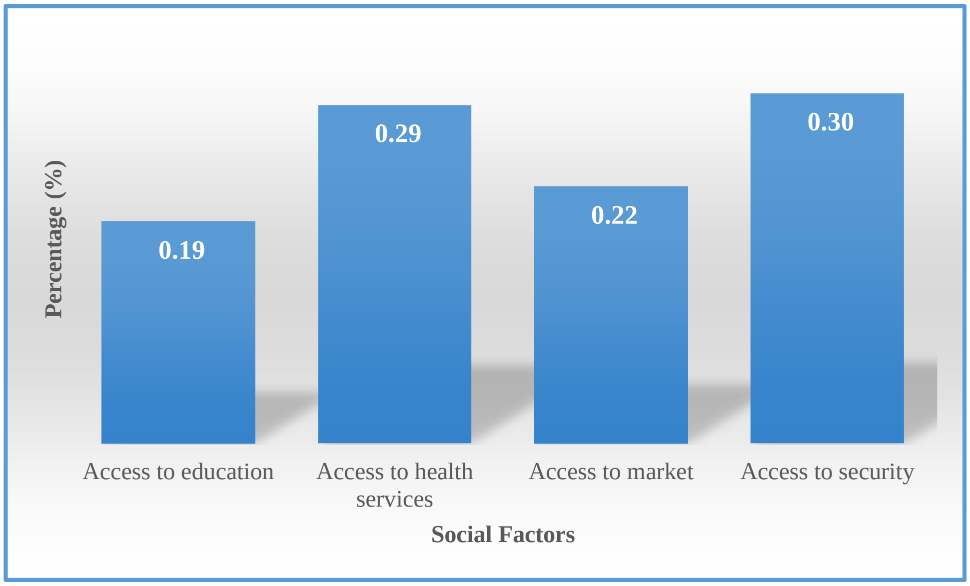

Figure 5.8: Relative weights of social infrastructure criteria

5.8 Cartographic Modelling

General form of the suitability model. The model used for this application utilizes GIS-based overlay analysis to identify suitable land parcels and involves the creation of a suitability raster for the location of new settlement schemes. The general form of the suitability model is represented by equation 5.1:

$$S = \sum_{i=1}^{n} w_i \, C_i \prod_{j=1}^{m} r_j \quad (5.1)$$

Where:

S – Suitability for housing schemes

W_i – weight for each criterion i obtained from the pairwise comparison

C_i – the suitability of each criterion considered in the study

r_j– restriction (acceptable distance for each criterion such as road, water trunk, surface water, airfield etc.)

The Restriction Model captures the various restrictions identified earlier. This involves the creation of a restriction Boolean raster from using equation 5.2 and figure 5.9:

$$S = \sum_{i=1}^{n} w_i \, C_i (r_{environmental} \times r_{social} \times r_{economic}) \qquad (5.2)$$

Where:
$R_{environmental}$ – restriction related to environmental criteria
R_{social} – restriction related to social criteria
$R_{economic}$ – restriction related to economic criteria
The resulting raster will consist of zeros and ones, where zeros (0s) represent restricted or unsuitable cells and ones (1s) represent viable or suitable cells.

The Suitability Model involves creating a suitability raster model using the weights from the pairwise comparison and five-point classification scale ranging from 1 to 5, where 1 represents least suitable areas and 5 most suitable areas. The model is represented in equation 5.3 and figure 5.10.

$$S = (w_{env}c_{env} \times w_{soc}c_{soc} \times w_{ecn}c_{ecn}) \prod_{j=1}^{m} r_j \qquad (5.3)$$

Where:
$w_{env}c_{env}$ represents the weights and criteria for environmental factors
$w_{soc}c_{soc}$ represents the weights and criteria for social factors
$w_{ecn}c_{ecn}$ represents the weights and criteria for economic factors

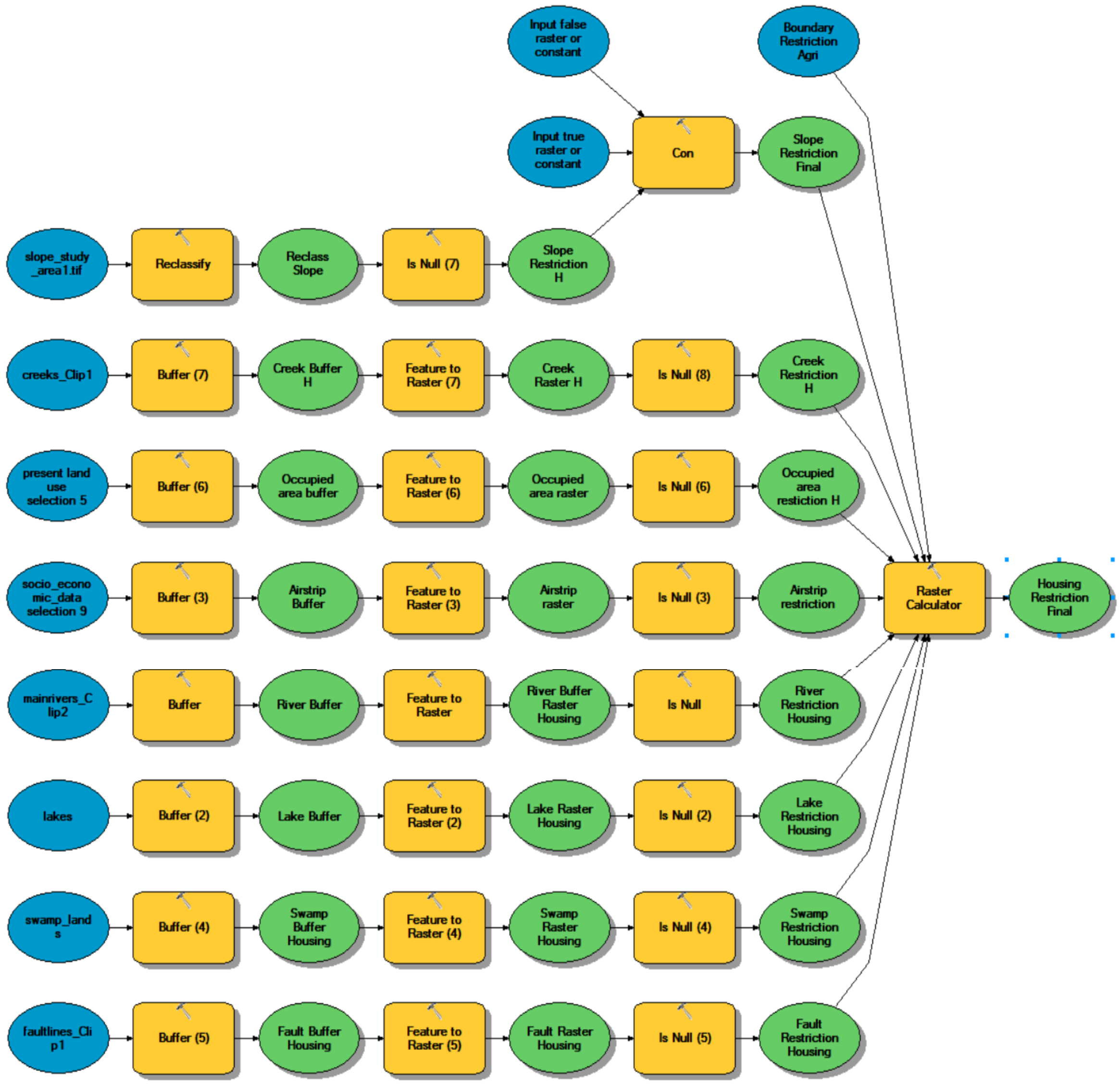

Figure 5.9: Restriction model for housing suitability model

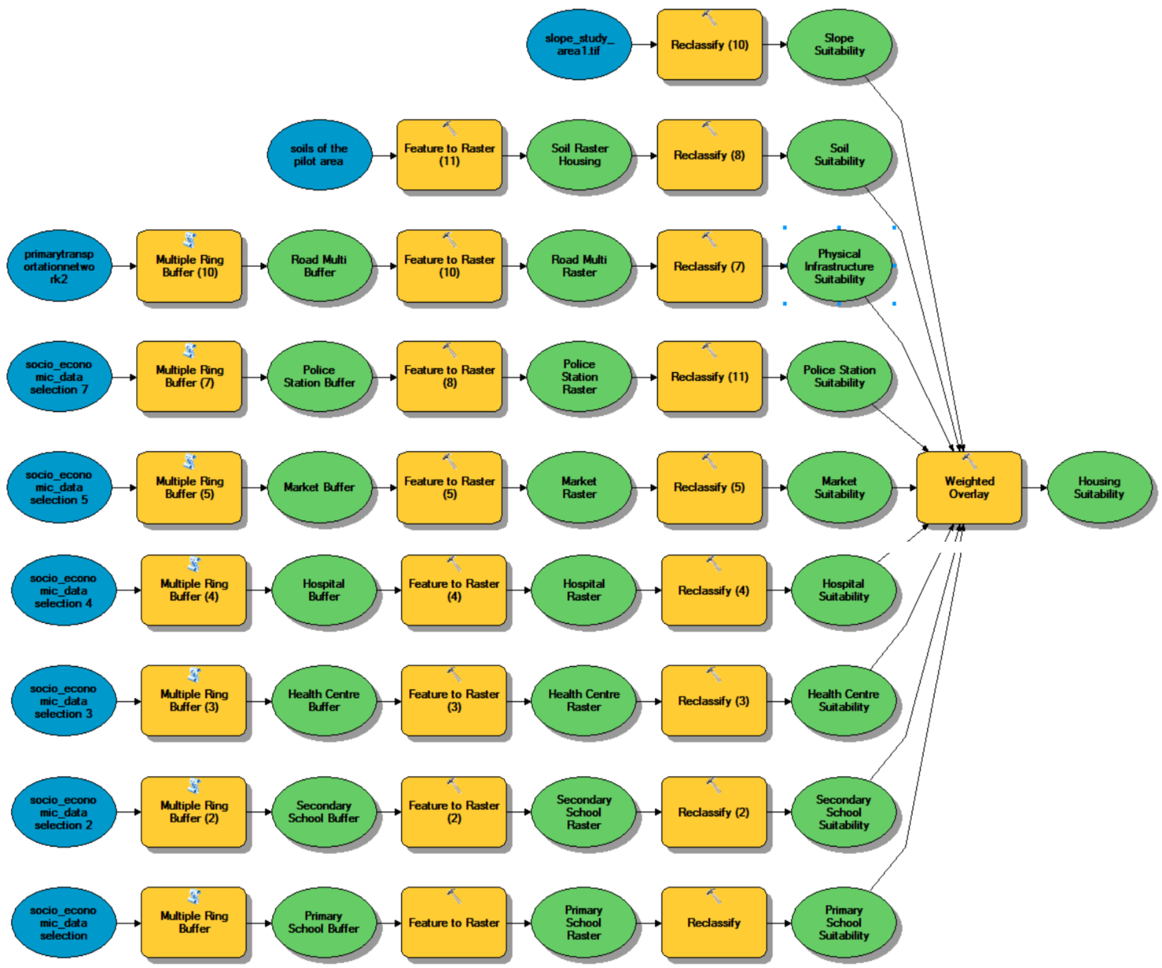

Figure 5.10: Suitability model for housing suitability model

The most suitable housing model involves identifying the best parcels of land for housing development by combining the first two models. Figure 5.11 below provides a modified version of the land parcel model.

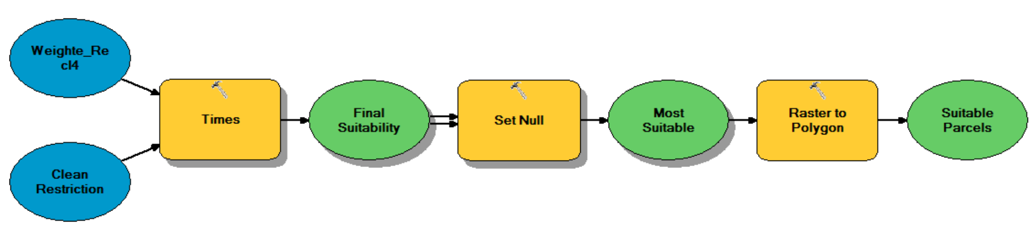

Figure 5.11: Cartographic model for housing suitability model

The above models were created in ArcGIS version 10. This exercise utilised the data from the Sub-Regional Land Use Plan (GLSC 2004) and included the shapefiles for water bodies (creeks, rivers, essential canals), socio-economic infrastructure (schools, hospitals, fire stations, police stations, markets, recreational facilities), roads and trails, drainage and irrigation networks, land capability, land drainability, land use, and land tenure. The staff of the GIS Department of Guyana Water Incorporated (GWI) generated elevations maps, water supply maps, sensitive geological areas, and protected areas.

5.9 Preparation of Thematic Input Map Layers and GIS Analysis

The input thematic data layers required for the suitability analysis were obtained from the relevant State agencies. These datasets were evaluated for accuracy and consistency before being used in ArcGIS model builder. The maps generated from the cartographic models are presented and discussed in this section.

5.9.1 Restrictions Model

GIS data layers of water bodies that exist in the pilot area were prepared and presented in chapter 5. The stakeholders recommended that housing development should be undertaken within prescribed proximity from the various water bodies, such as lakes and rivers to protect them from human-induced contaminations but close enough for social, recreational activities. These restrictions are depicted in figures 5.12 and 5.13. Figure 5.14 shows the areas which are restricted and unrestricted based on land tenure of the study area. It also shows how the various regions which are occupied as well as the parcels which are vacant. Since the vacant lands are publicly owned, there is tremendous scope for housing development in the study area. Consequently, a significant proportion study area would be suitable for acquisition for housing purposes.

Figure 5.15 shows the slope of the study area. It is not surprising that approximately 76.5 percent of the total study area is within the acceptable level of 0-15 degrees. These areas also have significant overlaps with those that are unoccupied, publicly owned and comprise of natural vegetation. Figure 5.16 shows the restriction from geological fault areas when housing development would be risky. Finally, the limitation regarding swampland is imposed to prevent housing development in the regions that may be prone to flooding and contain critical habitat. This restriction as depicted in figure 5.17.

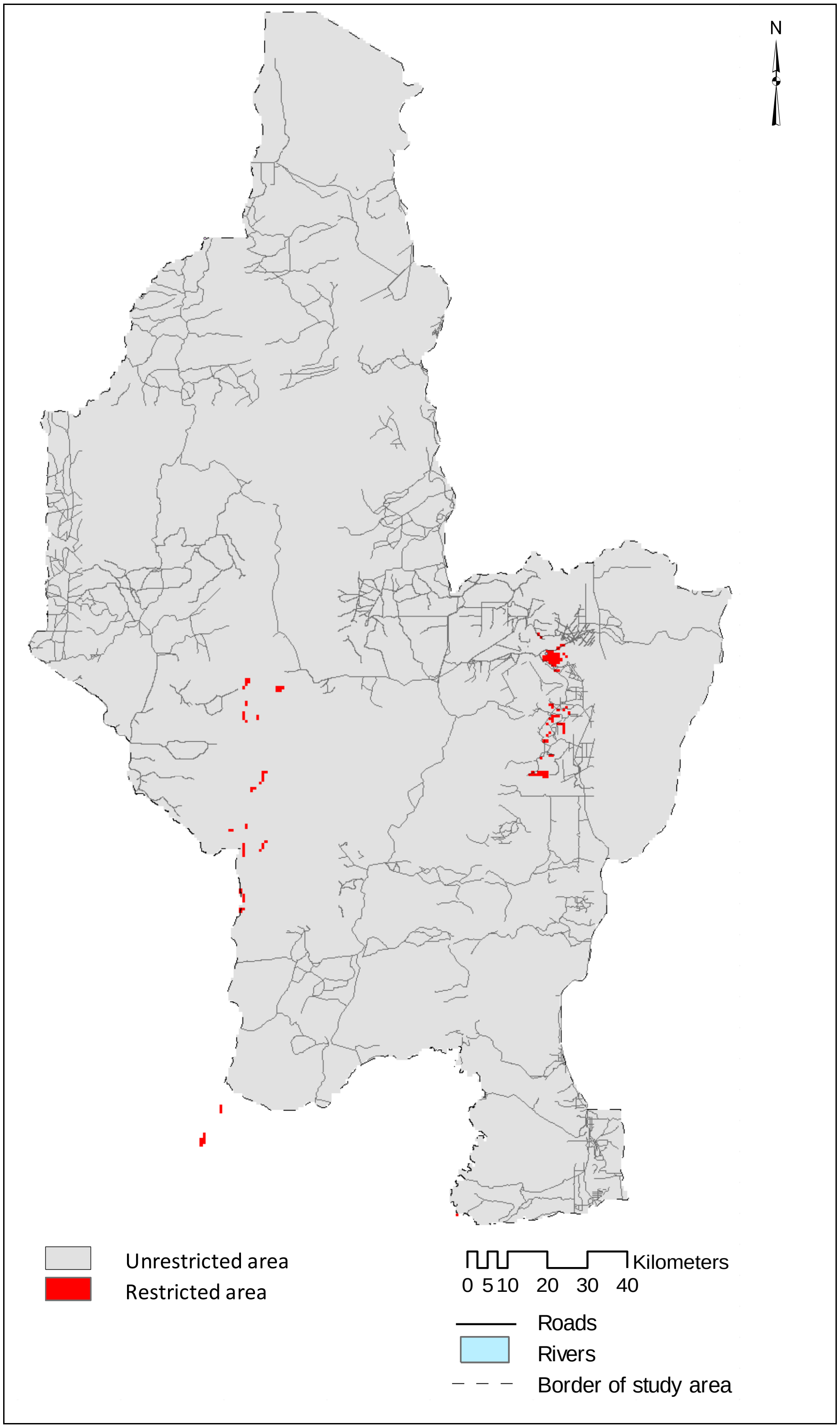

Figure 5.12: Lake restriction

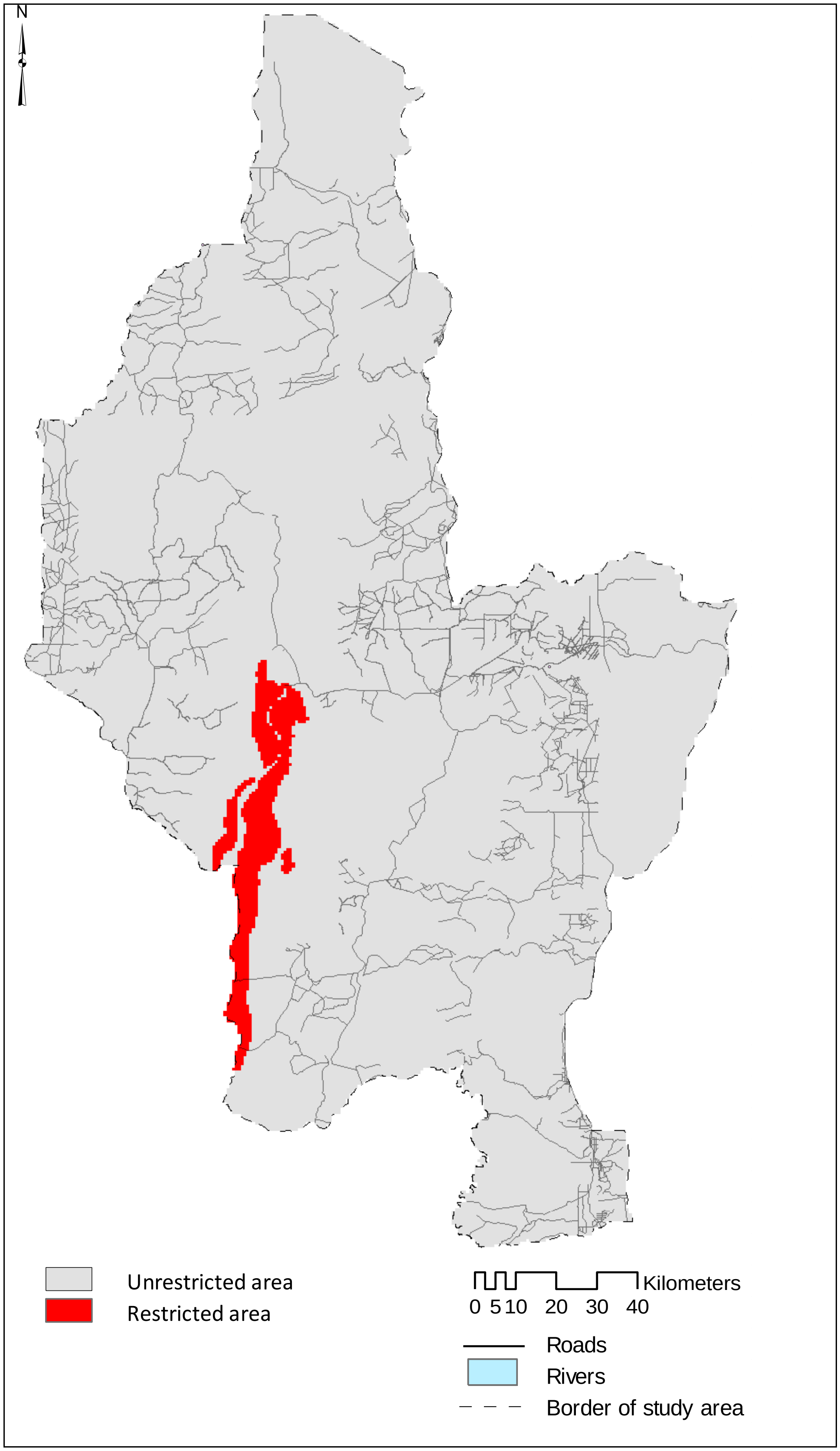

Figure 5.13: River restriction

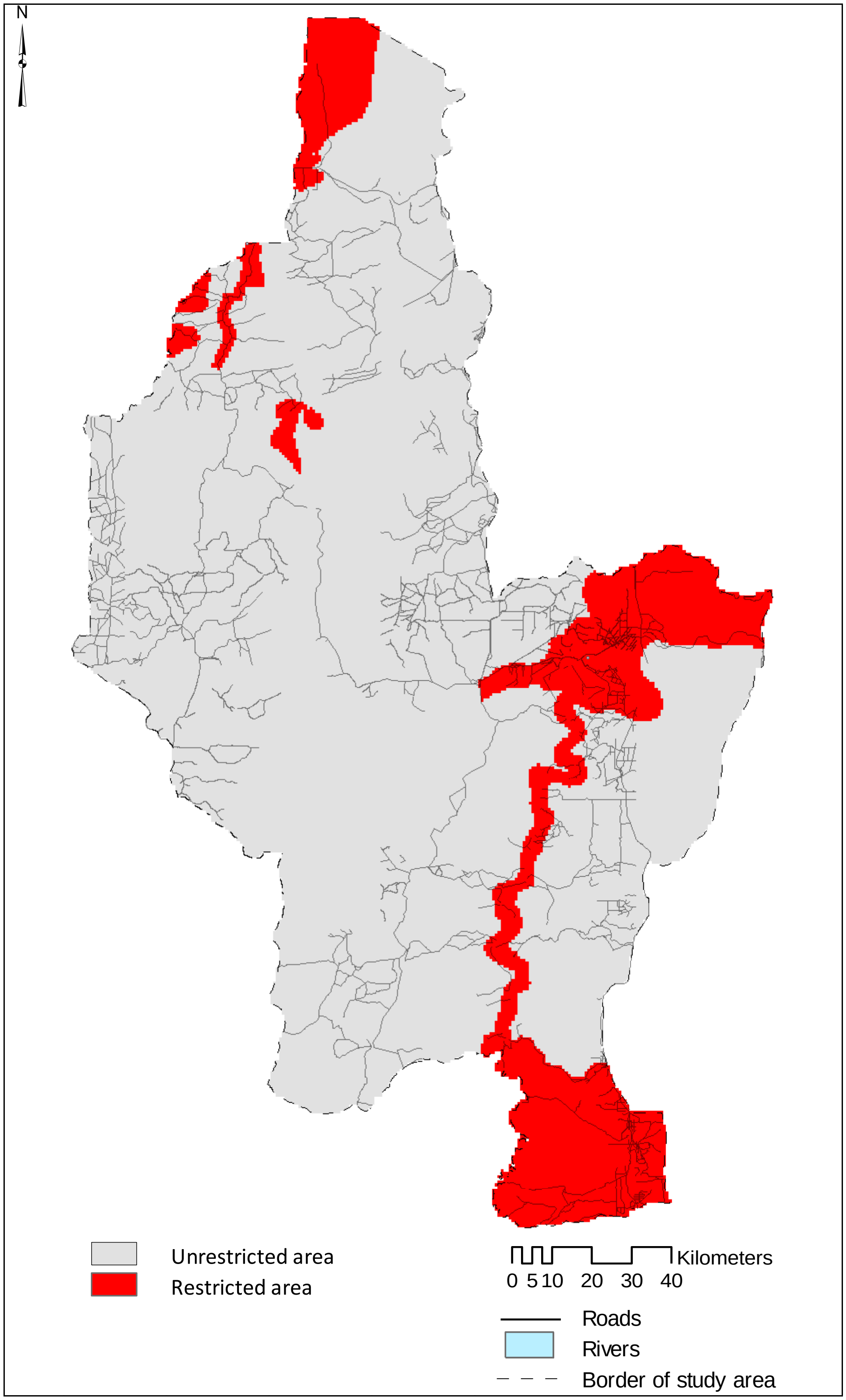

Figure 5.14: Land tenure and land use restrictions

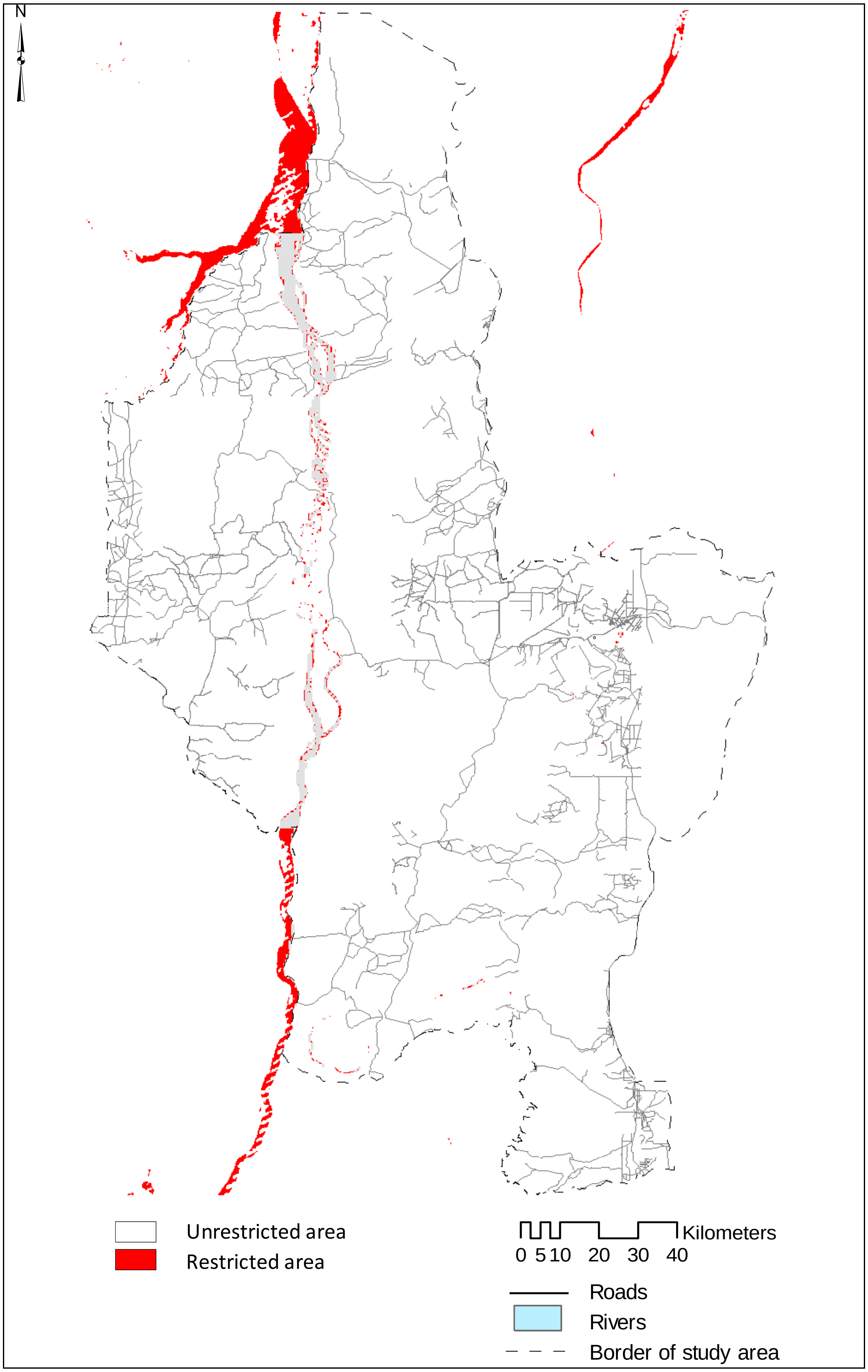

Figure 5.15: Slope restriction

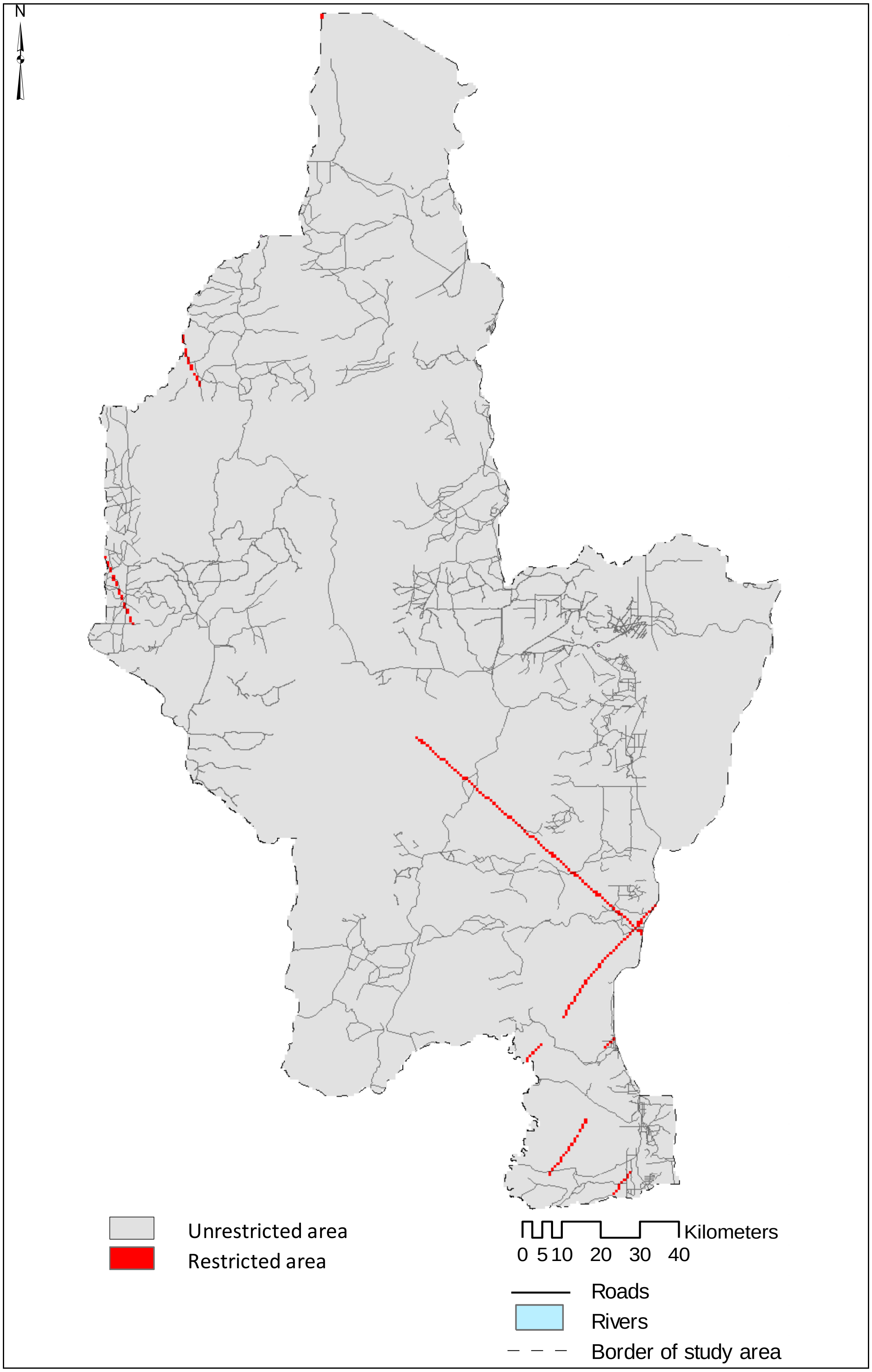

Figure 5.16: Geological sensitive restriction

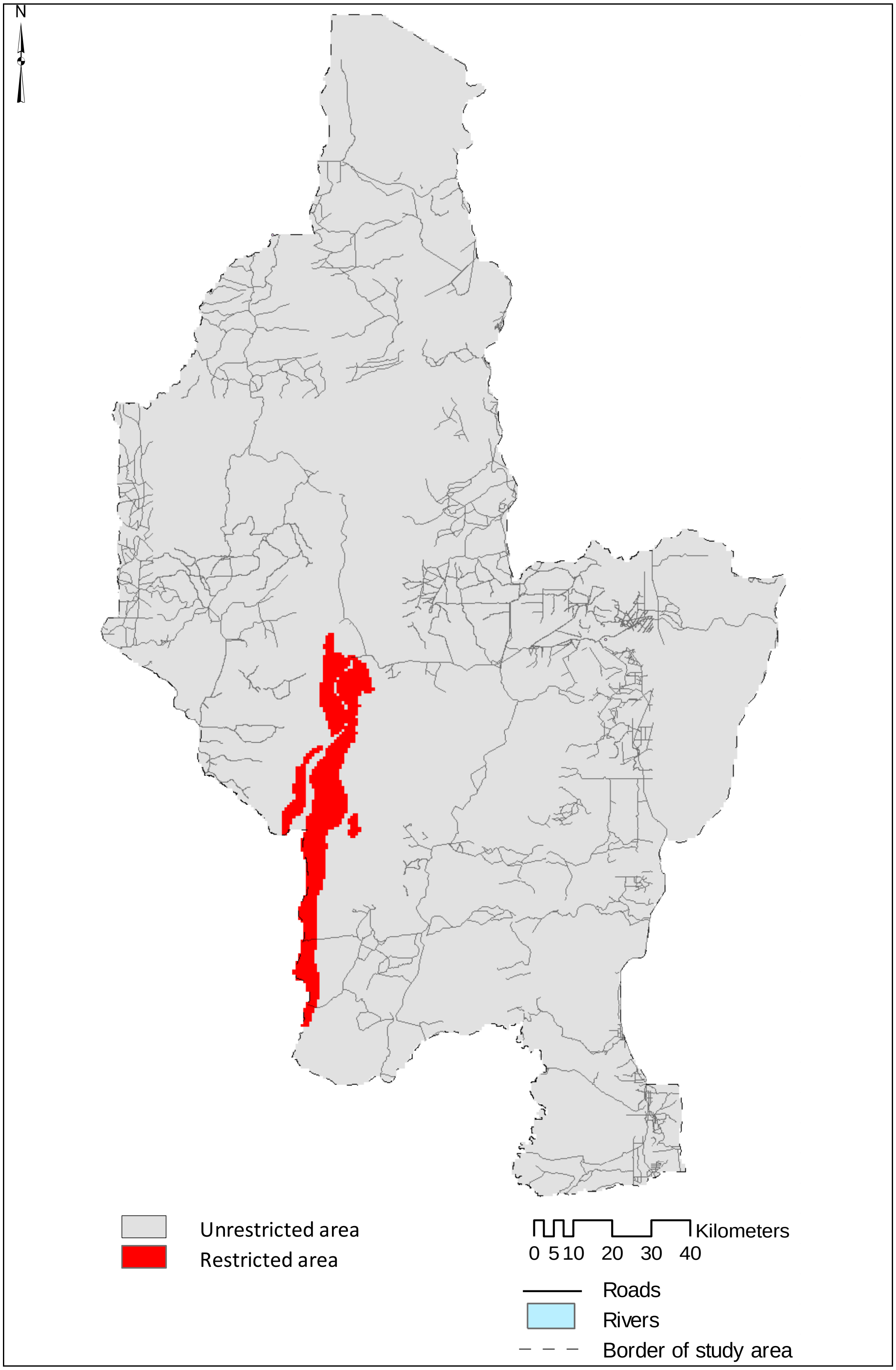

Figure 5.17: Swampland restriction

Figure 5.18: Final restriction

5.9.2 Suitability maps

The study area has one major road that runs along the coast and several minor as discussed in chapter 4. It is noteworthy that drainage, power lines, and water distribution network are laid along the shoulders of these roads. Based on the operating regulations of the CHPA, housing development is only encouraged in areas which are within close proximity to roads, drainage system, water, and power distribution networks. This suitability condition is intended to ensure that housing that the cost of housing development is minimized. Figure 5.19 shows the suitability of the study area based on its proximity to the critical physical infrastructure.

The suitability of a particular area for housing development is also contingent on its proximity to critical social infrastructures such as schools, health facilities (health centres and hospitals), markets and police station. As explained in chapter 4, there are numerous social facilities in the study area. The suitability of the study area based on proximity to these social facilities were also analysed.

Figure 5.20 shows the extent to which lands within the study area are tenured and occupied. The areas shaded in grey are state lands which are unoccupied and suitable for housing development.

Based on the operation regulations of the CHPA, housing development is permissible in very suitable in areas which are relatively flat. This suitability criterion is intended to avoid land degradation that may result from housing activities. Figure 5.21 shows the suitability of the study area based on this criterion.

To avoid the use of fertile land for housing purposes instead of agriculture, housing development is best suited in areas with soil classified as Class IV and moderately suitable in areas with Class III soil. Figure 5.22 shows the soils suitability of the study area based on this criterion.

When all the suitability criteria are combined, it produces the suitability map depicted in Figure 5.23. It is clear from the map that housing follows the physical infrastructure which explains the lateral expansion rather than vertical expansion of housing in Guyana.

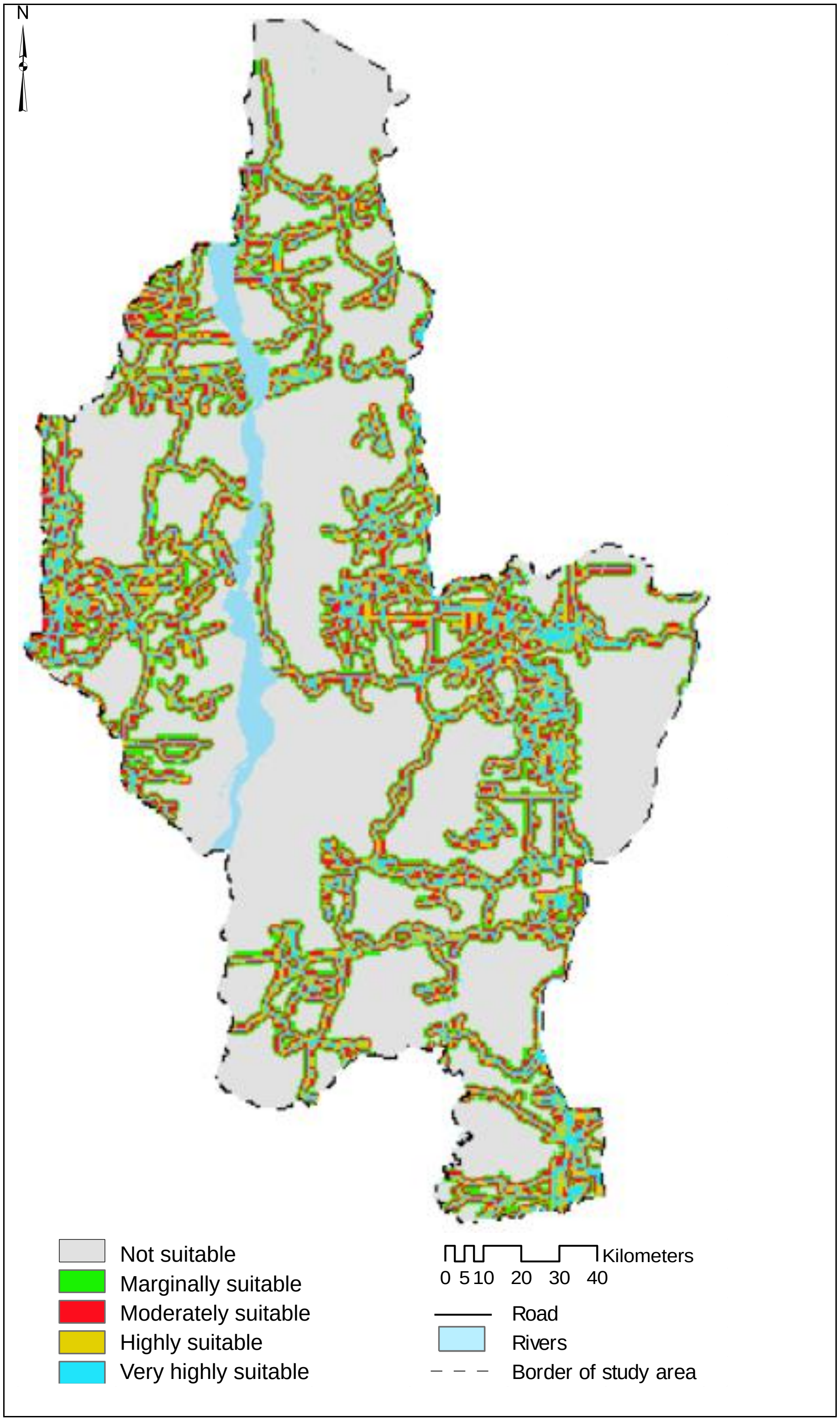

Figure 5.19: Suitability of study area based on proximity to key physical infrastructure

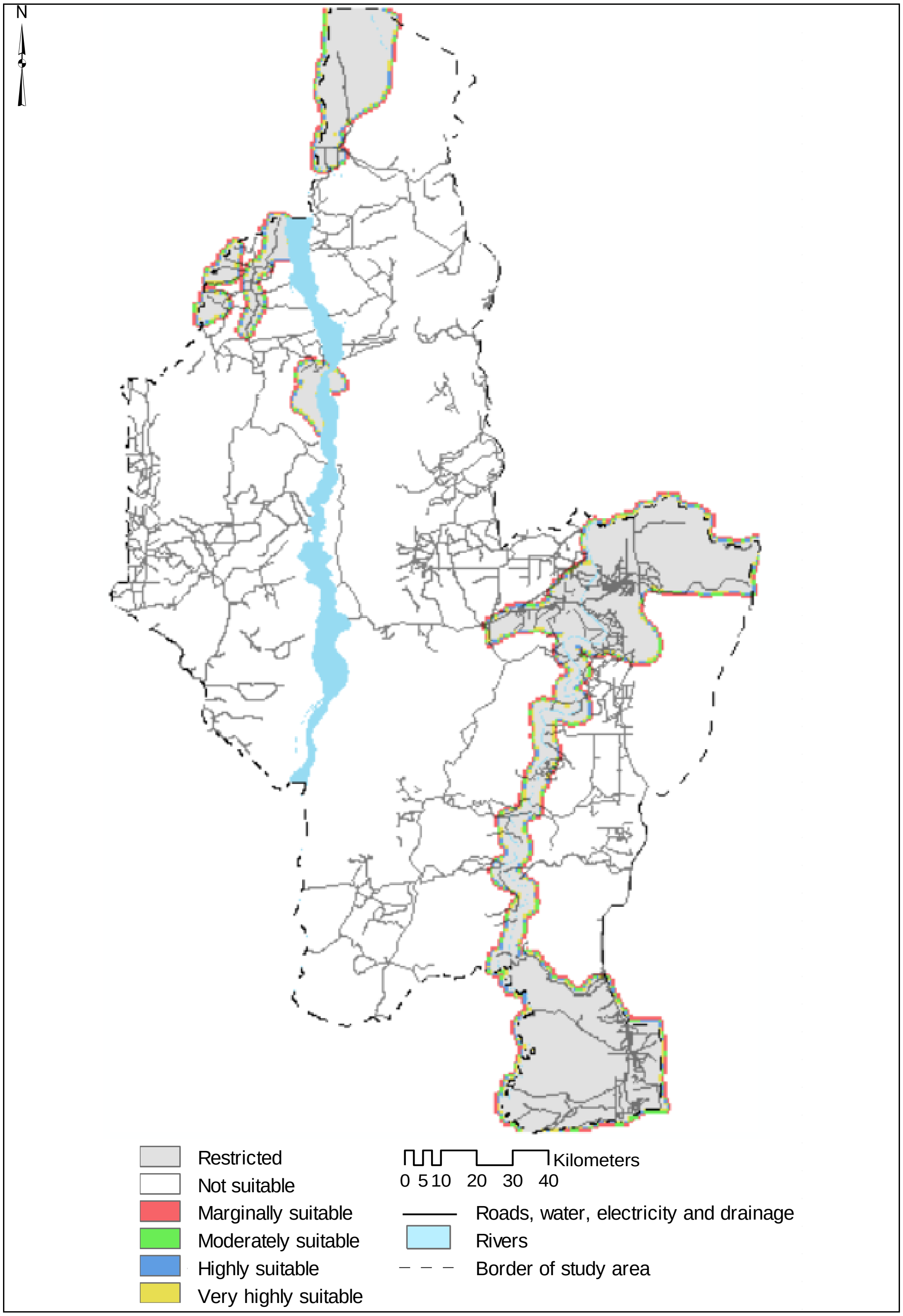

Figure 5.20: Land tenure and occupation

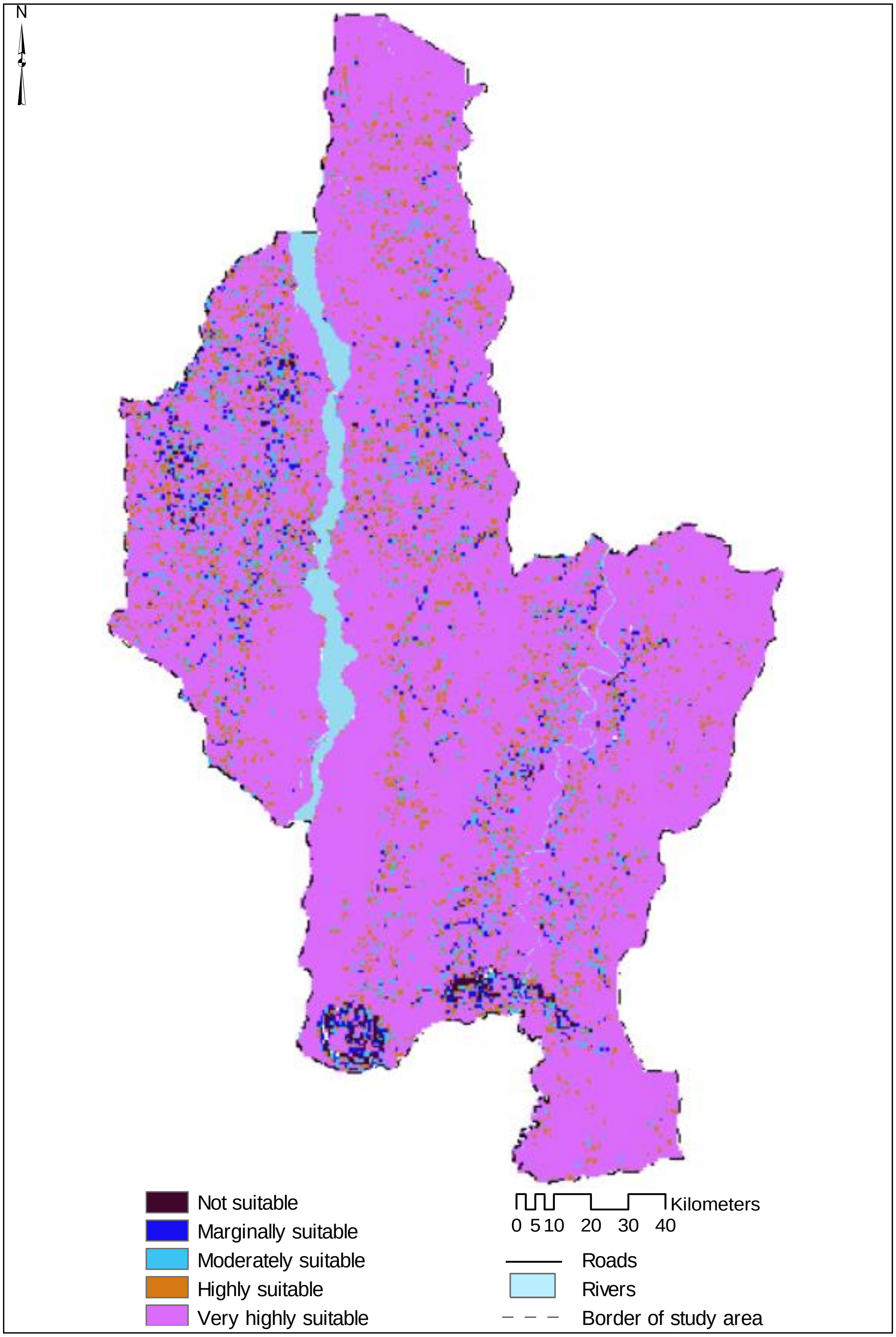

Figure 5.21: Slope suitability

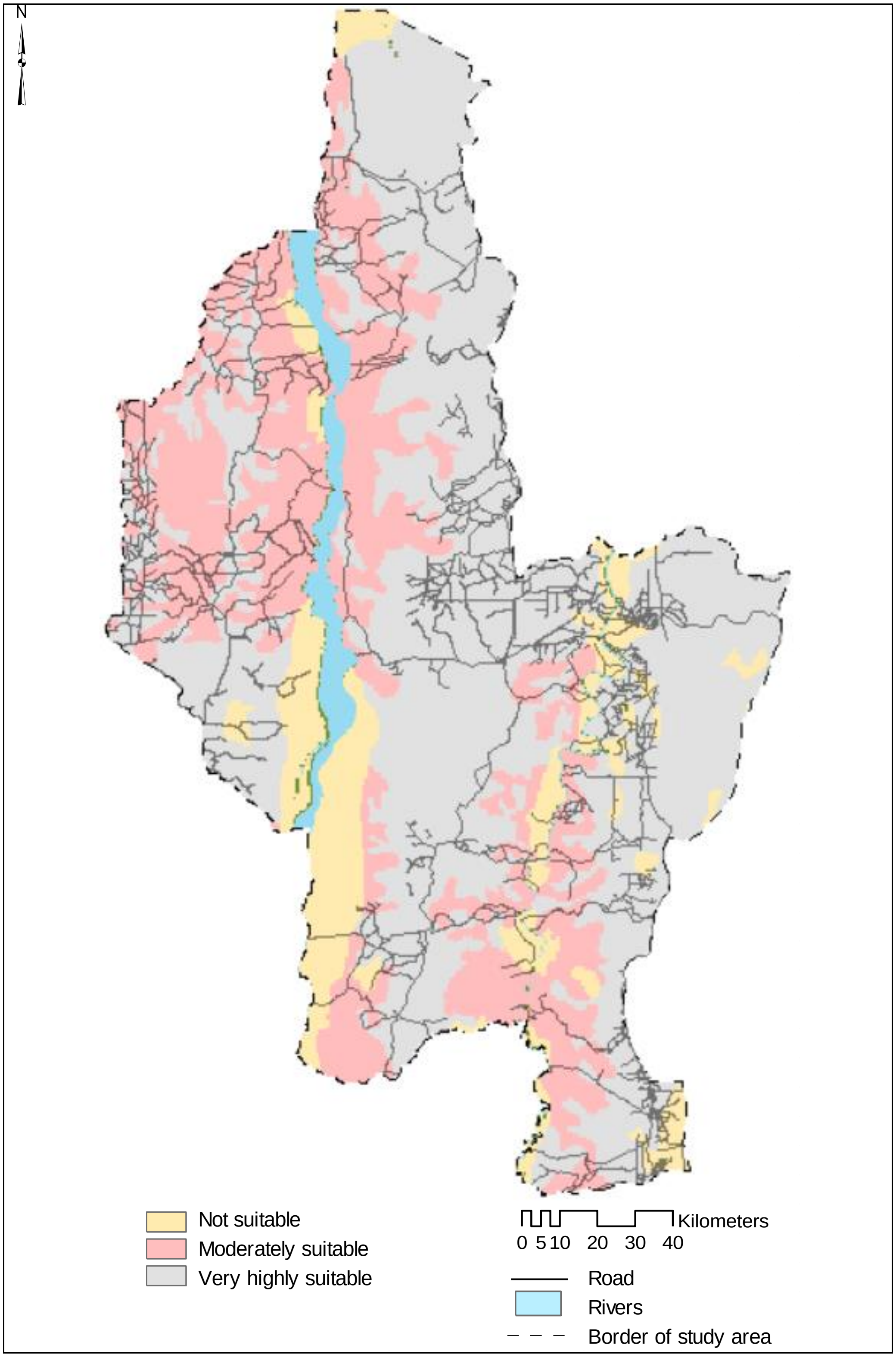

Figure 5.22: Soil suitability

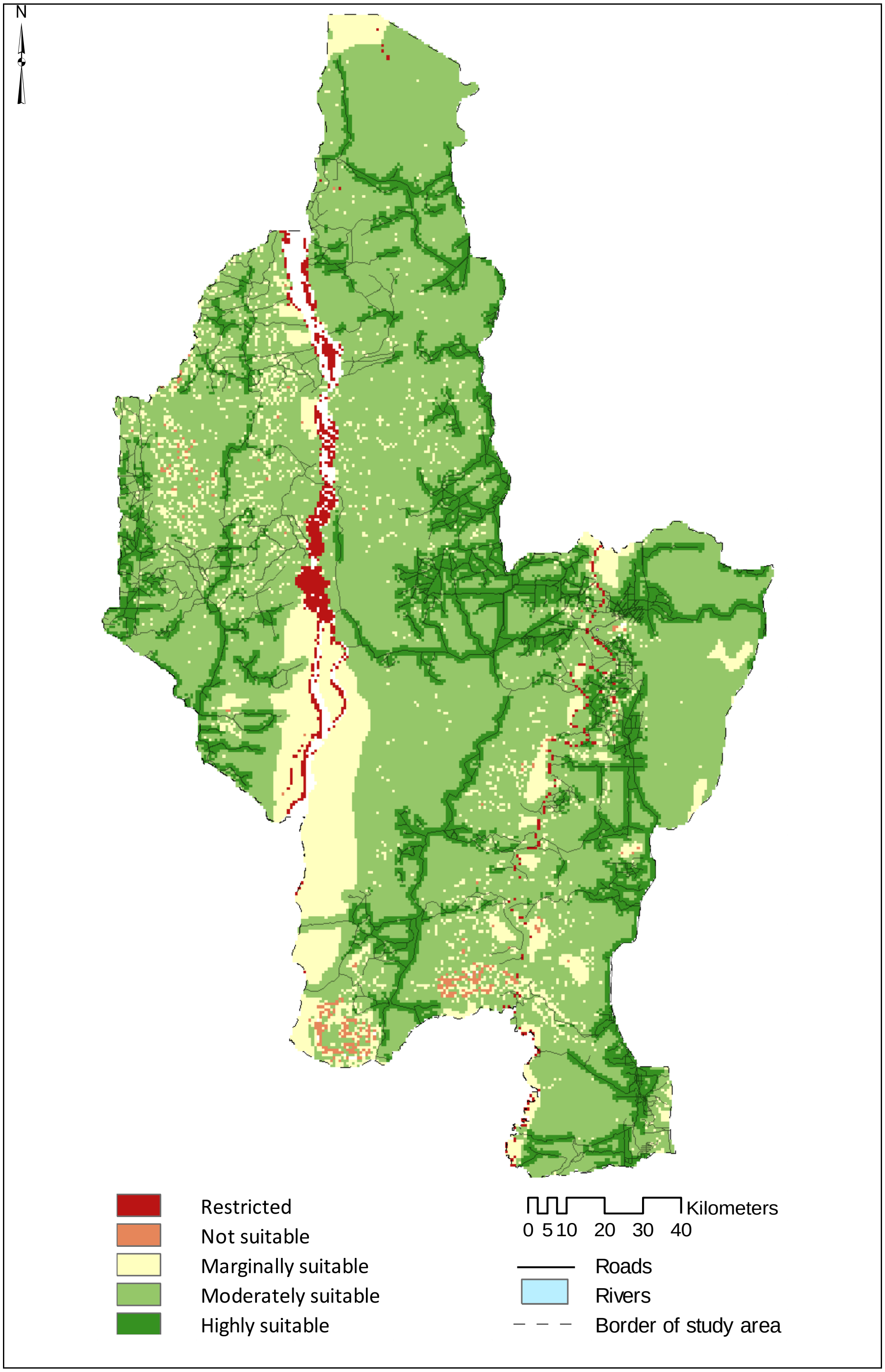

Figure 5.23: Final suitability

5.10 Results of the Suitability Analysis

The analysis was performed in three stages. Stage one entails the performance of the cartographic environmental constraints or restriction model as presented in figure 5.18. In phase two, the suitability analysis was performed, and the results as shown in figure 5.23. The most suitable housing sites were identified by combining the outputs from stage one and stage two. The results are presented in figure 5.24. The results reveal that there are 386 suitable land parcels that satisfy all the suitability criteria simultaneously. These land parcels occupy 614.1 square kilometres which are approximately 12.8 percent of the study area.

Highly suitable: The most considerable portion of the study area is highly suitable for housing. Based on the results, approximately 1,514 land parcels with a total area of 1,956 square kilometres falls within this classification. These land parcels satisfy all the mandatory and non-mandatory suitability criteria considered. Specifically, these land parcels were located in areas within safe distances from water bodies (creeks, rivers, and lakes), airstrips, and swamplands as well as satisfy all the suitability criteria simultaneously. Since these land parcels are within close proximity to existing social and economic infrastructure and located in areas that are unoccupied, relatively flat and owned by the state, it is possible to develop new schemes to accommodating approximately 23,847 house lots, with each costing less than US$2,750 to develop. The dark green regions in the map below highlight these land parcels.

Moderately suitable: Only 6.6% of the study area or 318.5 square kilometres of the study area is moderately suitable. Approximately 1054 land parcels fall within this category. However, the size of these parcels is small and inadequate for developing major schemes.

Marginally suitable: The smallest portion of the study area, approximately 0.4% is marginally suitable. These land parcels are not only small but fail to satisfy all the mandatory and non-mandatory criteria at the same time. The total area of these parcels is 21.5 square kilometres.

Not suitable: Approximately 39.6% of the study area (1,905.8 square kilometres) is not suitable. This is due primarily to the range of restrictions imposed. The land parcels which falls under the category of ‘not suitable’ also fails to satisfy the various suitability criteria.

If the suitability criteria regarding proximity to physical and social infrastructure are relaxed, more lands would be suitable for housing development. In other words, the results are extremely sensitive to these criteria. However, this would require a shift in policy stance whereby government.

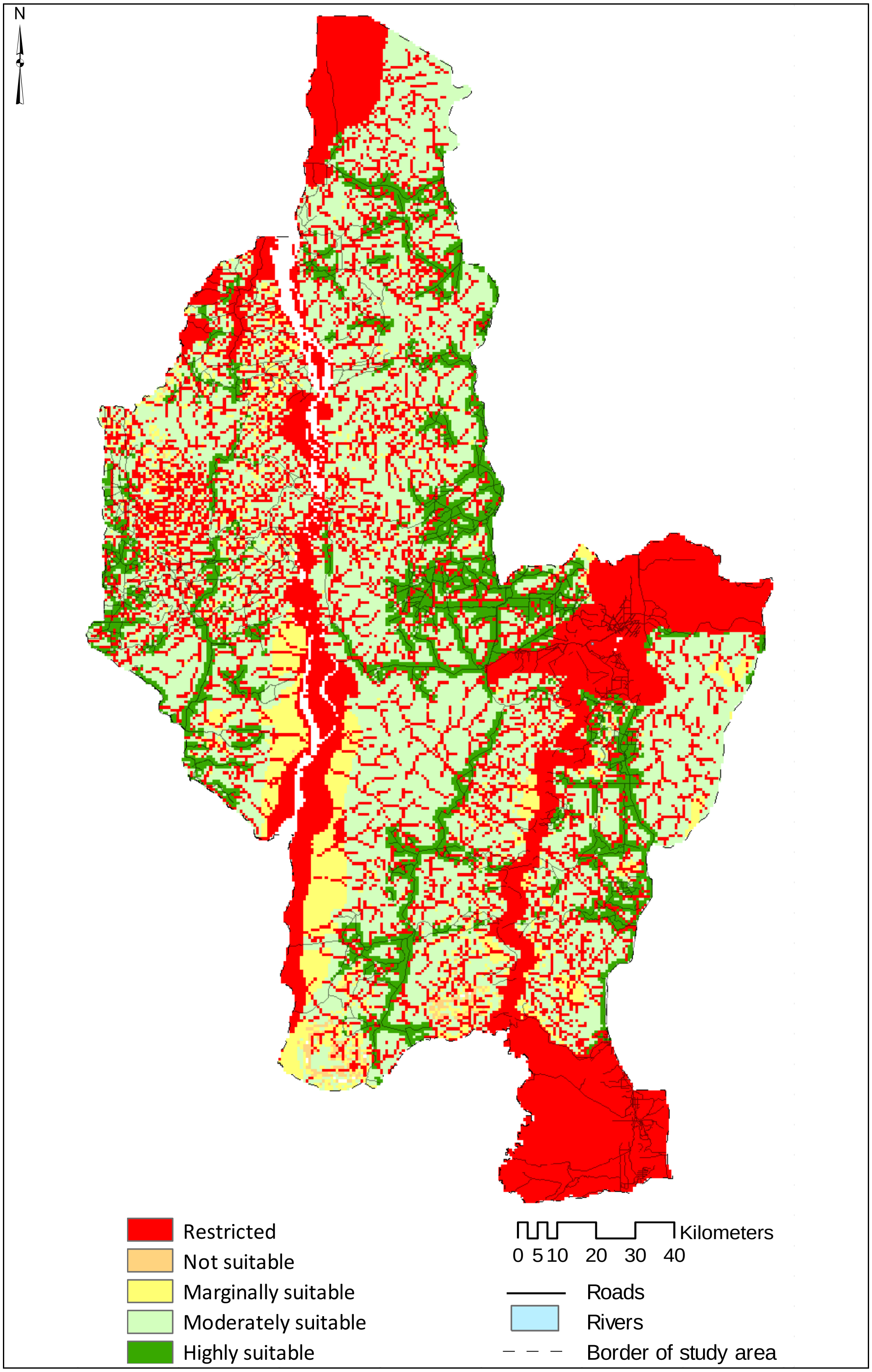

Figure 5.24: Land parcels suitable for housing

5.11 Summary and Conclusion

The criteria and their weights have then combined with GIS overlay analysis, to determine the most suitable land parcels for future housing development in the study area. The results reveal that 386 suitable land parcels satisfy all the criteria. In particular, these land parcels were located in areas that were safe and within an acceptable distance from historical sites, natural habitats, and environmentally sensitive areas. The land parcels were also within close proximity to roads, water supply, schools, hospitals, markets, etc. Furthermore, the land parcels identified were capable of accommodating the development of approximately 23,847 house lots into new housing settlements without exceeding the maximum cost of US$2,750 per house.

It is noteworthy, that the most suitable parcels run parallel to the major road. This lateral form of housing development places a significant burden on the state to develop and maintain physical infrastructure. More importantly, these housing schemes settlements tend to be exceptionally far away from areas where economic activities are concentrated. This contributes also to low occupancy rates in new settlement schemes as beneficiaries of house lots have to travel long distances to get to work. By having to travel long distances, the recipients of government house lots also increase the carbon footprint of the country.

CHAPTER 6: APPLICATION OF THE SAHP TO AGRICULTURE SUITABILITY ANALYSIS

6.1 Problem Definition

The agriculture sector has always featured prominently in Guyana’s national development agenda. This is evident from the individual attention attached to the sector in every significant development strategy formulated and pursued in Guyana since independence; including the National Development Strategy: 2001-2010, Poverty Reduction Strategy, National Competitiveness Strategy of 2006, and the Low Carbon Development Strategy of 2009.

Given the critical role the agriculture sector plays in the socio-economic development of the country; it is not surprising the sector has attracted significant attention from policymakers. Indeed, the sector provides approximately thirty-three percent of total employment and accounts for more than twenty-five percent of the country’s GDP. The sector is also a primary foreign exchange earner - accounting for fifty percent of the country’s total export earnings. It is envisaged the sector will continue to be an essential catalyst and pillar of Guyana's growth trajectory due mainly to:

i. Guyana's commitment to reduce poverty and hunger with the ultimate aim of achieving Sustainable Development Goal (SDG) 1 and 2;
ii. Guyana's desire to become the 'bread basket of the Caribbean' as envisioned in the Jagdeo’s Initiative;

iii. Guyana's intention to exploit the market opportunities for agriculture produce due to the continuous growth in the global population which is expected to reach nine billion by 2025; and

iv. Guyana's desire to become self-sufficient in terms of meeting the local demand for food.

A central feature underlying these strategies is the need to open up more lands for agricultural activities. This strategic imperative, however, is at risk since the agriculture sector has to compete with other economic sectors for the country's limited land resources. In recent times the competition has intensified, with growing incidences of land use conflicts. The potential for ongoing conflict is high, given the fact that some of the country's fertile lands are equally suitable for other uses such as timber harvesting, mining, and housing.

This chapter addresses the identification of suitable agricultural lands using the MCDA/SAHP technique which incorporates GIS. The identification process considers several factors that were selected based on a review of the existing literature, as well as consultations with stakeholders and experts at the MOA and GLSC. The criteria selected for the study were grouped into three broad categories, namely, environmental, economic and social. The weights attached to the selected criteria were computed based on the pairwise comparison technique developed by Saaty (1980).

6.2 Objective of the Agriculture Suitability Model

The primary objective of the analysis is to identify land parcels for agriculture that are most suitable for agriculture and would serve to maximise the economic gains while safeguarding the environment and promoting the wellbeing of citizens. In order to achieve this objective, the land parcel would have to satisfy the following criteria:

i. it should be fertile;
ii. it should have access to adequate rainfall or fresh surface water;
iii. it should be easily accessible;
iv. it should be easily drainable and benefit from adequate drainage and irrigation; and
v. it should be relatively inexpensive to acquire and develop.

Further, the land parcels identified would be subject to the following constraints:

i. it should be unoccupied;
ii. not more suitable for other types of socio-economic activities, such as, mining, logging, housing;
iii. it should not be ideal for providing eco-services; and
iv. it should not be situated on a sensitive hydrogeological area.

The general methodology and specific evaluation procedure developed in chapter 5 (sections 5.3 and 5.4) and presented in figure 5.1 will be followed in this application.

6.3 Suitability Criteria Selection

There is extensive research which evaluates land suitability for agriculture development. This literature applies to a variety of qualitative and quantitative techniques. To a large extent, the extant literature also draws on various evaluation frameworks among which include the Framework for Land Evaluation (FAO 1976).

Notwithstanding, a limited number of studies from the existing literature applies the spatial Analytic Hierarchy Process (AHP) to evaluate the suitability of land for agriculture activities. One of the earliest studies Eastman et al. (1995) to illustrates the spatial AHP technique. In this study, the authors utilized four criteria to identify land in Nepal for agriculture uses: proximity to water (for irrigation), proximity to markets, and soil capability as important land suitability factors. The study also highlighted slope gradients, access to roads and land occupation as constraints. Holzkämpera, Calancaa, and Fuhrera (2010) extended the literature by considering a different suite of criteria for evaluating the suitability of land for several essential crops in Switzerland. The requirements were based on climatic conditions and included indices on drought, excess rainfall, frost and heat stress. More recently, Nyeko (2012) examined the suitability of land for forest and agriculture development in Northern Uganda. The study employed seven criteria for selecting lands for agriculture purposes. These include land use, Normalized Difference Vegetation Index (NDVI), population, water, settlement, rainfall, and road.

These criteria proposed in the literature were discussed with experts at the MOA and GLSC. The experts consulted agree that some of the criteria suggested by Eastman et al. (1995) and Nyeko (2012) should be employed in the suitability analysis. In this study, the criteria were grouped into three broad categories, namely environmental, economic and social factors. They were also grouped into constraints and suitability criteria. The discussion which follows provides a detailed description of the eleven criteria and the ranking attached to each criterion by the experts.

6.3.1 Environmental Factors

Environmental factors refer to those criteria which are aimed at enhancing the economic gains from agricultural activities, as well as restricting farming in certain areas to avoid environmental harm. The environmental factors highlighted by the literature and accepted by the experts include fertile land and lands which either benefit from adequate rainfall or existing drainage and irrigation systems or are within close proximity to creeks (freshwater bodies). The environmental constraints, on the other hand, restrict agricultural activities in any area designated as wetlands, sensitive hydrogeological environment, historical/cultural sites, critical habitats, occupied areas, flood-prone areas, roads, creeks, and any land capable of soil erosion or land degradation. Land tenure, land cover and land surface (slope and altitude) were also identified as essential constraints.

Soil Erosion

This is a non-mandatory criterion which restricts farming in areas with slopes greater than fifteen degrees. The experts regard land with slopes greater than fifteen degrees as prone to erosion or landslides due to increased pressure or the disruption of natural vegetation. These risks are notably higher where the soil is loose. Table 6.1 shows the suitability ranking based on slope (or land surface).

Soil Suitability

In this study, soil suitability is used since it considers the fertility of the soil as well as the various limitations. This suitability criterion requires that farming activities be undertaken in areas with Class I-II soil that is areas with fertile soil and minimum restrictions such as such as soil toxicity, physical limitations (inadequate drainage), and excess soluble salts. It is necessary for this suitability condition to be satisfied to maximize the economic gains from farming. A score ranging from 1 to 3 is attached to the three categories of soil as shown in table 6.1.

Ecological Risk

This criterion restricts agricultural activities within a specified proximity to areas designated as wetlands. In this study, wetlands are generally identified based on the presence of hydric soils, hydrophytic vegetation, and wetlands hydrology. This requirement is intended to protect wetlands ecosystems which in turn perform numerous ecological functions (WWF (GUI) 2012). In this study, an area is assigned a score between one and five based on its proximity to wetlands as shown in table 6.1.

Hydrogeological Risk

This environmental criterion restricts the establishment of farms in any area designated as a sensitive hydrogeological environment, that is, a gravel pit excavated into or above a water table aquifer, areas underlain by a sole source aquifer or other sensitive aquifers, and designated wellhead protection area. This requirement is intended to prevent or minimize groundwater pollution risks, given the pervasive use of chemicals such as fertilizers and insecticides by farmers. A score between one and five is employed as shown in table 6.1.

Other Ecological Risk

This criterion restricts the establishment of farms within a prescribed proximity to areas designated as critical habitats, that is, areas where threatened or endangered species of fauna and flora are found. A five-point rating scale is employed to determine the suitability of an area based on its proximity to critical habitats as shown in table 6.1.

Flood Risk

This environmental criterion restricts the establishment of farms in any low lying flood-plain areas. This requirement is essential given the high water tables and the fact that it is often too costly and/or impractical to construct flood protection in these areas, which may be subject to overflows as much as fifteen feet. A five point rating scale is employed to determine the suitability of an area based on its proximity to flood-prone regions as shown in table 6.1.

Summary

The summary of the environmental factors, along with the ranking scheme for each criterion, is shown in table 6.1.

Table 6.1: Summary of environmental factors and suitability ranking

Agriculture Suitability Factors	Classification schemes	Ranking Scheme	Ranked Values
Soil capability (classes)	Class IV	Not suitable	1
	Class III	Moderately suitable	2
	Class I-II	Very suitable	3
Ecological risk (proximity to wetland in metres)	0-19	Not suitable	1
	20-39	Marginally suitable	2
	40-59	Moderately suitable	3
	60-79	Highly suitable	4
	> 80	Very highly suitable	5
Hydrogeological risk (proximity to sensitive hydrogeological in metres)	0-19	Not suitable	1
	20-39	Marginally suitable	2
	40-59	Moderately suitable	3
	60-79	Highly suitable	4
	> 80	Very highly suitable	5
Other ecological risk (proximity to critical habitats in metre)	0-19	Not suitable	1
	20-39	Marginally suitable	2
	40-59	Moderately suitable	3
	60-79	Highly suitable	4
	> 80	Very highly suitable	5
Flood risk (proximity to flood prone areas in metres)	0-19	Not suitable	1
	20-39	Marginally suitable	2
	40-59	Moderately suitable	3
	60-79	Highly suitable	4
	> 80	Very highly suitable	5
	Easy	Very highly suitable	5
Soil erosion (slope and Land surface in degrees)	>48	Not suitable	1
	28-48	Marginally suitable	2
	16-27	Moderately suitable	3
	6-15	Highly suitable	4
	0-5	Very highly suitable	5

6.3.2 Economic Factors

Economic factors are related to the cost of acquiring land and developing the same for agriculture purposes. In other words, these criteria include the price of land and the cost of developing physical infrastructure for new farming areas. The primary aim of these criteria is to minimize the fiscal pressures of the Government and private investors for the development and maintenance of new infrastructure around agricultural lands. These criteria are not mandatory but essential.

Acquisition Cost of Land

This criterion requires that the land be acquired at the lowest possible price. Generally, the value of land is strongly linked to the land tenure classes; with ‘public lands’ being the least costly and ‘private transported lands’ the most expensive. As a consequence, the GLSC which identifies land for agriculture purposes targets unoccupied public lands and rarely ever acquires private transported lands for agricultural development. Regarding suitability, a five-point rating scale based on tenure classes is utilized as shown in table 6.2.

Cost of Developing Critical Infrastructure

Roads, drainage and irrigation systems are considered important infrastructure for agricultural activities. The former is intended to allow farmers “easy access” to their farmlands. It also serves to ensure that the cost of transporting farm produce to market is maintained at reasonable levels. Drainage and irrigation system systems, on the other hand, is aimed at ensuring that farms have adequate access to water, as well as systems for discharging excess water that may threaten their crops.

There is no restriction regarding how much may be expended to develop critical physical infrastructure for opening-up lands for agricultural purposes. However, in selecting suitable parcels, those with access to well-developed road network and drainage and irrigation networks are preferred. In this regard, a proxy is used in the evaluation process which looks at the proximity of the land parcel from roads and drainage networks. The closer a land parcel is to roads and drainage and irrigation networks, the more suitable it would be for agricultural purposes. A five-point ranking system is employed to rank the suitability of land parcels based on their proximity to the paved thoroughfare or dry weather road as shown in table 6.2.

Access to Drainage and Irrigation System

This suitability criterion requires that farms be located within close proximity to creeks. The further away the land is from the drainage and irrigation network, the lower would be its suitability for agricultural purposes. A five-point rating scale is used for determining agricultural suitability as shown in table 6.2.

Summary

The summary of the economic factors, classification schemes, and ranked values, is presented in table 6.2.

Table 6.2: Summary of economic factors and suitability ranking

Agricultural Suitability Factors	Classification schemes	Ranking Scheme	Ranked Values
Acquisition cost (land tenure arrangements)	Private	Not suitable	1
	GUYSUCO	Marginally suitable	2
	Public co-operative	Moderately suitable	3
	Public Neighbourhood Democratic Council Estate	Highly suitable	4
	Public land	Very highly suitable	5
Accessibility to roads (proximity to road network in km)	> 3.2km	Not suitable	1
	3.2km	Marginally suitable	2
	2.4km	Moderately suitable	3
	1.6km	Highly suitable	4
	< 0.8km	Very highly suitable	5
Adequacy of drainage network (proximity to creeks in km)	> 3.2km	Not suitable	1
	3.2km	Marginally suitable	2
	2.4km	Moderately suitable	3
	1.6km	Highly suitable	4
	< 0.8km	Very highly suitable	5

6.3.3 Social Factors

Social factors are related to the proximity of agricultural lands to vital social services: schools, health centres, police stations, and water supply as well as historical and cultural sites. The primary aim of these criteria is to minimize the fiscal pressures of the Government to develop and maintain new farming communities and protect sites deemed to have historical or cultural values. It is noteworthy that this criterion is not a mandatory selection criterion. However, it is considered necessary for the experts at the workshop.

Key Social Infrastructure

This suitability criterion is related to the distance of land parcels in the study area from critical social infrastructure, such as schools, hospitals (health centres), police stations, potable water. This criterion is intended to preserve the well-being of farming families. It should be noted that this is a non-mandatory suitability criterion. Generally, the closer an identified land parcel is to key social facilities the higher would be its suitability for agricultural purposes. A five-point rating scale is used for determining the suitability of land parcels for agricultural purposes as depicted in table 6.3.

Historical or Cultural Sites

This criterion restricts the establishment of farms in an area with significant historical or cultural values. This requirement is intended to preserve the historical and cultural heritage of the country generally and the communities where these sites are domiciled. A five point rating scale is employed to determine the suitability of an area based on this criterion as outlined in table 6.3.

Summary

Table 6.3 presents a summary of the criteria, classification schemes, and ranked values for the social factors agreed to at the workshop for consideration in the site suitability for agricultural land use.

Table 6.3: Summary of social factors and suitability ranking

Agricultural Suitability Factors	Classification schemes	Ranking Scheme	Ranked Values
Access to Social Facilities (proximity of social facilities in kilometres)	> 9.6km	Not suitable	1
	9.6km	Marginally suitable	2
	8.85km	Moderately suitable	3
	8km	Highly suitable	4
	< 8km	Very highly suitable	5
Damage to historical or cultural sites (Proximity to historical or cultural site in metres)	0-19m	Not suitable	1
	20-39m	Marginally suitable	2
	40-59m	Moderately suitable	3
	60-79m	Highly suitable	4
	> 80m	Very highly suitable	5

6.4 Calculation of the Criteria Weights Using SAHP

The criteria above were utilized to construct a hierarchy to determine the suitability of a particular land parcel for agricultural purposes. The overarching goal of the hierarchy is the most suitable land parcel for farming, positioned at the apex. This is followed by the following three broad sub-objectives: environmental, economic and social. These sub-objectives are broken down further into specific criterion described above. Figure 6.1 provides the decision hierarchy model of new farming areas.

The relative weight of each criterion was obtained by following the pairwise comparison procedure developed by Saaty (1980). The method required that the experts rank each criterion based on a nine-point rating scale, with one signifying ‘equal importance’ and nine signifying ‘extreme importance.’ During this phase of the exercise, the experts/specialists at the Ministry of Agriculture (MoA) and Guyana Lands and Surveys Commission (GLSC) were asked to fill out a questionnaire (Appendix B). The data from the questionnaire were inputted into a set of comparison matrices that mirrors the hierarchy in figure 6.1. It is noteworthy that a comparison matrix was constructed for each level of the hierarchy.

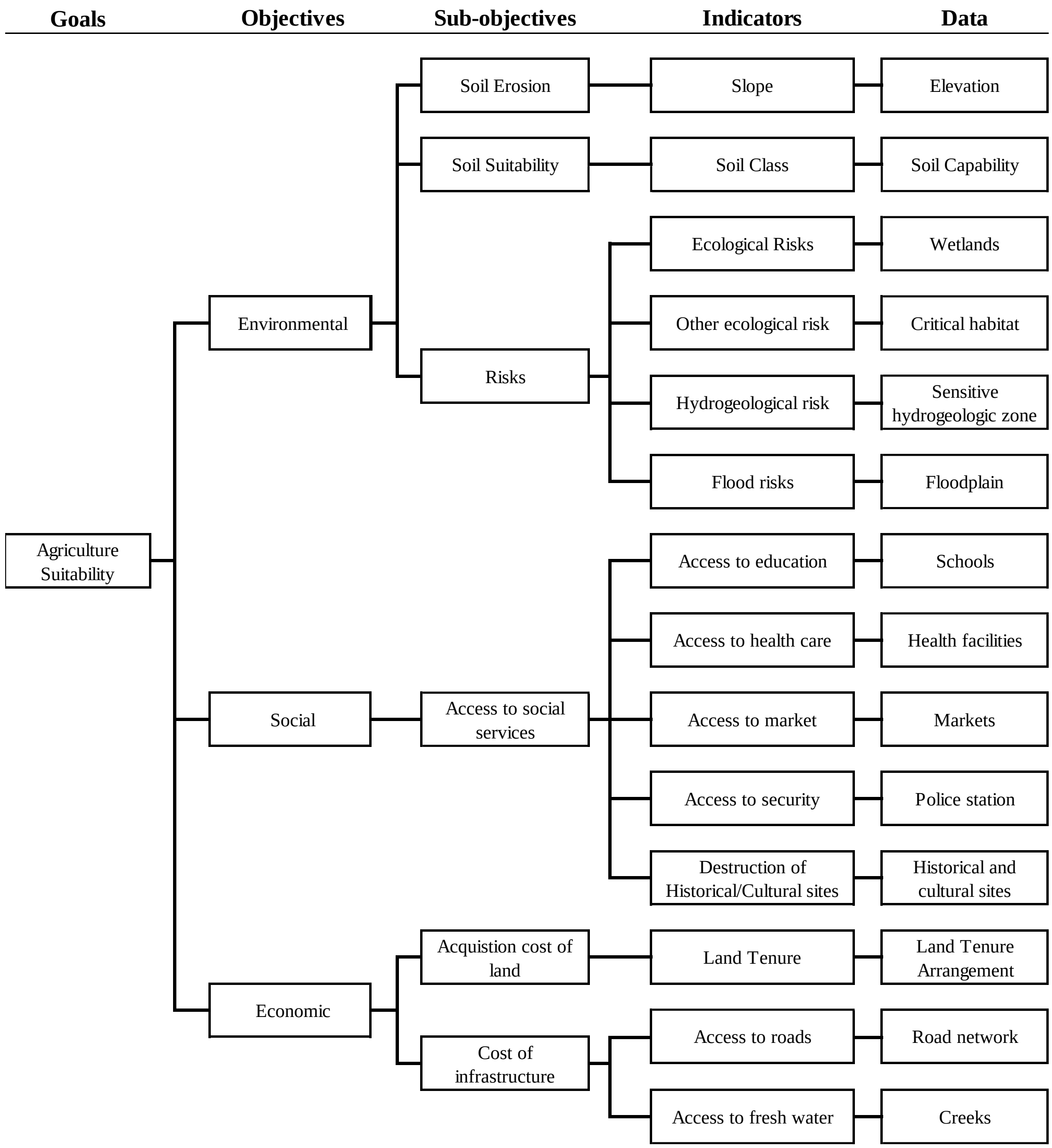

Figure 6.1: Hierarchy model and agriculture suitability

Based on the agreed factors, an MCDA/SAHP model was developed to evaluate the factors. The weights were computed by normalizing the matrices and extracting the eigenvalues using equations 4.1, 4.2, and 4.3 and standardized maps were generated in accordance with the Weighted Linear Combination (WLC) model using equations 4.4 and 4.5.

6.5 Ranking of the Criteria Using Stakeholders' Consultation

The key experts/specialists at the Ministry of Agriculture (MoA) and Guyana Lands and Surveys Commission (GLSC) were asked to rank the relative importance of environmental, economic and social factors as it relates to land suitability for sustainable farming. Figure 6.2 shows that Economic Factors were ranked above the Environment and Social Factors. The experts/specialists attributed the high ranking of economic factors to their direct impact on the viability of agricultural activities. They explained that the cost associated with constructing the requisite physical infrastructure (that is, roads and drainage and irrigation systems) is extremely prohibitive and more onerous when compared with other operational and capital cost. As such, when selecting an area for agricultural development access to roads and drainage and irrigation systems is paramount and often takes precedence over the environmental and social factors. They went on to explain that while it is ideal to undertake agricultural activities in areas with fertile lands if areas with fertile lands are inaccessible and do not benefit from adequate drainage and irrigation systems it may not be economically prudent to pursue such economic activities on these land parcels. They explained that it might be more financially feasible to undertake agricultural activities in areas with poor soil but with access to critical physical infrastructure than to pursue same in areas where fertile lands are available, but critical physical infrastructure is absent. They also noted that the availability of fertilizer and modern technology for engineering crops makes it possible to farm in areas with varying soil types, thus making environmental suitability factors less important than economic factors. However, environmental factors are ranked above social factors, since social facilities are normally constructed within proximity to lands developed for agricultural purposes where same may be absent.

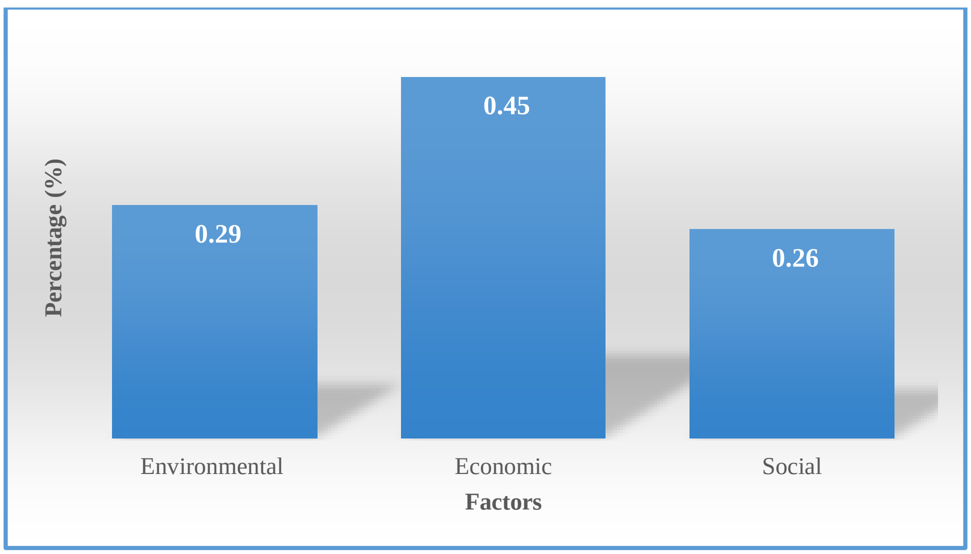

Figure 6.2: Weights for major indicators of land suitability analysis

6.5.1 Environmental Factors

At the workshop, the participants scored soil capability as the most critical environmental factor (figure 6.3). The participants explained that apart from the adverse environmental impact that may result from locating a new agricultural scheme on wetlands, it is hugely costly for farmers to utilize such lands for agricultural purposes. As such, they placed a high ranking on this criterion. They also noted that the use of pesticides and other chemicals for farming might pollute the country's groundwater resources and therefore avoid utilizing lands where the hydrogeological risk is high. As such, they ranked this criterion highly. Flood risk and soil erosion were environmental factors that attracted the lowest weights.

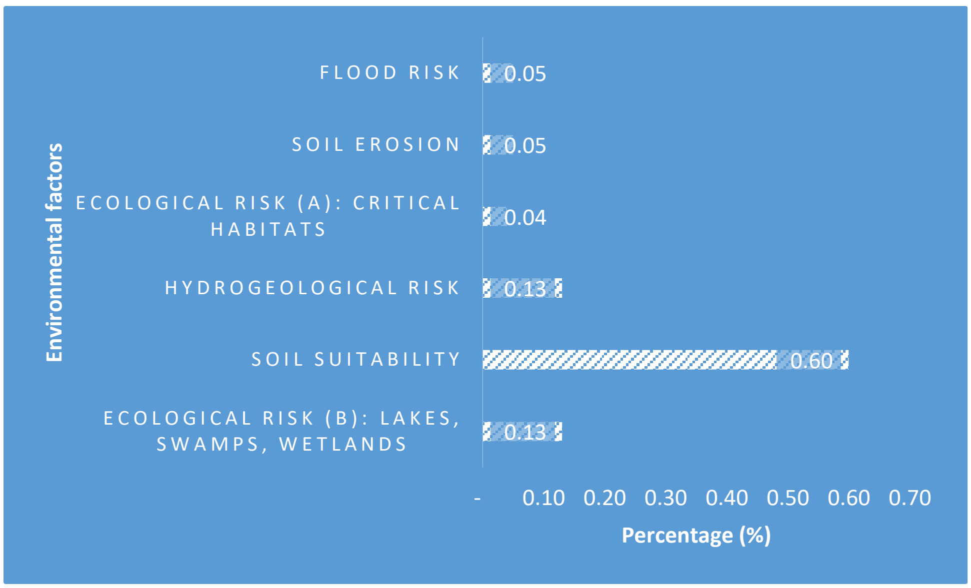

Figure 6.3: Relative weights of environmental factors

6.5.2 Economic Factors

The participants of the workshop ranked the acquisition cost of lands above infrastructure cost (figure 6.4). They indicated that persons who benefit from lands distributed by the government for agricultural purposes are responsible for developing infrastructure. As such, the cost of acquiring lands by the government is treated with greater importance.

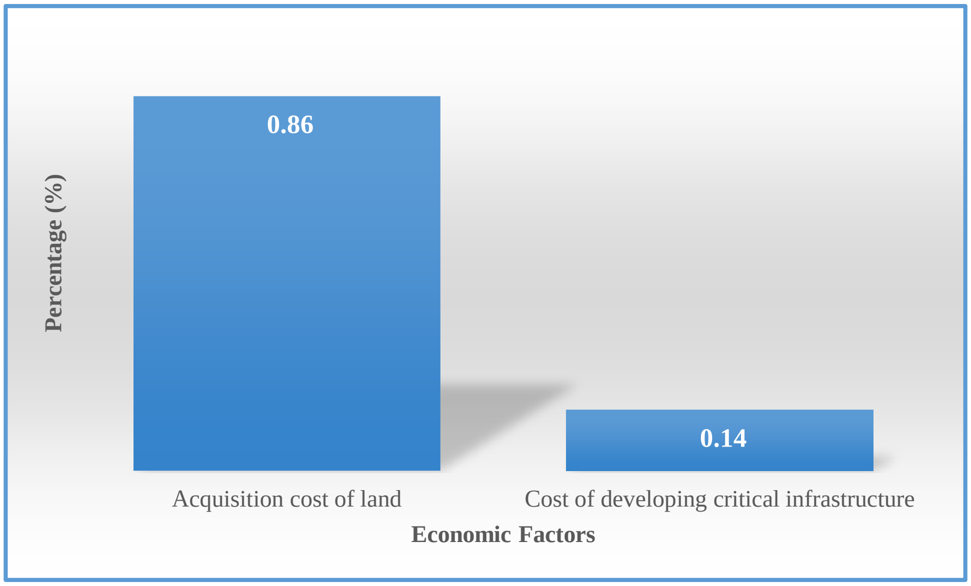

Figure 6.4: Relative weights of economic criteria

Concerning physical infrastructure (figure 6.5) road networks, drainage, and irrigation systems were ranked equally since they cost approximately the same to develop. Moreover, the Ministry of Agriculture and the Guyana Lands and Surveys Commission do not take on the responsibility of improving this physical infrastructure but transfer the same to farmers who are allotted agricultural lands.

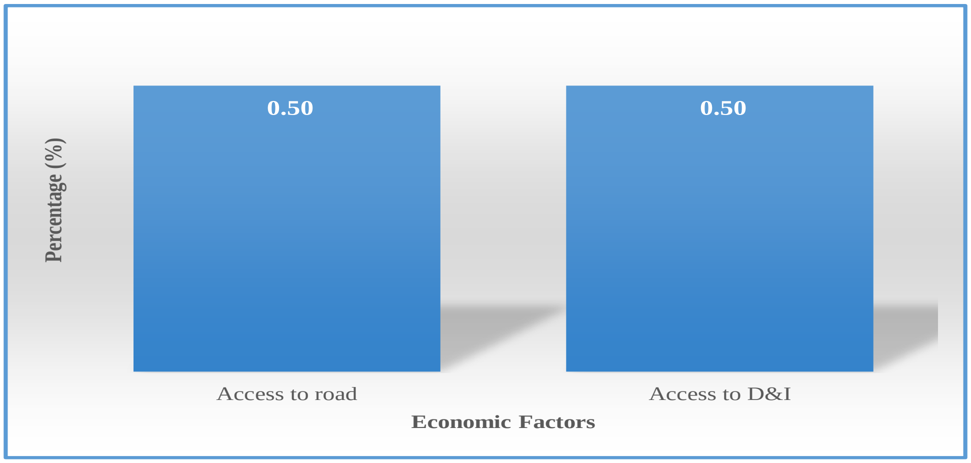

Figure 6.5: Relative weights of physical infrastructure

6.5.3 Social Factors

The participants of the workshop ranked the adequacy of all the social facilities equally since they are all equally important for maintaining the wellbeing of potential farming communities. Additionally, the various social facilities are similarly costly to construct, and the Government is usually responsible for building the same (figure 6.6).

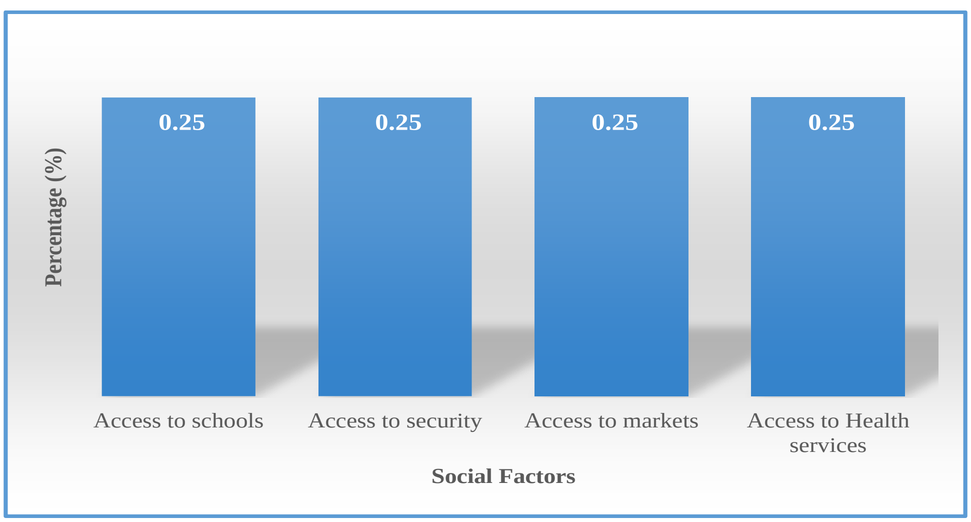

Figure 6.6: Relative weights of social infrastructure criteria

6.6 Cartographic Modelling

This case study employs Spatial Analytical Hierarchy Process (SAHP) to identify the most suitable land parcels for agricultural land use. The evaluation process was informed by the existing literature, as well as local policies, regulations and the views of experts at the Ministry of Agriculture and the Guyana Lands and Surveys Commission. The evaluation technique combines Multi-Criteria Decision Analysis (MCDA) and GIS-based overlay analysis.

It is envisaged that the most suitable land parcels would facilitate sustainable agricultural activities. Consequently, the area selected is expected to maximize the economic gains from farming while simultaneously protecting the environment and improving the social well-being of the country’s citizens. These competing objectives will only be achieved if a particular land parcel satisfies all the suitability criteria.

The exercise is based on the weighted parameters (map layers) that consider the various suitability criteria. The general form of the suitability model is represented by equations 5.1, 5.2 and 5.3 presented in chapter 5.

Restriction Modelling involves the creation of a restriction Boolean raster using equation 5.4 and 5.5. The cartographic model presented in figure 6.7 provides a schematic representation of the Restriction Model. The resulting raster model map consists of zeros and ones; where zeros (0s) represent restricted or unsuitable cells and ones (1s) represent viable or suitable cells.

Agriculture Suitability Model involves creating a suitability raster using the weights from the pairwise comparison and five-point classification scale ranging from one to five; where one represents least suitable areas and five most suitable areas. This was performed using the cartographic model presented in figure 6.8.

The most suitable agricultural lands were identified by combining the results of the first two models (figures 6.7 and 6.8). Figure 6.9 provides the final version of the housing suitability model. All the models are developed in ArcGIS version 10.

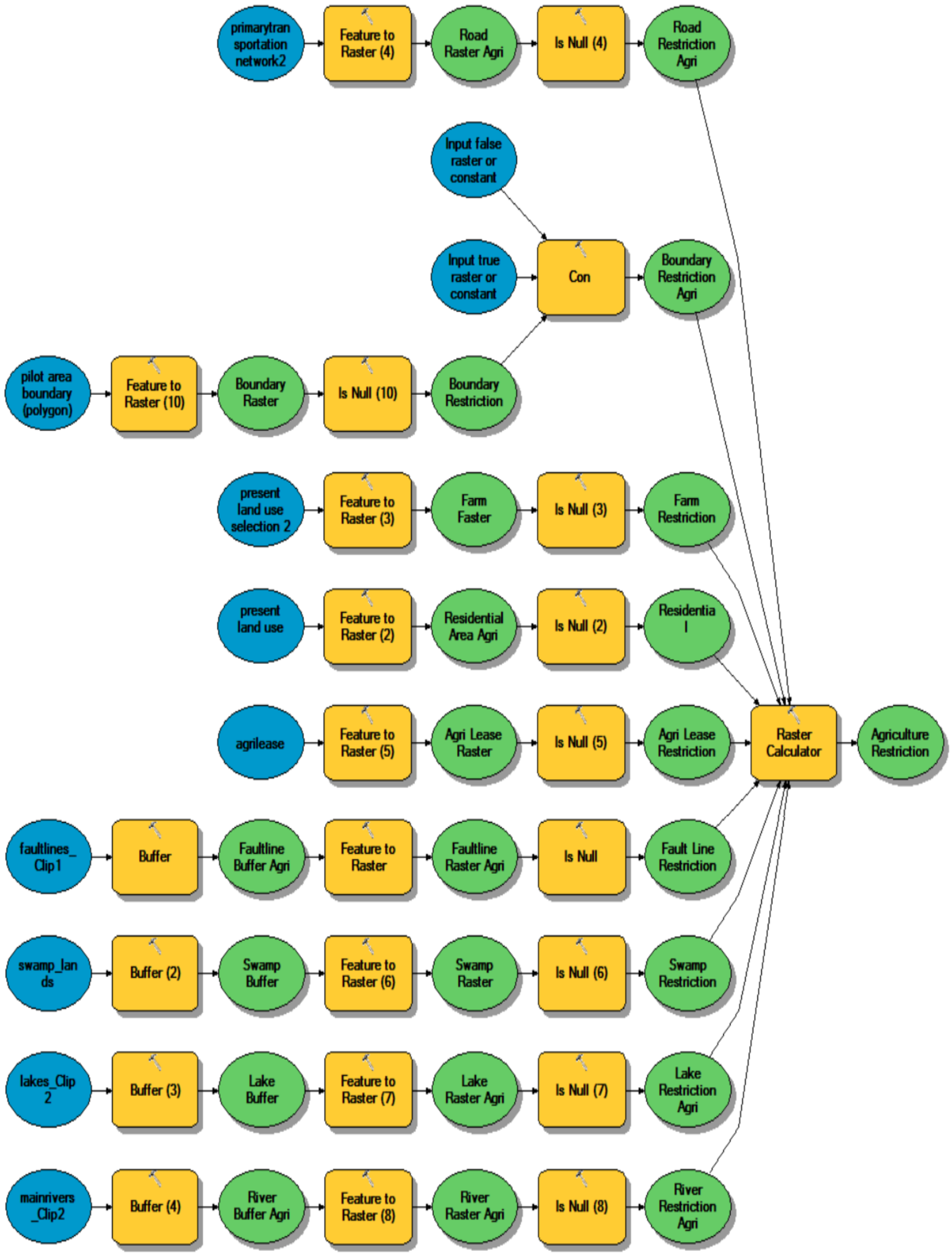

Figure 6.7: Cartographic model of the agriculture restriction criteria

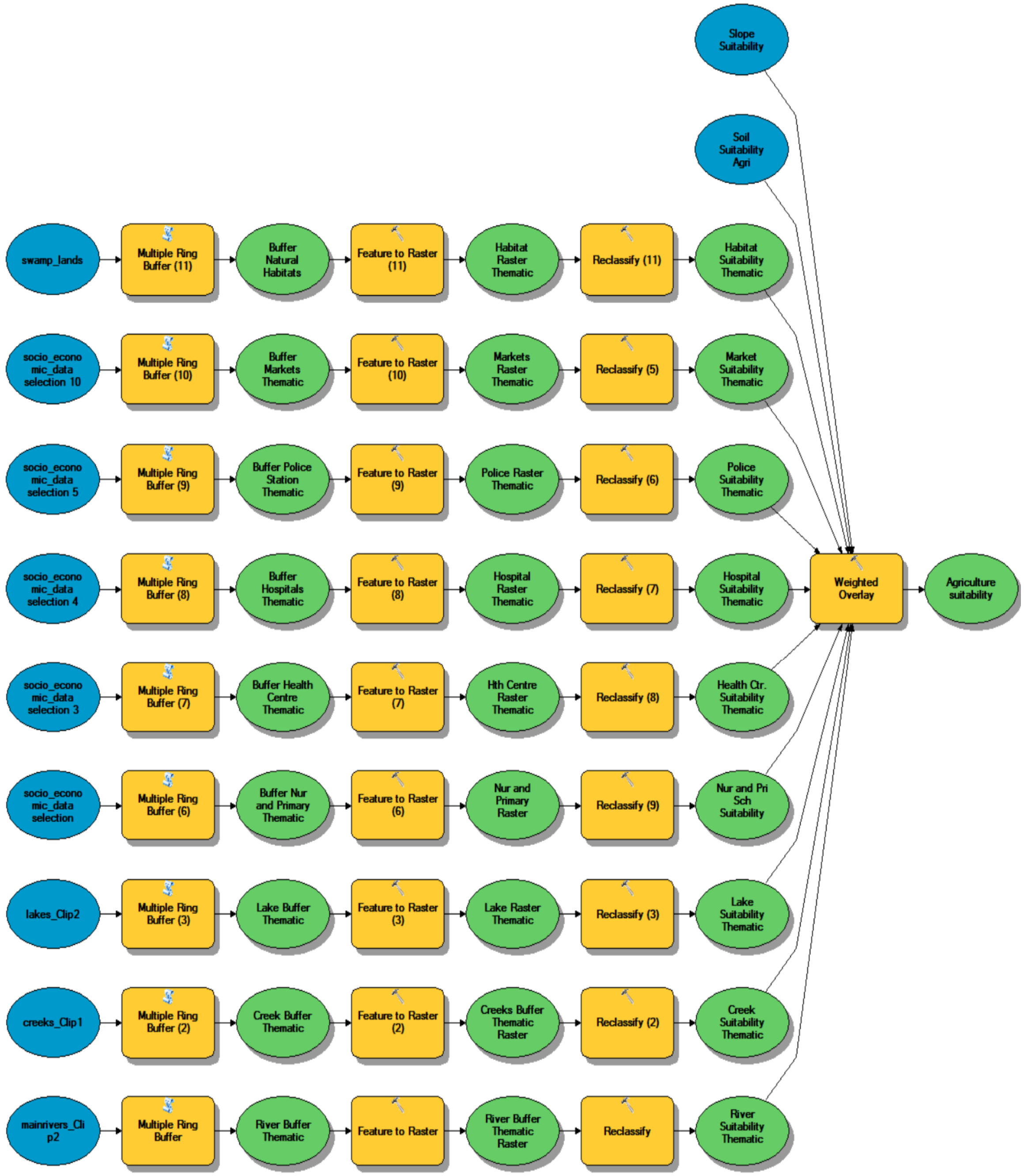

Figure 6.8: Cartographic model for the agriculture suitability analysis

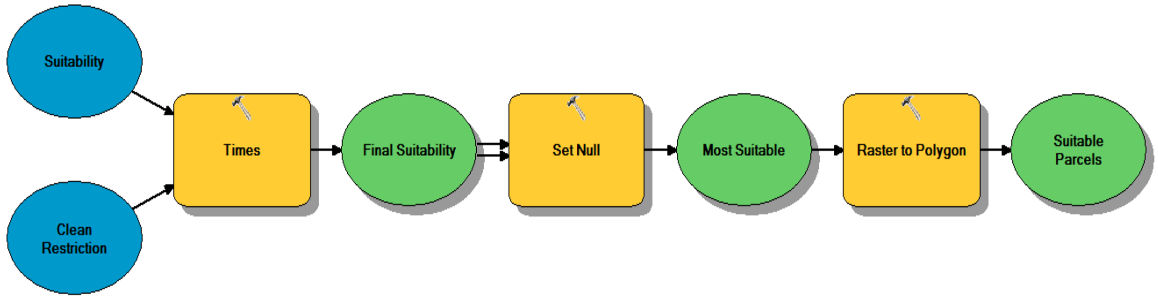

Figure 6.9: Cartographic model for the most agriculture suitability analysis

6.7 Preparation of Thematic Input Maps Layers and GIS Analysis

The input thematic data layers required for the suitability analysis were acquired from the relevant State agencies. These data were evaluated for accuracy and consistency before being used in ArcGIS model builder.

Most of the input GIS layers prepared for the housing suitability model were found relevant and reusable for the agriculture suitability model. Soils suitability layer was developed specially for this agricultural suitability modelling.

6.8 Results and Conclusion

The suitability and restrictions maps generated using the input data layers and presented below.

6.8.1 Suitability Based on Soil Type

There are six soil types in the study area that were placed into three broad land capability classifications: Class I-II, Class III, and Class IV (figure 4.29 in chapter 4). The land capability groupings take into consideration soil fertility and limitations such as soil toxicity, physical limitations (drainage) and excess soluble salts. Figure 6.10 below shows the suitability of various land parcels based on the land capability criteria. Only 12.5 percent of the study area is considered very suitable (Class I-II soil); with 29.6 percent and 57.9 percent regarded as moderately suitable (Class III soil) and not suitable (Class IV soil) respectively.

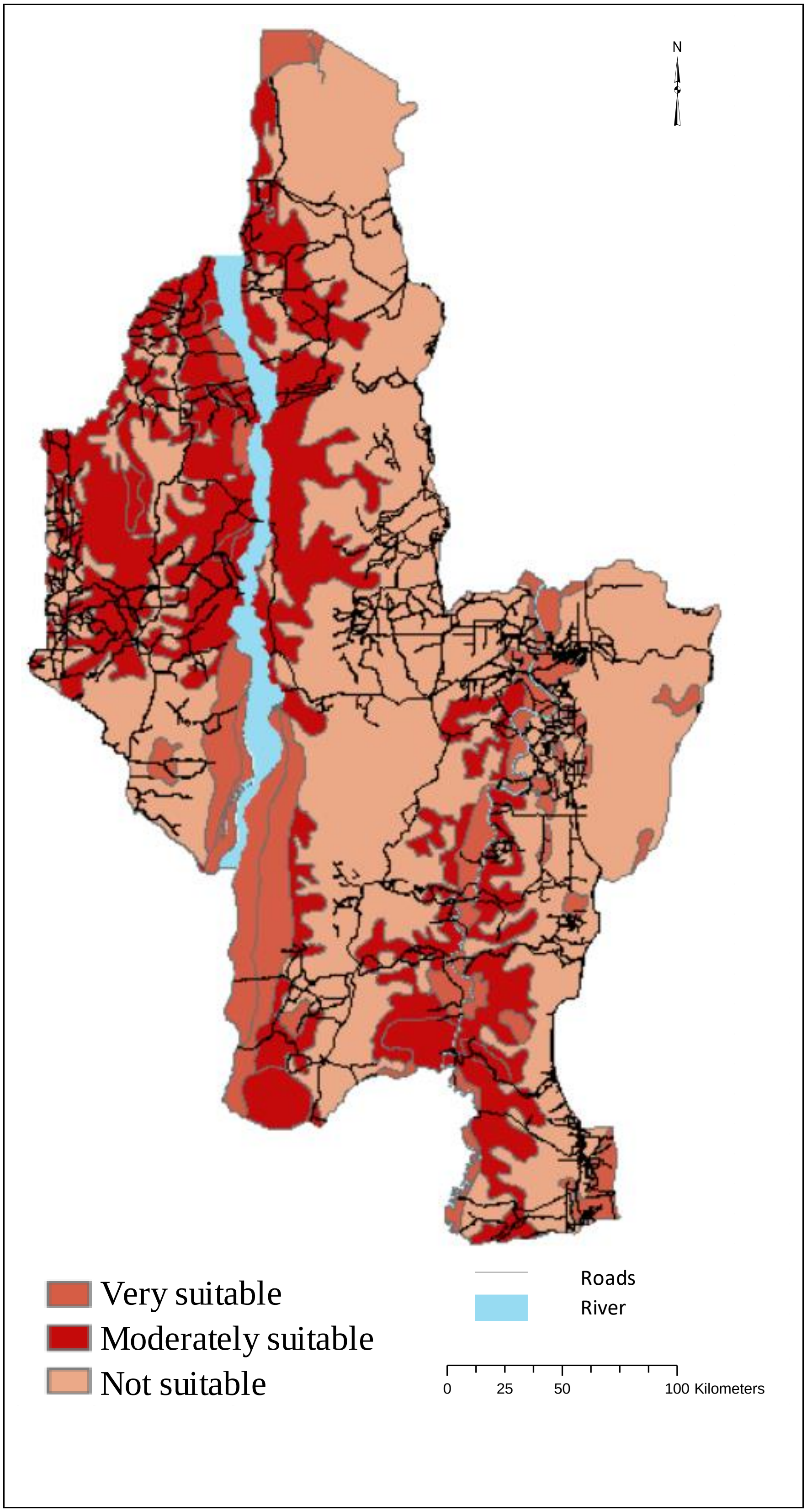

Figure 6.10: Suitability based on soil suitability

6.8.2 Suitability Based on Land Tenure

The most substantial portion (approximately seventy-three percent) of the study area is State Forest Land. The remainder of the study area comprises another agriculture lease issued by the Guyana Lands and Surveys Department and mining permits issued by the Guyana Geology and Mines Commission as well as private land already utilized for farming and residential purposes. Based on tenure arrangement we can, therefore, conclude that seventy-three percent of the study area is suitable for agriculture activities and the remaining areas restricted since they are currently occupied (figure.6.11).

6.8.3 Suitability Based on Proximity to Roads and Social Facilities

The suitability of the various land parcels in the study area based on the proximity to roads and social facilities, such as schools, health centres/hospitals, police station, and markets are presented in figures 6.12.

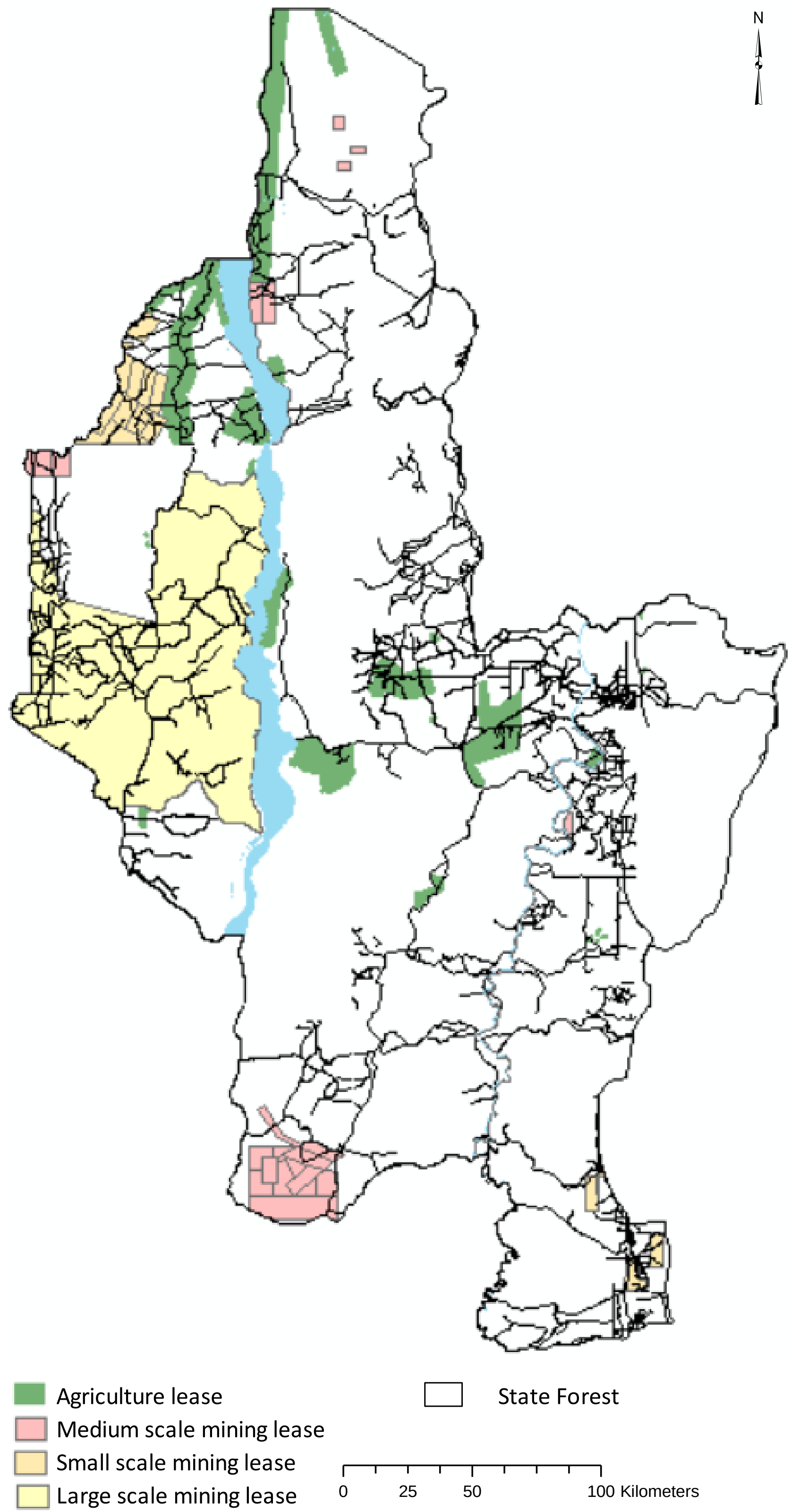

Figure 6.11: Land tenure restrictions

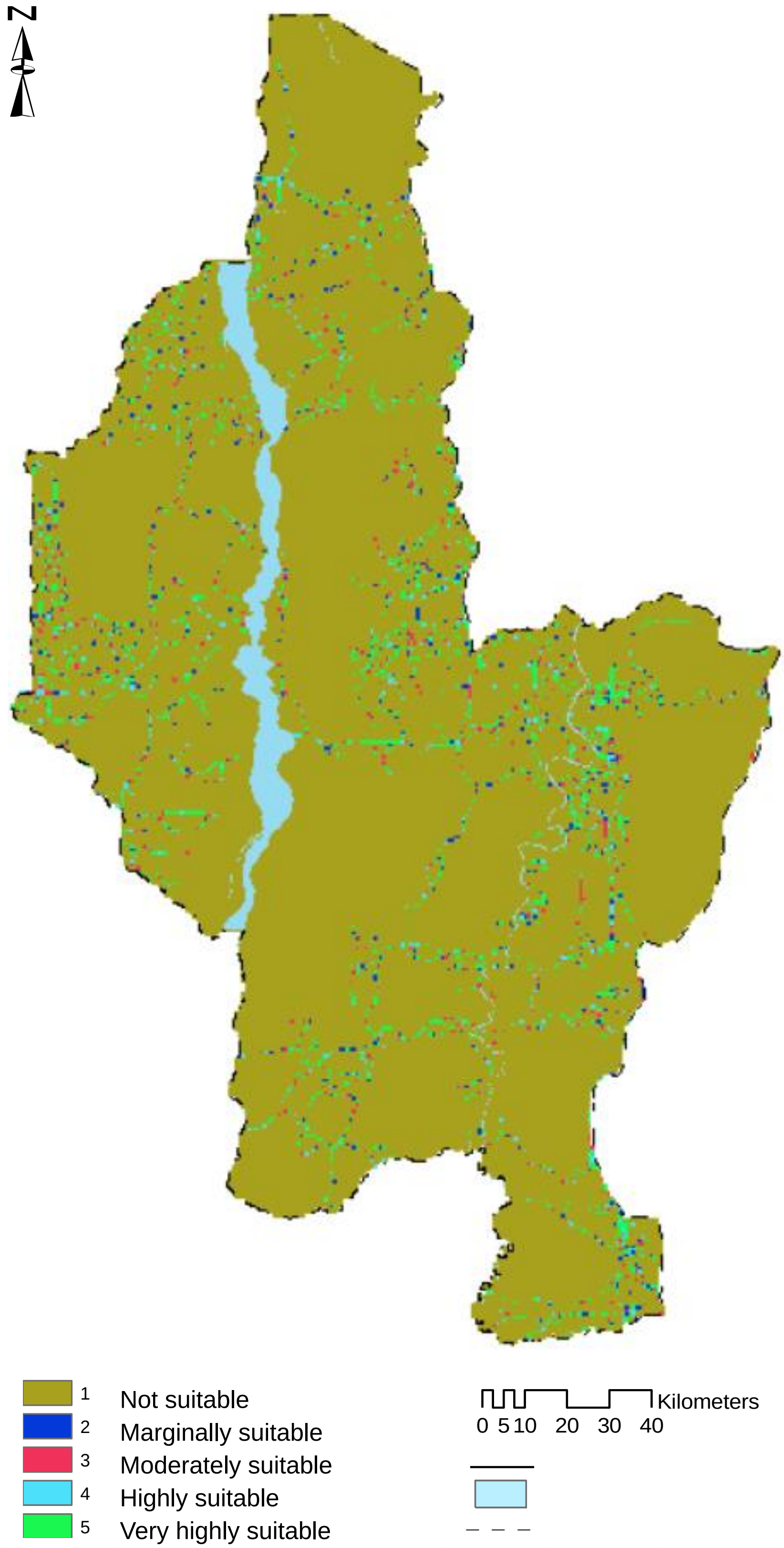

Figure 6.12: Suitability based on proximity to roads and social facilities

6.8.4 Suitability Based on Proximity to Water Bodies

Access to fresh water is an important suitability criterion for farming. The closer the land parcel is to creeks, therefore, the more suitable it would be for farming. However, farming is less suitable when it is within close proximity to rivers which can harm most crops grown locally or lakes that can be polluted with pesticides and herbicides. Figures 6.13 shows the suitability of the study area based on proximity to water bodies.

6.8.5 Suitability Based on Slope

Figure 4.31 in chapter 4 showed the elevation of the study area. It is noteworthy that more than ninety percent of the total planning area has a slope that falls within the acceptable level of 0-15 degrees. The suitability of the study area for agriculture activities, based on this criterion, is presented in figure 6.14.

6.8.6 Restrictions

Figure 6.15 shows the maps with all the restrictions combined (that is, wetlands, cultural sites, creeks, rivers, lakes, roads, occupied areas, and slope). Based on this figure agricultural activities are restricted in the areas shaded in white and permissible in the areas shaded in green. The restrictions to agricultural activities are based on wetlands, cultural sites, water bodies (creeks, rivers, lakes), roads (major and minor), occupied areas and slope.

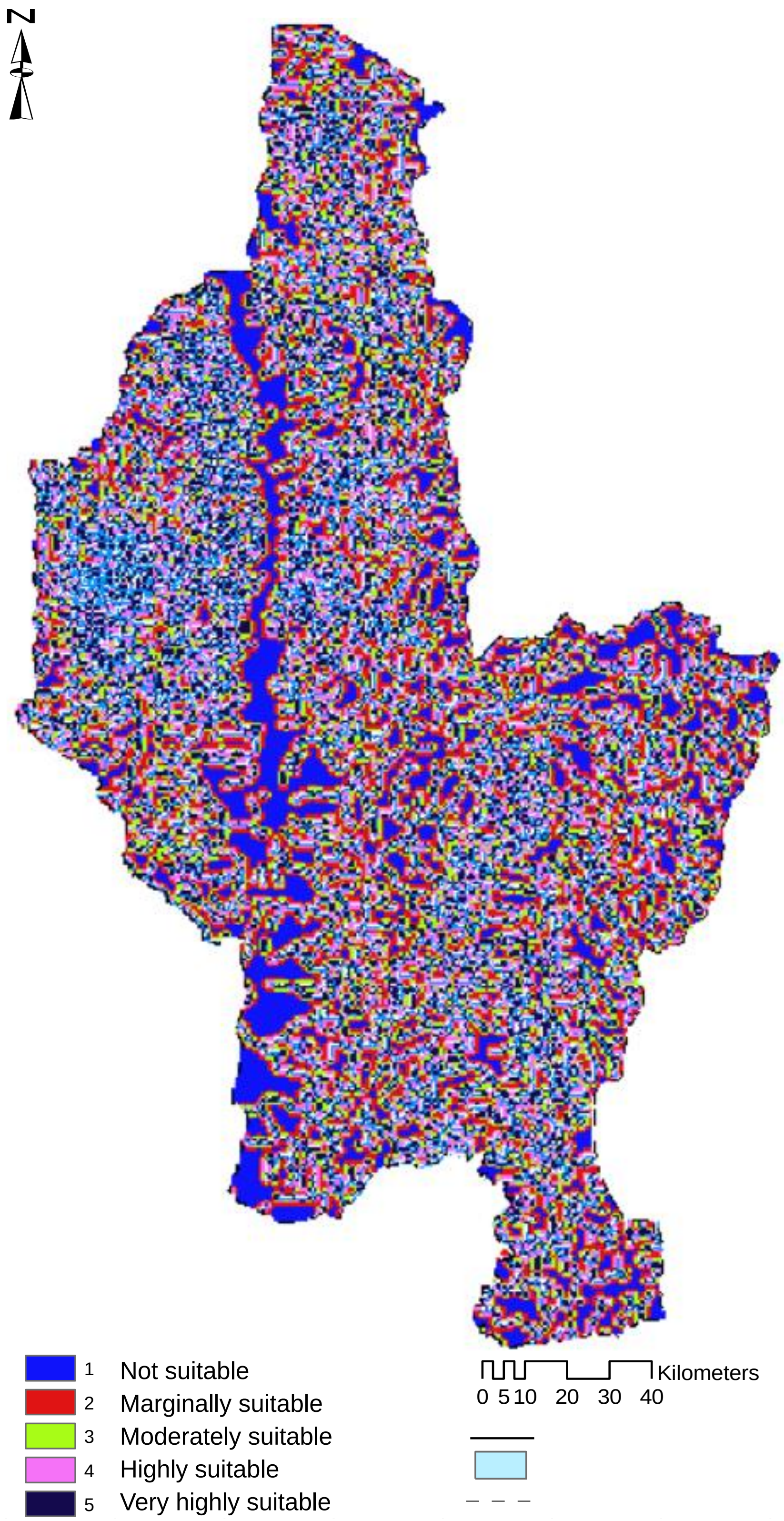

Figure 6.13: Restrictions to water bodies

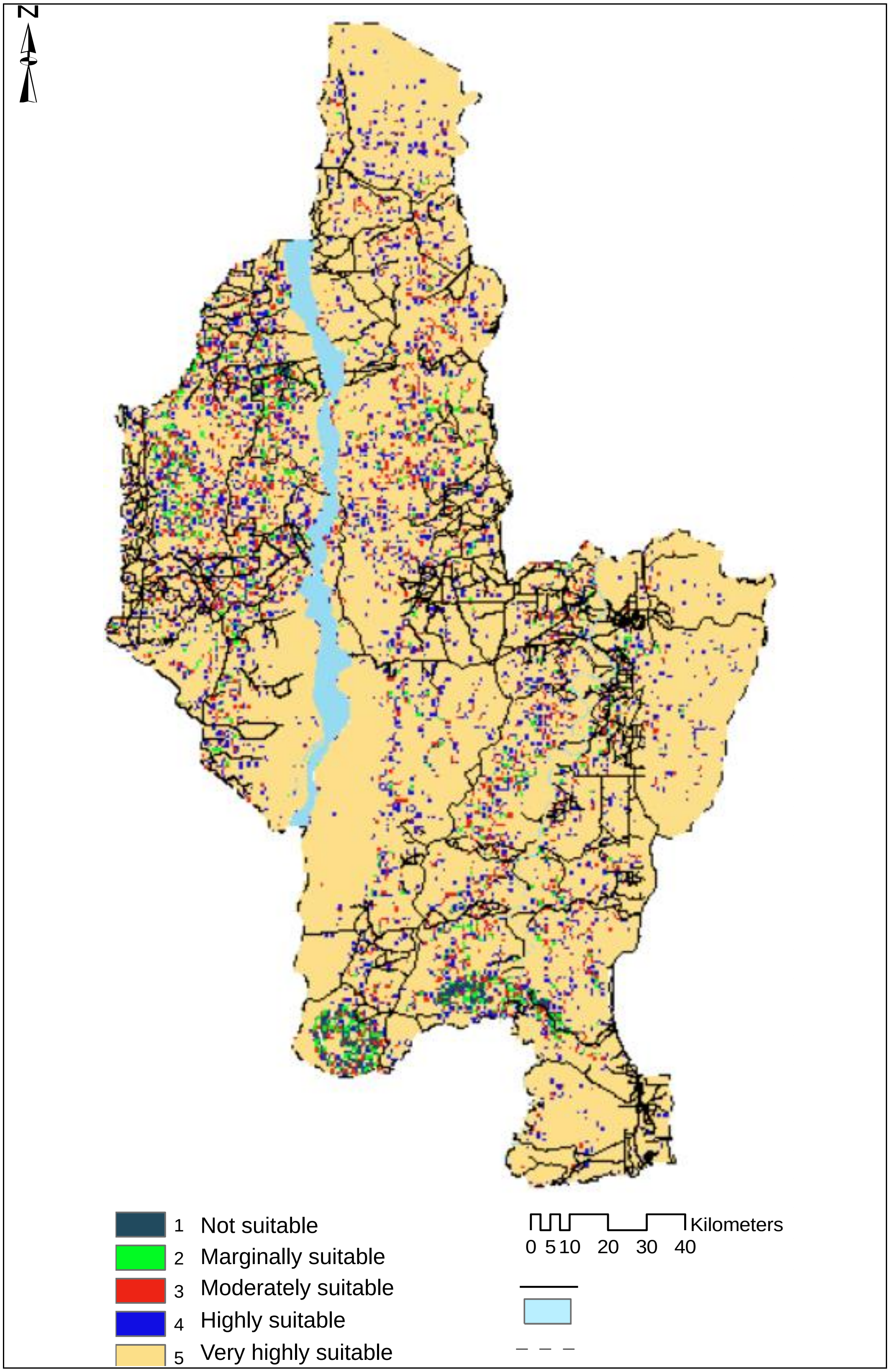

Figure 6.14: Slope suitability restrictions

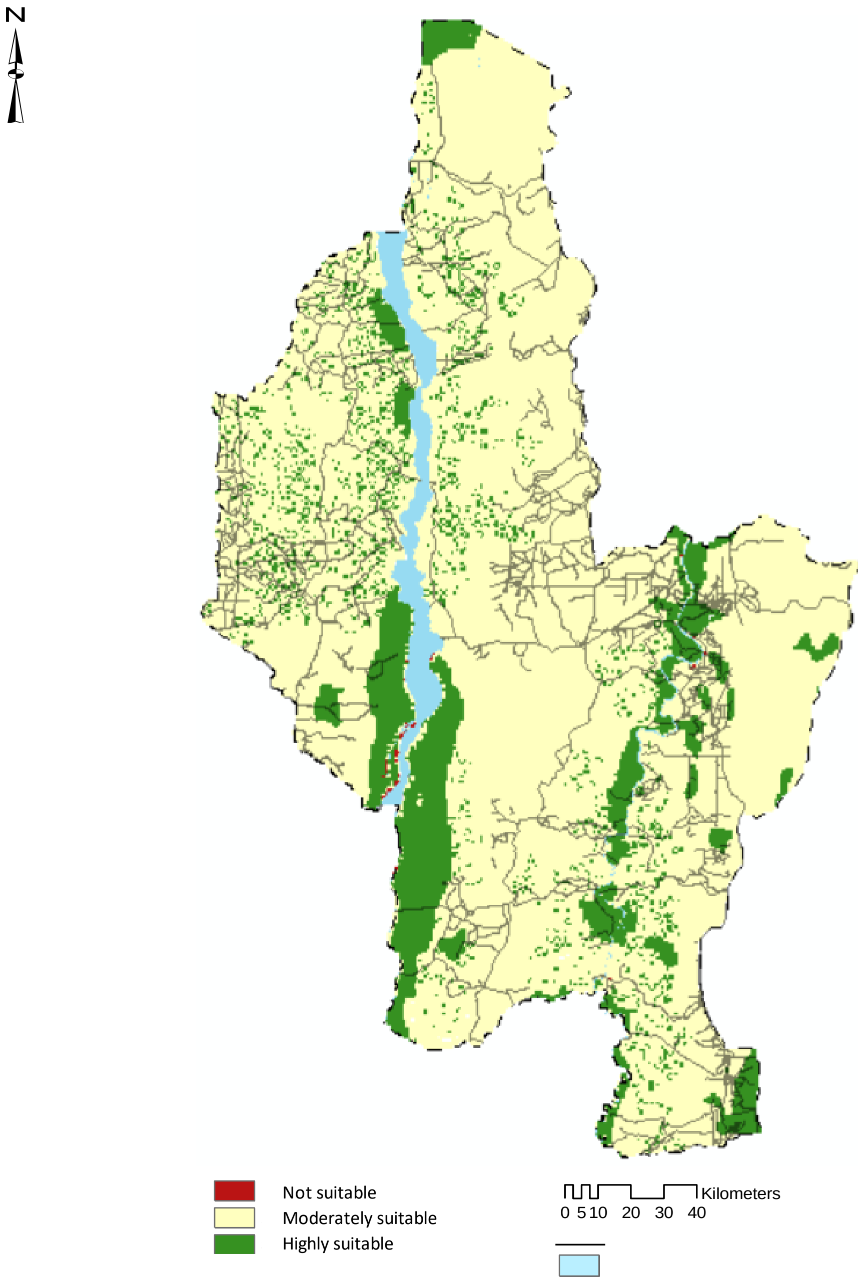

Figure 6.15: Suitability map without restrictions

6.9 Results

The suitability of the study area for agricultural activities, based on all the factors considered, is presented in figure 6.16. The areas shaded in green are very highly suitable for agricultural activities, while those in yellow and red are moderately suitable and not suitable respectively. When combined with the various restrictions also considered in this chapter, the final suitability for this type of economic activity is presented below.

The analysis identifies several land parcels with different suitability and potential for sustainable agricultural activities. The land parcels which are suitable conform with the suitability factors and constraints to varying degrees.

Highly suitable: Based on the results there are 178 land parcels which are scattered across the study area and very suitable for farming. These land parcels contain soil which is placed in land capability class I-II (good to moderate agricultural lands) and subject to minimal restrictions. The land parcels are relatively flat and within the prescribed proximity to surface water, roads, and markets. The total area occupied by these land parcels amounted to 515.8 square kilometres (or approximately 10.7 percent of the study area).

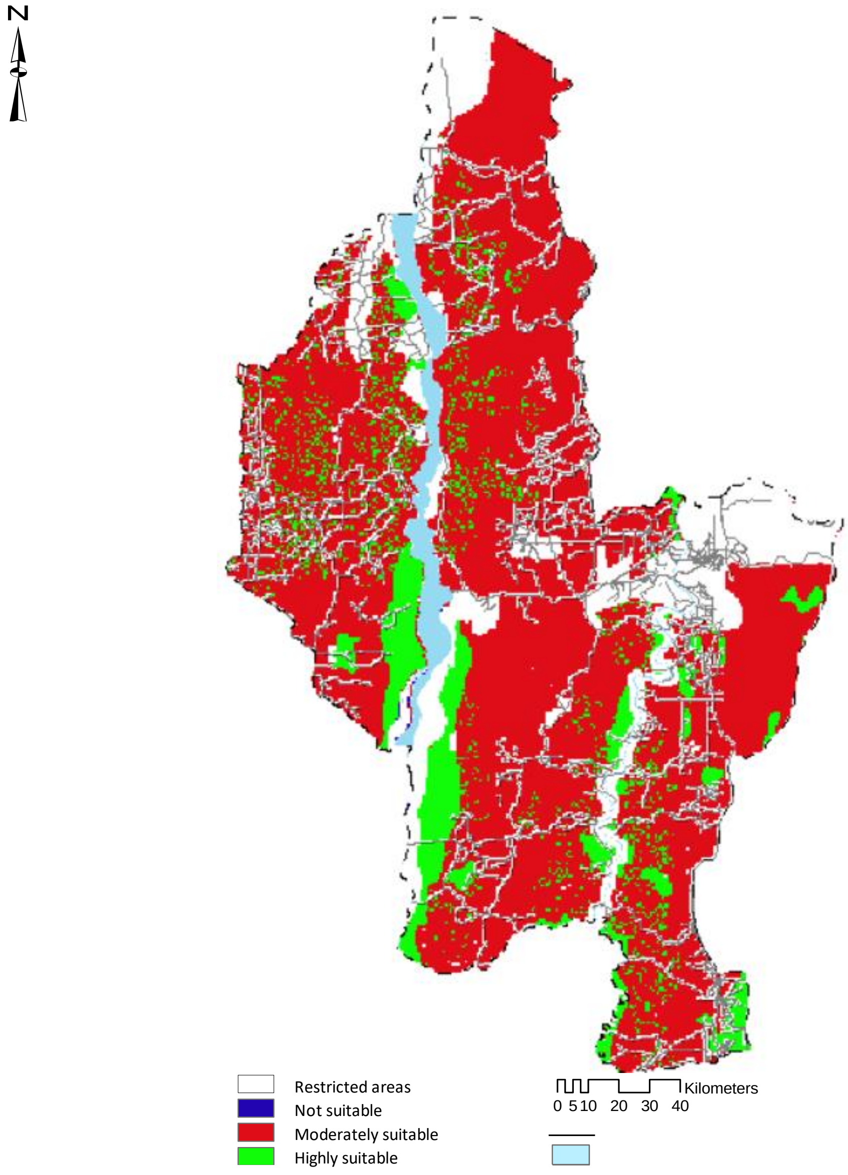

Figure 6.16: Final suitability

Moderately suitable: Approximately 1,511 land parcels which occupy 2,889.83 square kilometres (or 59.8 percent of the study area) are moderately suitable for agriculture. These land parcels are distributed across the study area and fall within the land capability class III (poor agricultural lands) which contain lands with severe restrictions and low fertility. The proximity of the land parcels surface water, roads and markets also render them moderately suitable.

Not suitable: The results reveal that the study area is dominated by lands which are not ideal for agriculture activities. Approximately 790 land parcels which occupy 2.33 square kilometres and accounts for less than one percent of the study area are not suitable for agricultural activities because they fall in the land capability class IV which has low fertility and severe restrictions. Moreover, these land parcels are not close to markets, roads and surface water.

6.10 Summary and Conclusion

The agriculture sector is one of the most important economic sectors in Guyana as it employs a significant portion of the labour force and accounts for more than fifty percent of total export earnings. As a consequence, the sector has always been at the centre of all of the major development strategies. This analysis aims to identify suitable land parcels for agricultural development using SAHP/MCDA technique which incorporates GIS. The model utilized eleven criteria agreed to by the stakeholders. The criteria were grouped into three broad categories, namely environmental, economic and social. The various criteria were ranked concerning their relative importance regarding agricultural suitability by key experts/specialists at the Ministry of Agriculture and Water using the pairwise comparison technique developed by Saaty (1980). Based on this exercise, the economic factors were given the highest weights, followed by the environmental factors and social factors.

The result reveals that there is only one land parcel that is very highly suitable for agricultural activities in the study area. Approximately 178 land parcels (or 9.8 percent of the study area) highly suitable for agricultural activities, while Approximately 1,511 land parcels which occupy (2,827.5 square kilometres or 25.4 percent of the study area) and 790 land parcels (which accounts for 46.8 or occupies 5214.6 square kilometres) are moderately suitable and not suitable respectively.

The land parcels which are moderately suitable or not suitable for agricultural activities are contiguous to those that are highly suitable for agricultural activities. These land parcels may, therefore, be used for housing schemes, agro-processing plants or even none traditional activities such as poultry rearing which can provide farmers with manure. The latter would allow farmers access to manure that could substitute for costly imported fertilizer.

CHAPTER 7: APPLICATION OF THE SAHP TO MINING SUITABILITY ANALYSIS

7.1 Problem Definition

The importance of harnessing the country's mineral resources sustainably is a central theme underlying various development paradigms pursued by the Government over the last three decades. Specifically, the different development paradigms require that mining activities be undertaken in an ecologically and socially friendly manner, while simultaneously optimizing the economic returns from all the activities that involve mineral extraction. Achieving these objectives simultaneously is often difficult since they are mutually exclusive or compete with each other. For instance, to optimize the economic gains from mineral extraction, some of the environmental and social considerations may have to be sacrificed, as mineral extraction may have to be undertaken in areas with significant social and ecological values. Unfortunately, there is evidence that the economic considerations supersede social and environmental concerns. A recent study by the Harvard Law School (2007), for instance, showed that Amerindian communities were adversely affected by uncontrolled small-scale and large-scale mining activities on their ancestral lands.

7.2 Objective of the Mining Suitability Model

The primary objective is to apply the Spatial Analytic Hierarchy Process (SAHP) to identify land parcels with the best potential for sustainable mining activities. The ultimate goal is to select land parcels that would serve to maximise the economic gains (or increase the scale of mining) from this type of economic activity while simultaneously protecting the environment and promoting the wellbeing of the citizens. To achieve this objective, the land parcel would have to satisfy the following criteria:

i. it should be rich with minerals (gold, diamond, bauxite);
ii. it should be easily accessible; and
iii. it should be fall within a mining district

Further, the land parcels identified would be subject to the following constraints:

i. it should be unoccupied
ii. not more suitable for other types of socio-economic activities, such as agriculture, logging, housing
iii. it should not be ideal for providing eco-services
iv. it should not be situated on a sensitive hydrogeological area
v. it should not be located close to sensitive water bodies

Further, the land parcel identified should conform to the constraints that are important for sustainable mining by the stakeholders.

The general methodology and specific evaluation procedure developed in chapter 5 (sections 5.3 and 5.4) and presented in figure 5.1 will be followed in this application.

7.3 Suitability Selection Criteria

There is extensive literature that employs Multi-Criteria Decision Analysis (MCDA) to evaluate the suitability of land for various purposes, including agricultural activities, mining, forestry, locating landfill sites, etc. (see for instance Malczewski and Ogryczak 1996). The literature, however, is deficient since it provides limited attention to land suitability examples and applications related to mining and quarrying activities. Based on the survey of the literature, Dey and Ramcharran (2008) is the only study which utilized MCDA to examine the suitability of mining activities in Barbados. In this study, the authors considered three alternative sites to support cement production in Barbados. Dey and Ramcharran (2008) utilize an extensive menu of suitability factors; grouped into four broad categories, namely: technical factors, environmental factors, social factors, and a national planning framework.

These criteria are further broken down as follows:

i. *Technical factors* are subdivided into resource availability (material quality, material quantity, and extraction permit), physical characteristics (land slippage, good drainage, a safe distance from potable water zone, impact on hydrology, distance from water table), economic factors (transportation costs, infrastructure cost, and potential risk);

ii. *Environmental factors* are subdivided into biological/ecological factors (encroachment on terrestrial flora and fauna, no encroachment on marine flora and fauna);

iii. *Social factors* (adequate roads and other infrastructure, other sensitive land use, the effect on heritage or conservation area, proximity to existing operations, visual intrusion);

iv. *National planning framework* (national policy, physical development, economic policy).

Given the paucity of research, several local experts were consulted to determine the criteria appropriate for land suitability analysis in the mining sector in Guyana. The experts noted that the Guyana Geology and Mines Commission (GGMC), the agency responsible for identifying and allocating lands for mining under the Mining Act 1989 (No. 20 of 1989), does not perform suitability analysis when assigning land parcels for mining. According to the experts, mining activities are only permissible when undertaken in areas covered by mining permits/licences. Thus, the most crucial criterion considered is the legal authority utilized by miners to extract minerals. The experts also noted that the Mining (Amendment) Regulations 2005 (No. 3 of 2005) prescribes two broad environmental restrictions which all miners are mandated to observe.

In this application, the criteria from the literature were combined with those recommended by the Mining (Amendment) Regulations 2005 (No. 3 of 2005) and local experts. Similar to the other applications, the criteria were placed into three major categories, namely environmental, economic and social factors. Below is a description for each criterion. The rationale and ranking of each criterion is also provided in the discussion which follows. It is noteworthy that the classification and ranking schemes used for this application were based on the guidelines in local regulations, as well as advice from experts since the literature was silent concerning these issues.

7.3.1 Environmental Criteria

Environmental criteria refer to those considerations which are regarded as essential for protecting the environment. The Mining (Amendment) Regulations 2005 (No. 3 of 2005) specifies two broad categories of environmental criteria. These are protected areas, and buffer zones.

The Regulations restrict mining operation in protected areas, defined as:

i. all lands within twenty metres of the low water mark of a river or navigable creek;
ii. specified nature reserves and parks;
i. any area up to thirty metres from and along a public road;
ii. any area up to one hundred metres from approved residences or any business or industrial development;

iii. a one-kilometre wide strip ground all around approved nature reserve or parks such as Kaieteur National Park and Iwokrama Rainforest Reserve area; and

iv. land on both sides of a river or navigable creek that is within twenty metres of the low water mark of each river or creek bank along the whole river.

Except for the proximity to human settlements, the 'buffer zones' are intended to:

i. reduce the risk of polluting the country's watercourses by minimizing disturbances to watercourse channels and riparian zones, as well as reducing soil disturbances within and near watercourses;

ii. protect areas with significant ecological value; and

iii. safeguard the country's road infrastructure.

Ecological Risks

This mandatory criterion restricts mining activities in areas with significant ecological and/or recreational value. These include approved nature reserves and parks such as Kaieteur Park and Iwokrama Rainforest Reserve area. A five-point rating scale is employed to determine the suitability of an area (or land parcel), based on its proximity to nature reserves and parks as shown in table 7.1.

Road Infrastructure Risk

This mandatory restriction requires that mineral extraction be undertaken within prescribed distances from public roads to protect this essential physical infrastructure. A five point rating scale is used for this criterion as shown in table 7.1.

Pollution of Water Bodies

This non-mandatory criterion was recommended by the experts consulted. Dey and Ramcharran (2008) also employed a similar criterion which restricts mining activities in areas prone to erosion and slippages. The local experts suggested that land surface with slopes greater than twenty-two degrees (or forty percent) are prone to land degradation and landslides, caused by increased erosion and pressure (or the disruption) of natural vegetation respectively. These environmental risks are notably higher when the soil is loose. In this study, a five-point rating scale as shown in table 7.1.

Soil Erosion

This non-mandatory criterion was recommended by the experts consulted. Dey and Ramcharran (2008) also employed a similar criterion which restricts mining activities in areas prone to erosion and slippages. The local experts suggested that land surface with slopes greater than twenty-two degrees (or forty percent) are prone to land degradation and landslides, caused by increased erosion and pressure (or the disruption) of natural vegetation respectively. These environmental risks are notably higher when the soil is loose. In this study, a five-point rating scale as shown in table 7.1.

Other Ecological Risks

This is a non-mandatory criterion recommended by the local experts. It is also similar to the biological factors employed in Dey and Ramcharran (2008), which suggested that mining activities are not undertaken in areas which encroached on terrestrial flora and fauna and marine flora and fauna. In this application, mining activities are restricted from lakes, swamps, and wetlands. This constraint is intended to protect wildlife habitats, as well as sustain aquatic diversity and its relationship to surrounding natural areas through nutrient retention and productivity exportation among other things. In the application, an area is assigned a score between one and five based on its proximity to lakes, swamps, and wetlands as shown in table 7.1.

Hydrogeological Risk

This non-mandatory environmental criterion was employed by Dey and Ramcharran (2008) and recommended by the local experts. Dey and Ramcharran (2008) suggested that mining activities be undertaken in areas where the impact on underground hydrology is negligible. In our application, this criterion restricts the establishment of mining activities in areas that are regarded as sensitive hydrogeological environments defined as: gravel pits excavated into or above a water table aquifer, areas underlain by a sole source aquifer or other sensitive aquifers, and designated wellhead protection area. This requirement is intended to reduce groundwater pollution risk and is assigned a score between one and five as shown in table 7.1.

Deforestation

The stakeholders indicated that there are five broad land cover classes employed to classify land uses in Guyana: abandoned land, pastureland, cropped land, land occupied by natural vegetation, and forest. The most suitable parcels for new mining developments are those which fall under the classification of with minimal vegetation. A five-point rating scale was employed to determine the suitability of an area based on this criterion as shown in table 7.1.

Summary

A summary of the environmental factors, the classification scheme adopted, and the ranking value agree to at the workshop is presented in table 7.1 below.

Table 7.1: Summary of environmental criteria, classification scheme and ranking scheme

Mining Suitability Factors	Basis for consideration	Classification schemes	Basis for classification scheme	Ranking Scheme	Ranked Values
Ecological risk (proximity to approved nature reserves and parks in kilometres)	Mining (Amendment) Regulations 2005	<1*	Mining regulations and expert advice	Not suitable	1
		1 – 2		Marginally suitable	2
		2 – 3		Moderately suitable	3
		3 – 4		Highly suitable	4
		>4		Very highly suitable	5

Table 7.1 (continued)

Mining Suitability Factors	Basis for consideration	Classification schemes	Basis for classification scheme	Ranking Scheme	Ranked Values
Road infrastructure risk (proximity to roads in metres)	Mining (Amendment) Regulations 2005	<100*	Mining regulations and expert advice	Not suitable	1
		100 – 200		Marginally suitable	2
		200 – 300		Moderately suitable	3
		300 – 400		Highly suitable	4
		>400		Very highly suitable	5
Pollution of river and creeks (proximity of rivers and creeks in metres)	Mining (Amendment) Regulations 2005	< 20*	Mining regulations and expert advice	Not suitable	1
		20 – 29		Marginally suitable	2
		30 – 39		Moderately suitable	3
		40 – 49		Highly suitable	4
		> 50		Very highly suitable	5
Soil erosion (land slope In degrees)	Dey and Ramcharan (2008) and recommended by experts	>22	Expert advice	Not suitable	1
		15-22		Marginally suitable	2
		10-15		Moderately suitable	3
		5-10		Highly suitable	4
		0-5		Very highly suitable	5
Other ecological risk (proximity to lakes, swamps and wetlands in kilometres)	Dey and Ramcharan (2008) and recommended by experts	<1	Expert advice	Not suitable	1
		1 – 2		Marginally suitable	2
		2 – 3		Moderately suitable	3
		3 – 4		Highly suitable	4
		>4		Very highly suitable	5
Hydrogeological risk (proximity to sensitive hydrogeological environments in metres)	Dey and Ramcharan (2008) and recommended by local experts	0-19	Expert advice	Not suitable	1
		20-39		Marginally suitable	2
		40-59		Moderately suitable	3
		60-79		Highly suitable	4
		> 80		Very highly suitable	5

Table 7.1 (continued)

Mining Suitability Factors	Basis for consideration	Classification schemes	Basis for classification scheme	Ranking Scheme	Ranked Values
Deforestation	Land cover as a basis for land degradation and ecological reservation	Forest	Expert advice	Not suitable	1
		Natural vegetation		Marginally suitable	2
		Cropped land		Moderately suitable	3
		Pasture		Highly suitable	4
		Abandoned land		Very highly suitable	5

* Buffer distance stipulated in the Mining (Amendment) Regulations 2005

7.3.2 Economic Factors

Economic factors are related to the economic gains from various mining activities. This, in turn, is closely linked to ‘type of operation’ permitted by the Guyana Geology and Mines Commission (GGMC) under the Mining Act 1989 (No. 20 of 1989). The type of mining activity facilitated on a particular land parcel is dependent on the lithological unit present therein. For instance, gold mining is facilitated in areas with Greenstone while bauxite extraction is facilitated in areas with Gabbro. Stone quarrying operations and sand mining are with Migmatites/Granitoid and Fluvial and Marine Sands respectively. Gold extraction is the most lucrative mining activity undertaken in Guyana. This is followed by bauxite mining and the extraction of quarry minerals (such as sand and stone). The economic gains from stone quarrying operations are generally higher than those obtainable from sand mining. Given the preceding, the type of mining activity is ranked, based on the lithological units, as shown in table 7.2.

Table 7.2: Summary of economic factors, classification scheme and ranking scheme

Mining Suitability Factors	Basis for consideration	Classification schemes	Ranking Scheme	Ranked Values
Type of mining operation (lithological units)	Expert advice	Other (marine clays and other geological units excluding fluvial and marine sands, granitoid and migmatites, gabbros and greenstone)	Not suitable	1
		Fluvial & Marine Sands	Marginally suitable	2
		Granitoid and Migmatites	Moderately suitable	3
		Gabbros	Highly suitable	4
		Greenstone	Very highly suitable	5

7.3.3 Social Factors

Social factors are related to the proximity to human settlements and areas with cultural/historical/archaeological and spiritual significance. The former seeks to minimize the social impacts on human settlements. The latter, on the other hand, is intended to preserve the historical and archaeological resources of the country.

Damage to Historical/Archaeological/Spiritual Sites

This non-mandatory criterion restricts mineral extraction in areas with significant historical or cultural values. These include historical, archaeological and spiritual sites. The primary aim of this criterion is to preserve the country’s historical and cultural heritage. A five-point rating scale is employed to determine the suitability of an area based on this criterion as shown in table 7.3.

Human Settlements

This mandatory criterion as prescribed by the Mining (Amendment) Regulations (2005) restrict mineral extraction within specified distances from human settlements to minimize the adverse health impact of mining on citizens. In essence, the further away the land parcel is from human settlements, and the higher would be its suitability for mineral extraction. In this regard, a five-point rating scale is used for determining the suitability of a land parcel for mining activities as shown in table 7.3.

Summary

A summary of the social factors, the classification scheme adopted, and the ranking value agree to at the workshop is presented in table 7.3.

Table 7.3: Summary of social factors and suitability ranking

Forest Suitability Factors	Basis for consideration	Classification schemes	Ranking Scheme	Ranked Values
Damage to heritage/archaeological/spiritual sites ((proximity to these sites in kilometres) *	Dey and Ramcharran (2008) and expert recommendation	<1	Not suitable	1
		1 – 2	Marginally suitable	2
		2 – 3	Moderately suitable	3
		3 – 4	Highly suitable	4
		>4	Very highly suitable	5
Risk to human Settlements (proximity in metres)	Mining (Amendment) Regulations 2005	<100*	Not suitable	1
		100 – 200	Marginally suitable	2
		200 – 300	Moderately suitable	3
		300 – 400	Highly suitable	4
		>400	Very highly suitable	5

* Buffer distance stipulated in the Mining (Amendment) Regulations 2005

It is noteworthy that the buffer for human settlements is a mandatory requirement in the Mining (Amendment) Regulations 2005, while the buffers to heritage or conservation areas were drawn either from the literature (see for instance Day and Ramcharran (2008) or recommended by experts. The proximities selected for the latter are similar to those used for nature reserves and parks.

7.4 Calculation Weight Criteria Using SAHP

The criteria above were utilized to construct a decision hierarchy for determining the suitability of a particular site for sustainable mining activities. The overarching goal in the hierarchy is sustainable mineral extraction or mining. This is followed by three broad sub-objectives, namely, environmental, economic and social which are broken down further into more specific criterion. A total of ten criteria were identified and used for the suitability analysis. Figure 7.1 provides the decision hierarchy model for selecting new areas for mineral extraction.

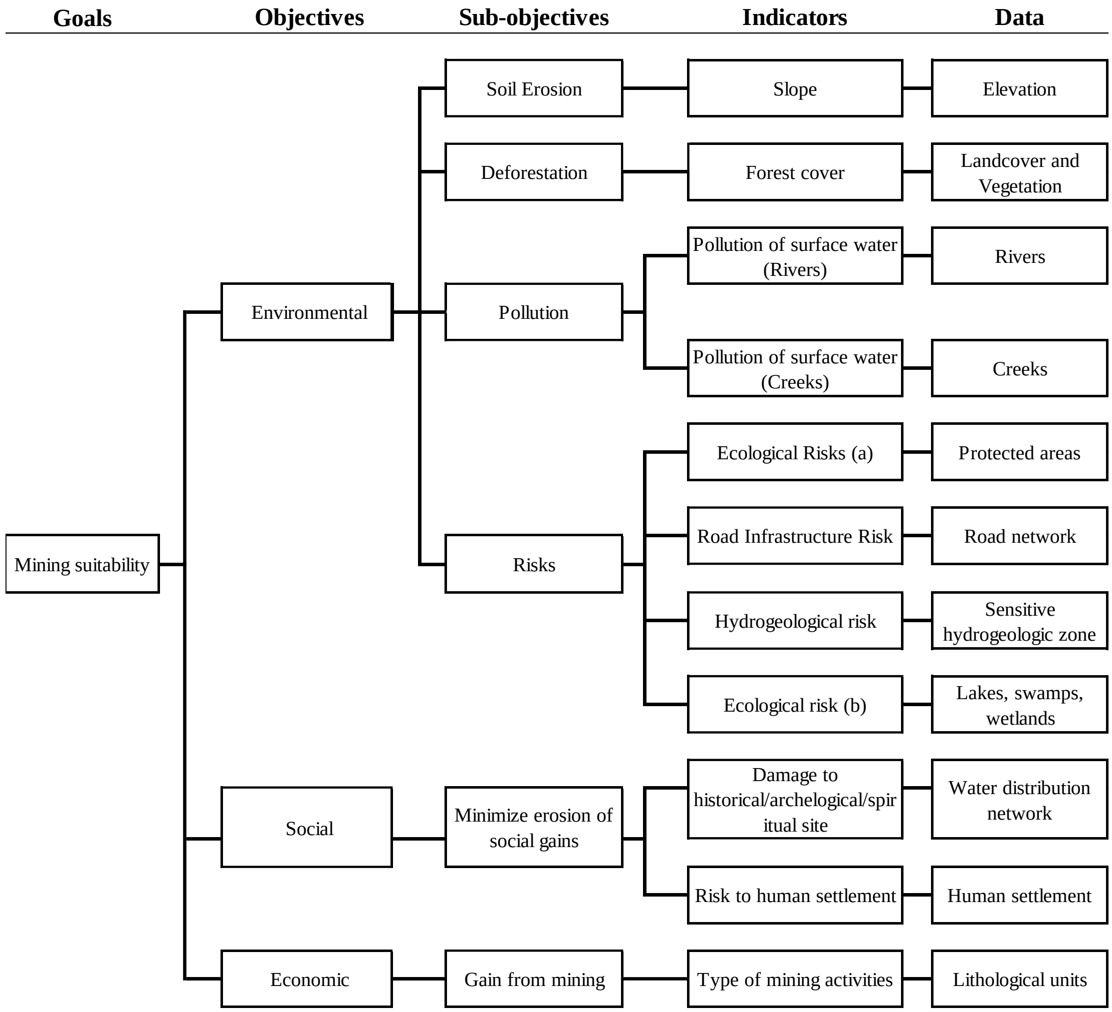

Figure 7.1: Analytic hierarchy process (AHP) mining

The relative weight of each criterion was obtained by following the pairwise comparison procedure developed by Saaty (1980). Consequently, the nine-point rating scale proposed by Saaty (1980) was utilized, with one signifying ‘equal importance’ and nine signifying ‘extreme importance.’ During this phase of the exercise, experts from the Guyana Geology and Mines Commission (GGMC) were asked to fill out a questionnaire at a formal workshop. The data from the questionnaire were inputted in a set of comparison matrices that correspond with the hierarchy in figure 7.1.

Based on the agreed factors, an MCDA/SAHP model was developed. The weights were computed by normalising the matrices and extracting the eigenvalues using equations 4.1, 4.2, and 4.3 and standardised maps were generated using the Weighted Linear Combination (WLC) model captured by equations 4.4 and 4.5 in chapter 4.

7.5 Ranking of the Criteria using Stakeholders' Consultation

The computed weights suggest that the expert regard the environmental factors as more important than the economic and social criteria. The higher ranking of environmental factors in the decision hierarchy was attributed to the emphasis placed on protecting the environment in the Mining (Amendment) Regulations 2005. Based on figure 7.2, it is also clear that economic criteria were placed above social factors for two main reasons. Firstly, the experts explained that mining activities are driven principally by economic considerations rather than social factors. Secondly, it was explained that mining activities are generally carried out in remote areas, away from human settlements and areas with significant social or ecological values. As such, economic factors are considered more important than social factors.

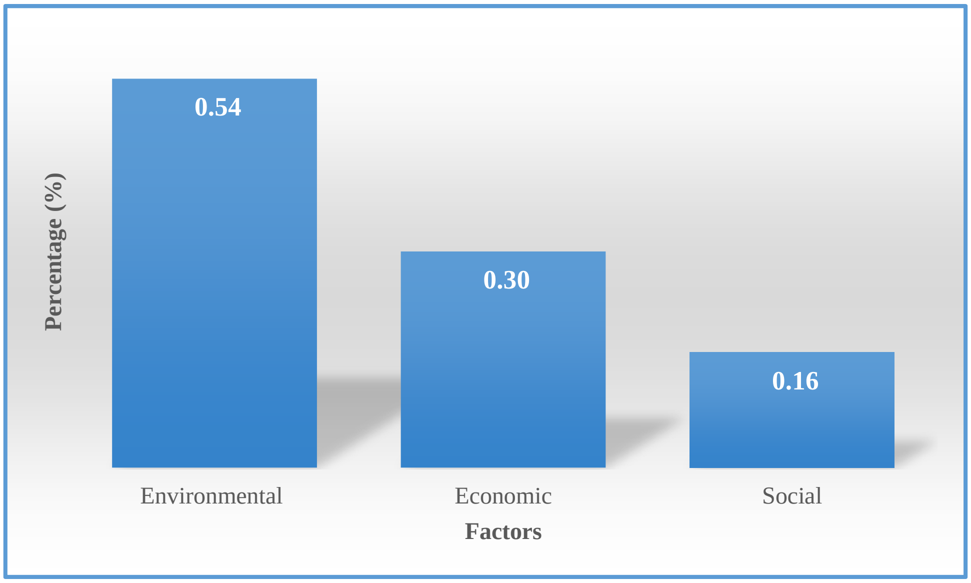

Figure 7.2: Weights for major indicators of land suitability analysis

7.5.1 Environmental Factors

The experts explained that the buffer areas for creeks, public roads and nature reserves, and parks are specifically mandated in the Mining (Amendment) Regulations 2005, whereas the other environmental factors (buffer areas for lakes, swamps, and wetlands, sensitive hydrogeological areas, and landscape) are not mandatory restrictions for mining activities in Guyana. Thus, the environmental compulsory restrictions are ranked equally and above the non-mandatory environmental factors (figure 7.3). The experts also ranked the non-mandatory factors as equally important.

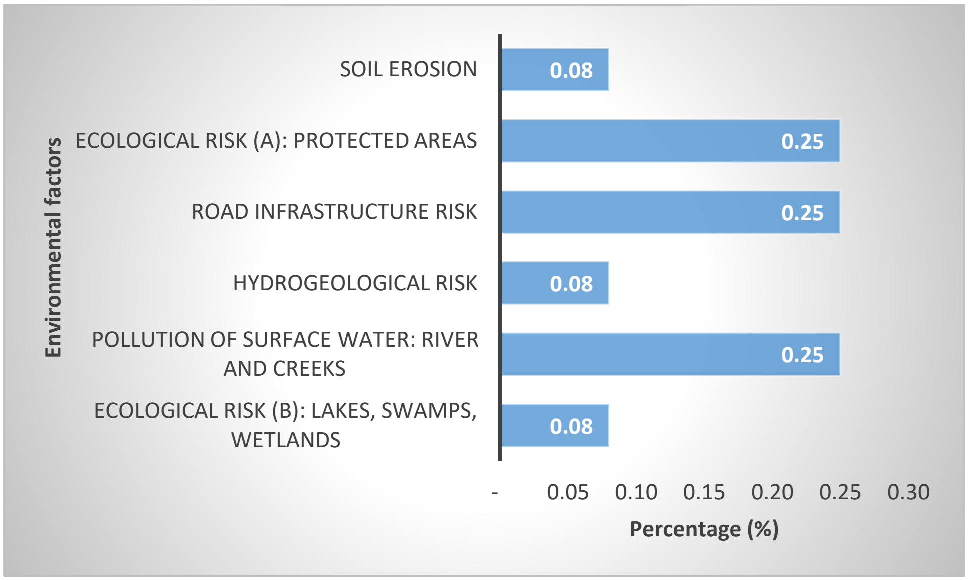

Figure 7.3: Weights for environmental factors

7.5.2 Economic Factors

With respect to the economic factors, the experts ranked the ‘type of mining operation’ as important as thirty percent (figure 7.2). According to the experts, the economic value from mining is influenced primarily by the type of mineral extracted.

7.5.3 Social Factors

The experts ranked the buffer for heritage and conservation areas above the buffer for human settlements (figure 7.4). It was explained that mining activities are more likely to be undertaken in areas contiguous to heritage or conservation sites than areas with significant human settlements. Thus, the potential impact of mining is more significant for heritage and conservation areas when compared with human settlements.

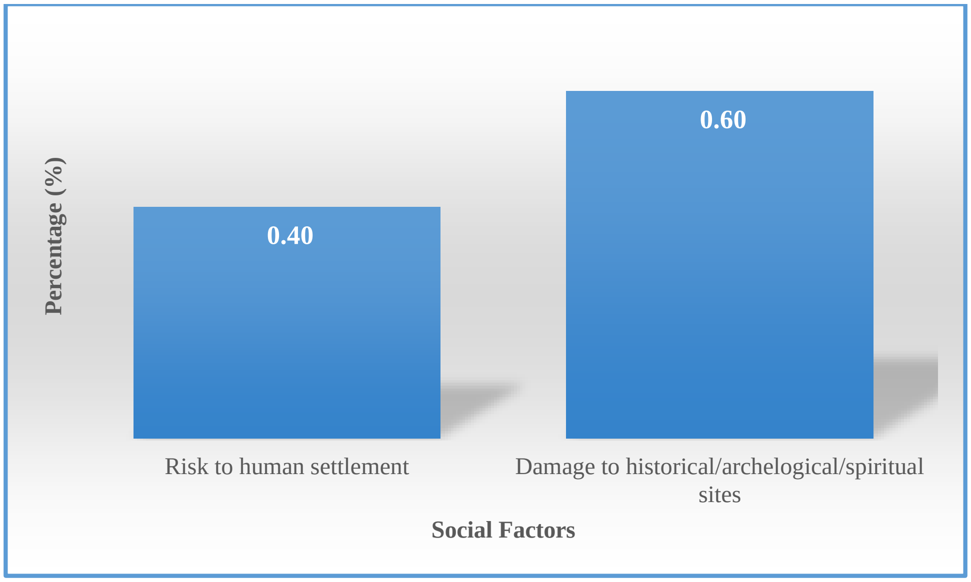

Figure 7.4: Weights of the social factors

7.6 Cartographic Modelling

This case study employs spatial Analytical Hierarchy Process (AHP), that is, a Multi-Criteria Decision Analysis (MCDA) technique that incorporates GIS-based overlay analysis. The method is utilized to identify the most suitable land parcels for mineral extraction. The evaluation process was primarily informed by the existing literature, as well as local policies and regulations that govern the forestry sector.

Based on the criteria used, the suitability analysis is expected to identify land parcels that allow for the maximization of the economic gains from mining while simultaneously protecting the environment and improving the social well-being of the country's citizens. These competing objectives are achieved if a particular land parcel satisfies a fundamental criterion, that is, it allows for the highest economic returns based on the type and scale of mining activity. Further, the land parcels identified would be subject to the following constraints:

i. it should be unoccupied
ii. should be within an acceptable distance from conservation areas, buffer areas, human settlements, heritage or conservation areas, sensitive hydrogeological areas, lakes, swamps and wetlands and areas with a slope greater than twenty-two degrees.

The exercise is based on the weighted parameters (map layers) that consider the various suitability criteria. The general form of our suitability model is represented by equations 5.1, 5.2 and 5.3 presented in chapter 5.

Restriction Model that captures the various restrictions identified earlier. This involves the creation of a restriction Boolean raster using equation 5.4 and 5.5. The cartographic model presented in figure 7.5 provides a schematic representation of the Restriction Model.

Mineral Extraction Suitability Model involves creating a suitability raster using the weights from the pairwise comparison and the five-point classification scale, where one represent least suitable areas and five most suitable areas. The model is represented using equation 5.4 and 5.5. Figure 7.6 provides a schematic representation of the mineral suitability model.

Most Suitable Parcel Model This model is intended to identify the land parcels for different scales of mining operations, namely, large-scale, medium-scale and small-scale. Figure 7.7 provides a schematic representation of the most suitable land parcels mode for mining purposes.

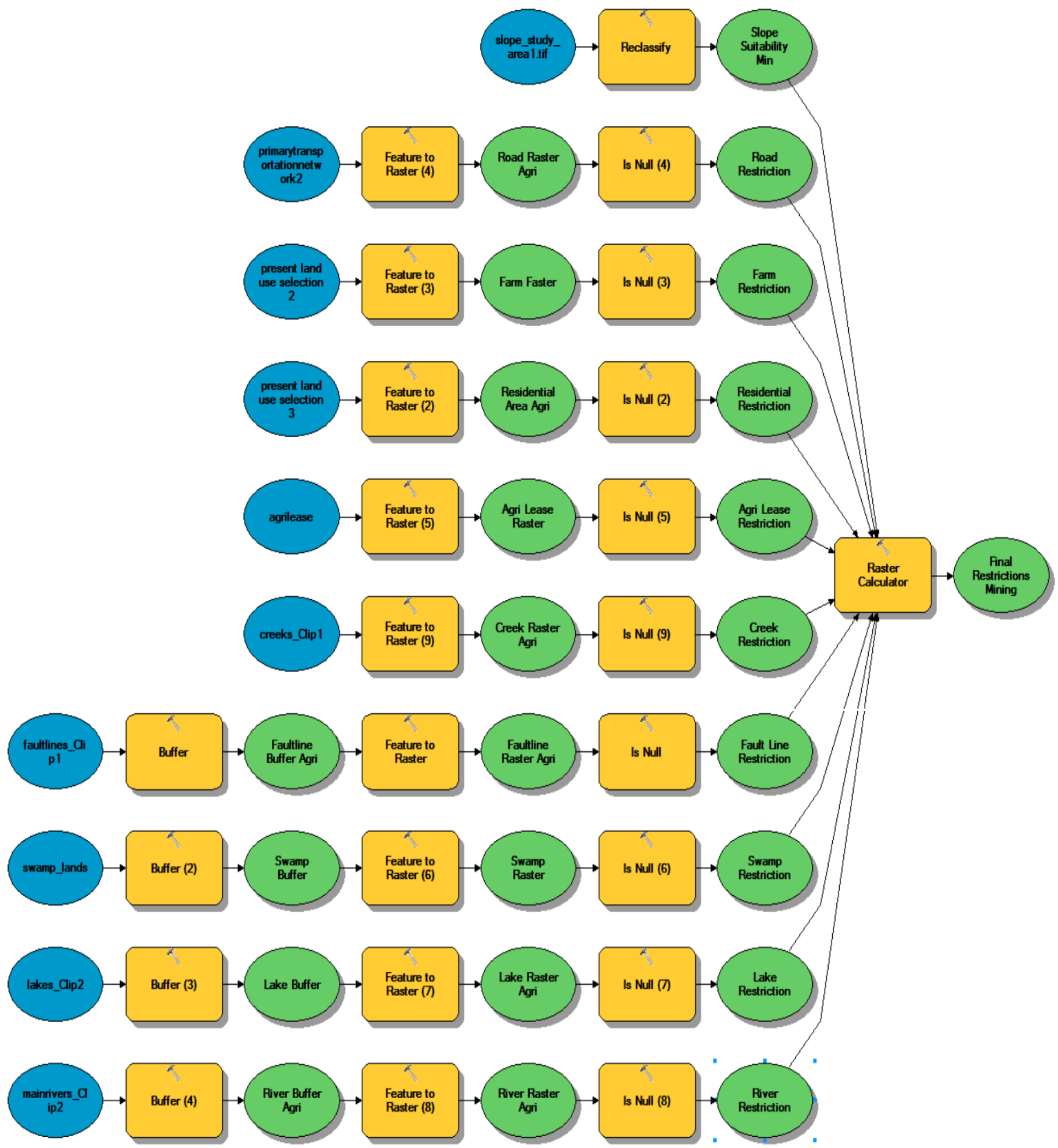

Figure 7.5: Cartographic model of the mining restriction criteria

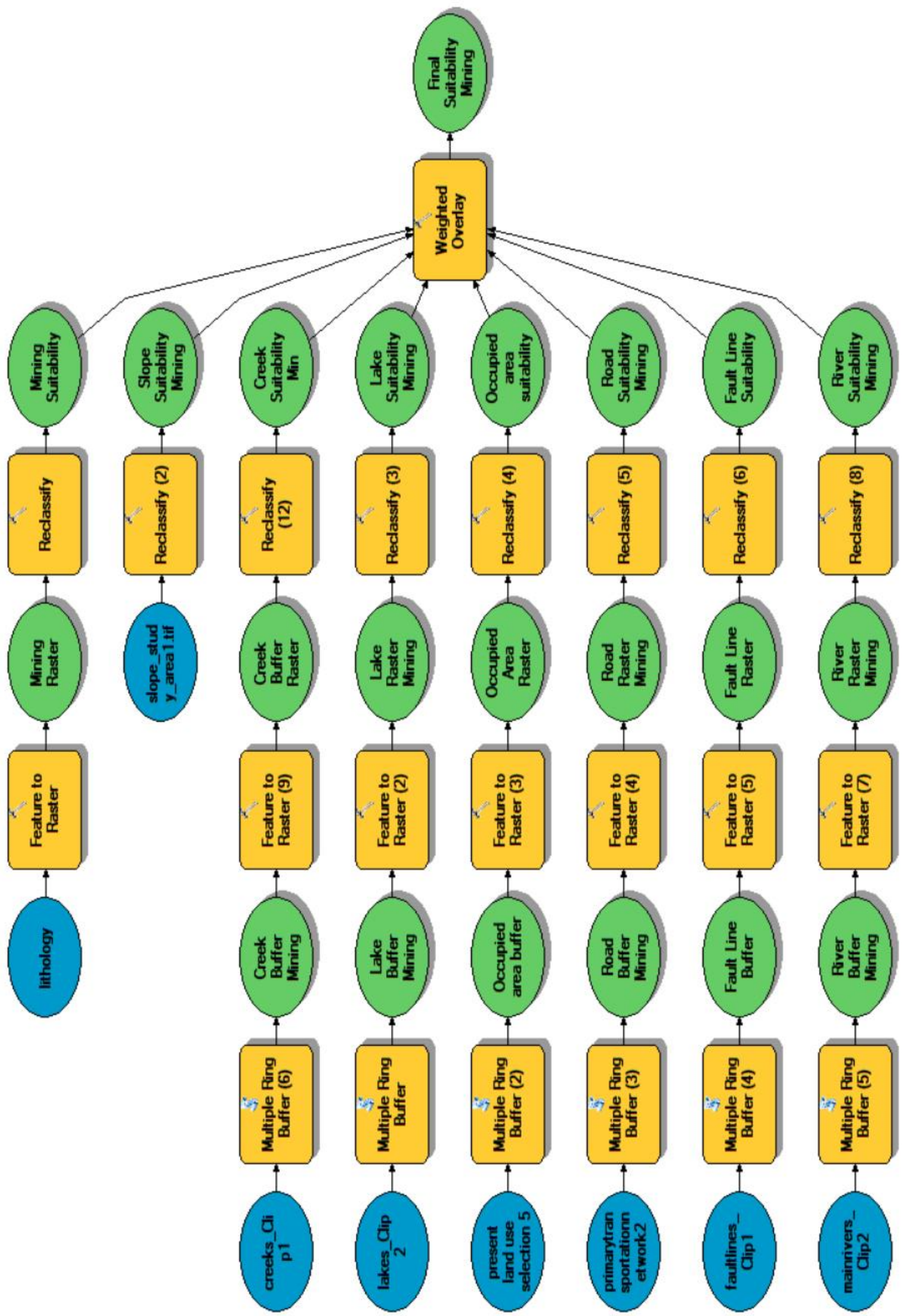

Figure 7.6: Cartographic model for the mining suitability analysis

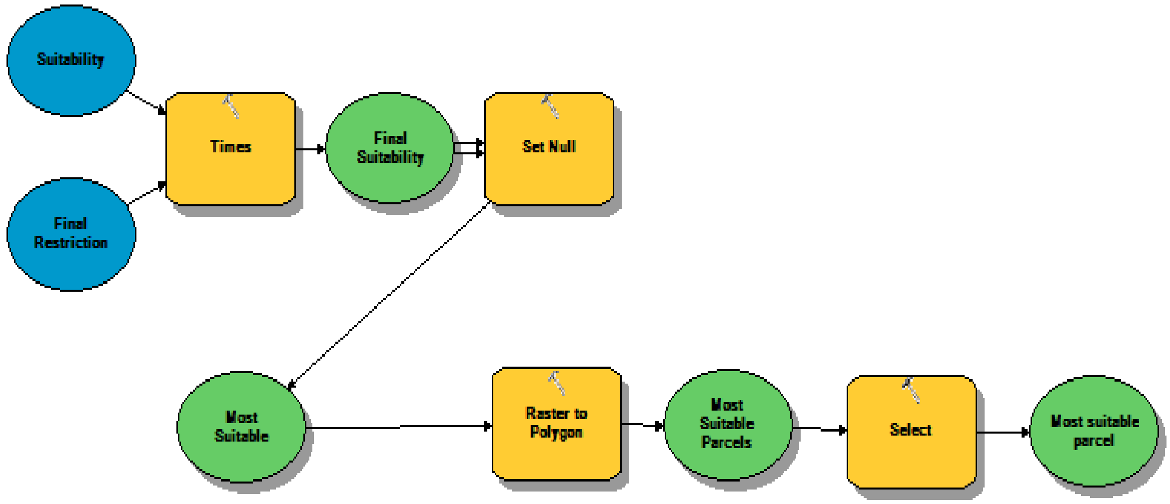

Figure 7.7: Cartographic model for the most suitable land for mining

The above models are created in ArcGIS version 10. This exercise utilizes data from the Baseline Study for Regional Land Use Plan (GLSC 2004) which provides extensive spatial data for an area straddling three administrative regions. Elevations maps were generated from these datasets.

7.7 Preparation of Thematic Input Map Layers and GIS Analysis

The input thematic data layers required for the suitability analysis were acquired from the relevant State agencies. Most of the input GIS layers prepared for the housing suitability model were found relevant and reusable for the mining suitability model. Human settlement and mining activities layers were explicitly generated for this mining suitability modelling.

7.7.1 Environmental Factors

The following additional thematic map layers were prepared to evaluate the environmental factors: land slope, water bodies, and land tenure.

Suitability maps

Suitability based on proximity to water bodies

The suitability of the study area based on the proximity of land parcels to rivers, lakes, and creeks are depicted in figures 7.8, 7.9, and 7.10 respectively.

Suitability of study area based on slope

Figure 7.11 shows the slope of the study area which contains land parcels with slopes that ranges between one percent and twenty-two percent.

Suitability of study area based on land tenure

Within the study area, several land parcels have been allocated by the GLSC and GGMC. There are also several residential communities in the study area. These areas are therefore not available for mining or any other economic activities. The most significant portion (approximately 73%) of the study area is State Forest Land which is unoccupied (figure 7.12).

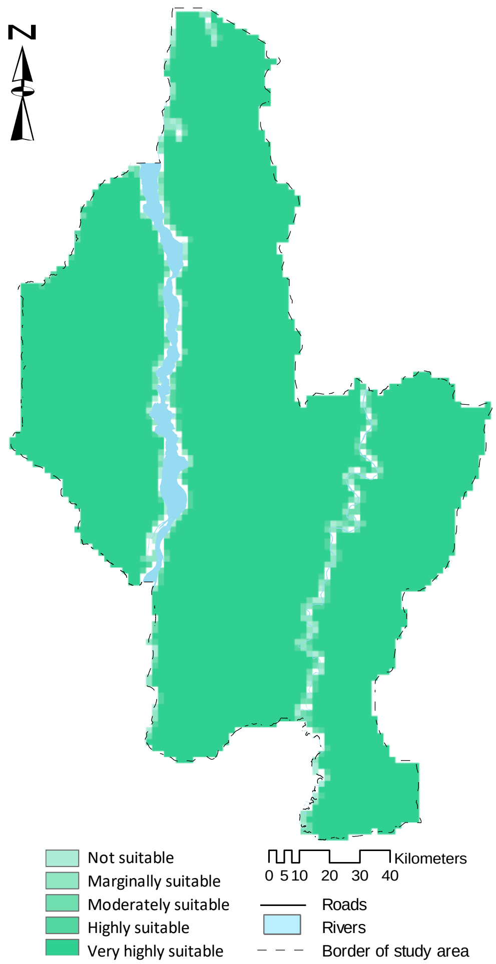

Figure 7.8: Suitability based on proximity to rivers

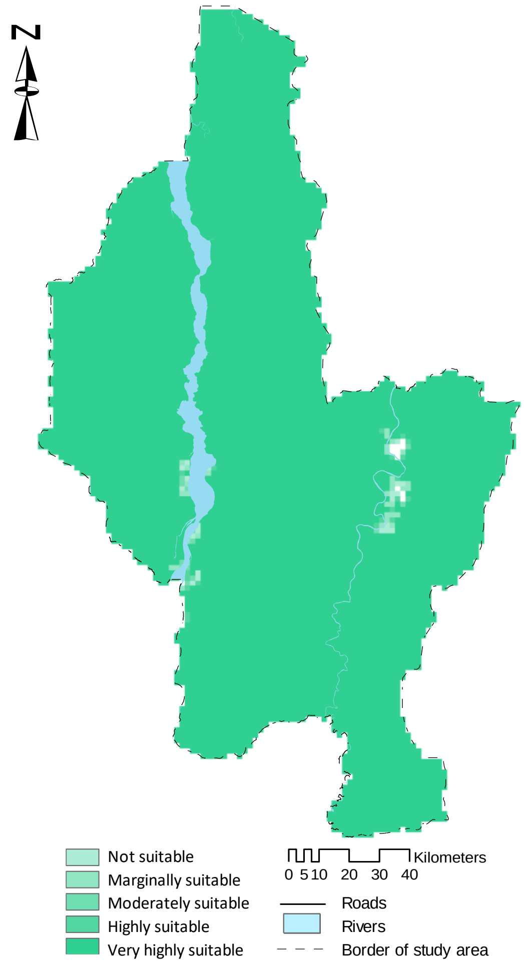

Figure 7.9: Suitability based on proximity to lakes

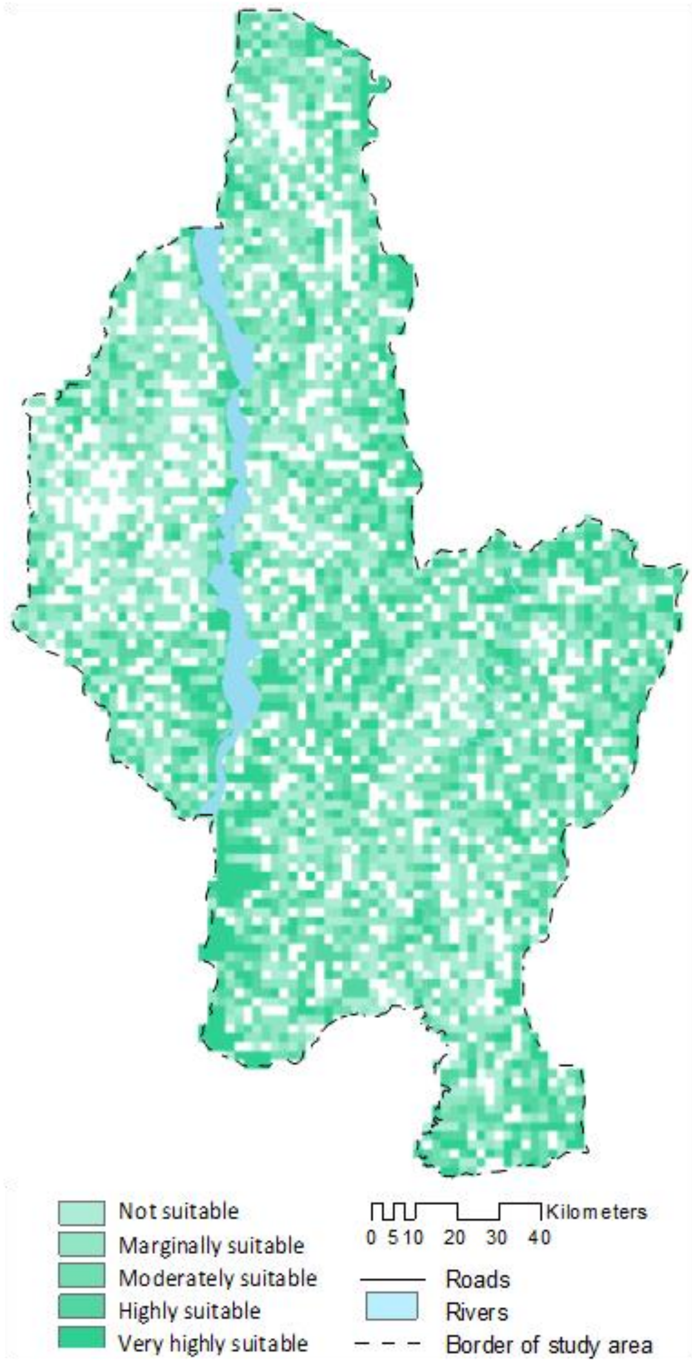

Figure 7.10: Suitability of study area based on proximity to creeks

Suitability of study area based on lithology

Figure 7.13 shows the suitability of the study area based on the lithology of the study area. Four of the lithological units facilitate various mining activities in the study area. The most suitable areas contain Greenstone that is ideal for gold mining, followed by those with Gabbro, Migmatites/Granitoid and Fluvial and Marine sands that supports bauxite extraction, stone/quarrying, and sand mining respectively.

7.8 Results

7.8.1 Mining Restrictions Model

As noted earlier mining is not permitted in areas which are currently occupied or within prescribed proximity to human settlements, heritage or conservation sites, water bodies (lakes, rivers, and creeks), approved nature parks, public roads and, sensitive hydrogeological environments and with slopes higher than forty percent. The maps showing these restrictions are presented below. It is noteworthy that there are not heritage and conservation sites, approved nature parks in the study area. Figure 7.14 shows the results from the restriction model which combines all the restrictions. The green areas represent land parcels which satisfy all the constraints simultaneously. Mining is not restricted in the areas shaded in white.

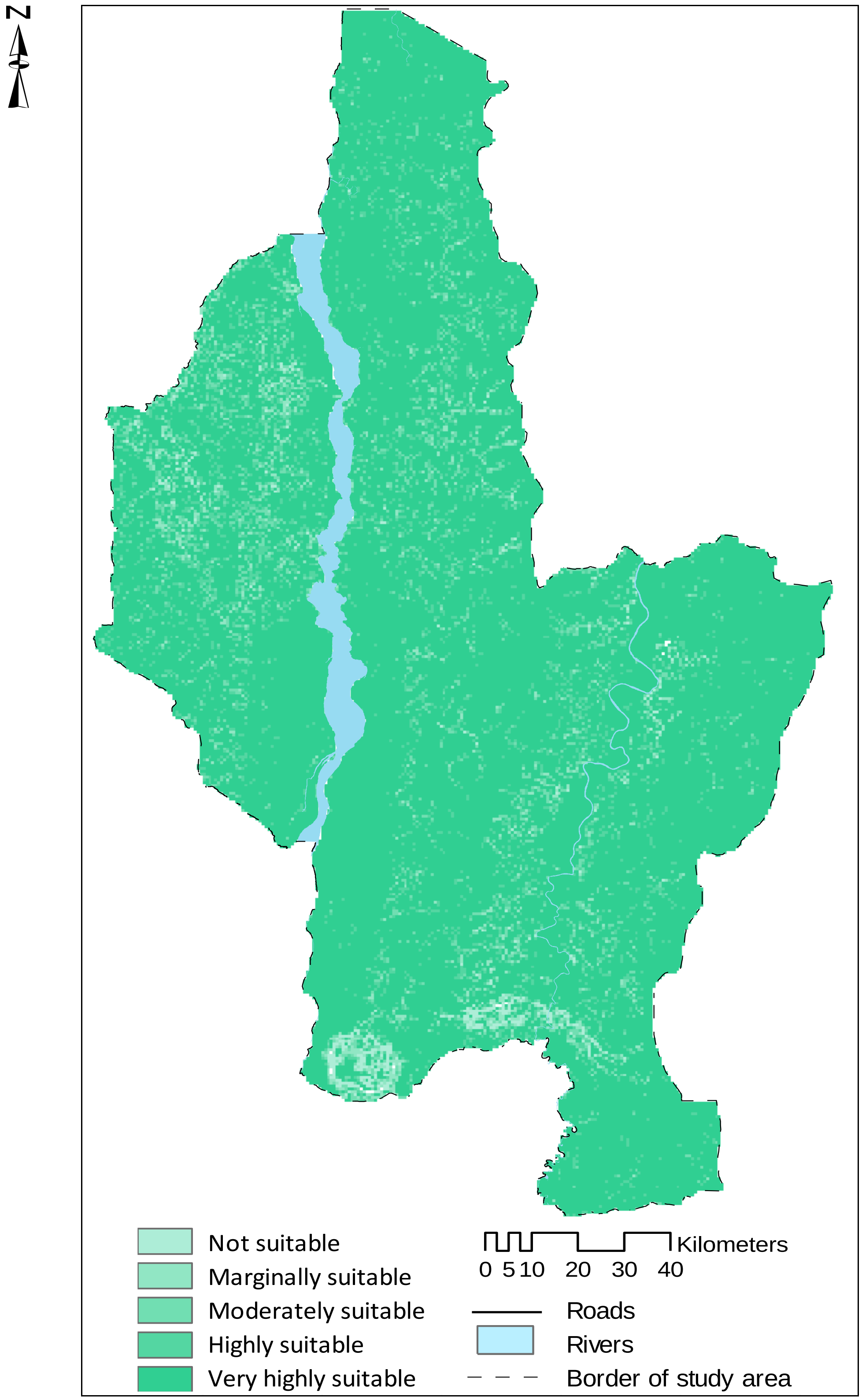

Figure 7.11: Suitability of study area based on slope

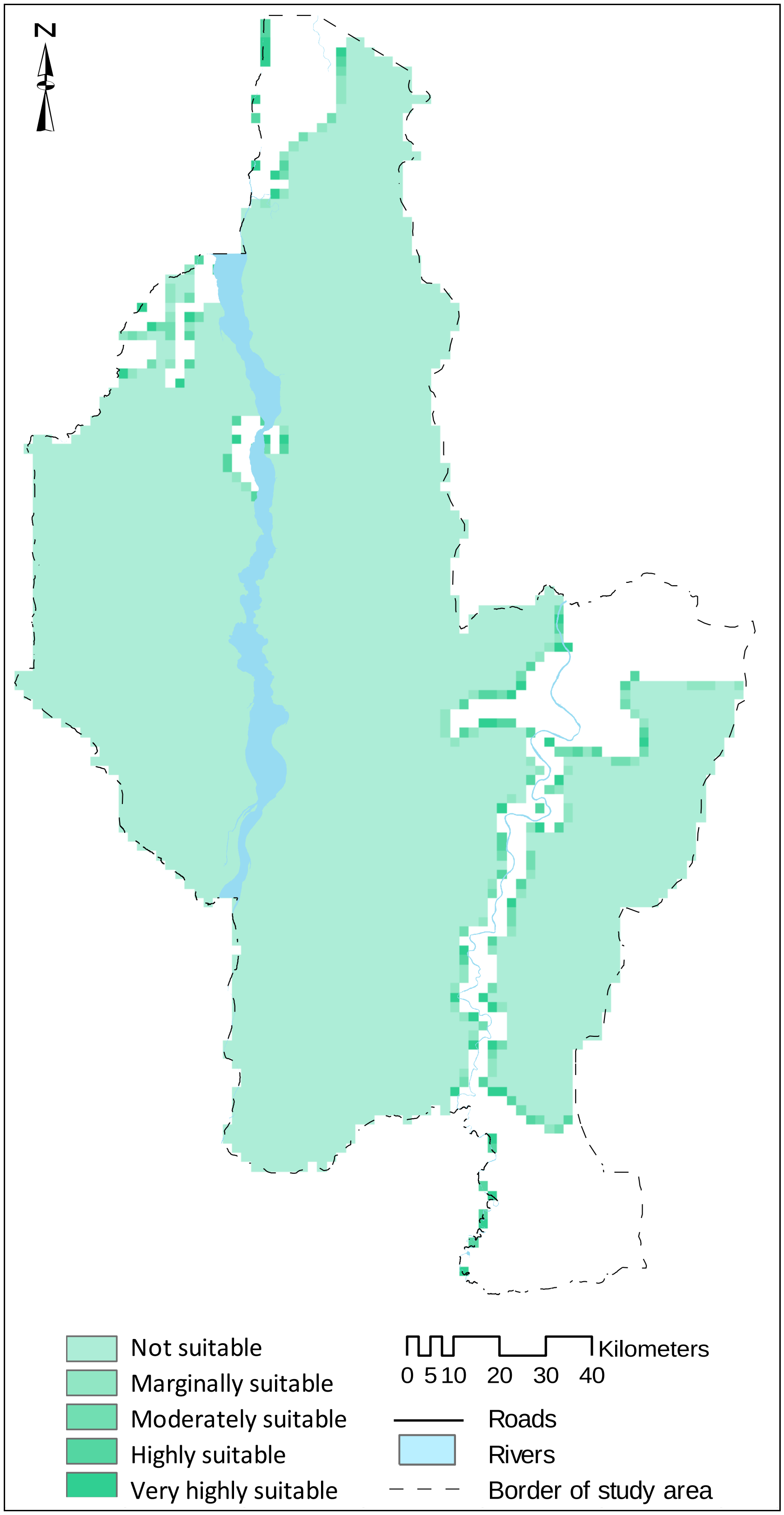

Figure 7.12: Suitability based on land tenure

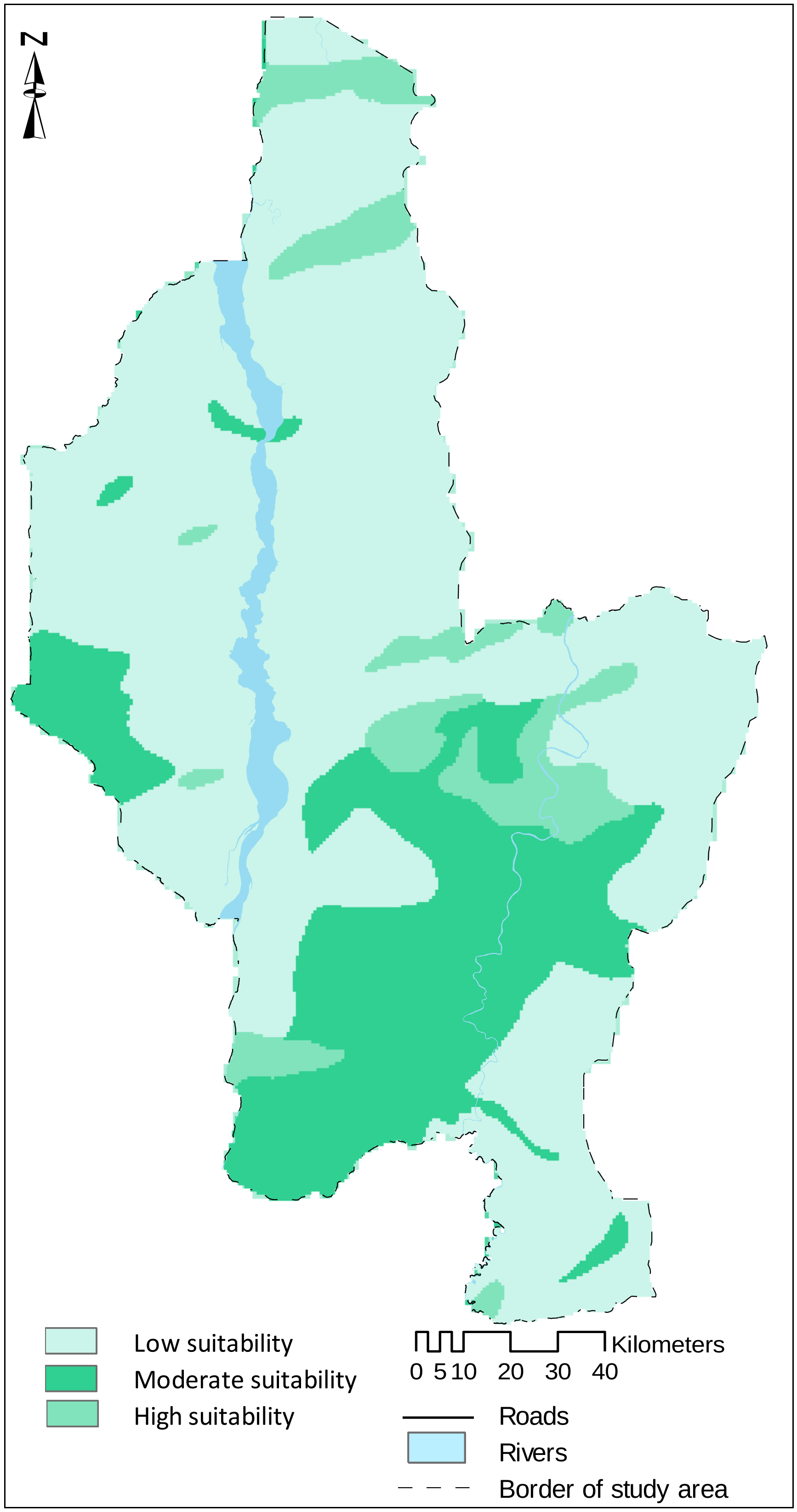

Figure 7.13: Suitability based on the lithological units in the study area

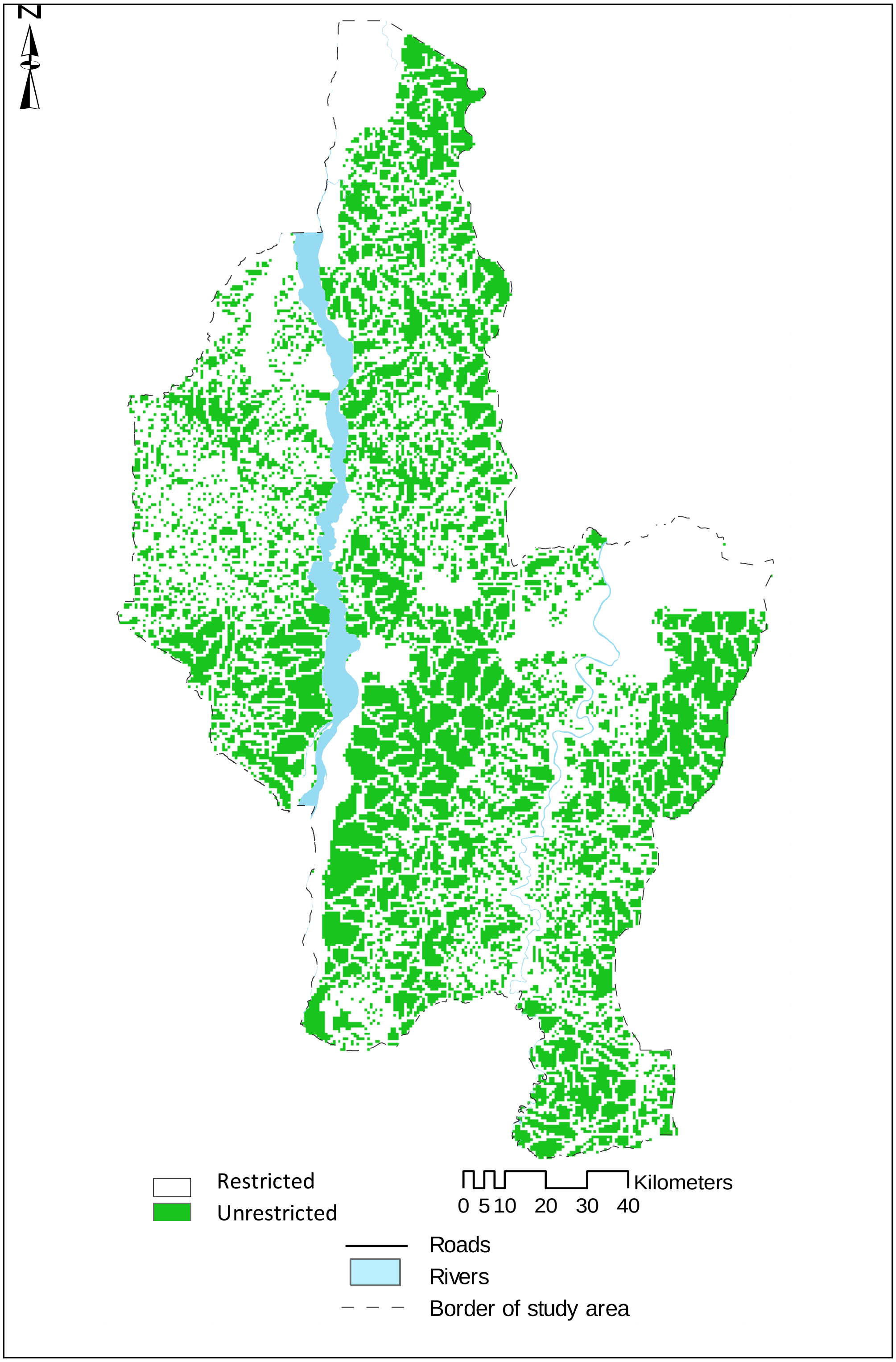

Figure 7.14: Final restrictions model

7.9 Final Mining Suitability Model

The results from the final model capture the land parcels that are suitable for various mining activities in the pilot area after taking into consideration all the environmental, economic, and social factors. Figure 7.15 depicts the suitability of different areas for the mining activities. The dark green areas are suitable for gold extraction (very highly suitable for mining). The areas shaded in light green are ideal for bauxite mining (moderate suitability for mining) and quarry operation and sand mining (low suitability for mining). The areas shaded in red are not suitable for mining while those shaded in red are restricted to mining activities.

Low Suitability: A total of 201 land parcels which occupies approximately 1457.6 square kilometres (or 31.5% of the study area) has low mining potential. The low suitability is due to the restrictions and lithological units which are only capable of facilitating quarry operation and sand mining. These mining activities generate relatively lower socio-economic benefits when compare to gold and bauxite mining.

Moderate suitability: Based on the results, a total of forty-one land parcels which occupies approximately 829 square kilometres (or 17.9% of the study area) is moderately suitable for mining. While these land parcels primarily facilitate quarry operation and sand mining, there are also minimal opportunities for gold extraction.

Very High suitability: The results suggest that 110 land parcels which occupy approximately 190.1 square kilometres (or 4.1% of the study area) have high mining suitability. These land parcels are ideal for small and medium scale gold mining and bauxite extraction. These mining activities can be facilitated on these land parcels without violating the restrictions imposed.

7.10 Summary and Conclusions

The mining sector is one of the most important economic sectors in Guyana. This sector employs over 13,000 persons directly and indirectly (GGMC 2012). It also accounted for over ten percent of the country's Gross Domestic Product (GDP) and earned more than US$200 million annually over the period 2000-2012. The analysis reveals that only 4.1% of the study area allows for sustainable mining activities. Specifically, the land parcels which fall within this suitability classification allows for large and medium scale gold and bauxite mining sustainably. Approximately seventeen percent of the study area is moderately suitable while the most considerable portion of the study area has low suitability. The sensitivity of the results to the various criteria is assessed by relaxing each criterion individually. This essentially involves zero-rating each criterion and re-running the models. Based on the results, the results are more sensitive to the restriction on creeks. When this criterion is relaxed, over fifteen land parcels were deemed highly suitable for small-scale gold mining activities. Given the number of creeks and the closeness of these watercourses these results are not surprising. When the other restrictions are relaxed, the results remained unchanged.

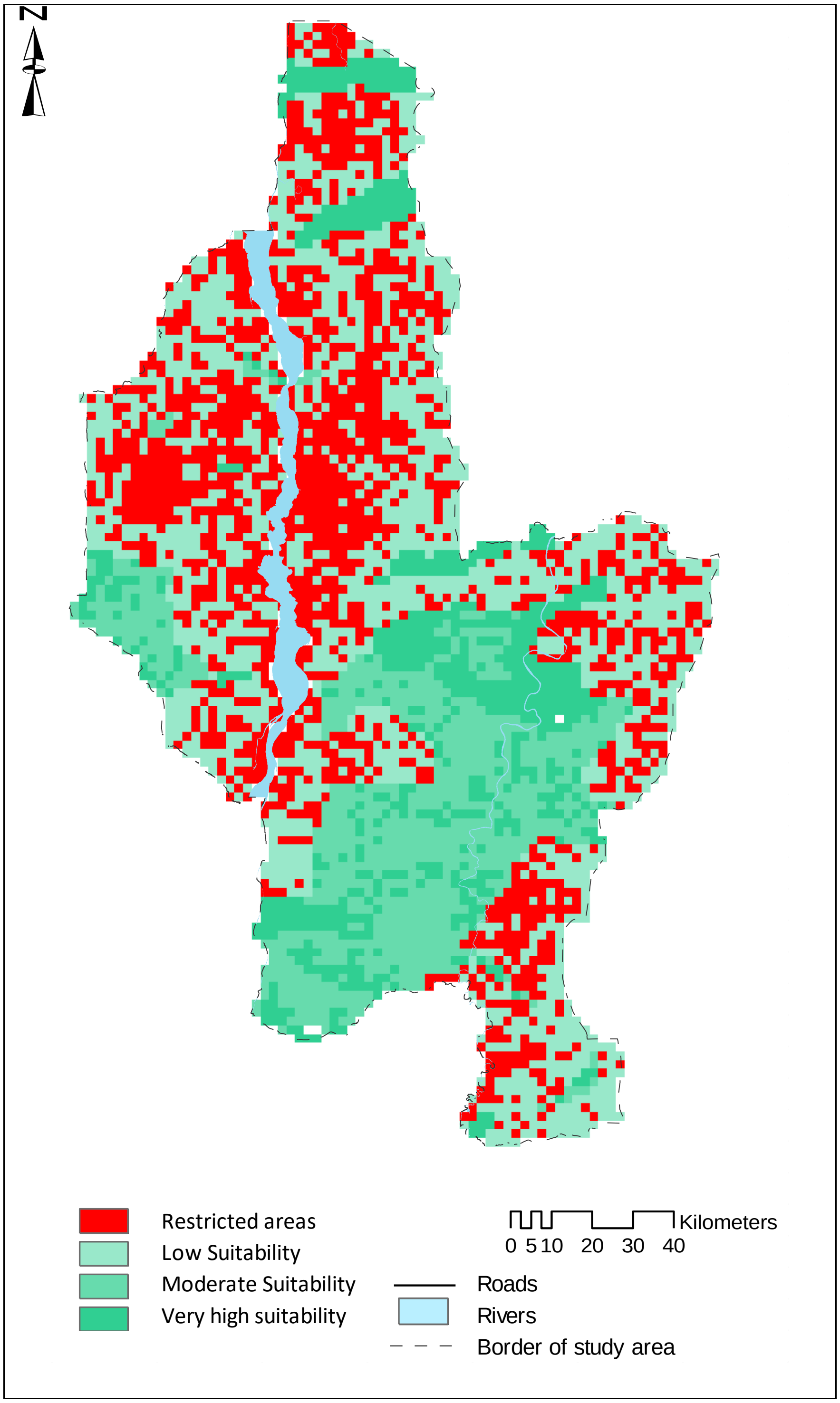

Figure 7.15: Final suitability model

CHAPTER 8: APPLICATION OF THE SAHP TO FORESTRY SUITABILITY ANALYSIS

8.1 Problem Definition

The forest occupies approximately eighty percent of Guyana's landmass; of which a significant portion is suitable for timber extraction and post-harvest agriculture (GOG 2010). Indeed, existing soil assessment maps indicate the presence of substantial arable soils in forested regions. Based on a recent study, approximately 2.2 million hectares and 760 thousand hectares of Class 1 soil and Class ½ soil respectively are covered by the country's forest. The Class 1 soil is exceptionally suitable for rice farming while the Class ½ soil is ideal for palm oil plantations and high-end vegetable cultivation (GOG 2010). If the forest is harvested and the cleared lands used optimally for post-harvest agriculture, the economic value of the country's forest is estimated to range between US$4.3 billion and US$23.4 billion (GOG 2010). Soil assessment maps suggest that within the forested regions there exist significant arable soil. Based on GOG (2010) approximately 2.2 million hectares and 760 thousand hectares of Class 1 and Class ½ soil respectively exist within the country's forested regions. The Class 1 soil is suitable for rice farming while the Class ½ soil is ideal for palm oil plantations and small-scale farming of high-end vegetables.

Substantial mineral deposits also reside below the sub-surface of the forested region. Data indicates that substantial mineral-rich land and gold deposits exist in the country's forested region. According to GOG (2010), the forested region is occupied by approximately 2.9 million hectares of land with gold. Estimates suggest the presence of about 9.2 million ounces of gold below the sub-surface of roughly 2.7 million hectares of forested land.

Additionally, the country's forest provides enormous eco-services and offers significant opportunities for eco-tourism, recreation and scientific research (GOG 1996/2000). According to the GOG (1996/2000), the forest serves as a reservoir for biodiversity, prevents soil erosion, regulates and purifies the country's water supply, and ensures environmental stability.

Given its economic and eco-services potentials, it is therefore not surprising the forestry sector has always been treated as a critical component of the country's development paradigm. The importance attached to the sector is clearly reflected by the attention it has attracted in several development strategies pursued by the Government of Guyana since the country gained independence. These include: The National Development Strategy (NDS 2001-10), National Competitiveness Strategy (NCS 2006) and Low Carbon Development Strategy (LCDS 2009). All of these strategies promote the exploitations of the country's forestry resources in an eco-friendly and sustainable manner.

8.2 Objective of Forestry Suitability Model

The primary objective of the model to identify forested areas with the best potential for sustainable forest products extraction in keeping with the development strategies discussed previously. The suitability analysis applies the MCDA/SAHP process.

The general methodology and specific evaluation procedure developed in Chapter 5 (sections 5.3 and 5.4) and presented in figure 5.1 is observed in this forestry application.

8.3 Criteria Selection, Description and Ranking

The literature which employs Spatial-Geographic Information System (GIS) to analyze the suitability of land for various purposes are extensive. Notwithstanding, only a limited number of studies utilize this technique to evaluate the suitability of land for timber extraction. More importantly, there is no available study which examines the suitability of timber extraction within the context of a 'Green Economic Model'. In this regard, this study will contribute to the existing literature by filling these gaps.

Bizuwerk et al. (2005) is one of the few studies to employ GIS to determine the suitability of land for livestock, crop production and forest in Ethiopia. The authors utilize five criteria for the suitability analysis. These include soil, erosion hazard, rainfall, slope and distance from water sources. The study finds that lands were improperly utilized and managed in Ethiopia based on their suitability analysis.

More recently, Nyeko (2012) examined the suitability of land for forest and agriculture development in Northern Uganda. The study employs seven criteria to determine the suitability of land parcels for these development activities. The author grouped the requirements into two broad categories, namely, suitability criteria and constraints. Minimum vegetation cover, low population density, and adequate rainfall and accessibility are regarded as suitability criteria while land elevation and existing land use are classified as constraints.

The criteria proposed in literature were discussed with the stakeholders and key informants at the Guyana Forestry Commission (GFC). Based on the discussion, four major restrictions were identified for timber harvesting. These criteria are outlined in the GFC Code of Practice for Timber Harvesting (2002) and include the prescribed buffer for protected areas, watercourses, areas with cultural or historical significance as well as areas susceptible to degradation. For this study, the criteria are placed into three broad categories, namely environmental, economic and social factors. Below is a description of the criteria and the ranking attached to each criterion by the experts.

8.3.1 Environmental Factors

Environmental factors refer to those criteria which are intended to protect the environment. According to experts consulted at the Guyana Forestry Commission (GFC), timber extraction is prohibited within specified distances from areas designated as:

- Protected areas including conservation areas
- Site susceptible to land degradation
- watercourses [rivers, creeks, gullies, waterways, swamps, and lakes]

The GFC Code of Practice for Timber Harvesting (2002) delineates the restrictions mentioned above.

Protected Areas

Protected areas including conservation areas and critical habitats – this criterion restrict timber extraction in areas regarded as conservation areas and critical habitats, that is, areas where threatened or endangered species of fauna and flora cohabitates. This criterion is imposed to minimize the ecological risk of logging.

Site Susceptible to Land Degradation

This is a mandatory criterion which restricts timber harvesting in areas where the slope of the land surface is more than twenty-two degrees (or forty percent) to reduce the risk of environmental degradation caused by soil erosion. According to the experts of the Guyana Forestry Commission (GFC), land surface with slopes greater than twenty-two degrees (or forty degrees) is prone to land degradation and landslides caused by increased erosion and pressure (or the disruption) of natural vegetation respectively. These environmental risks are notably higher when the soil is loose.

Watercourses

This is a mandatory selection criterion according to the Guyana Forestry Commission's Code of Practice for Timber Harvesting (2002). In essence, this criterion seeks to reduce the risk of polluting the country's watercourses by minimizing disturbances to watercourse channels and riparian zones as well as reducing soil disturbances within and near watercourses which includes rivers, creeks, gullies, waterways, swamps, and lakes.

Lakes, Swamps and Wetlands

This criterion restricts timber extraction in areas designated as lakes, swamps, and wetlands. This restriction is intended to protect wildlife habitats as well as sustain aquatic diversity and its relationship to surrounding natural areas through nutrient retention and productivity exportation among other things (see table 8.1 for the classification scheme and ranking for this criteria).

The study assigns a score between one and five to an area depending on its proximity to the various watercourses. Table 8.1 provides a summary of the environmental factors, classification schemes and ranked values used for the suitability analysis.

Summary

The summary of the environmental factors, classification schemes and ranked values used for the suitability analysis are provided in table 8.1.

Table 8.1: Summary of environmental factors and suitability ranking

Forestry Suitability Factors	Classification schemes	Ranking Scheme	Ranked Values
Critical Habitat (Proximity in metre)	< 20	Not suitable	1
	20 – 29	Marginally suitable	2
	30 – 39	Moderately suitable	3
	40 – 49	Highly suitable	4
	> 50	Very highly suitable	5
Slope and Land surface (degrees) 20 degrees	0-5	Not suitable	1
	6-15	Marginally suitable	2
	16-27	Moderately suitable	3
	28-48	Highly suitable	4
	> 48	Very highly suitable	5
Watercourses: Rivers (metre)	< 30	Not suitable	1
	20 – 39	Marginally suitable	2
	40 – 49	Moderately suitable	3
	50 – 59	Highly suitable	4
	> 60	Very highly suitable	5
Watercourses: Creeks (metre)	< 20	Not suitable	1
	20 – 29	Marginally suitable	2
	30 – 39	Moderately suitable	3
	40 – 49	Highly suitable	4
	> 50	Very highly suitable	5
Watercourses: Gullies (metre)	< 10	Not suitable	1
	11 – 19	Marginally suitable	2
	20 – 29	Moderately suitable	3
	30 – 39	Highly suitable	4
	> 40	Very highly suitable	5
Watercourses: Waterways (metre)	< 5	Not suitable	1
	5 – 10	Marginally suitable	2
	11 – 15	Moderately suitable	3
	16 – 20	Highly suitable	4
	> 20	Very highly suitable	5
Lakes, swamps and wetland (Proximity in metre)	< 20	Not suitable	1
	20 – 29	Marginally suitable	2
	30 – 39	Moderately suitable	3
	40 – 49	Highly suitable	4
	> 50	Very highly suitable	5

8.3.2 Economic Factors

8.3.2.1 Forest Capability

This is a non-mandatory mandatory suitability criterion which requires that logging is undertaken in areas with the greatest potential for timber harvesting to ensure maximum economic returns from logging. The stakeholders developed six sub-types, namely, forest with the highest commercial importance, forest with the highest commercial importance with severe logging restrictions, forest with moderate commercial importance, forest with low commercial importance and forest with no commercial importance, and forest with the greatest importance proposed for conversion.

Adequacy of Key Physical Infrastructure

This is a non-mandatory mandatory suitability criterion which requires that the new areas for timber extraction be within a one mile radius from roads or trails. This suitability criterion is intended to reduce the cost for this type of economic activity. In this regard, a five-point ranking system is employed to determine the suitability of land based on this criterion as outlined in table 8.2.

Summary

A summary of the forestry suitability factors, classification schemes adopted and their ranked values are provided in table 8.2.

Table 8.2: Summary of economic factors and suitability ranking

Forestry Suitability Factors	Classification schemes	Ranking Scheme	Ranked Values
Forest capability	Forest with no commercial importance	Not suitable	1
	Forest with low commercial importance	Marginally suitable	2
	Moderate commercial importance	Moderately suitable	3
	Forest with highest commercial importance with severe logging restrictions	Highly suitable	4
	Forest with highest commercial importance	Very highly suitable	5
Adequacy of key physical infrastructure* (proximity in miles)	> 2	Not suitable	1
	2	Marginally suitable	2
	1½	Moderately suitable	3
	1	Highly suitable	4
	<½	Very highly suitable	5

8.3.3 Social Factors

Social factors are related to the proximity to human settlement and areas with cultural/historical/archaeological and spiritual significance. The former seeks to minimize the social impacts on human settlements. The latter on the other hand is intended to preserve the historical and archaeological resources of the country. The GFC Code of Practice for Timber Harvesting (2002) restricts timber extraction within specified distances from areas of cultural importance which includes: historical sites; archaeological and spiritual sites; farms; human settlement; areas required for community needs (resort, scientific parks).

The social factors, which are mandatory requirements according to the GFC Code of Practice for Timber Harvesting (2002), are considered in the current study. It is noteworthy that some of these factors are also employed in the literature (Nyeko 2012).

Historical/Archaeological/Spiritual Sites

This criterion restricts timber extraction in areas with significant historical or cultural values. These include: historical site, archaeological and spiritual sites. The primary aim of this criterion is to preserve the country's historical and cultural heritage.

Human Settlements

This criterion restricts timber harvesting in any area twenty metres from human settlement settlements (that is, housing settlement areas) and areas required for community needs (resorts, scientific parks, and areas with tourism potential). In essence, the further away the land parcel is from the human settlement the higher would be its suitability for timber extraction.

A five-point rating scale is employed to determine the suitability of an area based on these criteria. Table 8.3 provides a summary of the social factors, classification schemes and ranked values used for the suitability analysis.

8.6.3.1 Summary

The summary of the social factors, classification schemes and ranked values used for the suitability analysis are provided in table 8.3.

Table 8.3: Summary of social factors and suitability ranking

Forest Suitability Factors	Classification schemes	Ranking Scheme	Ranked Values
Historical or cultural sites (Proximity in metre)	< 20	Not suitable	1
	20 – 29	Marginally suitable	2
	30 – 39	Moderately suitable	3
	40 – 49	Highly suitable	4
	> 50	Very highly suitable	5
Human Settlement and areas required for community needs (proximity to human settlement network in metres)	< 20	Not suitable	1
	20 – 29	Marginally suitable	2
	30 – 39	Moderately suitable	3
	40 – 49	Highly suitable	4
	> 50	Very highly suitable	5

8.4 Calculation and Discussion of Criteria Weights using MCDA/SAHP

The criteria as mentioned above were utilized to construct a hierarchy for determining the suitability of a site for sustainable timber harvesting as prescribed in the various national development strategies, that is, the National Development Strategy (NDS 2001-2010), National Competitiveness Strategy (NCS 2006), Low Carbon Development Strategy (LCDS 2009). The overarching goal is sustainable development of the forestry sector. This is followed by three broad sub-objectives, namely, environmental, economic and social which are broken down further into specific criterion. Figure 8.1 provides the decision hierarchy model for selecting new areas for sustainable timber harvesting. The ten criteria described above are used for the computational process.

The relative weight of each criterion was obtained by following the pair-wise comparison procedure developed by Saaty (1980). Consequently, the nine-point rating scale proposed by Saaty (1980) was utilized; with one signifying ‘equal importance’ and nine signifying ‘extreme importance’.

During this phase of the exercise, experts from the Guyana Forestry Commission (GFC) were asked to fill out a questionnaire in Appendix B. The data from the questionnaire were inputted in a set of comparison matrices that correspond with the hierarchy in figure 8.1. In this regard, a comparison matrix was constructed for each level of the hierarchy.

Based on the agreed factors, an MCDA/SAHP model was developed to evaluate the factors. The weights were computed by normalising the matrices and extracting the eigenvalues using equations 4.1, 4.2, and 4.3 and standardised maps were generated by the Weighted Linear Combination (WLC) model using equations 4.4 and 4.5 in chapter 4.

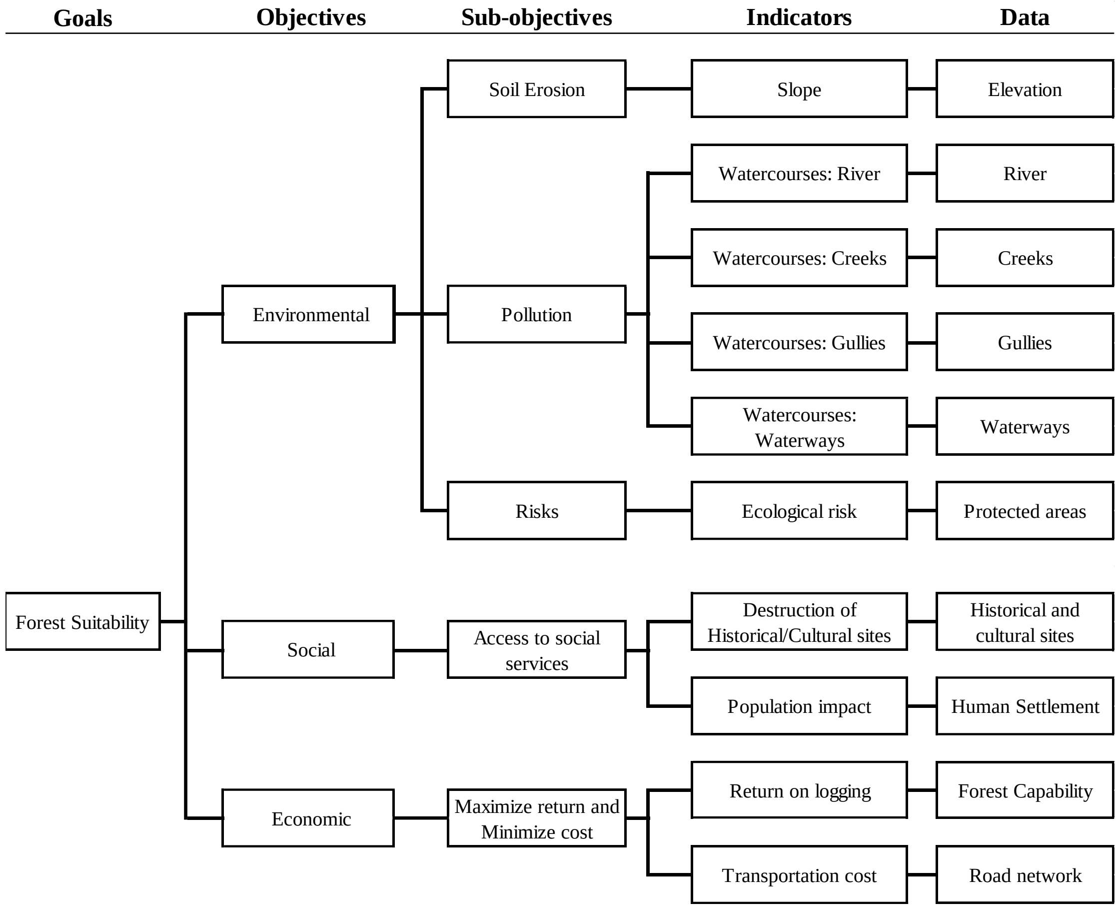

Figure 8.1: AHP for forest suitability

8.5 Ranking and Weighting of Criteria

The pairwise matrices along with the weight assigned to each criterion by the experts are provided in figures 8.2, 8.3, 8.4, and 8.5. These weights were discussed with the experts at the workshop. This was done to verify the rationale for ranking the various criteria.

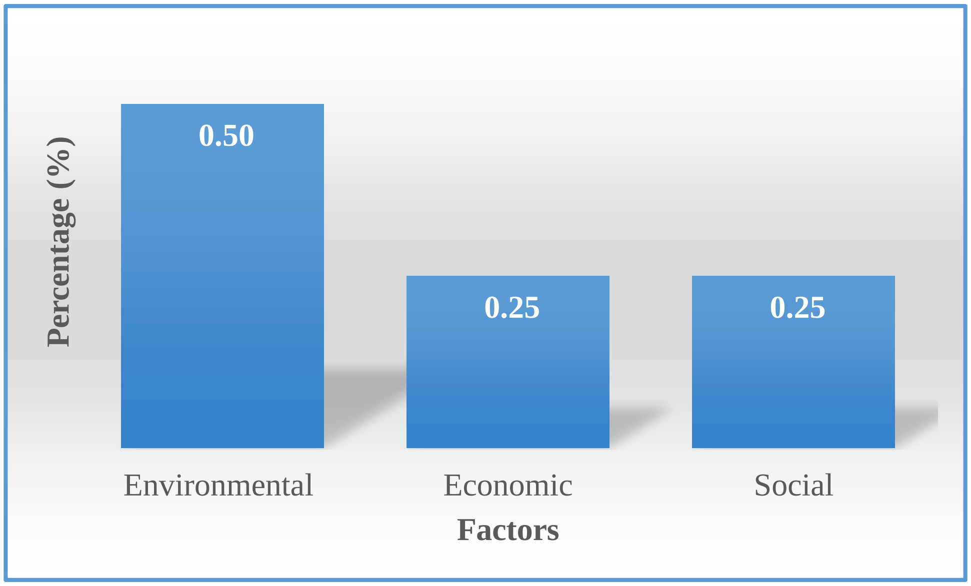

Figure 8.2: Weights for major indicators of land suitability analysis

8.5.1 Environmental Factors

The participants attached different weights to the various environmental factors. Protected areas which include critical habitats and conservation sites were identified as the most important environmental factor as shown in figure 8.3. This was followed by the various watercourses of which creeks and other watercourses were ranked highly. The expert noted that their ranking of these factors is based on the importance attached to same by the Code of Practice for Timber Harvesting.

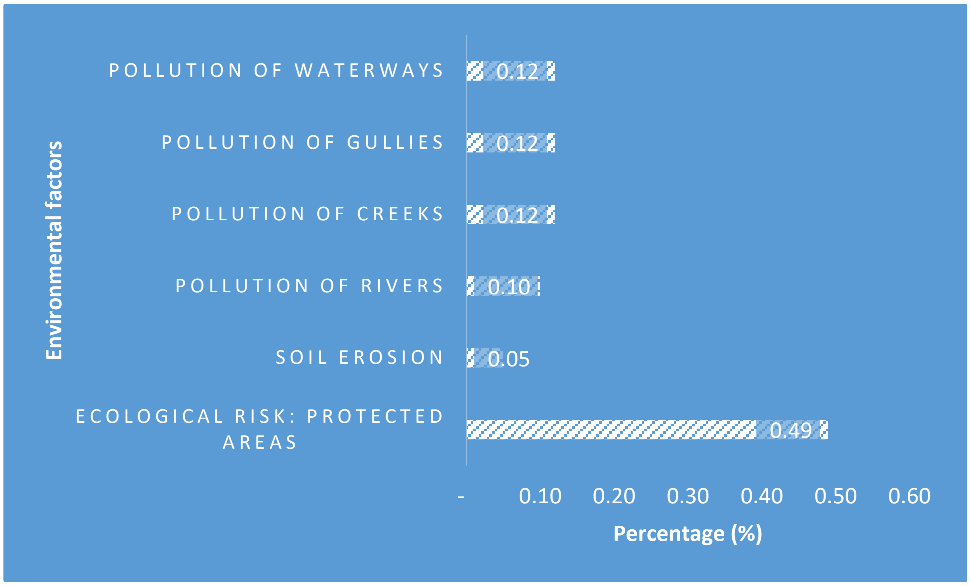

Figure 8.3: Relative weights of environmental factors

8.5.2 Economic Factors

The participants of the workshop ranked the return on logging above the infrastructure cost (figure 8.4). They indicated that while various cost minimization strategies may be employed to overcome the absence of roads and trails (e.g., the use of creeks to transport the logs), it is difficult to enhance returns when the area selected for logging does not possess high-value timber in commercial quantities. It is therefore important to make the selection based on forest capability.

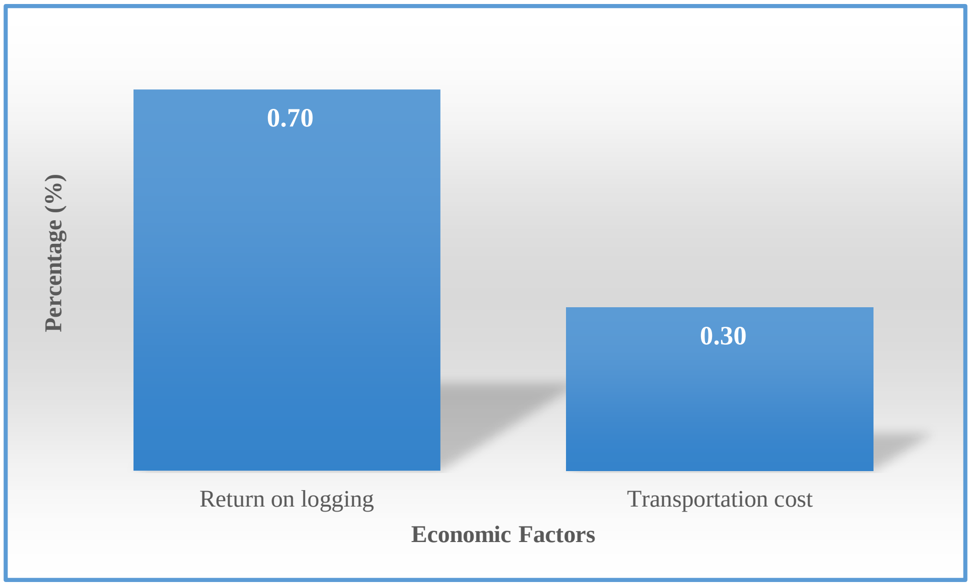

Figure 8.4: Relative weights of economic criteria

8.5.3 Social Factors

Concerning the social factors, distance from human settlement and areas required for community needs were ranked marginally above historical and cultural sites (figure 8.5). The participants indicated that timber harvesting is more likely to adversely impact on human settlements and areas required for community needs than historical and cultural sites, thus the ranking.

8.6 Cartographic Modelling

This model employs again uses the MCDA/SHAP procedure. The technique is utilized to identify the most suitable land parcels for timber extraction. The evaluation process was primarily informed by the existing literature, as well as, local policies and regulations that govern the forestry sector.

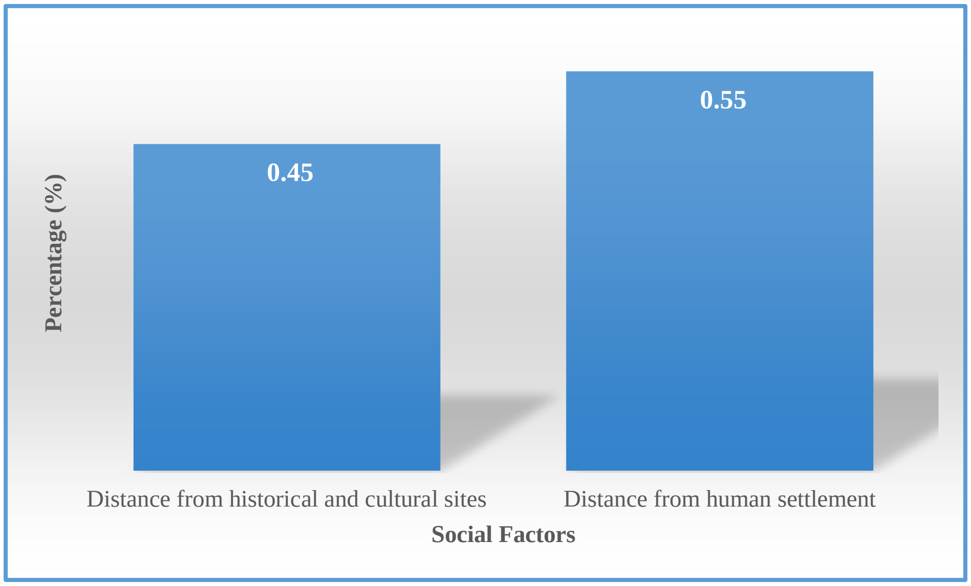

Figure 8.5: Relative weights of social criteria

It is envisaged that the most suitable land parcels for forestry allow for the maximization of the economic gains (or increase logging) while simultaneously protecting the environment and improving the social well-being of the country's citizens. These competing objectives will be achieved if a particular land parcel allows for the highest return on timber extraction.

Further, the land parcels identified would be subject to the following constraints:

- it should be unoccupied; and
- should be within an acceptable distance from conservation areas, buffer areas, human settlements, heritage or conservation areas, sensitive hydrogeological areas, lakes, swamps and wetlands and areas with a slope greater than twenty-two degrees.

The exercise is based on the weighted parameters (map layers) that consider the various suitability criteria. The general form of the suitability model is represented by equations 5.1, 5.2 and 5.3 presented in chapter 5.

Restriction Model that captures the various restrictions identified earlier. This involves the creation of a restriction Boolean raster using equation 5.4 and 5.5. The resulting raster will consist of zeros and ones; where zeros (0s) represent restricted or unsuitable cells and ones (1s) represent viable or suitable cells. Figure 8.6 below provides a schematic representation of the Restriction Model.

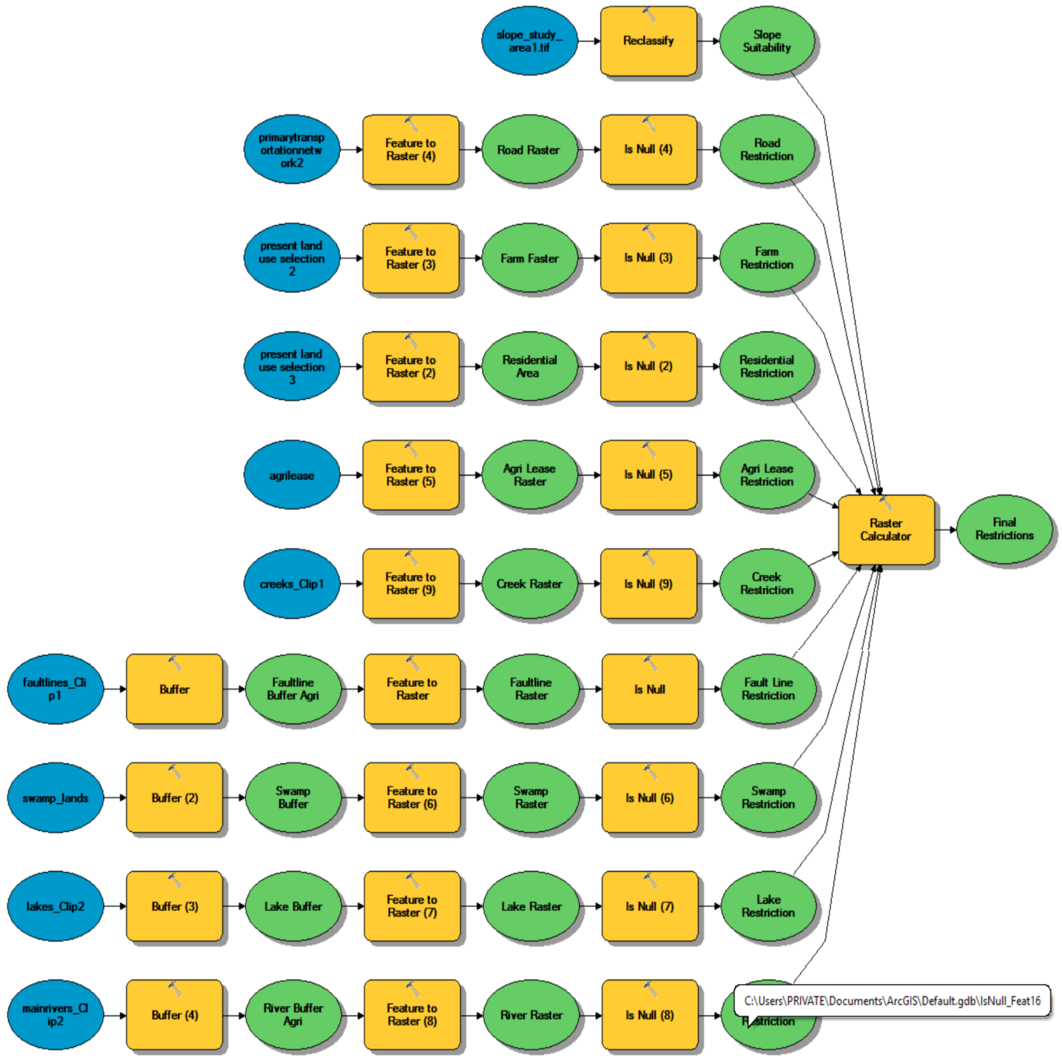

Figure 8.6: Cartographic model of the forestry restriction criteria

Timber Extraction Suitability Model involves creating a suitability raster using the weights from the pairwise comparison and five-point classification scale ranging from one to five; where one represent least suitable areas and five most suitable areas.

Figure 8.7: Cartographic model for the forestry suitability analysis

The selection of the most suitable land for forestry land use involves the combination of the first two models. Figure 8.8 below provides a modified version of the land parcel model.

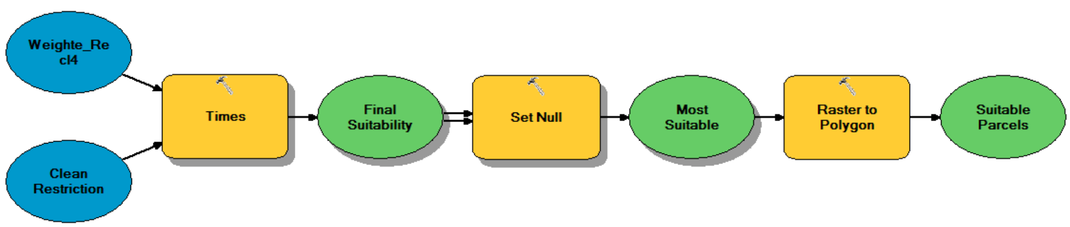

Figure 8.8: Cartographic model for the most suitable land for forestry

8.7 Preparation of thematic maps and empirical results

8.7.1 Environmental Factors

Land susceptible to degradation: the study area consists of four land form units, namely, Alluvial, Highland, Hills and Isolated Mountains. The slopes of these units ranged from less 1% to 22%. Based on the GFC Code of Practice for Timber Harvesting (2002) timber extraction should not be undertaken in areas with a land surface is more than twenty-two degrees (or forty percent). Figure 4.31 in Chapter 4 showed the slope of the study area.

Water bodies map: The main water bodies in the study area includes seven rivers, namely, Big Winiperu River, Anarika River, Arakwa River, Arampa River, Arawai River, Arawakai River, Makuba River, Arisauru River and Aritak River. The study area also has numerous creeks, lakes, and ponds. Figures 4.23 in Chapter 4 showed the major water bodies and was compiled from 18 topographic map sheets at a scale of 1:50,000.

Land Tenure: The land-use activities in the study area were assigned by the GFC, GLSC, and GGMC. The largest portion (approximately seventy-three percent) of the study area is State Forest Land, most of which are leased by the GFC as Timber Sales Agreements (TSA), and State Forest Permission (SFPs) and Wood Cutting Leases. State Forest Permissions (SFPs) are given for areas smaller than 20,000 acres and only valid for one year; Wood Cutting Leases (WCLs) are granted for areas between 20,000 and 60,000 acres and valid for three to ten years; Timber Sales Agreements (TSAs) are granted for more than 60,000 acres and valid for twenty to twenty-five years. Approximately five percent of the study area was assigned by the Guyana Lands and Survey Commission (GLSC) as agricultural leases which are valid for twenty-five years (figure 4.27 in chapter 4). The figure 4.27 in Chapter 4 depicted the agricultural leases granted by the GLSC in the study area. The map was compiled with 1:50,000 stock sheets from the Land and Surveys Commission. The Guyana Geology and Mines Commission also granted various leases for mining in the study area (figure 4.27 in chapter 4). These included: Prospecting Licenses (PLs) granted for 500 to 12,800 acres, Small Scale Prospecting License issued for 150 to 1,200 acres, and quarry licenses for the extraction of sand, stones, gravel, and any other industrial minerals. It is important to note that there are no protected area or conservation sites in the study area.

8.7.2 Social Factors

Human settlements and archaeological/spiritual/historical sites: there are no archaeological and/or spiritual sites within the study area. However, is one historical site, Kyk-over-al. There is also twenty-four settlement area; of which Linden and Bartica are regarded as ‘organized settlements’ and the others ‘unorganized or ‘ad-hock’ settlements (figure 4.22 in chapter 4). The population in these settlement areas ranged between five and 22,492 inhabitants. Figure 4.22 shows the settlement areas along with the population: Rockstone (200 inhabitants), Bartica (6,909), Makouria (101 inhabitants), Akyma (69 inhabitants), Three Friends (129 inhabitants), Coomacka Lands (366 inhabitants), Old England (260 inhabitants), Lucky Spot (37 inhabitants), Mahaicabili (77 inhabitants), Sebaru or Aurora (5 inhabitants), Lanaballi (250 inhabitants), St Mary's (94 inhabitants), Monkey Jump (44 inhabitants), Kumaka or Sherima (34 inhabitants), Wineperu (156 inhabitants), Anarika (220 inhabitants), MacKenzie (22,492 inhabitants), Wismar (3,340 inhabitants), Christianburg (2,732 inhabitants), Malali (34 inhabitants), Agatash (185 inhabitants), Ituni (1,000 inhabitants), Mobilissa (101 inhabitants), and Teperu (30 inhabitants). It is noteworthy that the settlement areas are all equipped with various social facilities, such as, schools, churches, police stations, health centres, hospital, and community centres. These facilities are intended to satisfy the community needs.

8.7.3 Economic Factors

Infrastructure (Roads and trails map) - the primary transportation system in the study area comprises major roads as well as numerous minor roads and trails. There are eight major roads of varying lengths. These include: Bartica-Potaro Road, Ituni Road, Kwakwani Road, Linden – Rockstone Road, Sand Hill – Makouria Road, Soesdyke – Linden Highway, and Wismar – Rockstone Road. The area also has over 500 minor roads and trails connected directly or indirectly to the major roads. Figures 4.32 and 4.33 in chapter 4 delineated the road and trails in the study area and was compiled with topographic maps at a scale of 1:50,000.

Forest Types: a significant portion of the study area contains forest with either great commercial importance or moderate commercial importance. A sizeable portion of the study area also contains forest with low and no commercial importance. The map in figure 4.26 depicts the commercial importance of forest types in the study area and was compiled with 1:50,000 topographic maps, Landstat TM Data 1:100,000 (1992), and Field Verification 2001.

Potential Post Harvest Activities Agriculture: there are six soil units in the study which are placed into three broad categories, namely class I-II (good to moderate agricultural land), class III (poor agricultural land), and class IV (non-agricultural lands). Approximately 56.2 percent of the study area (approximately 56.2 percent) is occupied by class IV type soil. The remainder of the study area is occupied by class III soil (approximately 28.8 percent), class I-II soil (approximately 12.1 percent) and the main rivers (2.9 percent). Figure 4.30 depicts the soil capability of the study area and was compiled with topographic maps at a scale of 1:50,000 from the National Agricultural Research Institute (NARI).

The input thematic data layers required for the suitability analysis were acquired from the relevant State agencies. These data were evaluated for accuracy and consistency before being used in ArcGIS model builder. Most of the input GIS layers prepared for the housing suitability model were found relevant and reusable for the forestry suitability model. Soils suitability layer was prepared specifically for the forestry suitability modelling.

8.8 Results

8.8.1 Restriction and Suitability Maps from Cartographic Models

Figure 8.9 shows the suitability of the study area based on the capability of the State Forest. The other suitability factors considered included: slope suitability, land tenure and land use suitability and suitability based on proximity to water bodies.

The results from the restriction model are depicted in figure 8.10 while the results from the suitability model are presented in figure 8.11. As explained in chapter 4, the forest in the study area was classified as follows: forest with the greatest commercial importance (very highly suitable for logging), greatest commercial importance with severe restrictions (highly suitable), moderate commercial importance (moderately suitable), low commercial importance (marginally suitable), conversion forest and no commercial importance (not suitable).

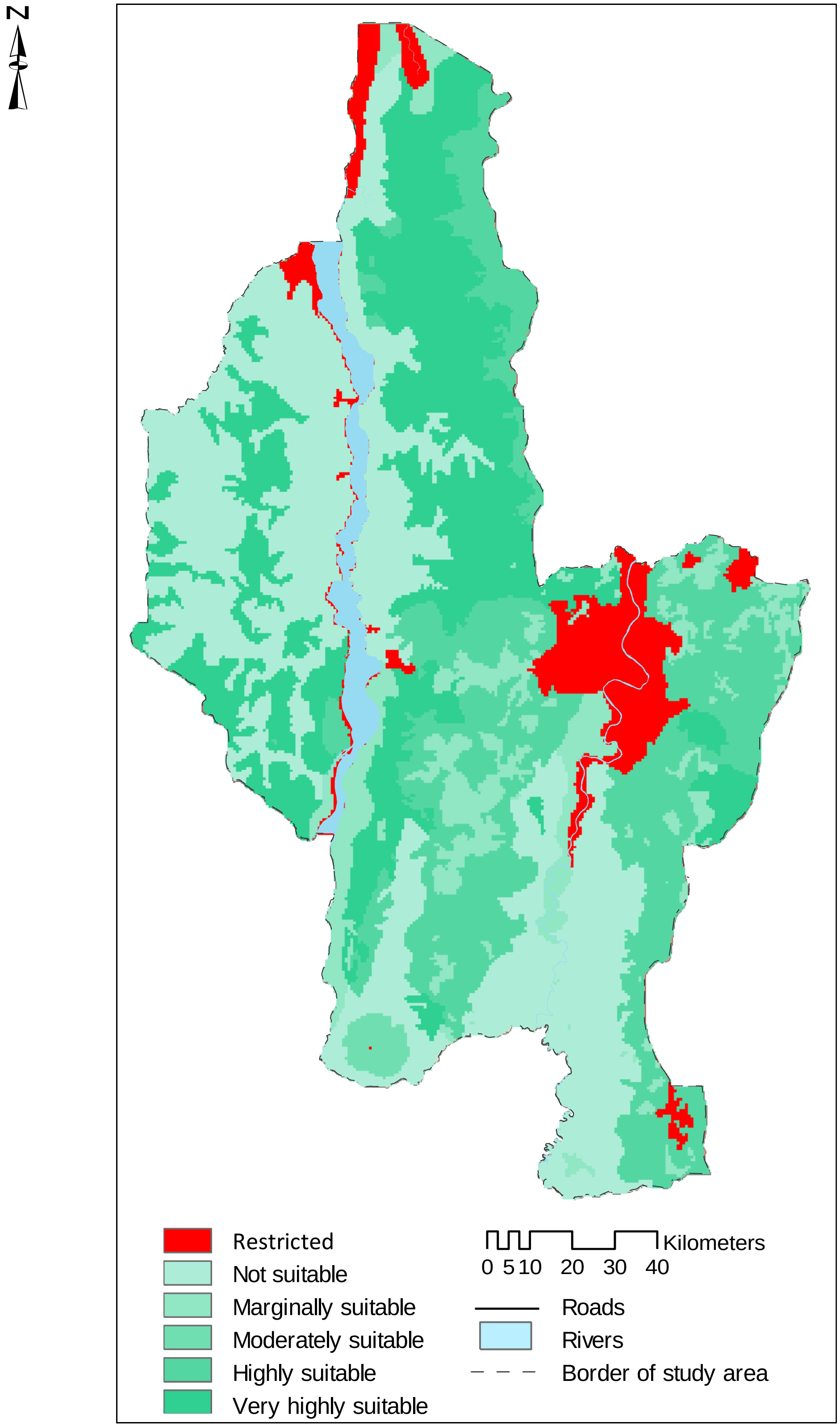

Figure 8.9: Suitability based on forest capability

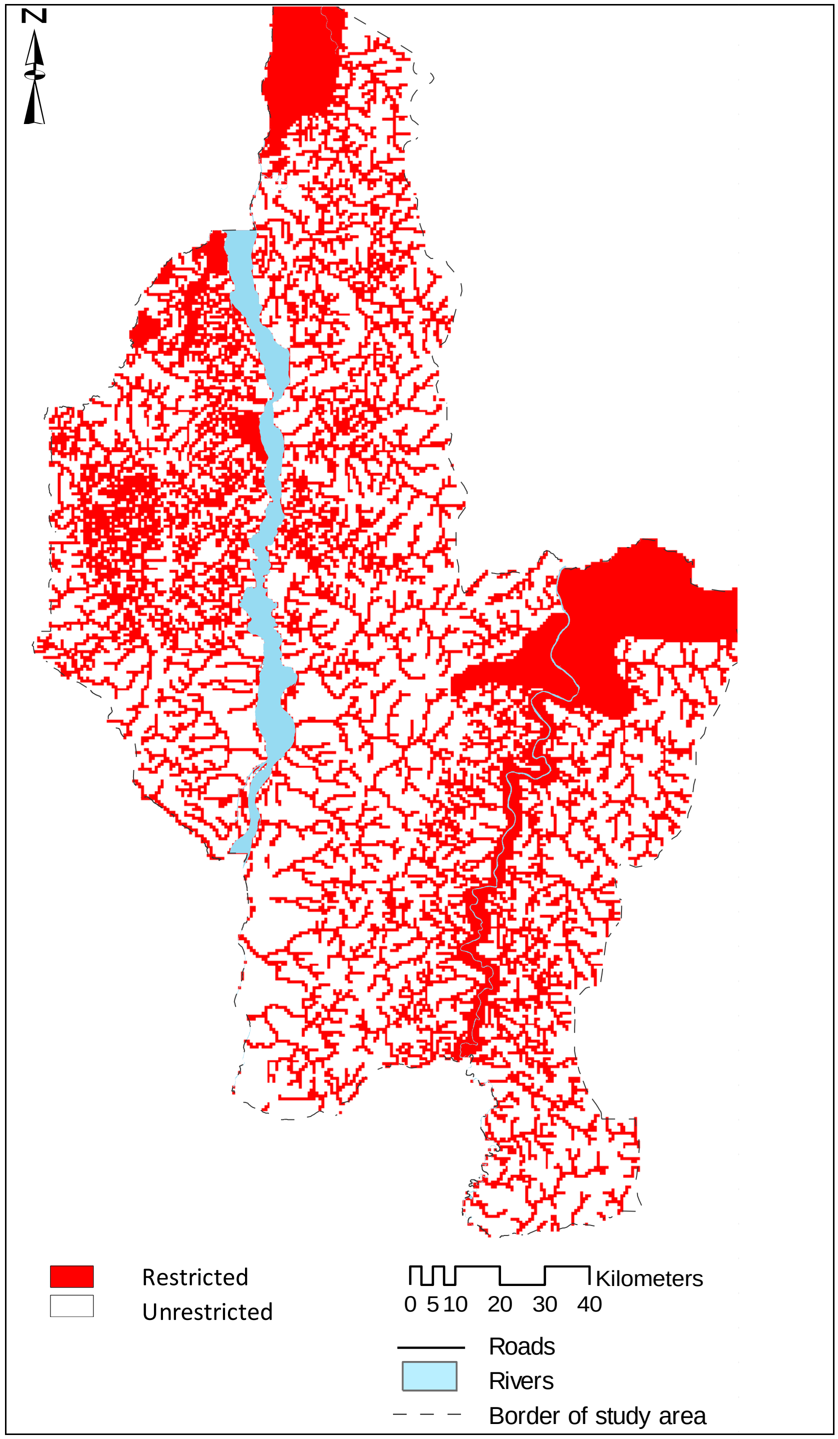

Figure 8.10: Restrictions

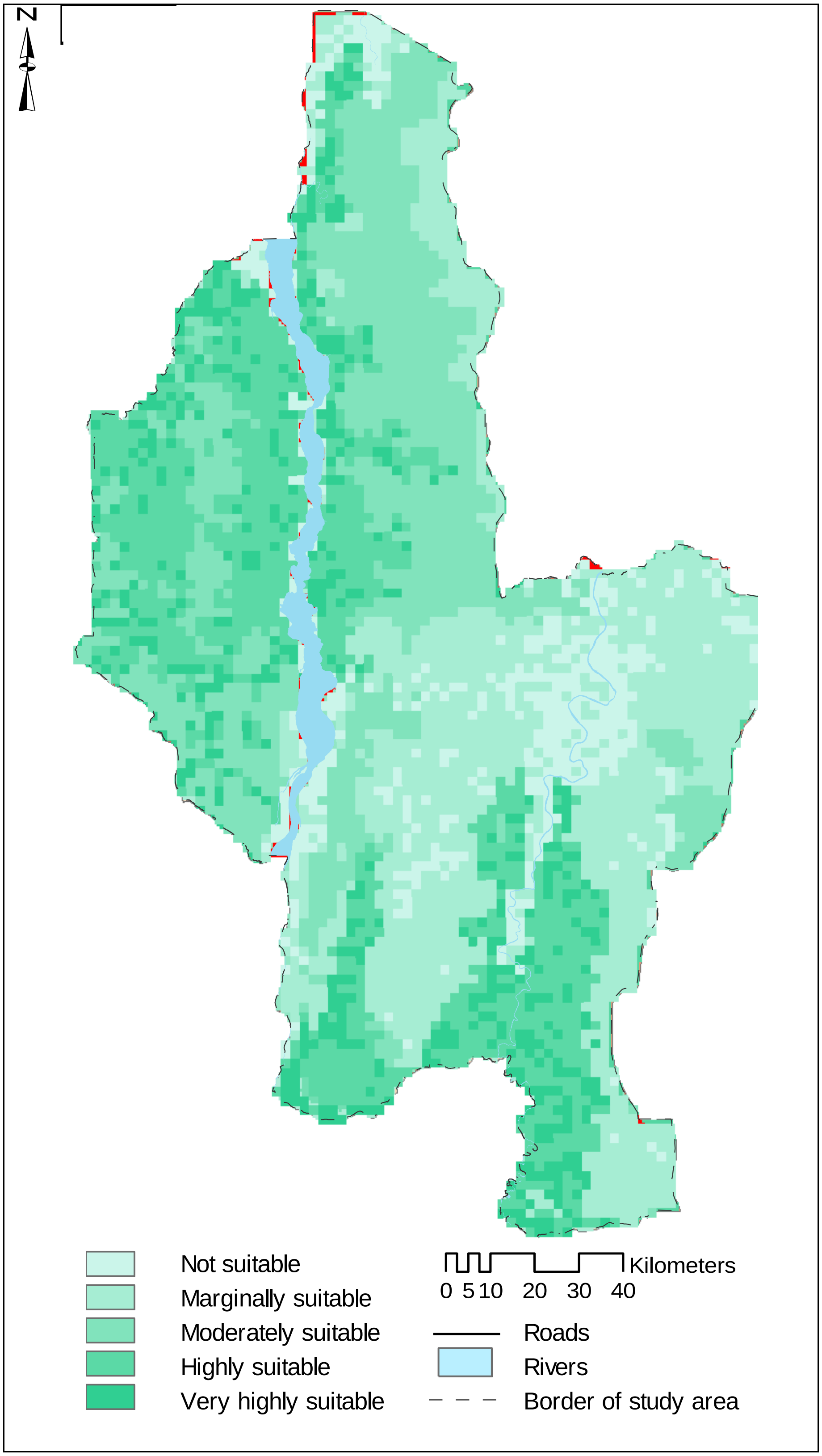

Figure 8.11: Final suitability

8.9 Analysis of Empirical Results

The results suggest the following:

Not suitable: Even though over seventy percent of the study area is covered with forest, a total of ninety-seven land parcels which occupies approximately 43.1 percent of the area (or 2,075.09 square kilometres) is not suitable for commercial utilization of timber according to the final model. The presence of restrictions coupled with the preponderance of low-value timber in the study area is responsible for this outcome. It is noteworthy, that the land parcels that are classified as 'not suitable' sits on minerals possess tremendous potential for tourism and environmental services that can be leveraged under the forest protection agreement between Guyana and Norway.

Marginally suitable: A total 112 land parcels which occupy approximately 8 percent (or 375.49 square kilometres) of the study area is marginally suitable for logging. Again the various restrictions, as well as the availability of limited high-value timber, is responsible for this portion, which is scattered across the study area, being placed into this category.

Moderately suitable: According to the results a total of ninety-eight land parcels which accounts for 16.8% of the study area (or 895.92 square kilometres) is moderately suitable for logging. The land parcels which falls into this classification are sparsely occupied by high-value timber and affected by the various restrictions imposed.

Highly suitable: Based on the results, a total of 230 land parcels which accounts for approximately 11.2% of the study area (or 541.86 square kilometres) are considered highly suitable for logging. The land parcels which are placed into this classification are characterized by high-value timber. However, there are severe restrictions for the commercial harnessing the timber on these parcels.

Very highly suitable: Finally, the results revealed that 169 land parcels which account for 6.6% of the study area (or 320.19 kilometre) have the highest potential for commercial utilization of timber. The land parcels placed into this category have a concentration of high-value timber which can be commercially harnessed without violating the restrictions imposed. Notwithstanding the concentration of the high-value timber, selective logging is possible. As a consequence, logging can occur without much disruption to the environment and forest cover. This is true for the entire country.

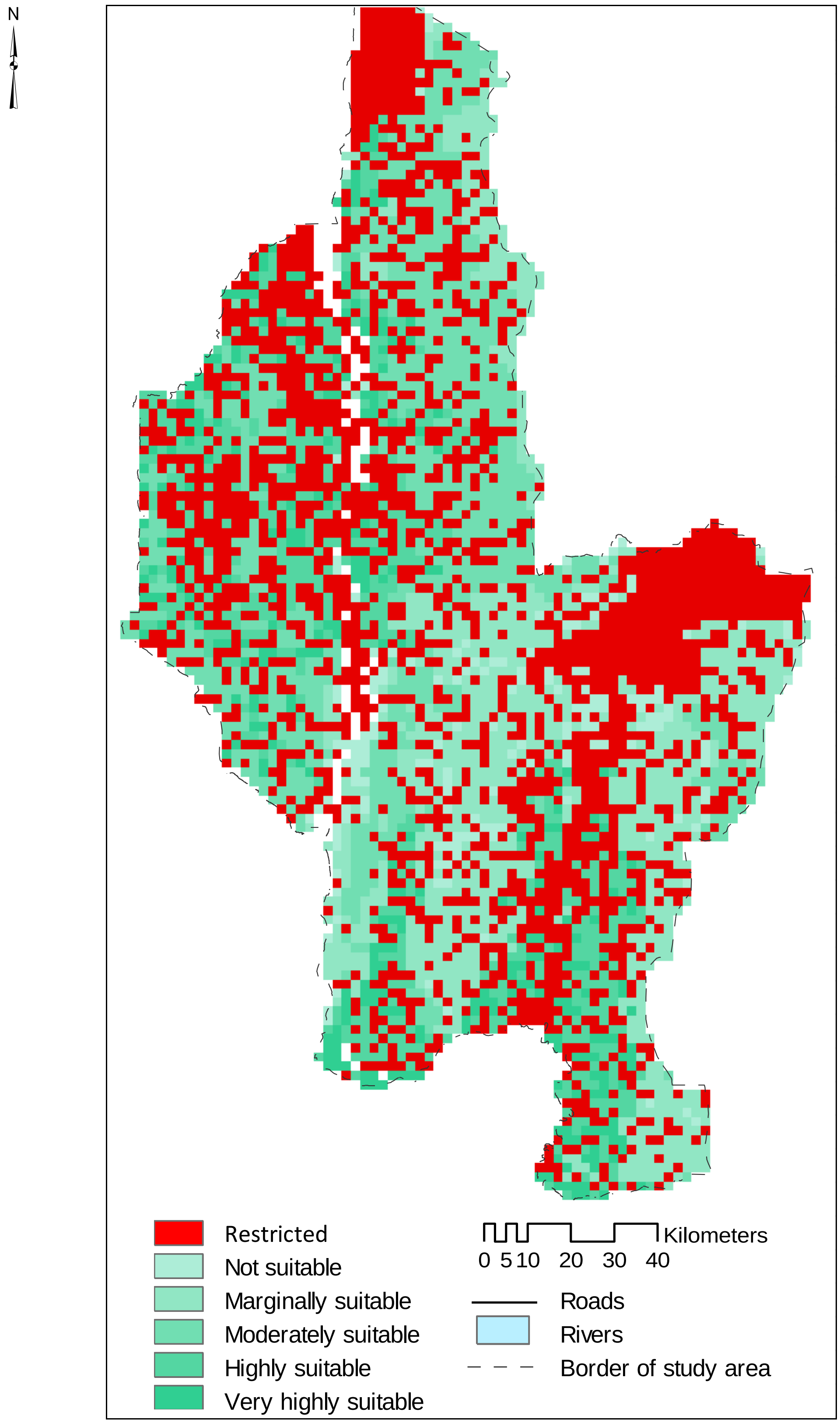

Figure 8.12: Final suitability model

8.10 Summary and Conclusion

The forestry sector is one of the most important economic sectors in Guyana; contributing approximately four percent to Gross Domestic Product (GDP), employs over 20,000 directly in hinterland communities and earns over US$30 million annually from exports. It is therefore not surprising that this sector features prominently in all the development strategies. Indeed, this sector is at the heart of the Low Carbon Development Strategy.

The analysis reveals that eleven land parcels are very highly suitable for timber extraction and gold mining; 641 land parcels which are highly suitable for timber extraction and rice cultivation; 185 land parcels which have high value timber and ideal for the cultivation of high-end vegetables; while 798 land parcels contain high-value timber but not suitable for mining or post-harvest agricultural activities and therefore marginally suitable for timber extraction. Most of the study area is not suitable for timber since they contain low-value timber and unsuitable for mining or post-harvest agricultural activities. The analysis also reveals that there are significant land parcels in the study area with limited potential for logging. However, these land parcels overlap with areas where agricultural and mining activities may be feasible. In the next chapter, the models will be recalibrated to determine the best arrangements for utilizing land parcels with the capabilities for multiple economic activities in a sustainable manner.

CHAPTER 9: IMPLEMENTATION OF THE INTEGRATED MODEL AND ITS GOVERNANCE SYSTEM

9.1 Introduction

This chapter focuses on how the integrated land management model developed in chapter 4 may be implemented in Guyana to facilitate sustainable land management and planning. As noted in chapter 4, the proposed land management model allows for integrated decision-making, improved governance and transparency through inclusivity, effective monitoring and evaluation of land use activities, and promotes ecological and environmentally sustainable land use. The model is also capable of addressing problems such as land conflicts and suboptimal use of land resources which are associated with the ‘silo-type’ decision making by the local land use agencies.

In order to undertake the deliberative phase of the model, the stakeholders from the various land use agencies who participated in the first set of consultations were invited to another round. This time, however, they were joined by other stakeholders, such as, residents, community leaders, Neighbourhood Democratic Councils (NDC), and at-risk groups, who are often excluded from the decision making process regarding land management and land use planning.

The remainder of the chapter provides details on the governance system for the integrated model. It emphasizes the operationalization of the problem-solving module which utilizes spatial multi-criteria evaluation techniques in a GIS system to generate land use plans with cross-sectoral linkages effectively. The results from the problem-solving module are presented and discussed in the chapter.

9.2 Towards an Integrated Governance Model for Sustainable Land Management in Guyana

The preceding chapters of this thesis discussed land management issues confronting Guyana: overlapping jurisdictions, overlapping interests, multiple objective goals, little involvement of stakeholders in land use decision-making processes, and lack of current and accurate data on the status of land resources. In this chapter, an integrated land governance model was designed with the goal of overcoming the current governance issues confronting not only Guyana but several other developing countries.

9.2.1 Design Parameters of the Governance Model

The integrated governance model is designed with the following in characteristics:

(a) To shift the focus from departmental objectives to collective national developmental goals.

(b) To shift the focus from hierarchal declarative top-down approach to consultative and collaborative approach.

(c) To shift the focus from State Agencies' control and dominance to stakeholder participatory decision-making process.

(d) To shift from static political policy regimes to dynamic data-driven policy regimes.

(e) To shift from the development of departmental silo databases to the development of a national spatial data infrastructure [NSDI].

The proposed governance model is depicted in Figure 9.1

Figure 9.1: Integrated land management governance model in support of integrated land management

At the apex of the model is the National Land Management Council (NLMC). The terms of reference and membership composition of the Council are presented below.

9.2.2 Terms of Reference

The following are the terms of reference of the NLMC

- Formulate land policy in support of social, economic and environmental goals of the country.
- Develop strategies and measures that will address exogenous risks that may negatively impact on land resources of the country.
- Develop strategies and measures that will mitigate endogenous risks that may arise out of unsustainable land use.
- Provide budgetary support for capacity building and institutional development activities of land-related agencies.
- Present develop land policies and land use plans for parliamentary approvals.

9.2.3 Membership Composition of the NLMC

The proposed membership of the Council is as follows:

- President or Prime Minister (Chair)
- Minister for National Security
- Minister for the Communities
- Minister of Finance
- Minister for the Environment
- Minister of Public Administration

- Private Sector Representative
- Representative of the Ministry of Indigenous Peoples' Affairs
- Representative of Opposition Parties

It is envisaged that the council will meet at least every quarter and at any other times deemed necessary by its members.

The work of the NLMC will be supported by a broad-based National Land Development and Land Allocation (NLDLA) Coordinating Agency. The Agency is the technical implementation arm of the Council. Its TOR and composition are presented below.

9.2.4 Terms of Reference of the NLDLA

The following are the terms of reference of the Agency:

- Implement national land policies and strategies.
- Develop and implement monitoring and evaluation tools and reporting mechanisms in support of the land policy.
- Review and prepare draft stakeholders driven land policy for the council's deliberation and approvals.
- Prepare draft land use plan after the consultative process for the Council.
- Prepare a financial budget for effective and efficient land management.
- Provide policy directive for the development, maintenance, and use of NSDI.

- Prepare after consultation with stakeholders, annual reports on the state of national land resources.
- Engage and maintain active involvement of the civil society organisations in all land management matters and decisions.

9.2.5 Membership Composition of the NLDLA

The proposed membership of the Coordinating Agency are as follows:

- Heads of Land-related Agencies: GLSC, GGMC and GFC.
- Representatives of Regional Democratic Council (RDC), Neighbourhood Democratic Council (NDC), and Indigenous Communities.
- Community-Based Organisation and Non-governmental Organisations (Miner /Agriculture /Forestry)
- Private Sector – Construction Industry

The Chairmanship of the Agency is to be elected by its members. The work of the Agency shall be supported by three working groups (WG): Land Policy Working Group (LPWG), Land Utilization Working Group (LUWG), and the Community Engagement Working Group (CEWG).

The Land Policy WG will be responsible for the monitoring and evaluation of land policy and proposition of changes in response to national developmental goals. It will, on an annual basis, present key performance indices of land policy and their contributions to national developmental goals. Land Utilization WG will be responsible for providing technical advice to the Council through the Coordinating Agencies on land suitability and land allocation for all major land-related investment in the country. It will have access to a well-equipped research unit that will be able to quantify and qualify the impact of current land use to guide future land suitability modelling. It will produce an annual report on the current state of land utilization in the country.

Community Engagement WG will be responsible for soliciting and encouraging participatory approaches to land development and land allocation. The WG will develop mechanisms for a bottom-up approach to land development initiatives through public education, public awareness, timely consultation and active engagement that will lead to a community sense of ownership in all policy dimensions. The work of the CEWG should cut across race, education, language, gender, disability and location barriers.

The membership of the three working groups should be such that it has a mix of technical and social partners; gender balanced with intentional inclusion of youths and academic institutions. For efficiency, the membership of each working group should not be more than ten persons.

9.2.6 National Spatial Data Infrastructure

In order to ensure that the works of the Council and the Agency are current and factual, a National Spatial Data Infrastructure management agency should be established through the amalgamation of the GLSC with other spatial data management agencies of the Government. This agency will be charged with the responsibility of designing, developing, and maintaining national spatial databases with related metadata and functional policy that guides the use of these databases. Its work will entail the harmonization and standardization of existing databases currently housed in the silos of different departmental agencies.

The primary goals of the NSDI Agency are:

(a) To eliminate duplication of efforts in spatial data collection and management
(b) Ensure that land resource data is accurate, current and consistent throughout the country
(c) Encourage active use of spatial data across public and private sectors through a deliberate mainstreaming programme
(d) Undertake regular national data collection and updating actions on a five-year cycle
(e) Take full advantage of technological innovations in support of data collection, data management, and data analysis, and data dissemination
(f) Produce a biennial atlas of land resource utilization in the country

9.3 The Land Management Framework

Module 2: The second module was operationalized by creating a group to mimic the National Land Management Council comprising representatives from the primary land use sectors and other government officials (figure 9.2). Unlike the first set of consultations, however, government officials/representatives were joined by members from the private sector, regional and local governments, and at-risk groups to assist in determining the best uses for the land parcels in the study area (figure 9.2). Each category of stakeholder had a unique interest. The table 9.1 provides a list of the stakeholders and their stakes.

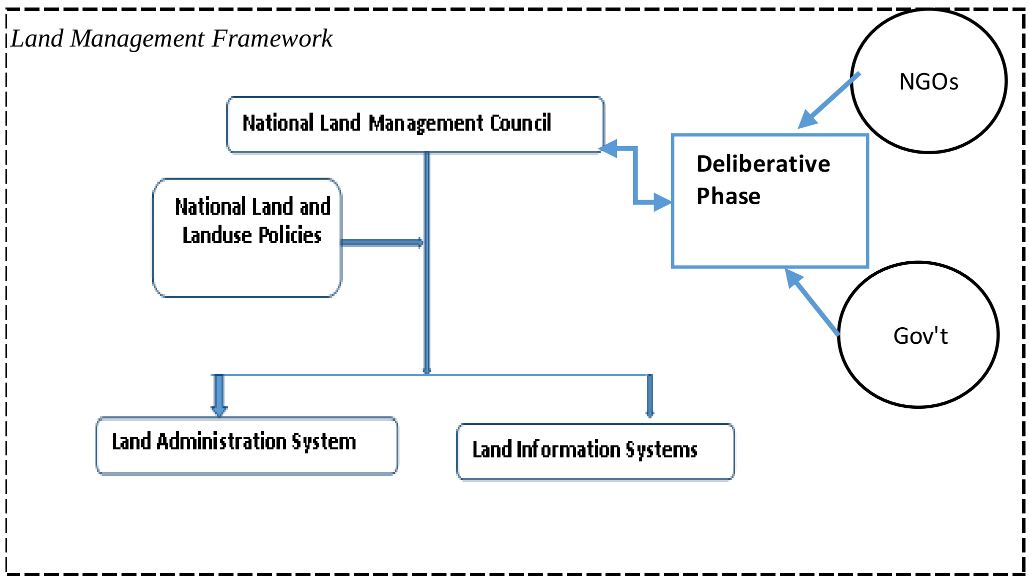

Figure 9.2: Module – National land management framework

Following specific land use suitability analysis undertaken for Housing, Agriculture, Mining and Forestry in chapters 5, 6, 7, and 8 respectively, the stage is set now for an integrated analysis.

Module 3 Deliberative Module (Operational Problem Solving and Implementation Framework). Module three of the proposed model was operationalized by systematically implementing the steps for spatial multi-criteria decision analysis developed in chapter 4. A presentation was made to the stakeholders illustrating the procedure for applying the Spatial Multi-criteria Decision Analysis framework. It also highlighted (i) issues and challenges surrounding land management and planning in Guyana, (ii) policy environment, and (iii) the need for integrated land management and planning tools.

Table 9.1: Stakeholders who participated in consultation

Stakeholders	**Type**	**Stakes**
Guyana Women Miners Association	NGO	Promote the interest of women miners
Guyana National Youth Council	NGO	Promote the interest of youths
Guyana Agriculture Producers Association	NGO	Promote the interest of farmers
Guyana Tourism and Hospitality Association (Guyana)	NGO	Promote the interest of businesses in the tourism industry
Guyana Gold and Diamond Miners Association	NGO	Promote the interest of small miners across Guyana
Community Development Council	NGO	Promote the interest of citizens at the local level
Guyana Lands and Surveys Commission	Government	Promote the development of land records
Guyana Geology and Mines Commission	Government	Promote the interest of the government with respect to mining
Guyana Forestry Commission	Government	Promote the interest of the government with respect to forest products
Ministry of Indigenous Peoples' Affairs	Government	Promote the interest of government with respect to the first people of Guyana
Ministry of Communities	Government	Promote the interest of government with respect to local government issues
Environmental Protection Agency	Government	Promote the interest of government with respect to environmental issues.

There was a consensus among the stakeholders that the existing land planning system was deficient. Given this situation, the stakeholders were asked to decompose the problem in the form of a hierarchical structure with the specific goals for each sector that are decomposed into sub-goals or criteria levels. To assist the groups, they were provided with the hierarchical structures previously developed. They accepted the overall objective of sustainable land use as the ultimate goal with sub-goals that included economic, environmental and socials considerations.

With the assistance of experts possessing knowledge in GIS, the stakeholders were asked to identify specific indicators for determining the suitability and constraint indicators for each of the four land uses. During this stage of the process, the stakeholders were also required to develop a ranking for various land uses, as well as, protocols for resolving potential conflicts between and among the different sub-groups.

Finally, the various restrictions and suitability criteria were utilized to design and implement an integrated model that generates land use maps with cross-sectoral linkages. Specifically, the model was aimed at identifying the best area for a particular economic purpose (mining, logging, housing, agriculture) while taking into consideration the various restrictions and aspiration of other competing sectors. The result was a land use plan that fulfilled the objectives of the stakeholders.

9.4 Results and Discussion

9.4.1 Mining Suitability

The stakeholders agreed that the lithological units should dictate the type of mining activities permitted in the study area. In this regard, they agreed that gold mining should be undertaken in areas with Greenstone while bauxite, stone/quarrying, and sand mining should be restricted to areas with Gabbro, Migmatites/Granitoid, and Fluvial & Marine Sands respectively. Since gold extraction is the most lucrative mining activity, the areas with greenstone were awarded a ranking of 5, followed by bauxite (4), stone/quarrying (3) and sand mining 2. The stakeholders awarded (1) to areas where these activities were not feasible, and zero (0) to areas closed to mining.

Figure 9.3 provides information on the land parcels selected for various mining activities. Approximately 8.5 percent of the study area was suitable for gold mining, followed by 2.2 percent, 21.9 percent and 67.3 percent for bauxite, stone and quarrying operations and sand mining respectively (table 9.2).

Table 9.2: Land parcels identified for various mining activities

Type of mining	**Ranking**	**Area**	**%**
Gold	5	409	8.6
Bauxite	4	107	2.2
Quarry	3	1,052	21.9
Sand mining	2	3,231	67.3
Total		**4,800**	**100.0**

9.4.2 Forestry Suitability

The stakeholders in this sub-group agreed that the commercial importance of the forest should determine the suitability of a particular area for logging. They developed a five-point rating system where five was attached to areas where there is forest with the greatest commercial importance followed by areas with forest with the greatest importance but significance (4), moderate commercial importance (3), low commercial importance (2), non-commercial importance and greatest importance proposed for conversion forest (1) and areas restricted to logging (0). Figure 9.4 below provides the various classifications developed by these stakeholders.

Table 9.3: Land parcels identified for logging activities

Classification of forest	**Ranking**	**Area**	**%**
Greatest importance	5	1,524	31.7
Greatest importance with restrictions	4	41	0.8
Moderate importance	3	1,214	25.3
Low importance	2	1,100	22.9
Non-commercial	1	385	8.0
Greatest importance proposed for conversion Forest	1	94	2.0
Restricted	0	443	9.2
Total		**4,800**	**100.0**

Approximately 31.7 percent of the study area comprised forests with the greatest commercial importance (table 9.3). However, the group identified vast swathes of forests with low commercial importance (22.9%), 25.3 percent with moderate commercial importance, and 8.0 percent with non-commercial importance (table 9.3).

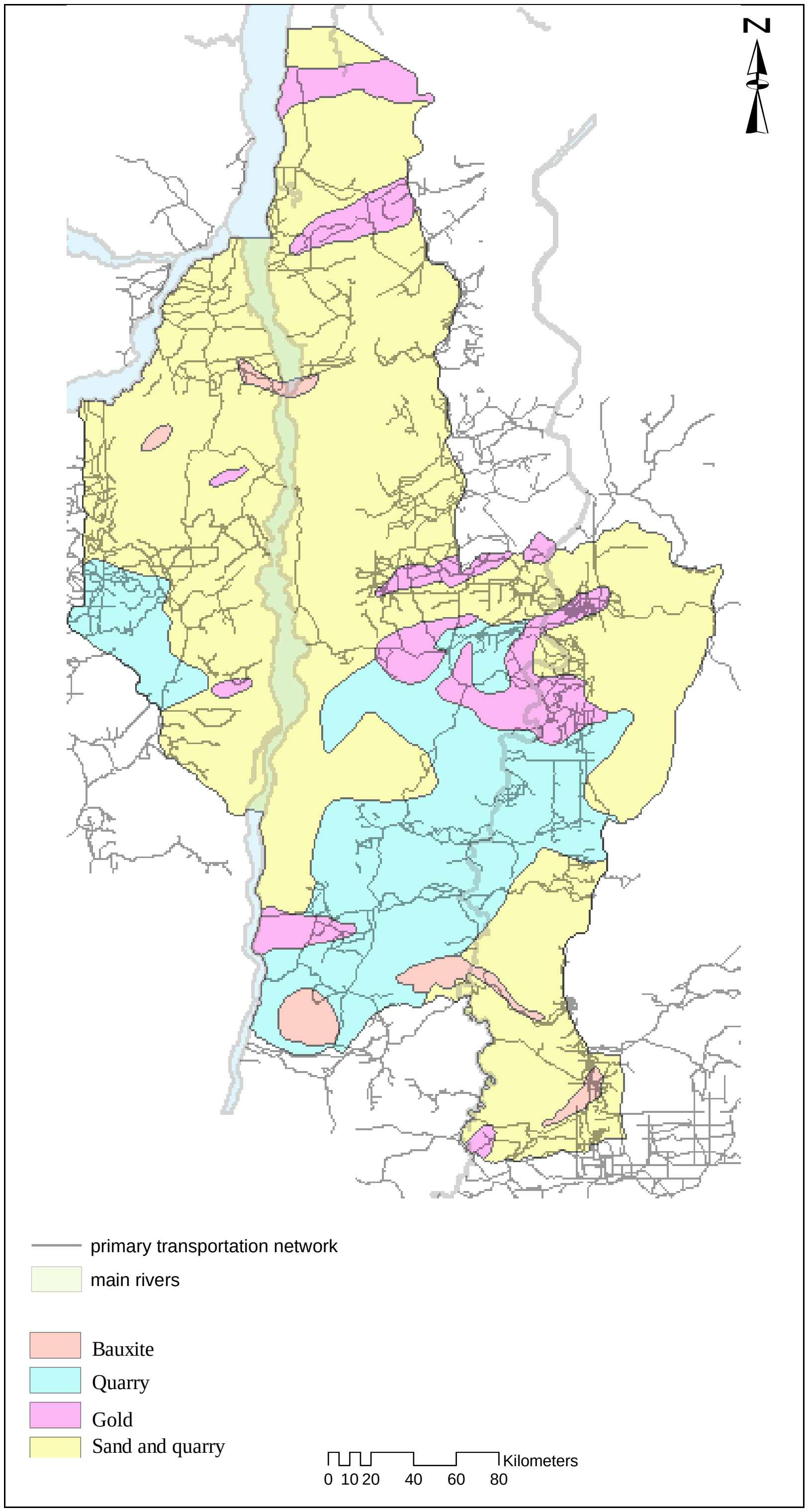

Figure 9.3: Areas selected for mining activities

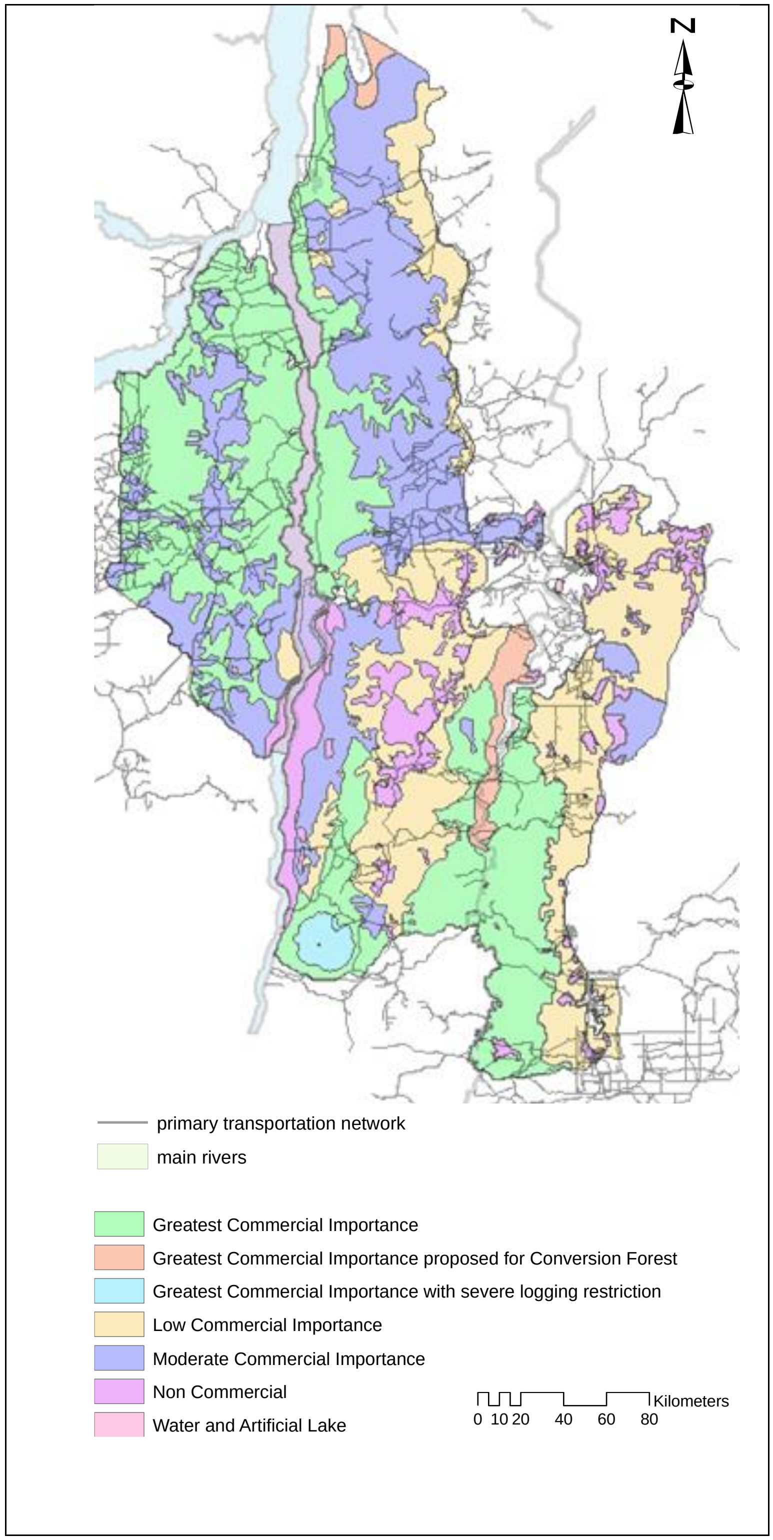

Figure 9.4: Areas selected for forestry activities

9.4.3 Agriculture Suitability

The agriculture stakeholder's sub-group agreed that the soil type should determine whether agriculture activity is permitted in a particular area. In this regard, they developed three broad classifications for soil in the study area, class I-II soil, class III soil and class IV soil. The class I-II soil was deemed very suitable for agriculture and given the highest ranking of three while class III and class IV soil were given rankings of two and one respectively (figure 9.5). Table 9.4 shows that only 12.5 percent of the study area was considered very suitable for agriculture (Class I-II soil). The remaining areas consisted of lands which were not ideal for farming (Class III and Class IV).

Table 9.4: Land parcels based on soil type

Soil type	Ranking	Area (km^2)	%
Class I-II	1	506	12.5
Class III	2	1,403	29.6
Class IV	3	2,736	57.9
Other		155	3.2

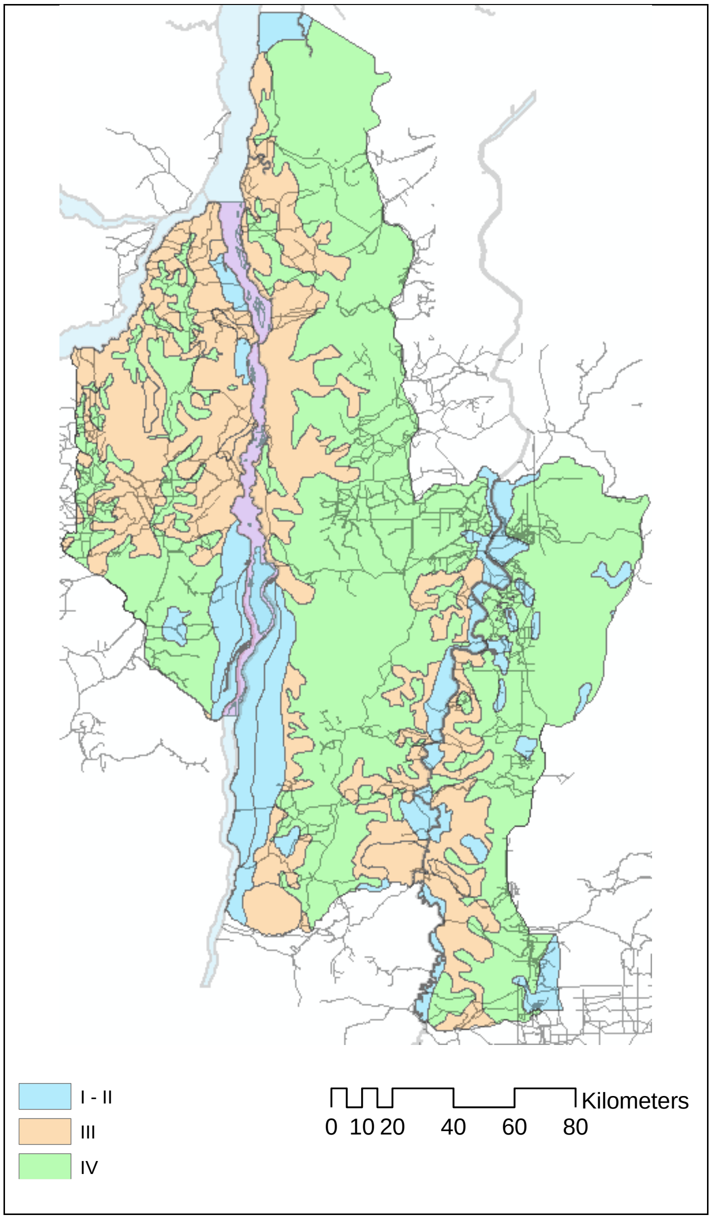

Figure 9.5: Soil capability classifications

9.4.4 Housing Suitability

The stakeholders agreed that the best areas for housing would be those where there is potential the demand for housing is high, and the cost for developing infrastructure is relatively low. They went on to associate housing demand to growth in the segment of the population who are eighteen years and older (>=18 years old). Meanwhile, they linked the cost of infrastructure to the availability of social and economic facilities, such as road, water transmission network, schools, health centres/hospital, markets, and police station. The figures below show the schools (figure 9.6), police station (figure 9.7), markets (figure 9.8) and health facilities (figure 9.9) in the study area along with the roads.

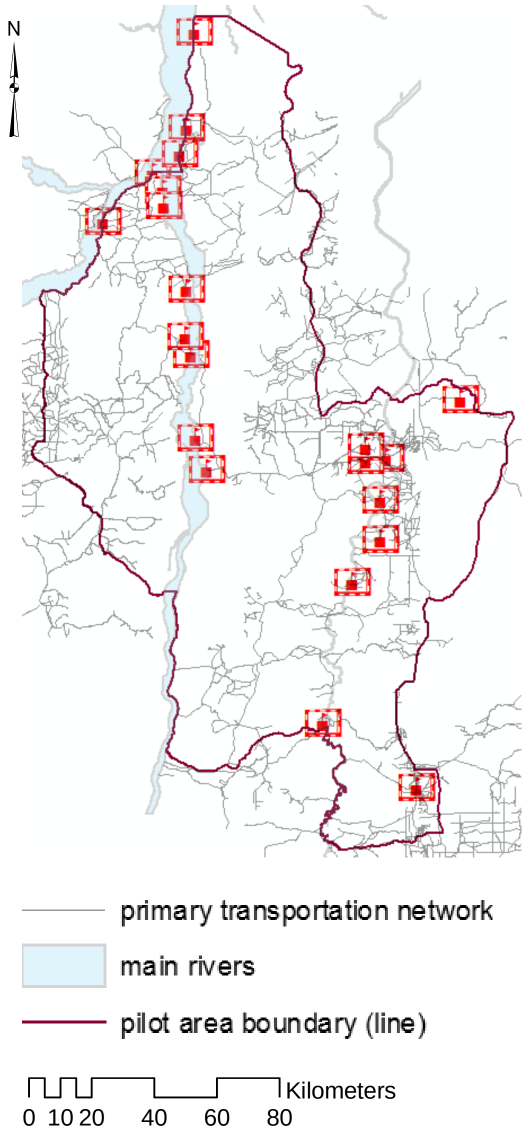

Figure 9.6: Location of schools

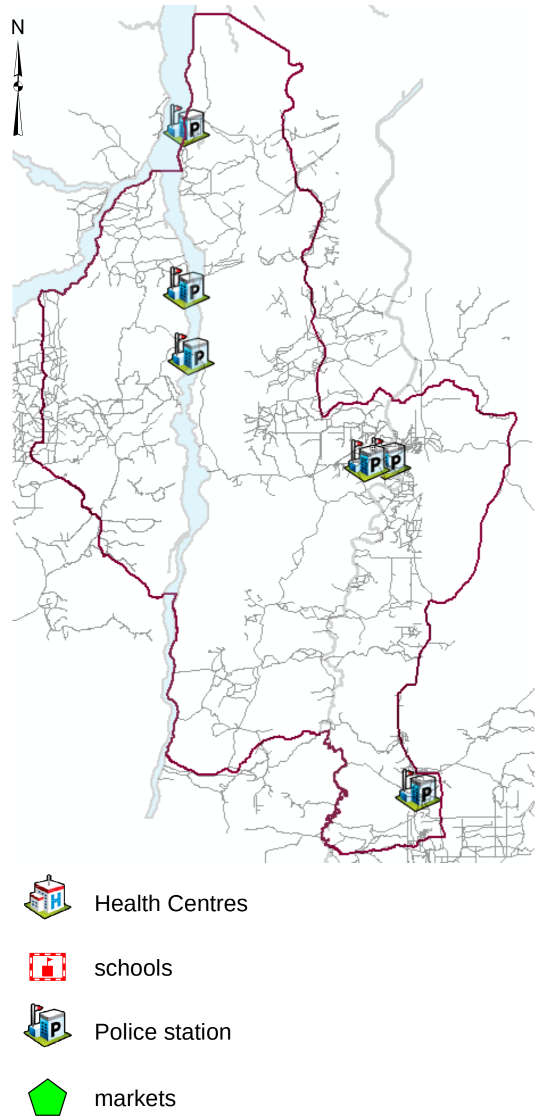

Figure 9.7: Location of police stations

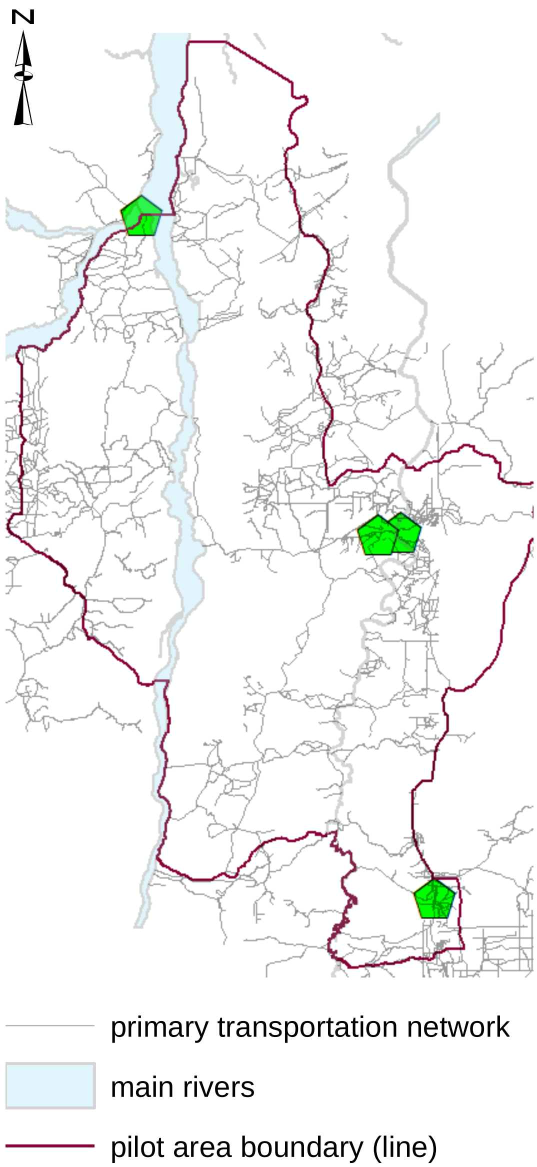

Figure 9.8: Location of markets

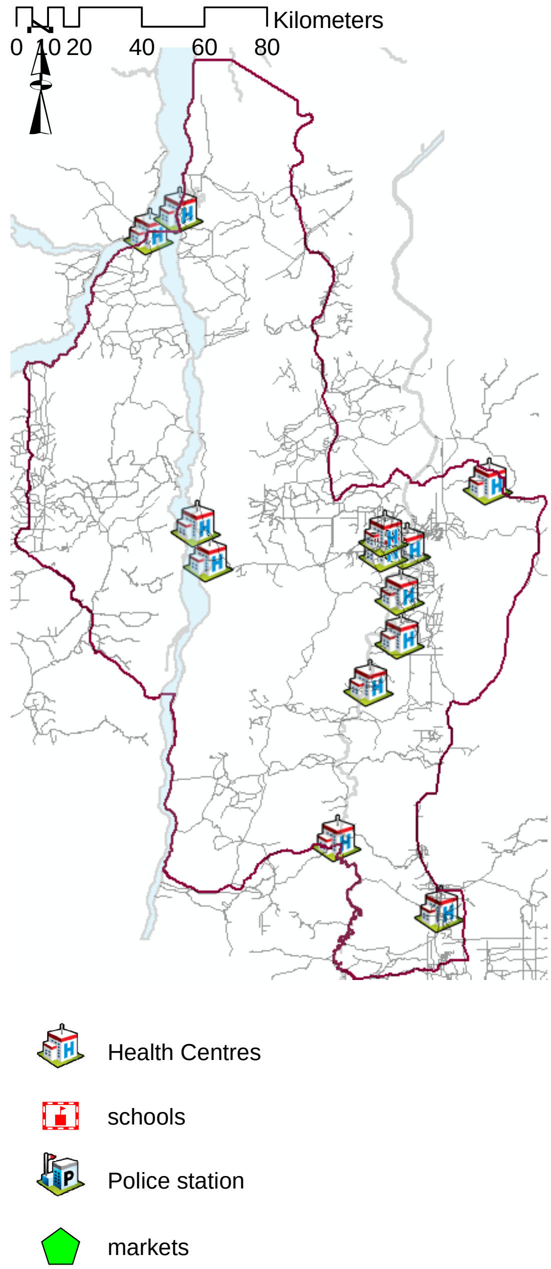

Figure 9.9: Location of health facilities

9.5 Protocols Developed for Resolving Conflicts: Mining and Forestry

The results of the mining suitability model and the forestry suitability model were integrated to determine the land parcels that are suitable for both activities. It was observed that significant overlaps existed between the land parcels ideal for various mining activities and land parcels with forestry with commercial importance. Substantial overlaps also existed between land parcels with considerable mining potential and forestry. The figures below show that forest with the greatest or moderate commercial importance overlapped with areas with potential for gold mining (figure 9.10), bauxite extraction (figure 9.11), quarry and stone extraction (figure 9.12) and sand mining (figure 9.13). This situation explains, to some extent, the land conflicts between miners and loggers explained in chapter 3. The stakeholders in the mining and forestry sub-groups were, therefore, requested to develop protocols for resolving these conflicts. They were also required to identify restrictions to reduce the environmental damage from these economic activities as well as suitability criteria for determining the best land parcels that would maximize the social and economic returns from mining and logging.

The mining and forestry sub-groups agreed to the following protocols where mining opportunities conflict with logging opportunities:

- Priority should be given to the resources that have the highest current market value.

- Priority should be given to the resources that have the least level of land degradation during the extraction process.
- The assignment of responsibility for land rehabilitation of the land shall be assigned at the time the decision is made.
- National policy on resource reservation and preservation shall have priority over resource exploitation.

In this regard, they unanimously agreed that mining and logging should be allowed in areas where forest with highest commercial potential and best mining prospects exist. They pointed out that the economic and social benefits can be maximized if logging is done before mining. However, they concurred that since these activities would contribute to significant degradation of the forest, the loggers and miners should share the responsibility of restoring the area once these economic activities are completed.

The experts agreed mining should be permitted in areas with the best mining prospects but low-value forest. They, however, contend that green technology should be utilized and the mined out areas should be restored in the end.

Meanwhile, they recommend moderate logging as the main economic activity for areas where medium scale and small-scale logging can take place, but mining prospects are limited. However, the loggers should be responsible for replanting trees during their operations.

Finally, they agree that mining and logging should not be permitted in areas where the forest has no commercial importance and mining is not economically feasible. Notwithstanding, the protocols for joint uses by the miners and loggers, the stakeholders in this sub-group maintained the ranking for mining and logging (table 9.5).

Table 9.5: Ranking of mining and forest logging opportunities

Mining capability	**Ranking**	**Forest capability**	**Ranking**
Gold	5	Greatest commercial importance	5
Bauxite	4	Greatest commercial importance with restrictions	4
Stone	3	Moderate commercial importance	3
Sand	2	Low commercial importance	2
No mining potential	1	No commercial importance	1
Closed	0	Restricted	0

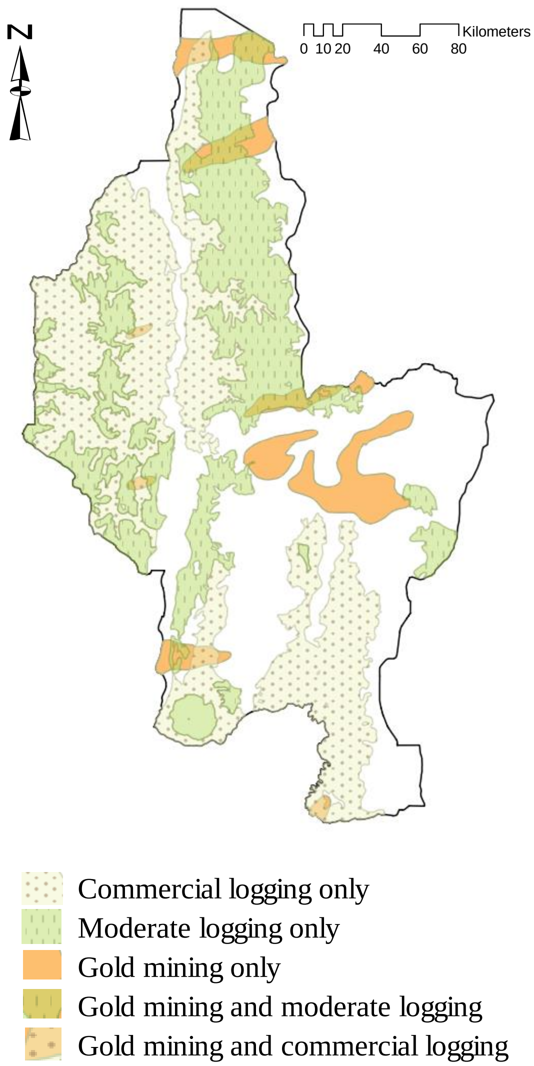

Figure 9.10: Overlaps between land parcels with gold mining potential and forestry

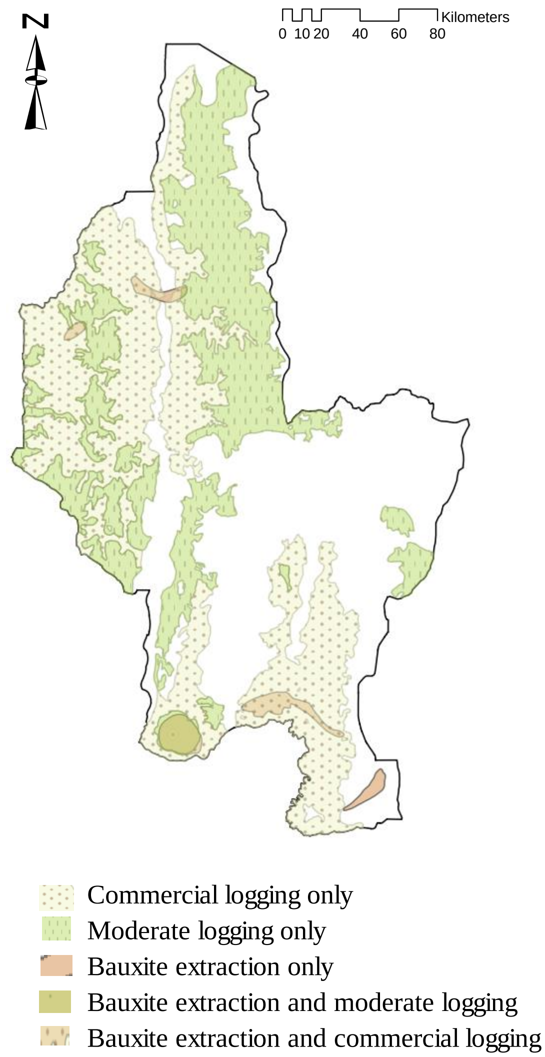

Figure 9.11: Overlaps between land parcels with bauxite potential and forestry

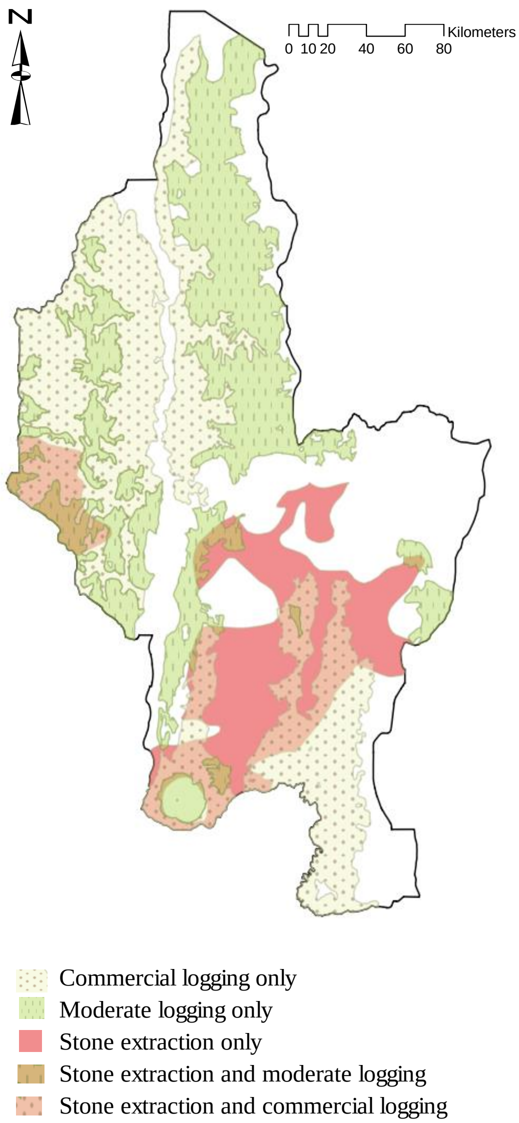

Figure 9.12: Overlaps between land parcels with stone extraction potential and forestry

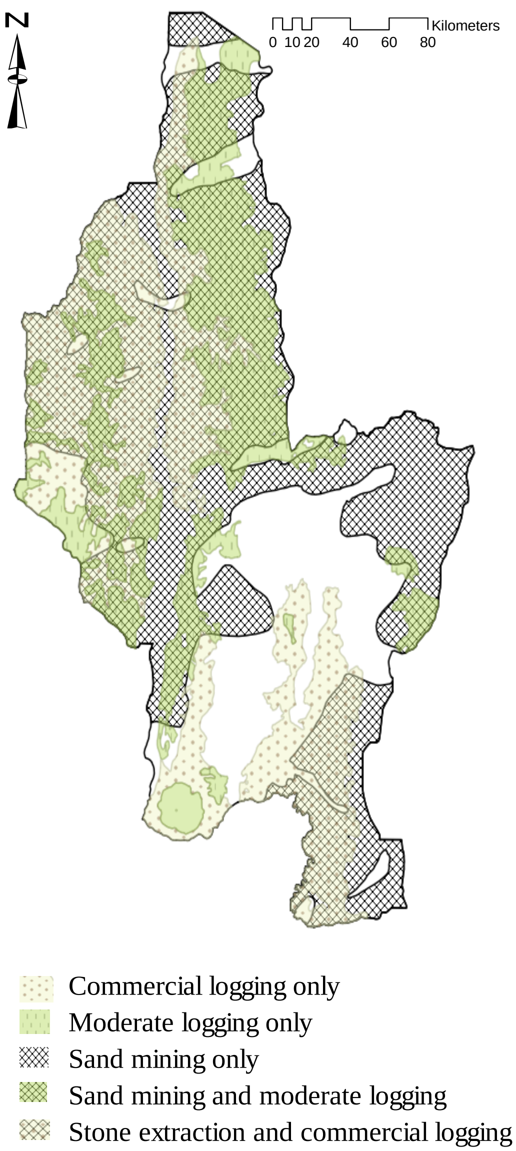

Figure 9.13: Overlaps between land parcels with stone extraction potential and forestry

The stakeholders from the mining and forestry sub-group also examined the various restrictions, both statutory and non-mandatory, that businesses are expected to observe in the mining and forestry sector as well as those previously recommended (see chapters 8 and 9). Where there were conflicts between the statutory requirements, the stakeholders opted for the maximum restriction. For example, according to the GFC Code, the required distance of logging from a river is 30m. However, the Mining Regulation requires that mining activities be undertaken no less than 20m from rivers. In this case, the stakeholders opted for the maximum restriction of 30m. The critical restrictions that the experts agreed to are contained in the table below.

Table 9.6: Ranking for various mining and logging constraints

Environmental	**Forestry**	**Mining**	**Compromise**	**New Weights**
Mandatory				
Protected areas	> 20 m	> 20 m	> 20 m	0.09
Land slope	< 20^0	*n.a*	< 20^0	0.06
Watercourses				
River	> 30 m	> 20 m	> 30 m	0.05
Creeks	> 20 m	> 20 m	> 20 m	0.05
Public roads	*n.a.*	> 100 m	> 100 m	0.09
Non-mandatory				
Lakes, swamps and wetland	*n.a.*	> 1 km	> 20 m	0.07
Sensitive hydrogeological environments	*n.a.*	>19	> 20 m	0.14
Tourism		New		
Closed area		New		
Hydro catchment area		New		
Social				
Mandatory				
Human settlement and farms	> 20 m	> 100 m	> 100 m	0.10
Historical sites and cultural sites	> 20 m	*n.a.*	> 20 m	0.06

The expert agreed to three new criteria to cater for the hydro potential and tourism. Within the study area, there were two potential sites for hydro and one area with significant tourism potential. An area that was closed to mining was identified by the experts as well as one where tourism potential is high. These criteria were therefore added as restrictions.

The stakeholders also ranked the various criterion using the pairwise comparison procedure. The restrictions and weights were then used to generate three models, namely, the restriction model, suitability model and one that identified the land parcel. The results from restricted models with the old and new criteria are presented in figures 9.14, 9.15, and 9.16. Based on these results, mining and logging activities are only permitted in the blue areas (figure 9.14, 9.15, and 9.16). With the new restrictions, sizeable portions of the study area would not be available for mining and logging.

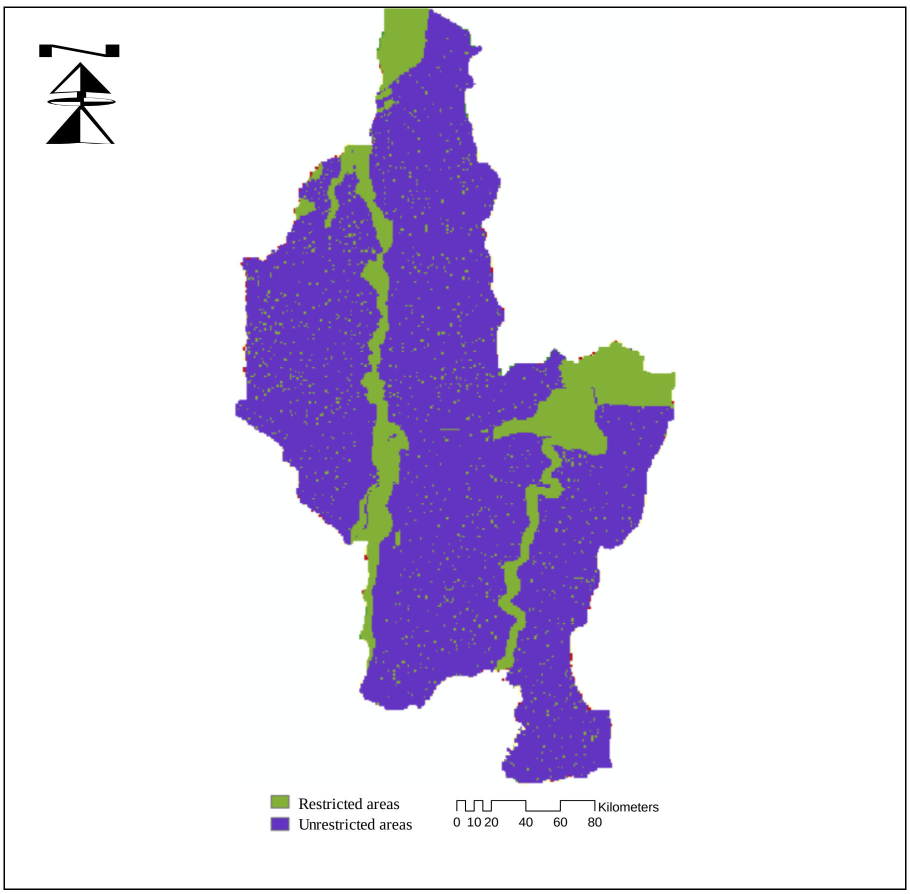

Figure 9.14: Restriction model for mining based on old criteria

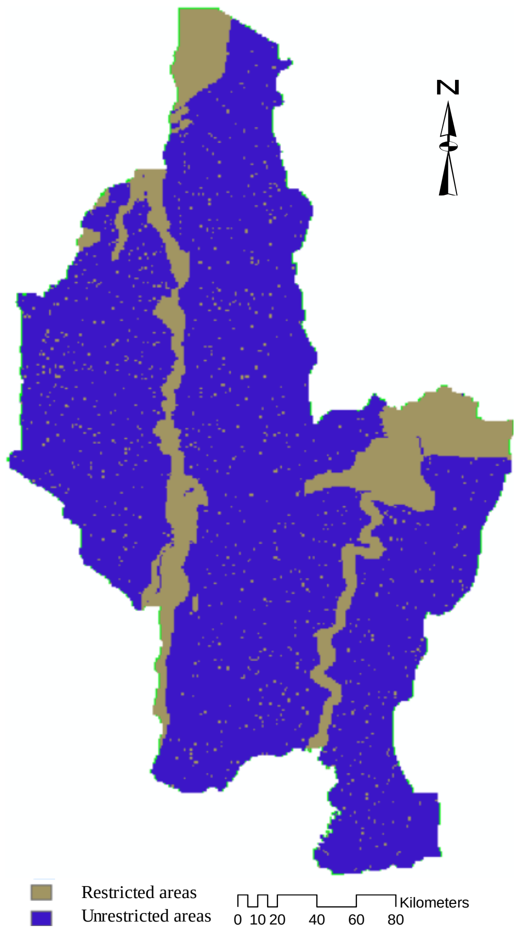

Figure 9.15: Restriction model for forestry based on old criteria

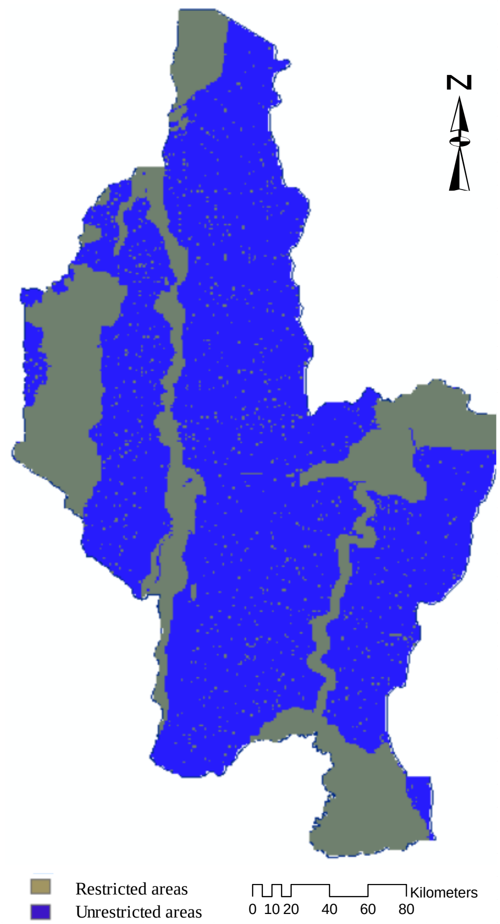

Figure 9.16: Restriction model for both sectors based on new criteria

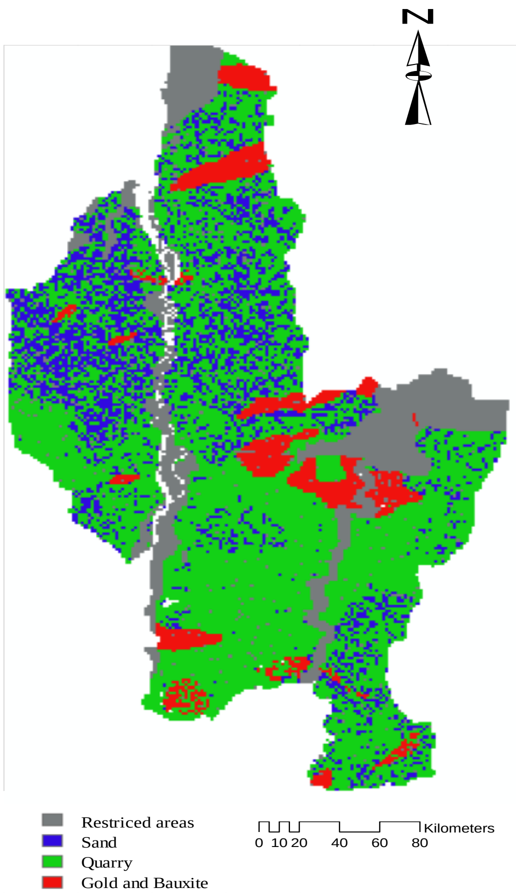

Figure 9.17: Areas selected for mining activities based on old criteria

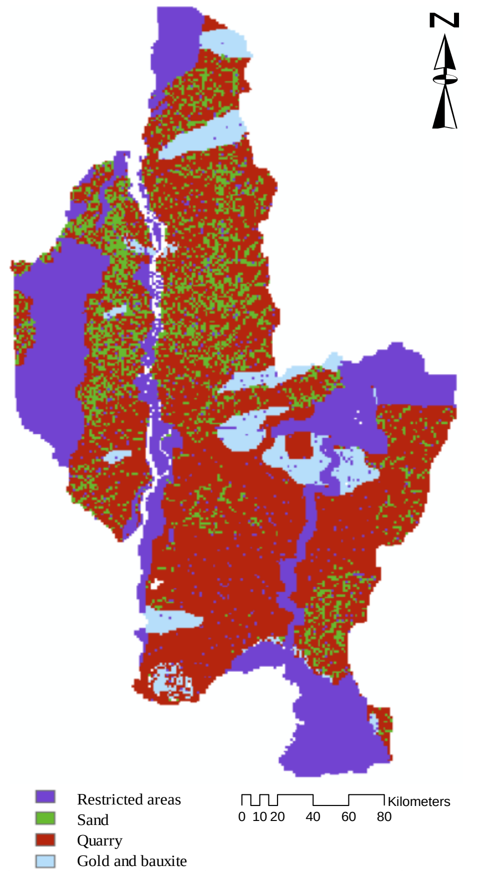

Figure 9.18: Areas selected for mining activities based on new criteria

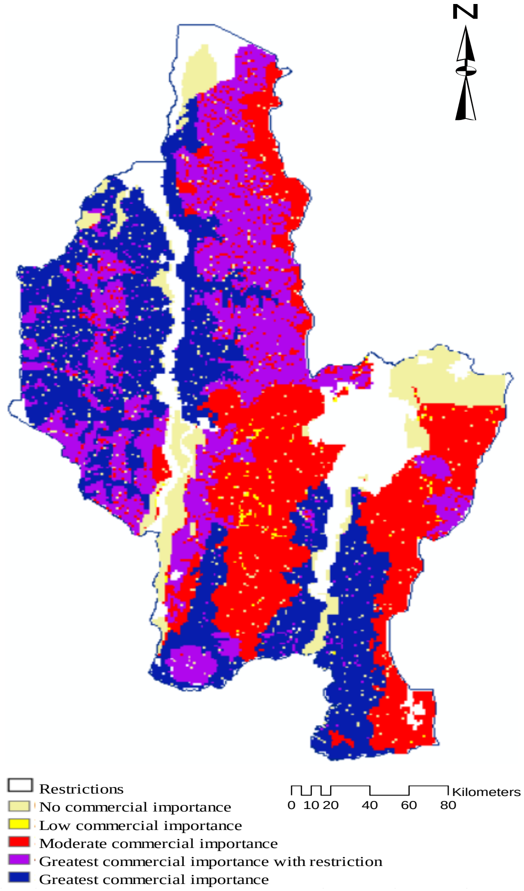

Figure 9.19: Areas selected for logging based on old criteria

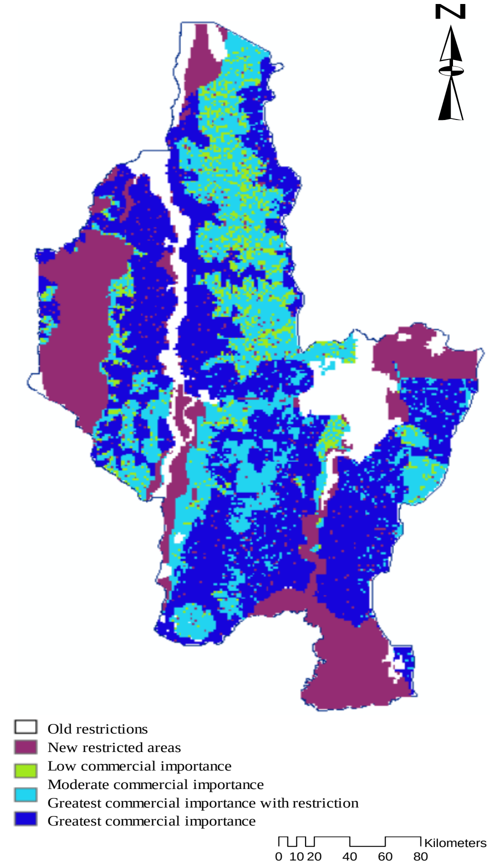

Figure 9.20: Areas selected for logging based on new criteria

9.6 Protocols Developed Resolve Conflicts: Agriculture and Housing

Overlaps also existed in areas with significant agriculture and housing opportunities. This is understandable since both activities occur in areas that are relatively flat. The stakeholders in the housing and agriculture sub-groups, therefore, agreed to employ the following protocols to address these conflicts:

- In communities where there is a projected high demand for housing, housing will have priority over land with low agricultural potentials.

- Lands with high agricultural values will have priority over housing development.
- At all times, agricultural lands should be located as close to market as possible (Market Access).
- At all times, housing lots should be located to reduce the cost of social and economic infrastructure.

The stakeholders developed the ranking system based on table 9.7.

Table 9.7: Ranking of housing and agriculture opportunities

Housing	Ranking	Agriculture	Ranking
High demand for housing and cost of economic and social infrastructure is low	3	High (Class I-II)	3
Moderate demand for housing and cost of economic and social infrastructure is modest	2	Moderate (Class III)	2
Low demand for housing and cost of economic and social infrastructure is high	1	Low (Class IV)	1

These protocols were intended to achieve the following objectives:

- to improve the green economy, reduce footprint by vertical housing developing;
- to bring housing and agriculture within acceptable proximity;
- to reduce the cost of social and economic services (cost of infrastructure);
- centric development rather than linear development (development along roadsides vs. growth pole); and
- dampen the effect of an announcement on real estate prices.

The stakeholders re-examined the various restrictions that were recommended in chapters 6 and 7. The combined the criteria and used the pairwise comparison procedure to rank each. The criterion and ranking are provided in the table 9.8.

Table 9.8: Ranking of constraints for housing and agriculture

Environmental Factors	**Agriculture**	**Housing**	**New Criteria**	**Weights**
Wetlands and critical habitats	> 19 m	> 19 m	> 19 m	0.03
Land slope	*< 5 degrees*	*< 5 degrees*	< 5 degrees	0.02
Watercourses				
River		> 19 m	> 19 m	0.03
Creeks			> 20 m	0.02
Flood prone areas	> 19 m	> 19 m	> 19 m	0.04
Aircraft land sites		> 3 m	> 3 m	0.02
Historical sites		*> 19 m*	> 19 m	0.02
Archaeological and spiritual sites			> 20 m	0.02
Lakes, swamps and wetland	> 19 m	> 19 m	> 19 m	0.02
Sensitive hydrogeological environments	> 19 m	> 19 m	> 19 m	0.04
Social Factors				
Physical infrastructure: Roads	*0.8 km*	< ½ m	< ½ m	0.22
Physical infrastructure: D&I	*0.8 km*		*0.8 km*	
Social Infrastructure				
School		< 5 m	< 5 m	0.02
Health Centre		< 5 m	< 5 m	0.03
Market		< 5m	< 5m	0.02
Police station		< 5m	< 5 m	0.03
Tourism		New		
Closed area		New		
Hydro catchment area		New		
Economic Factors				
Drainability	Easy		Easy	0.20
Fertility	Very high fertility		Very high fertility	0.33

Models were generated with the new criteria and weights to identify the best land parcels for housing and agriculture.

The results from the restriction model and final suitability model are presented in the figures 9.21, 9.22, 9.23. Figure 9.23 shows areas where housing and agriculture activities are restricted in the areas.

Figure 9.25 shows areas that are most suitable for agriculture, while figure 9.27 depicts areas that are best for housing development.

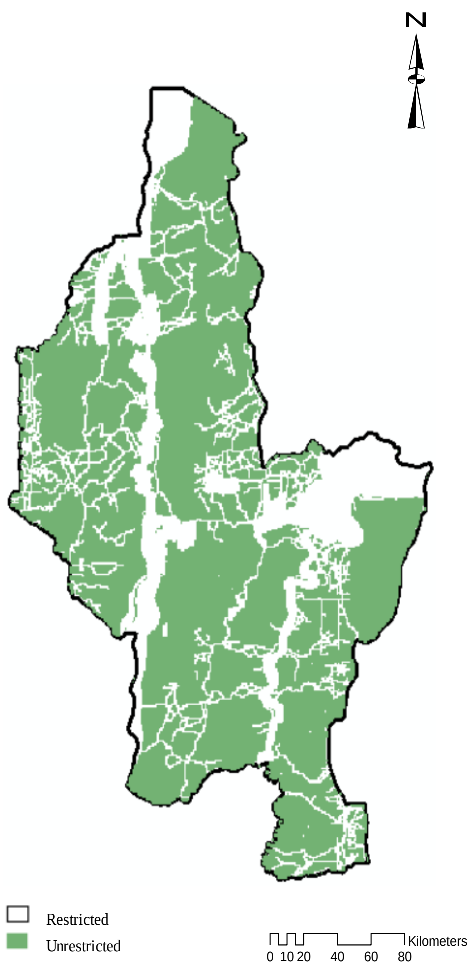

Figure 9.21: Restriction model for agriculture based on old criteria

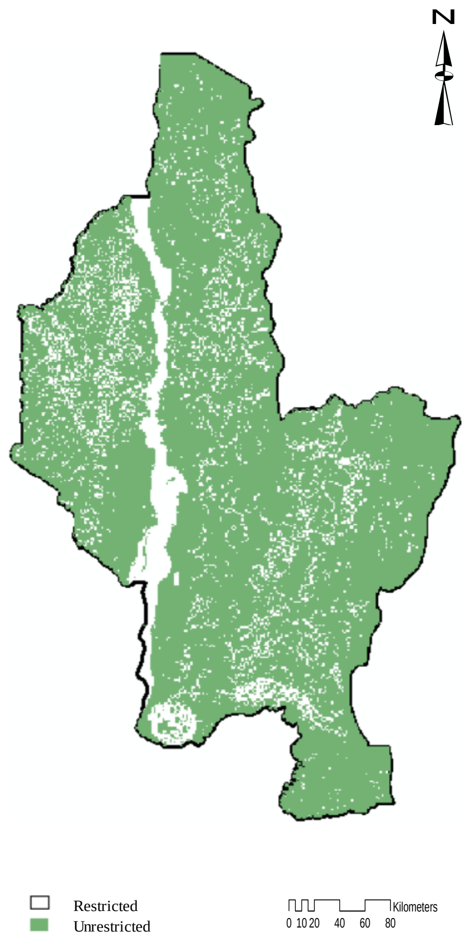

Figure 9.22: Restriction model for housing based on old criteria

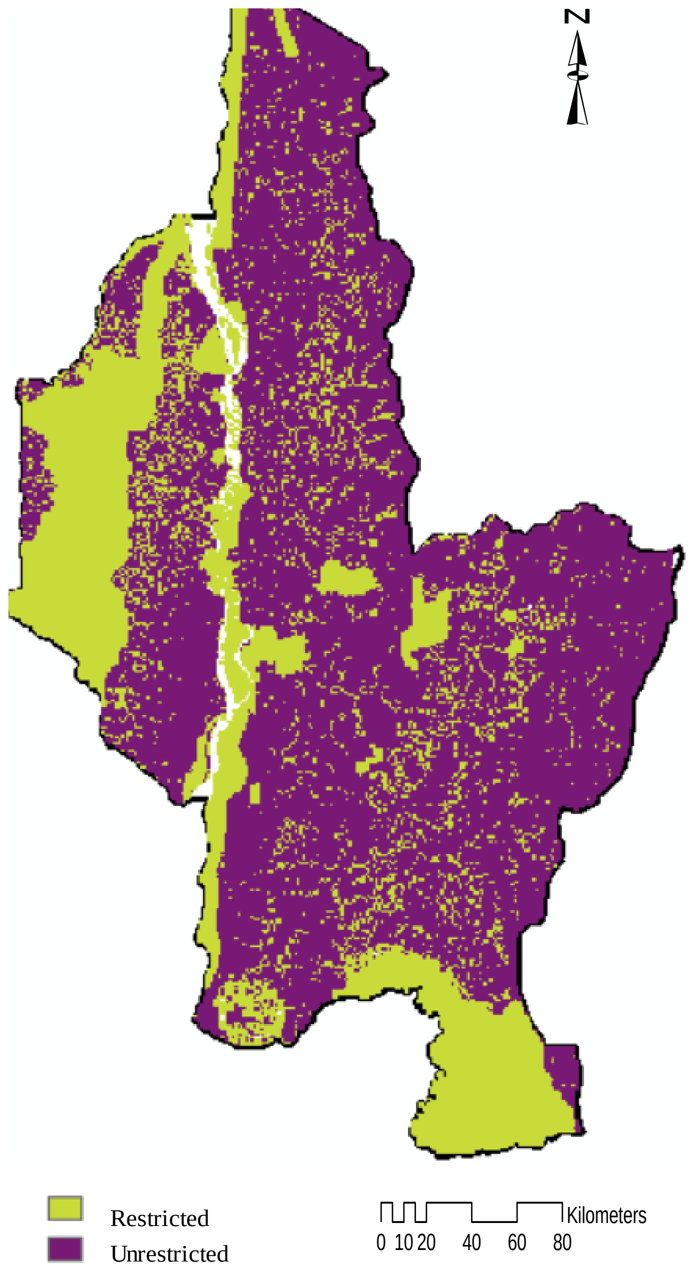

Figure 9.23: Restriction model for both sectors based on new criteria

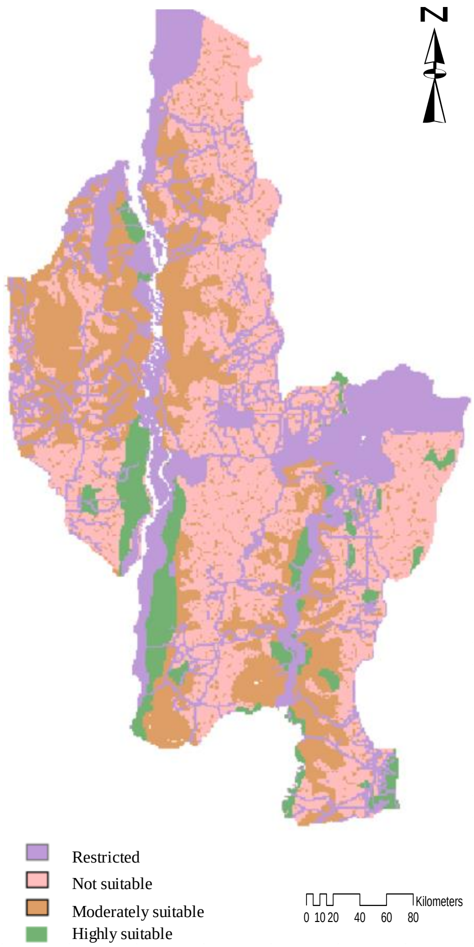

Figure 9.24: Areas selected for agriculture based on old criteria

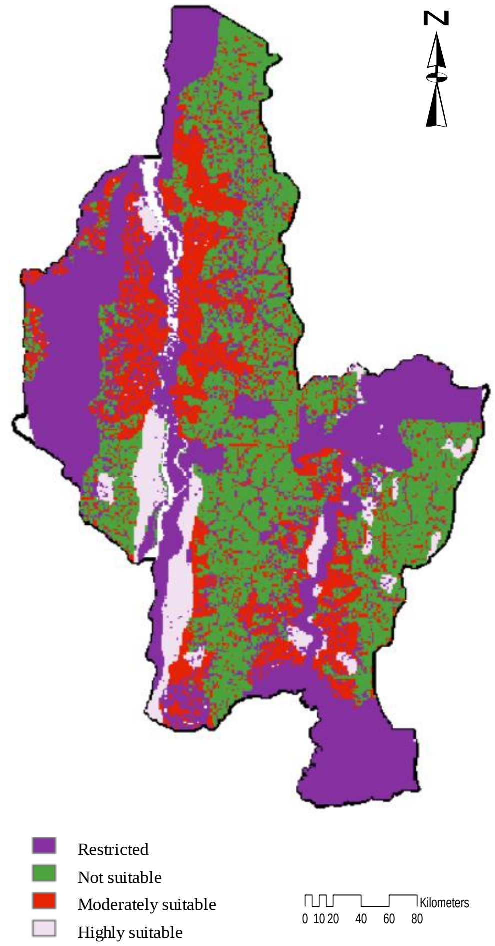

Figure 9.25: Areas selected for agriculture based on new criteria

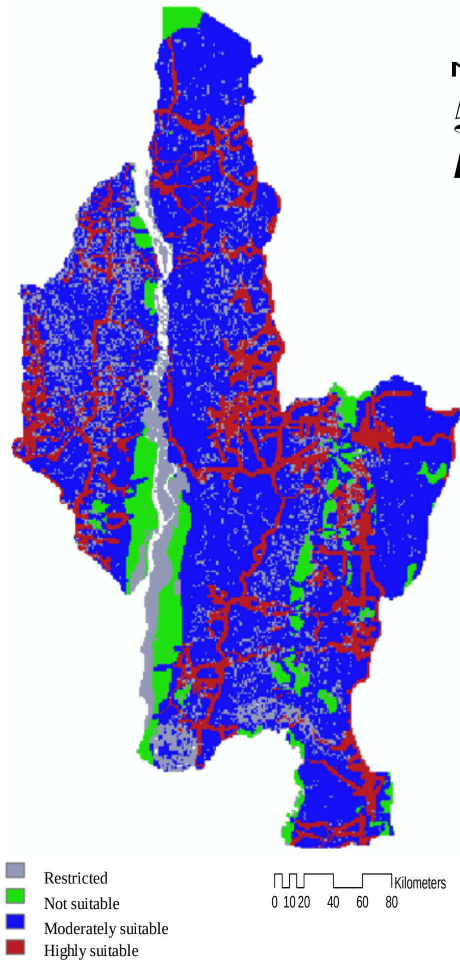

Figure 9.26: Areas selected for housing based on old criteria

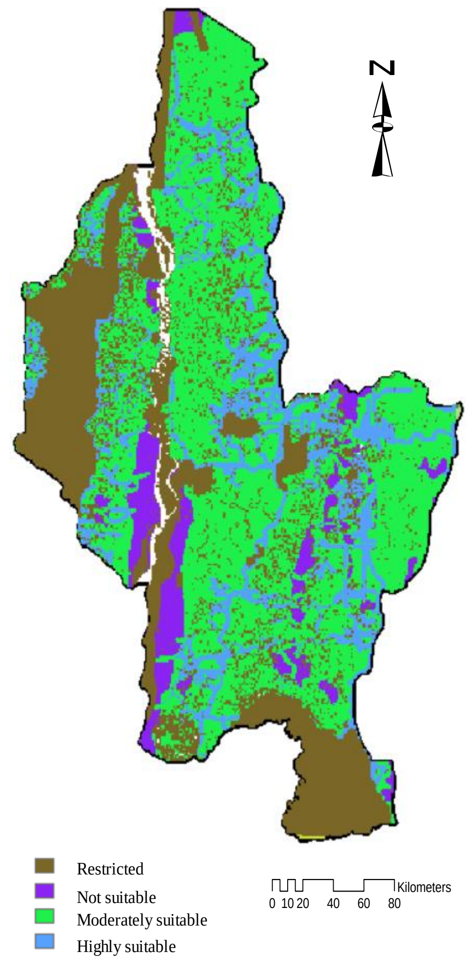

Figure 9.27: Areas selected for housing based on new criteria

Modules 4 of the model could not be implemented since it involves monitoring and evaluation activities aimed at identifying new internal and external factors that have implications for land management, institutional assessments and the review of the land management framework for gaps.

Module 5 was partially implemented by requesting stakeholders to recommend possible measures to address some of the problems they encountered during the consultations. The stakeholders agreed that legislative reform is necessary to facilitate common land uses where there is overlapping jurisdiction. They also decided that institutional strengthening is essential for implementing the proposed model since there are inadequate technical, human and financial resources available for performing same.

Conclusion

This chapter illustrates how the land management model may be applied to resolve the land management and planning issues. The model allows for participatory decision making and employs the Spatial Analytic Hierarchy Process and GIS to determine the suitability of land for different purposes while taking into consideration other competing uses and restrictions to promote sustainable land management.

During the consultation, stakeholders from the primary land use sectors were brought together to conduct assist with the development of land use plans that were not only beneficial to their respective sector but competing for land use sectors.

CHAPTER 10: CONCLUSIONS AND FUTURE WORK

10.1 Research Problem and Objectives

Guyana, like several developing countries, is endowed with numerous natural resources: fresh water, expansive forest, agricultural lands, and minerals resources such as gold, manganese, and diamond. The country's current development hinges on the exploitation of these resources. Logging, large and small-scale farming and mining accounts for more than a significant share of the country's Gross Domestic Product (GDP) generate substantial foreign exchange and create jobs.

Apart from competing for the same land resources, some of the activities are not currently undertaken sustainably. Mining and logging, for example, are primarily responsible for the destruction of the country's forest cover and pollution of its waterways. The environmental damage caused by mining and logging is non-trivial and has gained the attention of policy makers and regulatory agencies responsible for encouraging sustainable practices.

It is, therefore, necessary for the country to chart a strategy that would allow for the optimal harnessing of its natural resources while minimizing the environmental impact and maximizing the social and economic gains. This is particularly important since Guyana has embarked on a low carbon development pathway with the adoption of the Low Carbon Development Strategy. The research focused on developing an integrated land management models that may be used to overcome institutional and technical issues confronting land management agencies.

10.2 The Integrated Land Management Model

Spatial Analytic Hierarchy Process (SAHP) models were adapted to illustrate how key economic activities can be pursued in accordance with best practices, prescriptions of industry experts, and aspirations of policymakers. Four critical economic activities were chosen: housing, agriculture, mining, and forestry. These activities were chosen selected for the following reasons:

(i) they require significant land resources,

(ii) they provide the best opportunities for economic and social development but creates the highest environmental risks, and

(iii) they are more prone to vertical and horizontal overlapping jurisdiction.

The study area straddles three administrative regions in Guyana, namely, Region 3 (Essequibo Islands-West Demerara), Region 10 (Upper Demerara - Upper Berbice), and Region 7 (Cuyuni – Mazaruni). The area was selected because: (i) it has been identified as the new urban growth region of Guyana; (ii) it typifies a cluster of abundant natural resources that will provide the cushion for the possible fragility of the soon to be oil and gas economy; (iii) is characterized by an extensive range of economic/land use activities, including mineral extraction, logging, housing, and commercial agriculture; and (iv) it has enormous potential for hydropower and tourism; which now feature as important economic/land use activities in the country’s Low Carbon Development Strategy (LCDS).

Industry experts, CBOs/NGOs and policymakers from the housing, mining, logging and agriculture sectors were also interviewed to gather primary data. The data was then used to derive the weights for the environmental, social and economic factors considered in the analysis. Additionally, desk research was undertaken to identify gaps in the land management framework to gather appropriate data for the thesis.

The Integrated Land Management Model was designed and developed to address the issues associated with horizontal and vertical overlapping jurisdictions in most developing countries. By integrating the five modules of the model, decision makers, land management practitioners, land developers, and the general public will have a holistic understanding of the inter-relations of actions needed for sustainable natural resource management. The model eliminates the current silo approach to land management. The model placed vital importance on Module IV (the monitoring and evaluation framework), an aspect which is commonly ignored in land management in developing countries. The dynamic nature of land resources management exacerbated by climate variability and disaster risk management dictated that considerable attention should be placed on monitoring and evaluation of land management decisions and practices. These will help to design corrective measures needed to attain national sustainable development goals.

The critical success factors in the application of the models are:

- Political support
- Administrative and managerial support
- Unhindered access to current and accurate data
- Effective use of information technology to integrate the various land agencies
- Open access to data and information products
- Transparent criteria supporting land management decisions
- Financial and legislative support
- The design and development of a robust NSDI that will serve current and accurate land information to all the stakeholders.
- Organizational reform to fit all land-related agencies into the new integrated land management model.

The ILMM offers numerous benefits.

a. Firstly, it would allow for integrated decision-making that would serve to overcome the problem of limited coordination among the land use agencies that is the source of land conflict.
b. Secondly, the model may be extended to involve all the stakeholders, including, Cabinet (highest decision making body in Guyana), private sector, (landowners, resource developers and other private land users), vulnerable groups (women, youths, and indigenous people), land use and

management experts, community leaders and individual citizens who may be affected directly and indirectly by land use decisions.

c. Thirdly, effective monitoring and evaluation of land use activities would overcome the challenge of ensuring that the country's land resources are not over-exploited.

d. Finally, it would ensure that the impact(s) of the various land use activities is/are considered in totality over time and space.

The model is effective in the following ways:

(a) provide a mechanism for integrating activities of land related agencies without diminishing the roles and responsibilities.

(b) provide a mechanism for harmonizing land policies and land development goals and objectives.

(c) provide direct oversight by a national land management council.

(d) offer a mechanism for monitoring and evaluation of the impacts of land use decision made.

(e) offers protocols for mitigating overlapping jurisdiction.

The model is however exposed to the following uncertainties and limitation;

(a) Unscientific nature of the criteria and weights.

(b) Availability and access to current and accurate land related data and information.

(c) Modernization of legislations to ensure that they are streamlined and supportive of sustainable land management trust (Planning Act, Land Law etc.).

(d) Availability of financial resources to support human resources development and acquisition and maintenance of information technology infrastructure.

(e) Administrative review and overhaul to eliminate or reduce bottlenecks and duplication in the administration process required by the model.

(f) Support for data sharing amongst all land-related data in a conducive environment.

(g) Expected changes in land development restrictions.

10.3 Multi-Criteria Decision Analysis

In order to give effect to the use of the ILMM, a SAPH application was developed using multi-criteria decision analysis (MCDA). The tool focuses on Module III of the ILMM. The application ensures that three key sustainable development factors: environmental, economic, and social are simultaneously considered in all land use management decisions. Land use problems were resolved by first defining the key objectives and the alternatives. These were followed by the development of evaluation criteria and constraints associated with the objectives. The evaluation of the criteria resulted in decision matrices, decision variables, and presentation of decision-makers' preferences. The GIS application developed will help to evaluate the criteria base of the weighting and ranking iteratively assigned to each criterion. Sensitivity analysis was performed to assess the robustness of the analysis before final decisions were made. The power of this application lies in the collaborative approach between the scientific experts and field practitioners in the iterative assignment of weights and ranks to the evaluation criteria.

The SAPH/MCDA application was tested in two pilot areas in Guyana. On one site, land use suitability analysis was performed for housing and agriculture development. Via the use of this application, conflicts associated with these land uses were minimized if not eliminated. At the other site, land use suitability analysis was performed for mining and forestry development. The common vertical overlapping jurisdiction was also eliminated through concession building and simultaneous consideration of environmental, economic and social factors and constraints.

Based on the analyses it is can be concluded that environmental preservation and socioeconomic prosperity does not necessarily have to be mutually exclusive. As a matter of fact, the analysis shows that our natural resources can be exploited to maximize the economic and social gains while preserving the environment simultaneously.

The critical success factors for the effective use of the SAPH/MCDA are as follows:

- GIS software that facilitates multi-criteria analysis
- Availability of GIS applications developer with current knowledge of computer software engineering tools
- Unhindered access to current and accurate GIS data layers
- Policy initiatives and incentives that encourage land management practitioners to have an on-going dialogue with land developers, the general public and policymakers.
- Transparency and repeatability of decision-making processes.

10.4 Key Findings

The key findings may be summarized thus:

a. Significant vertical and horizontal overlapping jurisdiction exists among and between the agencies responsible for managing the land resources of the country. This may be due to the: (i) sectoral approach to developing the legal and regulatory framework for land use and management; (ii) lack of coordination among the agencies responsible for managing the country's land resources; (iii) dearth of information on lands owned and administered by the various agencies, and (iv) the absence of a national Land Use Policy and laws that allows for multiple land use. Land conflicts which end in lengthy court battles have been the eventual outcomes.

b. Sustainable development necessitates the satisfaction of numerous economic, social and environmental criteria when determining land use;

c. Several of the environmental factors considered essential for sustainable development are common across the various sectors. These include: wetlands, sensitive hydrogeological environments, critical habitats, flood-prone areas, land use, and land cover, slope and land surface.

d. However, some environmental factors are unique to each sector. For instance, the fertility of the land was important for agricultural activities, lithological/geological units for mining, and the Economic Value of the Nation for logging.

e. The weighting attached to the various factors varied differed across the sectors (table 10.1)

Table 10.1: Weight attached to various factors

	Housing Suitability	**Agriculture**	**Mining**	**Forestry**
B_1	0.48	0.29	0.54	0.50
B_2	0.30	0.45	0.30	0.25
B_3	0.22	0.26	0.16	0.25

Note: A1 = B_1 = environmental factors, B_2 = economic factors, B_3 = social factors.

f. The experts ranked environmental factors more important than economic and social factors for housing, mining and forest exploration activities.

g. In the case of housing, environmental factors were ranked high because of the need to satisfy the mandatory requirements for site selection as set out in the Operation Regulations of Low-Income Settlement Programmes (LISPs).

h. The high ranking of environmental factors for mining was linked to the need to confirm with the environmental requirements in the Mining (Amendment) Regulations 2005 (No. 3 of 205).

i. The need to confirm with the prescriptions in the Forest Policy and Low Carbon Development, as it relates to harnessing the forest resources, is responsible for the high ranking of environmental factors by the experts from the forestry sector.

j. The experts from the agriculture sector ranked the economic factors above environmental and social. They attributed the ranking to the prohibitive cost for developing infrastructure and the relatively lower cost of using fertilizer to enrich the soil when it is not fertile.

k. The integration of qualitative and quantitative analyses in land management domain is one of the key originality of this dissertation.

10.5 Future Work

Even though this thesis has contributed by developing the ILMM and the SAPH tools, there is still much work to be done. These include:

(a) The legal framework governing land management needs special attention. There is a need to develop a coherent set of legislation that is modern and societal and culturally relevant to each country.

(b) Land policy framework, as opposed to land use policy, is generally non-existent in most developing countries. Where they exist, they are usually not current in addressing the issues of climate variability, disaster risk management, and low carbon economy.

(c) Land management decisions in developing countries are generally not data-driven due to the lack of current and accurate data to support multi-criteria decision analysis. A concerted effort needs to be made to build a national spatial data infrastructure to support land resources management.

(d) The current land management domains in developing countries do not accommodate general public and community participation. It is dominated by public officials who interact with land developers. Land, as a national asset, requires the active involvement of all stakeholders to ensure accountability and bring a high level of transparency to all land transactions and land use decisions. Building and monitoring such a coalition of stakeholders remains a challenge.

(e) The design and development of a distributed NSDI that holds and manages current and accurate land-related data made accessible to all stakeholders including the general public.

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APPENDIX A: LAND SUITABILITY PARAMETERS

Land Use	Objective	Criteria	Constraints
		Attribute Map layers	
Agricultural activities	Overall objective: Economic: increasing productivity of land and scale of farming. Environmental: protecting the environment by preventing soil erosion and soil degradation.	Land parcels should be: Fertile land (*Normalized Difference Vegetation Index - NDVI*) Accessible (*road network maps*) Adequate rainfall (*Rainfall maps*)	Land occupied or allocated to: Forest/Mining/Housing/Eco-Services/Amerindian Lands Wetland and inaccessible land (land use maps)
Forest	Overall objective: Economic: increasing wood production. Environmental: protecting the environment by preventing soil erosion, soil degradation and windbreak	Land parcels should be: Minimum vegetation cover (*Normalized Difference Vegetation Index - NDVI*) Low population (*settlement and road network maps*) Adequate rainfall (*Rainfall maps*)	Land occupied or allocated to: Agriculture/Mining/Housing/Eco-Services/Amerindian Lands (land use maps)
Mining	Overall objective: Economic: increasing mining activities. Environmental: protecting the environment by preventing soil erosion and soil degradation.	Land parcels should be: Minimum vegetation cover (*Normalized Difference Vegetation Index - NDVI*) Low population Reclamation possibilities Adequate rainfall (*Rainfall maps*)	Land occupied or allocated to: Forest/Mining/Housing/Eco-Services/Amerindian Lands Wetland and inaccessible land (land use maps)
Housing	Overall objective: Economic: increasing settlement programmes. Environmental: protecting the environment by preventing soil erosion, soil degradation, disruption of natural habitats.	Land parcels should be: Infertile land (*Normalized Difference Vegetation Index - NDVI*) High Population (*settlement maps*) Adequate physical and social infrastructure (*road and social infrastructure maps*)	Land occupied or allocated to: Forest/Mining/Agriculture/Eco-Services/Amerindian Lands Wetland and inaccessible land (land use maps)

APPENDIX B: QUESTIONNAIRE FOR CRITERIA EVALUATION

The 9 Rating scales
1 = equally important
3 = moderately *more* important
1/3 = moderately *less* important
5 = strongly *more* important
1/5 = strongly *less* important
7 = very strongly *more* important
1/7 = very strongly *less* important
9 = extremely *more* important
1/9 = extremely *less* important

	1/9	1/7	1/5	1/3	1	3	5	7	9
Environmental (B_1)									
Economic (B_1 - B_2)									
Social (B_1 – B_3)									
Economic (B_2)									
Social factor (B_2 – B_3)									
Wetland (C1)									
Surface water (C_1 – C_2)									
Sensitive hydrogeologic									
Distance from airport									
Historical and cultural sites									
Critical habitat									
Fault area									
Seismic impact zones									
Unstable area									
Floodplains									
Environmental risks									
Adequate size									
Land use									
Landscape									
Price of land									

	1/9	1/7	1/5	1/3	1	3	5	7	9
Infrastructure cost									
Adequacy of physical infrastructure									
Adequacy of social infrastructure									
Rivers									
Lakes									
Slope									
Altitude									
Road networks									
Water distribution networks									
Drainage networks									
Power distribution									
Water distribution networks									
Drainage networks									
Power distribution									
Drainage networks									
Power distribution									
Schools									
Health centre									
Market									
Police station									
Health centre									
Market									
Police station									
Market									
Police station									

APPENDIX C: LIST OF EXPERTS/SPECIALISTS CONSULTED

Name	Designation and Agency
Ms M. Pitt	Chief Executive Officer, Central Housing and Planning Authority
Ms D. Tudor	Director of Operations, Central Housing and Planning Authority
Mr R. Edinboro	Chief Development Planner, Central Housing and Planning Authority
Mr F. Wahab	Director of Projects, Central Housing and Planning Authority
Ms M. Jaikaran	GIS Specialist, Central Housing and Planning Authority

APPENDIX D: SUMMARY OF EVALUATION CRITERIA

Criterion	Data Requirements	Source
Wetland	Wetland/marsh lands	GLSC
Surface water	Main rivers and lakes/creeks/canals/ocean	GLSC
Sensitive hydrogeologic environments	Aquifers	GWI
Aircraft landsites*	Airports	GLSC
Historical or cultural sites	Historical or cultural heritage sites	GLSC/NT
Critical habitats	Critical habitat sites	GLSC/CI
Geological fault areas		
Seismic impact zones	Areas prone to earthquakes	
Unstable areas	Areas prone to landslides	GLSC
Flood prone areas	Flooding hazards	GLSC
Technological hazard zones	Present land use	GLSC
Adequate size and configuration		
Land use	Current land use and land cover	GLSC
Slope and land surface	Slopes/contours	GWI
Price of land*	Land tenure used as proxy	GLSC
Cost of developing infrastructure		
Adequacy of key physical infrastructure*	Infrastructure – roads networks, water trunk and drainage networks	GLSC
Adequacy of key social infrastructure*	Infrastructure – schools, health centres/hospital, and police station	GLSC

GFC – Guyana Forestry Commission; GLSC – Guyana Lands and Survey Commission; CI – Conservation International; NT – National Trust; *means information obtained from GLSC; ** means that information to be collected