# SOIL DEGRADATION AND ASSOCIATED SOCIO-ECOLOGICAL IMPACTS IN THE DRYLANDS OF NAKASONGOLA DISTRICT, CENTRAL UGANDA.

By

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**FRONT PIECE**

Soil degradation is a real threat to the environmental and socio-economic stability of the Nakasongola district, in central Uganda. Overgrazing coupled with droughts and poor soils, hence low resilience, have led to expansive bare lands on grazing lands. Sheet erosion and micro-rills are clearly observed in the foreground part of the photo taken on Mr. Lubega's farm.

**DECLARATION**

I declare that this thesis is a product of my own work and has not been submitted anywhere for the award of a similar or related degree in any University. All sources of information used have been correctly referenced and any other assistance rendered is fully acknowledged.

Signature: Signed by candidate

Author Date 30/10/2006

First supervisor ---------------------------------------- Date------------------------

Second supervisor ---------------------------------------- Date------------------------

## ABSTRACT

This study investigated the causes, magnitude and selected socio-ecological effects of soil degradation, with the ultimate goal of explaining and mapping the spatial and temporal variations of degradation in the dryland area of central Uganda.

A multi-pronged approach was employed. Remote sensing and GIS were applied to study/interpret the land use/cover in relation to soil degradation, and the field experiments were employed to estimate the magnitude of water erosion. The questionnaires/interviews were used to assess the knowledge and perceptions of resource users and planners as regards soil degradation in the area.

Soil degradation in the form of sheet wash, rills, gullying and compaction is an issue in the area, which is largely attributed to interplaying environmental and socio-economic factors. Land use/cover change in this fragile ecosystem seems to be the major triggering factor. Observations revealed that poorly managed grazing lands sometimes under bare patches are 'hot spot' areas. It was demonstrated that the bare patches have enlarged over the recent two decades. Runoff loss on severely degraded land was approximately two times that of non-degraded areas. Soil loss estimate was 20, 13 and ~2 t/ha on severely, moderately and non- degraded grazing lands respectively. Incipient gullies occur mainly on grazing lands, and yet little or no control measures have been adopted. Most resource users perceived soil degradation as a problem, although this is not reflected in its control. Severe soil degradation has impacted negatively on the ecosystem, undermining the rangeland productivity through increased surface runoff and nutrient depletion. It is postulated that continued degradation could lead to more xerophytisation of this environment.

In general, the degraded dryland of the Nakasongola district manifests the unbalanced human-land relationship in such a sensitive ecosystem. Further research is required to provide understanding especially on aspects not conclusively tackled in this study. There is need for urgent adoption of suitable practices backed by government regulations aimed at reversing degradation trend for improved livelihood and sustainable environmental conditions.

**Nakileza, Bob R.** **University of Cape Town,** **November 2005**

# PREFACE

Soil as a resource is the main support of the economy of Uganda and many people are largely dependent on it for their livelihoods. Thus degradation of the soil is of great concern and needs to be understood and placed in its right context.

This study deliberated on the causes, magnitude, socio-ecological effects and people's understandings plus perceptions of soil degradation in the Nakasongola district. Nakasongola district is located in central Uganda about 120 km northwest of Kampala. It is generally a dry sub humid area, gently to moderately undulating topography and dominated by soils of ferralsol type (Petric plinthosols). The human population is generally low though that of livestock (cattle) is relatively high. These factors interact affecting soil degradation.

The main approach to the study involved field measurements, questionnaire survey, remote sensing and GIS interpretation. Areas of varying levels of degradation were identified and mapped.

The thesis consists of eight chapters, organised in a logical sequence covering issues that the research targeted while at the same time enlightening the reader on relevant information to foster easy navigation of this piece of work. **Chapter one** provides a background to the problem, the aim, the theoretical and conceptual setting and how the thesis is structured.

**Chapter two** provides the reader with pertinent literature review. The soil degradation processes and approaches to the study are discussed so as to provide the framework for understanding the methodology adopted and processes under this study. Relevant literature is also reviewed in the discussion to enlighten the reader with the impacts and developments in the area of soil degradation. A summary of the discussions is presented at the end.

**Chapter three** covers the physical and socio-economic geography of the study area. The various aspects are discussed with respect to their role in influencing the soil degradation problem. The geographical characteristics of the study localities and experimental sites are also given.

**Chapter four** details the methods and techniques employed in the research to achieve the set objectives. The selection procedure for the study area is presented, and then followed by methods used in gathering and analysing the data.

**Chapters five, six and seven** present the findings and discussions of the study as per the objectives in Chapter 1. Chapter 5 addresses the status and distribution of soil degradation while chapter six covers the effects of soil degradation. Chapter seven presents and discusses the resource users' knowledge and perceptions and policy implications. The coping strategies are also examined.

Finally **Chapter eight** is about synthesis of the findings presented in the previous chapters. It also provides the conclusions and future directions of the study. The **Appendices 6, 7 and 8** include the questionnaires employed in the study.

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## CONTENTS

Page
FRONT PIECE i
DECLARATION iii
ABSTRACT iv
PREFACE v
ACKNOWLEDGEMENTS vii
CONTENTS ix
LIST OF ILLUSTRATIONS xiv

**CHAPTER 1: INTRODUCTION** 1

1.1 INTRODUCTION 1
1.2 SOIL DEGRADATION IN AFRICA 2
1.3 SOIL DEGRADATION PROBLEM IN UGANDA 4
1.4 THEORETICAL BASE OF THE STUDY 6
1.5 CONCEPTUAL FRAMEWORK 7
1.6 SIGNIFICANCE OF THE STUDY 9
1.7 PROBLEM STATEMENT 10
1.8 AIM AND OBJECTIVES 10
1.9 SUMMARY 11

**CHAPTER 2: LITERATURE REVIEW** 12

2.1 INTRODUCTION 12
2.2 CONCEPT AND PROCESSES OF SOIL DEGRADATION 12
2.2.1 Concept Of Soil Degradation 12
2.2.2 Processes And Types Of Soil Degradation 13
2.3 CAUSES OF SOIL DEGRADATION 14
2.4 FACTORS OF SOIL DEGRADATION AND EROSION 17
2.5 ASSESSMENT OF SOIL DEGRADATION 17
2.5.1 Experimental And Field Survey 18
*2.5.1.1 Experimental plot level* 18
*2.5.1.2 Field survey of erosion features* 19
*2.5.1.3 Catchment level* 19
*2.5.1.4 Global/continental level* 20
*2.5.1.5 Remote sensing* 20
2.5.2 Participatory rural appraisal 21
2.5.3 Nutrient Study Approaches 22
2.5.4 Modeling Approaches 23
2.5.5 The Regional Political Ecology Approach 29
2.6 IMPACTS OF SOIL DEGRADATION 30
2.6.1 Onsite-Effects 30
2.6.2 Off-Site Effects 32
2.7 LOCAL KNOWLEDGE AND COPING MECHANISMS OF SOIL DEGRADATION 33

2.7.1 Local knowledge 33
2.7.2 Coping mechanisms 35
2.10 SOIL DEGRADATION RESEARCH IN UGANDA 37
2.11 SUMMARY 41

**CHAPTER 3: GEOGRAPHY OF THE CENTRAL DRYLANDS** 43

3.1 INTRODUCTION 43
3.2 DRY LAND ENVIRONMENTS IN UGANDA 43
3.2.1 Concept 43
3.2.2 Distribution Of The Drylands In Uganda 44
3.2.3 Characteristics Of Drylands In Uganda 45
3.3 ECOLOGICAL BACKGROUND OF NAKASONGOLA 46
3.3.1 Location 46
3.3.2 Geology And Geomorphology 47
3.3.3 Soils 48
3.3.4 Climate and drainage 49
3.3.5 Vegetation 52
3.4 SOCIO-ECONOMIC BACKGROUND 53
3.4.1 Administration 53
3.4.2 Human population 54
3.4.2.1 Ethnic Composition 54
3.4.2.2 *Population Density, Structure And Growth* 54
3.4.3 Land Tenure 55
3.4.4 Land Use 58
3.5 STUDY LOCALITIES AND EXPERIMENTAL SITES 59
3.5.1 Introduction 59
3.5.2 The Migera Study Locality 59
3.5.3 The Wibisi Study Locality 59
3.5.4 Erosion Catchments And Experimental Sites 60
*3.5.4.1 Bizibitukula sub catchment* *61*
*3.5.4.2 Lubega sub catchment* *61*
*3.5.4.3 Machum sub catchment* *62*
3.5.5 Experimental Sites 64
3.6 SYNTHESIS 65

**CHAPTER 4: RESEARCH STRATEGY AND METHODS** 66

4.1 INTRODUCTION 66
4.2 RESEARCH STRATEGY 67
4.3 STUDY AREA AND SITES 68
4.4 RESEARCH METHODS 69
4.4.1 Identification of nature and extent of soil degradation 70
*4.4.1.1 Field survey of soil degradation* 70
*4.4.1.2 Gully erosion* 72
4.5 ASSESSING THE MAGNITUDE OF SOIL LOSS 73

4.5.1 Erosion Measurements 73
*4.5.1.1 Erosion measurements under natural rainfall* 74
*4.5.1.2 Rainfall simulation experiments* 75
4.6. METHODS TO DETERMINE ENVIRONMENTAL AND SOCIO-ECONOMIC CONDITIONS 78
4.6.1 Remote Sensing Image Interpretation And GIS Manipulation 78
4.6.2 GIS Manipulations And Erosion Prediction 78
4.6.3 Infiltration Capacity 80
4.7 METHODS TO ASSESS EFFECTS OF SOIL EROSION ON BIODIVERSITY, NUTRIENT STATUS AND SOIL DEPTH 81
4.7.1 Soil Sampling And Analysis 81
*4.7.1.1 Soil sampling for physical and chemical analysis* 82
*4.7.1.2 Soil moisture* 83
*4.7.1.3 Assessing changes in soil level* 84
*4.7.1.4 Soil sampling to determine the effect of degradation on soil biota* 84
*4.7.1.5 Measurement of land cover* 85
4.8 METHODS USED TO DETERMINE PERCEPTIONS OF LOCAL PEOPLE 85
4.8.1 Introduction 85
4.8.2 Survey Design 85
*4.8.2.1 Household survey* 85
*4.8.2.2 Survey of local authorities* 87
*4.8.2.3 Household survey procedure* 87
*4.8.2.4 Questionnaire/interview design* 89
*4.8.2.5 Pilot study and implementation of the survey* 88
4.9. EVALUATE COPING MECHANISMS ADOPTED BY LOCAL PEOPLE 89
4.9.1 Semi-Structured Interviews 89
4.9.2 Questionnaire and PRA 89
*4.9.2.1 Household questionnaire survey* 89
*4.9.2.2 Participatory Rural Appraisal* 89
4.9.3 Secondary Sources 90
4.10 DATA ANALYSES AND SPATIAL MODELING 90
4.10.1 Analysis Of Questionnaires 90
4.10.2 Data Analyses On Soils, Land Use And Erosion 90
4.11 SUMMARY 91

**CHAPTER 5: THE NATURE OF SOIL DEGRADATION IN NAKASONGOLA DISTRICT** 92

5.1 INTRODUCTION 92
5.2 FORMS AND DISTRIBUTION OF SOIL DEGRADATION IN NAKASONGOLA 92
5.2.1 Forms And Distribution Of Erosive Degradation 92
*5.2.1.1 Sheet erosion* 92
*5.2.1.2 Rill and gully erosion* 94
5.2.2 Non-Erosive Degradation Forms And Its Distribution 99
5.3 THE EXTENT AND SEVERITY OF SOIL DEGRADATION IN THE DISTRICT 100
5.3.1 Soil Erosion Prediction 101

5.4 PATTERN AND MAGNITUDE OF SOIL EROSION ON GRAZING LAND 104
5.4.1 Rangeland Erosion Plots Under Natural Rainfall 104
*5.4.1.1 Annual runoff losses on different degradation surfaces* 104
*5.4.1.2. Annual soil loss on different degradation surfaces* 107
*5.4.1.3 Annual runoff and soil losses on different slope positions* 109
*5.4.1.4 The relationship between rainfall, runoff and soil losses* 111
*5.4.1.5 Seasonal runoff and soil loss for different surface conditions* 113
5.4.2 Runoff And Soil Losses From Rainfall Simulation 116
*5.4.2.1 Runoff and soil losses* *116*
5.5 ROLE OF FACTORS INFLUENCING SOIL DEGRADATION 125
5.5.1 Environmental Factors 126
*5.5.1.1 Climate* 126
*5.5.1.2 Soil type and erodibility* 128
*5.5.1.3 Slope* 131
*5.5.1.4 Macro-fauna activity* 133
5.5.2 Socio-Economic Factors 134
*5.5.2.1 Land use/cover and practices* *135*
5.6 CONCLUSION 144

**CHAPTER 6: IMPACT OF SOIL DEGRADATION PROCESSES** 147
147
6.1 INTRODUCTION
6.2 CHANGES IN SOIL PHYSICAL PROPERTIES 148
6.2.1 Infiltration Capacity 148
6.2.2 Bulk Density And Porosity 152
6.2.3 Effect Of Erosion On Texture 155
6.2.4 Truncation Of Topsoil Horizons By Erosion 156
6.3 CHANGES IN SELECTED SOIL CHEMICAL PROPERTIES 158
6.4 CHANGES IN SOIL PROPERTIES WITH SLOPE POSITION 162
6.5 OTHER EFFECTS OF SOIL DEGRADATION 163
6.5.1 Effects Of Soil Degradation By Gullies 163
6.5.2 Effects Of Soil Degradation On Soil Macro-Fauna 165
6.6 SYNTHESIS 168

**CHAPTER 7: LOCAL KNOWLEDGE AND UNDERSTANDING OF SOIL PROCESSES** 170

7.1 INTRODUCTION 170
7.2 RESOURCE USERS 171
7.2.1 General Socio-Economic Profile Of The Respondents 171
7.2.2 Local Understandings Of Soil Processes And Change 173
7.2.3 Local Understandings Of The Causes Of Soil Degradation 178
7.2.4 Soil Degradation Severity Rating 180
7.2.5 Concerns About Soil Degradation 183

7.2.6 Relationship Between Soil Degradation And Respondents Characteristics 185
7.3 RESOURCE PLANNERS/MANAGERS 188
7.3.1 District Resource Managers 189
7.3.2 Local Village Authorities 190
7.4 COPING STRATEGIES 191
7.4.1 Introduction 191
7.4.2 Investment In Land Improvement 191
*7.4.2.1 Adoption of SWC practices* 191
*7.4.2.2 Gender analysis in adoption of the land improvement practices* 197
7.4.3 Off-Farm Income 198
7.4.4 Shift Drought- Tolerant Crops 201
7.4.5 Migration To Other Areas 201
7.4.6 Other Coping Actions 202
7.4.7 Household Group Initiative 204
7.4.8 District Strategies For Degradation Control 204
7.5 IMPLICATION OF THE UNDERSTANDING OF DEGRADATION FOR PUBLIC POLICY 206
7.6 CONCLUSIONS 207

**CHAPTER 8: SYNTHESIS, CONCLUSIONS AND FUTURE DIRECTIONS** 211

8.1 INTRODUCTION 211
8.2 SYNTHESIS 211
8.3 CONCLUSIONS 215
8.4 FINDINGS RELEVANT TO PREVIOUS WORK ON SOIL DEGRADATION 216
8.5 RECOMMENDATIONS AND WAY FORWARD 217

**REFERENCES** 219
**APPENDICES** 239

## LIST OF ILLUSTRATIONS

**Tables**


| | | |
|---|---|---|
| Table 1.1 | Recent rates of soil erosion measurements in fragile lands of sub Saharan Africa excluding Uganda (1995-2000) | 3 |
| Table 2.1 | Summary of soil degradation research in Uganda | 38 |
| Table 3.1 | General characteristics of dryland areas | 44 |
| Table 3.2 | Administrative units and distribution by sub-counties and parishes | 54 |
| Table 3.3 | Distribution of population in Nakasongola district by land area and sub county | 55 |
| Table 3.4 | Population changes and cultivable area in Nakasongola district | 58 |
| Table 4.1 | Summary of research strategy | 67 |
| Table 4.2 | Summary of research methods per respective objective | 69 |
| Table 4.3 | Biophysical indicators used in the study | 70 |
| Table 4.4 | Codes for soil degradation processes | 71 |
| Table 4.5 | Code system for magnitude of soil degradation | 71 |
| Table 4.6 | Code for degree of soil degradation processes | 71 |
| Table 4.7a | The severity of soil degradation by cross-matrix tabulation | 72 |
| Table 4.7b | Severity of soil degradation in the study area | 72 |
| Table 4.8 | Survey sample sizes and settlement population | 86 |
| Table 5.1 | Morphology of sampled gullies in the Nakasongola district | 96 |
| Table 5.2 | Average measurements of prominent gullies on grazing lands in Nakasongola | 98 |
| Table 5.3 | Variation of runoff loss for the degraded surfaces for the 2 years | 106 |
| Table 5.4 | A comparison of average soil loss on different range condition for 2001/2002 for each individual plot replica | 108 |
| Table 5.5 | Runoff and soil loss for some monitored rainfall storms on upper slope in Bizibitukula sub-catchment | 112 |
| Table 5.6 | Statistical analyses of the ERa values for the years 2001/2002 | 113 |
| Table 5.7 | Average seasonal runoff (mm) for different degraded areas in the year 2001 | 114 |
| Table 5.8 | Average seasonal runoff (mm) for different degraded areas in the year 2002 | 114 |
| Table 5.9 | Average seasonal soil loss (t/ha) for different degraded areas in the year 2001 | 115 |
| Table 5.10 | Seasonal and monthly soil loss (t/ha) for different degraded areas in the year 2002 | 116 |
| Table 5.11 | Runoff and soil losses for the different slope positions for the dry and wet simulation runs | 117 |
| Table 5.12 | Ponding and Runoff initiation time during the dry and wet experimental runs | 125 |
| Table 5.13 | Antecedent soil moisture during simulation experiments | 125 |
| Table 5.14 | Soil erodibility (Ki) on different soils and degraded slope positions in Migera, Nakasongola district | 130 |
| Table 5.15 | Main termite genera and intensity of activity related to degradation | 134 |
| Table 5.16 | Land use types identified in the Nakasongola district | 135 |
| Table 5.17 | Livestock population in Nakasongola district | 141 |
| Table 6.1 | Infiltration measurements on different levels of degradation soil surfaces | 149 |
| Table 6.2 | Bulk density for soils under different degradation conditions in Bizibitukula | 153 |

and Machum catchments, Nakasongola district
Table 6.3 Variation in soil properties for the different degraded soil surfaces on rangelands in comparison with the critical levels for Uganda agricultural soils 159
Table 6.4 Variation of physical and chemical soil properties with the slope position in Bizibitukula and Machum sub catchments in Nakasogola 162
Table 6.5 Summary of the observed effects of gully erosion in the Nakasongola district 164
Table 6.6 Population (mean counts/m²) of soil macro-fauna under different degradation conditions on grazing lands 166
Table 6.7 Population (Mean counts/m²) and distribution of soil macro-fauna under different management practices and degradation conditions on croplands 166
Table 6.8 Diversity of soil fauna under different degraded conditions 167
Table 7.1 Land ownership according to different resource users in Nakasongola district 173
Table 7.2 Resource user type and perception of a soil change 175
Table 7.3 Resource users' perception of wind as an erosive problem 175
Table 7.4 Change in soil quality and productivity according to resource user type 177
Table 7.5 Responses on the identification and ranking of soil degradation type in Nakasongola district 178
Table 7.6 Percentage responses on the causes of soil degradation by the different resource users 178
Table 7.7 Resource users' responses on secondary activity/land use contribution to soil degradation 180
Table 7.8 Water erosion severity rating by type of resource users 182
Table 7.9 Wind erosion severity rating by type of resource users 182
Table 7.10 Resource users rating of the seriousness of change in soil quality 183

Table 7.11 Resource users' observation of soil quality change on critical positions 183
Table 7.12 Problems perceived to be affecting crops 184
Table 7.13 Responses on perceived soil degradation related problems affecting livestock 185
Table 7.14 Perception of soil quality change by educational level 186
Table 7.15 Influence of educational level on perception of change in soil quality 186
Table 7.16 Response to reasons for non-adoption of conservation practices by resource users 194
Table 7.17 Response to the question How did you acquire this conservation practice/knowledge? 194
Table 7.18 Gully control methods under different land uses 196
Table 7.19 Pearson correlation testing relationship between socio-economic characteristics and adoption 197
Table 7.20 Soil water conservation decision-making controls by gender in Nakasongola district 197
Table 7.21 Soil water conservation responsibilities by gender in Nakasongola district 198

**Figures**

Figure 1.1 Conceptualisation of soil degradation in Nakasongola district 8
Figure 2.1 Summary of human-induced and natural degradation processes 13
Figure 3.1 Location of the dryland areas in Uganda 45

Figure 3.2 Population changes in the dryland areas by district (1960 - 1991) 46
Figure 3.3 Location of the study area in Uganda 47
Figure 3.4 A cross section of the geomorphology of the north Mengo 48
Figure 3.5 Soils of the Nakasongola district, according to FAO system 48
Figure 3.6 Mean monthly rainfalls for the Nakasongola district 50
Figure 3.7 Mean annual rainfall (mm) for the Nakasongola district 51
Figure 3.8 Vegetation types of the Nakasongola district 52
Figure 3.9 Distribution of the land ownership in the Nakasongola district 56
Figure 3.10 Location of the experimental sites in the selected sub-catchment of the Nakasongola district 60
Figure 3.11 Details of topography, landuse/cover and erosion features along Transect 3 from Sikye hill to Wabiguyo depression 64
Figure 5.1 Distribution of soil degradation forms along a typical slope profile in transect 1 93
Figure 5.2 Magnitude and distribution of soil loss in the Nakasongola district 101
Figure 5.3 Percentage area of the Nakasongola district affected by different type of soil erosion based on RUSLE severity classes 102
Figure 5.4 Average runoff losses from different degraded surfaces for two years 105
Figure 5.5 Runoff and soil losses for the year 2001 106
Figure 5.6 Runoff and soil losses for different plots in the year 2002 107
Figure 5.7 Average total runoff and soil losses for two years 2001/2002 107
Figure 5.8 Comparison of soil loss on different degraded surfaces 108
Figure 5.9 A comparison of average soil loss on different rangeland surface condition for 2001/2002 109
Figure 5.10 Runoff loss (mm) according to slope position 110
Figure 5.11 Average soil losses on different landscape positions for 2001/2002 111
Figure 5.12 Relationship between Rainfall, runoff and soil losses for the two experimental years 112
Figure 5.13 Mean runoff loss under different surface conditions for the two experimental years 114
Figure 5.14 Mean seasonal soil loss under different surface conditions for the two years 115
Figure 5.15 Relationship between runoff and soil loss under constant rainfall intensity on the upper slope position 119
Figure 5.16 Relationship between runoff and soil loss under constant rainfall intensity on the lower slope position 120
Figure 5.17 Relationship between runoff and soil loss under constant rainfall intensity on the mid slope position 121
Figure 5.18 Dry run soil loss for the different slope positions 122
Figure 5.19 Wet run soil loss for the upper, mid and lower slope positions 122
Figure 5.20 Runoff discharge for the wet run simulation on different slope positions 123
Figure 5.21 Runoff discharge for the dry run simulation on different slope positions 124
Figure 5.22 A historical climatic fluctuation in African lakes 127
Figure 5.23 Mean annual rainfall variations for the stations within and nearby Nakasongola district 128
Figure 5.24 Variation of soil degradation processes with topography along transect 1 in Bizibitukula sub catchment 132

Figure 5.25 Land use map based on Remote Sensing image interpretation 136
Figure 5.26 Historical profile derived from PRA 139
Figure 5.27 Spatial distribution of gullies in relation to livestock tracks and paths 140
Figure 5.28 Erosional features and associated land use along transect 3 143
Figure 6.1 Mean infiltration capacities for different slope positions on different degradation soil surfaces 150
Figure 6.2 Comparison of infiltration curves for different degradation levels in Nakasongola 150
Figure 6.3 Comparison of infiltration graphs for the soils under the same degraded conditions on the lower slope 151
Figure 6.4 Comparing the infiltration curves for the highly degraded and cultivated area 152
Figure 6.5 Variation of mean weight diameter under different soil degraded conditions 155
Figure 6.6 A hypothetical soil profile transition from a typical ferralsol 156
Figure 6.7 Variation of nutrients and texture with depth for different levels of degraded soils 161
Figure 6.8 Population (Mean counts/m$^2$) and distribution of soil macro-fauna under different management practices and degradation conditions for croplands 167
Figure 7.1 Percentage distribution of respondents in the sub-counties of Nakasongola district 171
Figure 7.2 Percentage of respondents that experienced soil changes in the different sub counties of the Nakasongola district 174
Figure 7.3 Soil degradation problems by different resource user type in the Nakasongola district 176
Figure 7.4 Severity rating of soil degradation by water erosion 181
Figure 7.5 Severity rating of soil degradation by wind erosion 181
Figure 7.6 Relationship between severity rating of soil erosion problem and respondents characteristics 187
Figure 7.7 Percentage adoption of SWC practices according to resource users in the Nakasongola district 192
Figure 7.8 Success in the control of soil degradation by different resource users 195

**Plates**

Plate 3.1 A typical land use/cover type in Machum sub catchment 63
Plate 4.1 Lay out of the erosion plot 74
Plate 4.2 Simulation experiment in the field in the Nakasongola district 77
Plate 4.3 Double ring infiltrometre 81
Plate 5.1 Sheet erosion on rangelands in Bizibitukula sub catchment in Migera 93
Plate 5.2 Gully erosion 97
Plate 5.3 Soil extraction for brick making near Migera town 100
Plate 5.4 Severe sheet erosion on grazing land 103
Plate 5.5 Quartzite concretions exposed as a result of removal of topsoil by erosion on the grazing land in Bizibitukula sub catchment, Migera parish 129
Plate 5.6 Bare soil patches in on a grazing land in Sija village after UWESO 131
Plate 5.7 Intensive erosion on cropland at the start of the wet season in Machum village 144
Plate 6.1 Variation in plant growth on the severely degraded and compacted area 154

| | | |
|---|---|---|
| Plate 6.2 | Typical soil profile of a ferralsol | 157 |
| Plate 6.3 | Erosion pins and collar painting on a boulder to measure the changes in soil depth | 158 |
| Plate 6.4 | Dangers of gully erosion: (i) to livestock (ii) siltation of water sources | 164 |
| Plate 7.1 | Charcoal burning activity- a threat to the fragile environment in Nakasongola district | 199 |

## Appendices


| | | |
|---|---|---|
| Appendix 1 | Glossary of the terms and abbreviations | 239 |
| Appendix 2 | Simulation and natural rainfall plot design and lay out | 240 |
| Appendix 3 | Details of soil characterisation | 241 |
| Appendix 4 | Details of sampled soil data in the Nakasongola district | 245 |
| Appendix 5 | The location and distribution of the villages sampled for questionnaires | 248 |
| Appendix 6 | Question survey on soil degradation in the dryland area of Nakasongola. Target population: Households | 249 |
| Appendix 7 | Questionnaire survey on soil degradation in the dryland area of Nakasongola. Target population: District officials | 255 |
| Appendix 8 | Questionnaire survey on soil degradation in the dryland area of Nakasongola. Target population: Village council officials | 259 |
| Appendix 9 | Letter of introduction to the district/local authority | 262 |
| Appendix 10 | Input data layers/maps for prediction of soil loss | 263 |
| Appendix 11 | Gully erosion measurements | 265 |
| Appendix 12 | Details of runoff plots data | 270 |
| Appendix 13 | Details on simulation measurements | 277 |
| Appendix 14 | Infiltration data | 281 |
| Appendix 15 | Soil macro-fauna data | 282 |
| Appendix 16 | Summary of tables on analysed questionnaire data | 285 |
| Appendix 17 | Characteristics of plots at the time of installation | 294 |
| Appendix 18 | Characteristics of plots at the time of installation | 295 |

# CHAPTER 1

# INTRODUCTION

## 1.1 BACKGROUND TO THE STUDY

Soil degradation is a process that describes human-induced phenomena, which lower the current and/or future capacity of the soil to support human life (FAO, 1979; UNEP, 1982; Stocking, 1998; Olderman *et al.,* 1991). It includes physical, chemical and biological degradation (Lal, 1997; UNEP, 1997). Soil degradation is a major global issue because of its adverse impacts on the livelihood of many people (Jacks and Whyte, 1939; Lal, 1997) particularly of the poor in developing countries (Anecksamphant *et. al.,* 1999); it affects food security, diminishing quality and quantity of water resources, induces loss of biodiversity and global climatic change. It has become one of the most threatening global environmental challenges affecting virtually all types of land use and soils. Of the various forms of soil degradation, water erosion is the most widespread, followed by wind erosion (Olderman *et al.,* 1991).

Erosion by water is highly detrimental to soils in terms of both volume of soil removed and land surface area affected; it accounts for 56% of the total degraded land surface of the world (Olderman *et al.,* 1991). It is recognised as a major problem arising from agricultural intensification, land degradation and global climatic change (Drake and Mulligan, 1996). Soil degradation is caused by overgrazing (35%), agriculture farming (28%), deforestation (30%), and overexploitation of the land to produce fuelwood (7%) and industrialization (4%) (Reich, *et al.,* 1998).

Agriculture forms the backborne of the economies of many countries in the developing world, and yet it increases the risk of erosion through vegetation disturbance as a result of land-use change, tilling or overgrazing. Up to 40% of the world's agricultural lands are seriously affected by soil degradation (Niemeijer and Mazzuto, 2002). Olderman *et al.,* (1990) estimated that 8.3% of dryland areas are degraded by human-induced water erosion and 13.2% experience accelerated wind erosion. In the drylands that are most prone to desertification, water erosion accounts for 71% of the total global soil loss (Reich *et al.,* 1998). By 1977, 57 million people were suffering from direct effects of land degradation. The number rose to 135 million people by 1984. More than 97% of the total world's food is derived from land, the remainder being supplied by the aquatic ecosystems. There is thus a looming danger to food production as degradation claims 6 million hectares of the global agricultural land per annum (Pimentel, 1993).

The processes of soil degradation are variable in space and time although the resultant environmental, economic and social consequences are not yet precisely understood (Lal, 1994). However, erosion is a more serious problem in developing countries because of their greater dependence on the soil resource. There is a growing concern that a decline in long-term soil productivity is seriously limiting food production in the developing world and that the problem is deepening (Scherr, 1999). According to Agenda 21 (UNCED, 1992), land degradation caused by over-exploitation of fragile resources and cultivation of marginal soils with no or low level of conservation is a key issue in soil resource management that requires urgent attention.

## 1.2 SOIL DEGRADATION IN AFRICA

Soil erosion is widely held to be the most obvious manifestation of soil and land degradation in Africa, and among the most chronic environmental and economic burdens of the continent (Ayoub, 1994). Soil fertility depletion through exploitative cropping contributes to land degradation, which further undermines the natural resource capacity to sustain the increasing human population. As a result, it has been argued that soil and water conservation should be a national priority in all sub-Saharan African countries (Ayoub, 1994). Sub-Saharan Africa (excluding South Africa) is the world's poorest developing region, with 29 out of 34 countries being among the poorest in the world (Eswaran *et al.*, 1996). Mabogunje (1995) indicated that sub-Saharan Africa endures environmental problems such as deforestation, soil erosion, desertification, wetland degradation and insect infestation, all of which impact on food security and livelihoods. Thus, improvement of the soil resource base is a potentially an important tool to help alleviate poverty and increase self-sufficiency in food. Demographics, a heavy burden of foreign debt and the absence of democracy have all accelerated environmental degradation in sub-Saharan Africa (Mabogunje, 1995).

A recent UNEP/ISRIC global assessment of soil degradation (GLASOD) (Oldeman, *et al.*, 1991) shows that about 494 million hectares of Africa's land surface are affected by soil degradation; 46% by water erosion; 38% by wind erosion; 12% by chemical deterioration and about 4% by physical deterioration, largely through soil compaction. Out of 494 million hectares, 124 million hectares are strongly degraded. The areas worst affected are rangelands (UNEP, 2002), which dominate the drylands. Indeed, Eswaran *et al.* (1996) observed that high intensities of water and wind erosion are associated with the semi-arid and sub-humid areas of Africa.

Water erosion assessment based on runoff plots and catchments in different isolated parts of sub Saharan Africa (Table 1.1) indicates high rates of soil degradation above the threshold 5 t/ha/yr (FAO, 1979), which raises much concern. The representativeness of the runoff plots and catchments may be questioned but, in the absence of available detailed and spatially well-distributed measurements, such data on erosion remain important indicators of the nature and extent of the problem.

**Table 1.1** Recent rates of soil erosion measurements in fragile lands of sub Saharan Africa excluding Uganda (1995-2000)

| **Country** | **Soil loss t/ha/yr** | **Environment** | **Scale** | **Author and year** |
|---|---|---|---|---|
| Ethiopia | 12.2 | Mountainous/Highland | Plot | Hurni (1986) |
| Kenya | 3.3 on grazing land; 16 on cultivated land; 1.1 in woodland | Dry sub humid to semi arid (Machakos) | Plot | Tiffen *et al.* (1994) |
| Rwanda | 1000 t/ $m^2$/yr | Sub humid | - | * |
| Tanzania | Sediment yield ($m^3/km^2/yr$) 446 (1960-69) 640 (1969-70) | Dryland- northern | catchment | * |
| South Africa | | | | |
| Zimbabwe | 50 from communal lands | Sub humid | Plot | CEP fact sheet, 2004 |
| Nigeria | 2000 ($m^3/km^2/yr$) | | - | * |

* Source: http://home.alltel.net/bundquist1/se4.html

Table (1.1) reveals high magnitude of degradation of soil resources upon which the economies of poor countries and their populations depend. In general, the east Africa region experiences high erosion particularly in the mountain or highland and dryland areas due to the increasing human population numbers coupled with elevated demand for farmland and livestock grazing. Soil losses in southern Africa may reach 2.5 t $ha^{-1}$ (equivalent to 300 million tonnes) annually (FAO, 2004). According to Percival and Homer-Dixon (1995), South Africa has lost 25% of its topsoil since 1900 and 55% of the country is threatened by desertification. The extensive drylands of the Karoo in South Africa are heavily degraded as evidenced by low vegetation cover and pronounced soil erosion particularly by gullies, caused by high sheep stock densities (ECI report, 1997-2001). In South Africa, there is less grazing per unit area and direct runoff is more rapid (Rabie and Theron, 1983). Overgrazing is responsible for more than half of all soil degradation in southern Africa (FAO, 2004). However, other factors such as climatic changes (rainfall variability and long term droughts) are important soil degradation determinants. Recurrent droughts are major factors in the degradation of cultivated land and rangelands. The two are interlinked; while drought increases soil degradation problems, soil degradation magnifies the effect of drought (FAO, 2004).

Soil degradation is not uniformly experienced in Africa. Recent studies indicate spatial and temporal variability e.g. certain studies in Africa (e.g. Tiffen *et al.*; 1994) have revealed less soil erosion and improvement in productivity despite high population growth. Analysis of environmental crisis and the policies based on it in Africa may indeed be misleading (Leach and Means, 1996). Boyd and Slaymaker (2000) have examined the concept of soil recovery and noted that conservation raises crop yields on selected parcels of land. Warren (2002) cautioned about land degradation and noted that research on land degradation in dryland Africa has concentrated mainly on nutrients and erosion.

Soil degradation in Africa also manifests in the form of nutrient loss. All African countries except Mauritius, Reunion and Libya have negative nutrient balance (Henao and Baanate, 1999). In the densely populated dryland areas, soils lose 60-100 kg of NPK per $ha^{-1}yr^{-1}$. High nutrient loss is associated with severe erosion and leaching, continuous cropping of cereals without rotation with legumes and inappropriate soil and water conservation practices. Soil mass loss and nutrient loss reduces crop yields. Yield reduction due to soil erosion ranges from 2-40%, with a mean loss of 6.2% for sub-Sarahan Africa (Scherr and Yadav, 1996).

## 1.3 SOIL DEGRADATION PROBLEMS IN UGANDA AND THE NAKASONGOLA DRYLANDS

The problem of soil degradation, particularly by water erosion, is not new in Uganda. The British colonial government in the 1920s raised concerns about soil erosion and declining soil fertility in the southwestern highlands (Farley, 1996). Erosion was unevenly distributed, being prominent - in the humid areas of central Uganda, in the mountainous/highland parts of southwestern and eastern Uganda, and in the relatively dry Karamoja region (Wayland and Brasnett, 1938). Gully and sheet erosion was seen as responsible for degraded land in some northern districts in the 1950s (Chenery, 1960). Experimental work in the 1960s at Namulonge and Serere research stations showed higher rates of soil erosion in the annual monocropping systems on cotton and maize (Temple, 1972). The actual situation on the farmers' lands, however, remained unclear since no systematic on-farm experiments were established.

Ahn (1977) observed that, although the erosion hazard has not been assessed quantitatively, it is widely held to be a major problem in the mountainous and highland areas in addition to the northern and central regions of Uganda, which are covered by coarse sandy loams and regarded as susceptible to interrill erosion. Estimates in the late 1980s by UNEP (1987) based on the Universal Soil Loss Equation (USLE) showed that the highland and mountainous areas experienced high rates of erosion, while most of the dryland areas experienced moderate erosion rates.

Indeed, soil degradation by water erosion affects large parts of the country (e.g. Tukahirwa, 1995; Bagoora, 1997; NEAP, 1992; NEMA, 2002). It is noted in the Ugandan 'Soils Policy' (NEMA, 2003) that many areas in Uganda are eroded and damaged while others are at risk of having their soils permanently destroyed. Available evidence from measurements of runoff shows that soil erosion by water is severe in Uganda and this threatens the country's economy largely dependent on agriculture. Studies in the Lake Victoria basin (Zake and Nkwine, 1995; Lufafa, 1999; Majaliwa, 2004); in the eastern highlands and Mt. Elgon (Nakileza, 1992; Tenywa *et al.*, 2003) and in the southwestern highlands of Kabale (Tukahirwa, 1995; Bagoora, 1997) revealed high rates of erosion, which constrains agricultural production and ecological conditions in the aquatic ecosystems. Increases in human and livestock populations in Uganda have prompted the stripping of grasslands and woodlands through overgrazing and contributed to the susceptibility of these ecosystems to soil degradation. Increased soil degradation in Uganda will continue to undermine the efforts to achieve success in the strategy for modernisation of agriculture. Knowledge of the current trends, evaluation of the processes, extent and causes of soil degradation are thus important, and this study aims to make a contribution along this line. An underlying premise of the study is that there is insufficient empirical and local-scale understanding of soil degradation and land users conservation behaviour, which leads to problems with solutions proposed to address degradation.

The Nakasongola dryland forms part of the central dryland zone of Uganda, which is susceptible to degradation due to land use changes and unsustainable land management practices (NEMA, 2002). This area represents a typical dryland environment with degraded patches, silted water sources, high population density and land use which contrasts with the more humid Lake Victoria basin located 100 km to the south. A project to combat desertification was initiated in this area by the Ministry of Agriculture Animal Industry and Fisheries (MAAIF) in 1998 but was short-lived (Muhwaya, pers. comm., 2001). The local communities were sensitised about desertification and a few trees were planted as part of the control measure. However, no detailed studies have been undertaken to generate baseline data on the magnitude and extent of soil degradation problem. MAAIF (1994) based on broad studies classified the extent and magnitude of soil degradation by erosion in Nakasogola district as ranging from medium to high and caused by overstocking and bushfires in the dry season. A case study research strategy is used in this study. The use of Nakasongola as a case study allows detailed analysis and understanding of such a complex problem transcending varying socio-economic and ecological conditions in the drylands of Africa, which can-not all be studied in detail due to limited financial and time constraints.

## 1.4 THEORETICAL BASE OF THE STUDY

Understanding the complexity of soil degradation requires use of integrated methodologies involving measurement of biophysical parameters and social studies. Both scientific and local knowledge that provides a more holistic understanding of soil degradation needs to be documented and integrated.

This research draws insights and emphases from political ecology (Blaikie, 1985) and core-periphery theory (Bartley and Bergesen, 1997; Worgu, 2000; Kema, 2005). Political ecology emphasises a multi-scale approach to environment-development analyses, considering scales of analysis from the local land user to global institutions (Blaikie, 1985). This approach also focuses on cultural construction of the environment and treats environmental problems as social problems, requiring negotiation of values and knowledge (Peet & Watts, 1996; Blaikie, 1985). Questions of environmental degradation can be further sought from analysis of the core and periphery. For instance, Worgu (2000) observed that intensification of export drive of primary resource materials as a basis for the modernisation of the periphery lead to environmental degradation and increase in poverty in the Niger Delta community.

Natural scientists have been criticized for viewing natural resource degradation as solely an environmental and not a social problem (Blaikie, 1987c). This has stimulated interest in the development of a social ecological perspective to enable a more informed understanding of the causes of soil degradation. Essentially, physical and social/economic systems have to be analytically integrated in explaining soil erosion (Blaikie, 1987) and soil degradation. The social/economic system is important and ignoring it leads to technocratic and physical examination of the processes of soil erosion and the immediate land uses leading to it, without any consideration of other political economic relationships at the local, regional and international scales, which determine the action of the land user in the affected area. An explanatory model developed by Blaikie (1987) isolates several social issues that are investigated in this study including characteristics of land users, land tenure and the attributes of land users. The model recognises land users as decision makers that can relate soil degradation to wider attributes. The model focuses on why soil erosion (soil degradation) occurs rather than controlling it. As Blaikie (1987) observed, it is difficult to attribute the effects of people upon soil erosion and therefore the approach suffers from the same weaknesses as any analysis, which attempts to assess or attribute soil erosion to specific land use decisions rather than causes.

## 1.5 CONCEPTUAL FRAMEWORK

The conceptual framework adopted in this study is given in Figure 1.1. The arrows indicate the relationships between the different elements of the framework such as the natural environment, modified environment under human intrusion, effects of human activities on the environment and adaptive response by the local people to the changed environmental conditions.

Crop farming and livestock keeping have modified the environment. In the absence of adequate land management practices, problems of accelerated degradation (e.g. soil erosion and fertility decline) have ensued under different land use/cover types. The effects of these changes have not been clearly explained, thus justifying the need for this study.

Morgan (1995) noted that semi-arid and semi-humid areas are highly vulnerable to soil erosion that frequently exposes sub-soils whose infiltration rate and water-holding capacity are lower than the original surface horizons (Moore, 1979a). Semi arid zones are susceptible to erosion due to higher erosive of rainfall and higher potential runoff (Thomas and Barber, 1989).

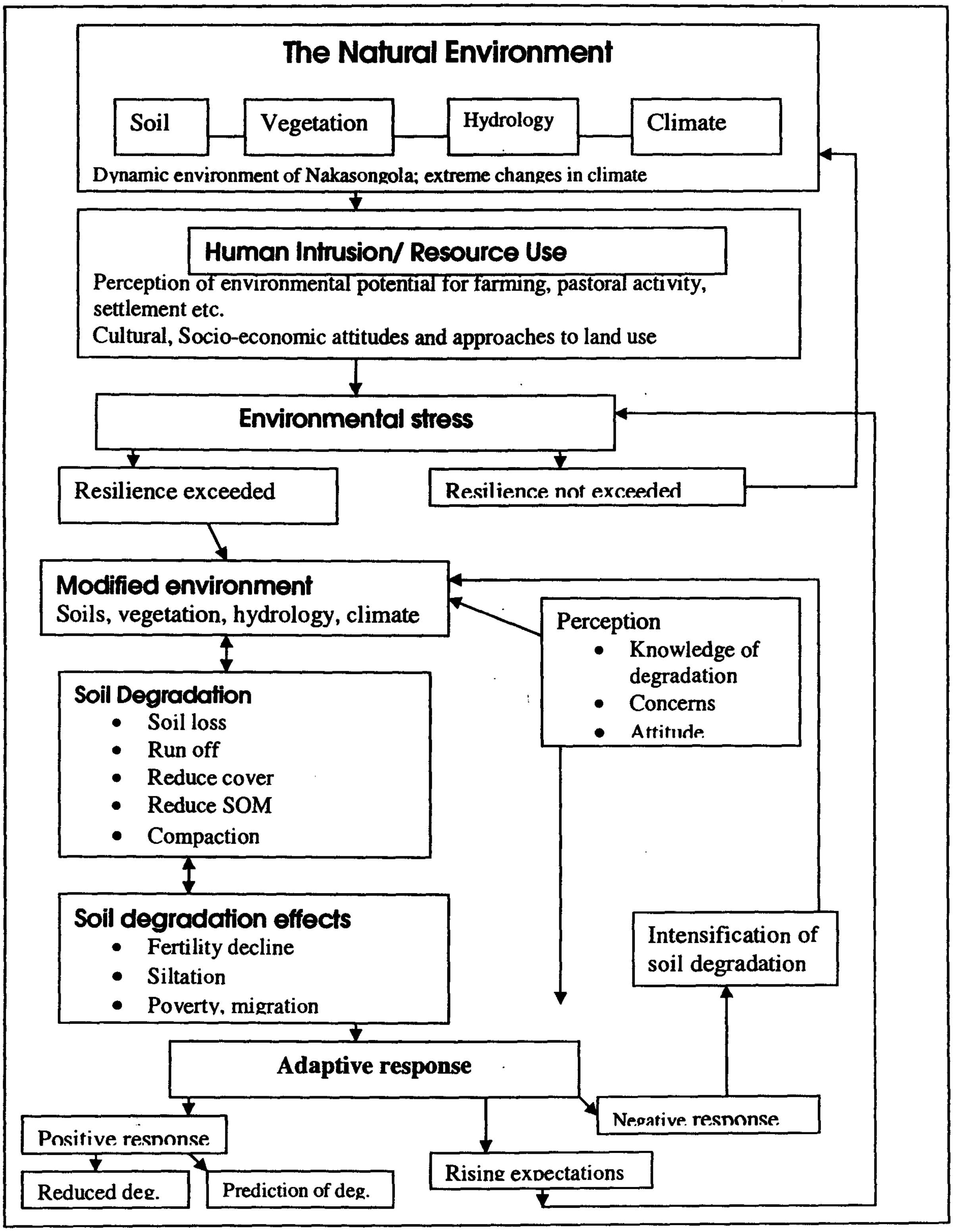



**Figure 1.1** Conceptualisation of soil degradation in Nakasogola district (Adapted and modified after Chisholm and Dumsday, 1987).

Loss of soil and water are bound together in the process of erosion, which involves both detachment and transport (Hudson, 1995; Morgan, 1995). The ecological sensitivity of this environment coupled with these changes including frequent climatic fluctuations (droughts) increases the risk to the area of desertification.

According to Downes as quoted by Morgan (1995) overgrazing and removal of vegetation cover for cropping and grazing causes exposure and crusting of the surface soil, reduces infiltration rates and results in greater runoff. The changes in land use and other factors including the nature of the soil, topography and increased surface runoff are known to result in gully erosion as long as the velocity or tractive force of the runoff exceeds a critical or threshold value (Morgan, 1995). However, these degradation processes are complex and vary from one area to another. Yet no explanation and documentation has been undertaken to increase the understanding of the processes. This study, therefore, dwelled on identifying the forms, distribution and causes of degradation.

Soil conservation at national, district or household level is affected by the perceptions and attitudes of the people to the problem of soil degradation. In a situation where people do not perceive soil degradation as a problem or perceive it but regard it as not being of any threat and therefore no adoption of conservation practices; this is categorized under negative response and usually leads to further environmental stress and soil degradation by positive feedback mechanisms. For positive response, people perceive environmental changes as a problem, as reflected for example in soil degradation, and actively ad conservation adopt conservation practices to control or minimize the problem. This eventually improves the environment by reducing degradation.

## 1.6 SIGNIFICANCE OF THE STUDY

The findings of this research will make a contribution towards:

i) Improved awareness about the nature, extent and magnitude of soil degradation problems in the central dryland region.

ii) Improved knowledge on management strategies for the adoption and promotion of soil and land conservation technologies. In particular the data may form an important input towards the on-going debate and efforts to combating desertification in the related environments in Uganda and other parts of the world.

ii) Generation of baseline data for evaluation of any soil and water conservation project implemented in the area in the future. For example, the findings of this research may be beneficial to monitoring the use of valley dam projects recently established by the government, through the Ministry of Agriculture, Animal Industry and Fisheries, in the area and many others yet to be implemented.

## 1.7 PROBLEM STATEMENT

This study investigates the soil degradation problem and its associated socio-ecological effects including the livelihood of the local people in Nakasongola district. Over the last three decades there has been widespread decline in crop and animal production in Uganda leading to poverty and rural population migration (NEMA, 1996). These are attributed to degradation of the soils and reduced agricultural production. The dryland environments of central Uganda are experiencing soil degradation and are at risk of accelerated degradation (NEMA, 1996; Kisamba-Mugerwa, 1995; UNEP, 1987). There is a need for intervention to reduce or mitigate the problem. Evidence of human activities such as overgrazing in the rangelands and the expansion of cultivation into areas originally reserved for dry seasonal grazing, is common (Kisamba-Mugerwa, 1995). These activities change the environment and affect sustainable use of soil resources. Hitherto, no comprehensive quantitative soil degradation studies have been undertaken in this area despite the need to generate data in guiding decision-making and land use planning. The nature, magnitude and extent of soil degradation in this area are poorly understood and the first step in combating soil degradation is to ascertain where and how rapidly soil is being degraded. The problem of soil degradation particularly in the central drylands has not been monitored and effective soil conservation measures have not been identified (Bagoora, *pers comm.*, 2001). This research aims to assess the nature and magnitude of soil resource degradation in the milieu of the past and present environmental and socio-economic conditions in Nakasongola dryland area and attempts to establish underlying and proximal mechanisms.

The perceptions of indigenous people in resource utilisation and management are central to the success of any conservation and planning. There has been limited research to understand local knowledge of soil degradation in the drylands of Uganda.

## 1.8 AIM AND OBJECTIVES

The aim of this study is to assess soil degradation and associated socio-ecological effects in the drylands of Nakasogola dryland in Uganda.

**Specific objectives:**

1. Identify forms of soil degradation and assess the distribution of the major associate processes in the Nakasongola drylands.
2. Assess the magnitude of the soil loss under different degraded surfaces in a dominant land use/ cover types.
3. Examine the environmental and socio-economic factors influencing the identified processes in the area.
4. Assess the effects of soil erosion on the biophysical environment including the agricultural and pastoral productivity.
5. Assess the perceptions of the local people with regard to the identified soil degradation problems and the impacts on land productivity.
6. Evaluate the coping mechanisms or strategies adopted by the local people in response to the soil degradation problem.

## 1.9 SUMMARY

This chapter has provided the general background that enlightens the global, regional and national perspective on soil degradation. The chapter also summarises the theoretical base and conceptual framework adopted by the study, and finally presents the significance, the research problem, and outlines the aim and objectives of the study. The next chapter presents a review of the concepts and causes of soil degradation, its assessment, impacts and the coping options including local knowledge.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

This Chapter places the study within the broader context of the debates on human-environment interactions and related impacts and adaptations through a review of the conventional concepts, definition of terms and opinions concerning soil degradation processes. It reviews the literature on the causes and factors of soil degradation, the approaches to the assessment of soil degradation including modeling, the impacts, coping measures and local knowledge.

## 2.2 CONCEPT AND PROCESSES OF SOIL DEGRADATION

### 2.2.1 Concept Of Soil Degradation

There is no universal consensus on the definition of soil degradation (Blaikie, 1985). This partly emanates from the varied professional interest (e.g. by natural and social scientists) in the subject. Blaikie and Brookfield (1987) contend that the term 'degradation' is perceptual; it implies at least a 'rank' scale of relative measurement and is open to multiple interpretations. Lal (1997) stressed that soil degradation must not be confused with land degradation. Barrow (1991) urged that the precise definition of land degradation is impossible due to a number of contributing factors. Soil degradation refers to the decline of specific soils' potential to support agricultural and/or ecological systems, but that land degradation is the substantial decrease in either or both of an area's biological productivity or usefulness due to human interference (Mainguet, 1994; Blum, 1997).

Thomas and Middleton (1994) urged that soil degradation is, by definition, a social problem. It is a human- induced phenomenon, which lowers the current and/or future capacity of the soil to support human life (UNEP, 1997). This study adopts the UNEP definition while also taking into consideration the practical difficulties in delineating the natural from the human-caused soil degradation. This is further highlighted by Stocking (1995), who contended that the "definition and measurement of the degradation process poses problems for the environmental manager because of difficulties of gaining data, interrelationship between the processes and errors inherent in the measurement methods".

### 2.2.2 Processes And Types Of Soil Degradation

The processes of soil degradation are the mechanisms responsible for the decline in soil quality, and encompass chemical, physical and physico-chemical deterioration, and biological types (Lal, 1997) although each of these may have distictive causes affecting it. The degradation processes, which may be human-induced or natural, are summarised in Figure 2.1.

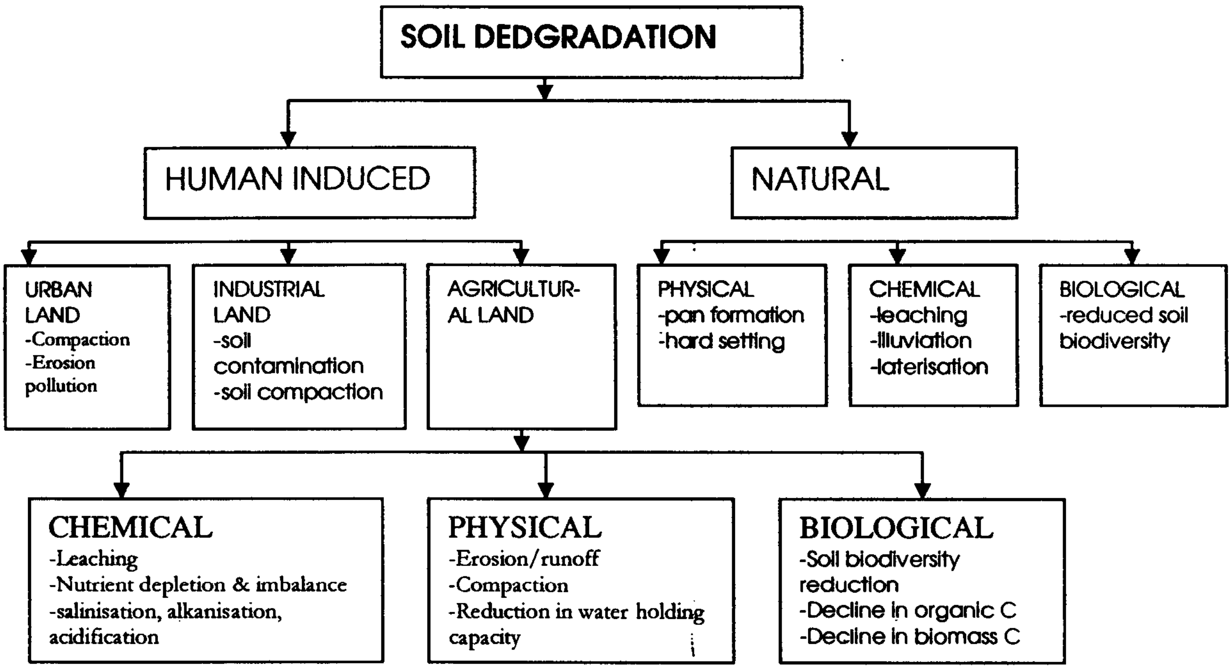



**Figure 2.1** Summary of human-induced and natural degradation processes

The main types of soil degradation processes (UNEP, 1997) include soil displacement due to water and wind erosion, and degradation resulting from the internal soil deterioration by physical and chemical deterioration. Soil erosion by water, compaction and crusting are prominent in Nakasongola district and are the focus in Chapters 5 to 8.

Chemical degradation includes a variety of processes related to leaching of bases and essential nutrients, and the build up of toxic elements (Lal, 1997). Thus, it entails changes in the soil salinity, acidity or alkalinity and a decline in nutrient status. Biological degradation is a reduction in the quantity of organic matter and living organisms, as well as in the rate of vegetation decomposition in the soil (Lal, 1997).

Physical deterioration is the re-arrangement of soil particles due to the removal of finer particles resulting in compaction, ablation of the topsoil, soil structural damage and detrimental changes in soil texture (UNEP, 1997; Lal, 1997). It often results in the decrease in infiltration capacity and plant water deficiency (Stocking, 1995).

Soil erosion by water is a three-phase process involving detachment of individual soil particles from the soil mass, their transport and deposition/sedimentation (Ellison in Hudson, 1981). The water erosion process is conveniently categorised as interrill erosion, and rill and gully erosion (Sharma in Laflen and Roose, 1997). Interrill erosion is the process of detachment and transport of soil by raindrops and very shallow flow. Channel erosion involves detachment and transport of soil due to flowing water and involves a different method of assessment and measurement (Laflen and Roose, 1997). Soil erosion may be described as natural or geological erosion and accelerated or human induced erosion depending on the rate. However, there are practical difficulties in distinguishing between human-induced from natural erosion.

Normal or geological erosion (morphogenesis) is generally defined (Hudson, 1981) as the process that occurs over a long geological period and slowly moulds the landscape/terrain (typically at rate of 0.1 to 1 t/ha/yr), allowing the formation of soil cover from the weathering of rocks and from alluvial and colluvial deposits (pedogenesis). Accelerated or human-induced soil erosion is, however, influenced largely by human activities that perturb the land-vegetation-climate equilibrium (UNEP, 1997).

The GLASOD studies have identified water and wind erosion as the most widespread of soil degradation processes, and that these pose a threat to future human livelihoods in the world's susceptible dry-lands (UNEP, 1997). However, the extent and severity of these processes are not clearly understood in dry-land environments, particularly on a larger scale.

## 2.3 CAUSES OF SOIL DEGRADATION

The socio-economic proximal and root causes of land degradation including soil degradation and low productivity on small scale-farms in Uganda have previously been summarised (Olson and Berry, 2003) as:

- Poverty and land fragmentation leading to over-exploitation of the land with inadequate soil and water conservation practices
- Increasing rural population densities with few non-farm income opportunities
- Inappropriate farming practices/systems including deforestation bush burning and overgrazing.

**Poverty, marginalisation and soil degradation**

One of the factors most closely associated with environmental degradation in the developing world is poverty (Batterbury and Forsyth, 1999), and yet this relationship is not always very clear. A well known analysis suggests that the poor are found disproportionately in the dryland, highland, and rainforest zones of the tropics, several of which have been identified by other researchers as 'critical' in terms of the quality of their natural resources base and the stresses placed upon them by humans (Kates and Haarmann cited by Batterbury and Forsyth, 1999).

Soil degradation has been explained in terms of what has been described as surplus extraction through the social relations of production and in the sphere of exchange (Blaikie, 1985). Surpluses may be extracted from cultivators who are then forced to extract 'surpluses' from the environment, which eventually leads to degradation. Peasant farmers, particularly in developing countries, are marginalized in various ways (e.g. exclusion from the formal world economic system) leading to loss of ability to control their own destiny. For instance, in Kenya, the build up of pressure for land in the Kikuyu reserve coupled with government encouragement of smallholders led to the marginalisation of the weaker sections of the peasantry to the more arid areas resulting in population pressure in those localities. Marginalisation through privatisation of land in Botswana, led to differentiation among the people; the marginalized peasants particularly the men were forced into migration to South Africa. However, degradation is not only caused by the poor marginalised sections of society but also by the rich in possession of land in fragile areas. For instance, the introduction of fixed boreholes in Botswana led to overgrazing in the surrounding areas on the ranches. And, furthermore the introduction of the plough contributed to overcultivation of the fragile environment causing loss of soil fertility. Blaikie (1985) cited varying cases on marginalisation and degradation but there is great complexity in terms of causes, differentiation and magnitude of resultant degradation. The majority of Uganda's population (80%) lives in rural areas and depends on agro-pastoralism for food and income, and yet the farmers are poor, with limited resources and numerous production constraints producing low yields (Olson and Berry, 2003). In the study area for this thesis, marginalisation has occurred through privatisation of the communal lands and encroachment of the livestock grazing lands. Efforts were made in this study to provide an understanding of soil degradation as a consequence of converting the communal to private lands.

Lack of capital hinders the land users from adoption of the necessary technologies to counter soil degradation (Olson and Berry, 2003) but instead promotes land use practices (e.g. deforestation, overgrazing) with damaging effects inducing increased erosion or other degradative processes. Olson and Berry (2003) note that middle income and poorer farmers in particular cannot afford to hire agricultural labour and inputs.

**Population and soil degradation**

So-called neo-Malthusian and neo-Boserupian thinking are highly influential in shaping the current population-environment debates (Mazzucato and Niemeijer, 2002). Population increase can lead to pressure on environmental resources hence degradation problems. This argument reflects the neo-Malthusian model. However, population-environment issues have generated interesting debates in the last few decades. The neo-Malthusian model has been challenged by recent evidence (e.g. Tiffen, *et al.*, 1994; Leach and Fairhead, 2000; Mazzucato and Niemeijer, 2002). For example, studies in the district of Machakos in Kenya (Tiffen, *et al.*, 1994) revealed that increasing population led to intensification and improved environmental conservation, thus supporting the Bosurepian theory, which holds that population pressure triggers experimentation, intensification and improved productivity other than degradation (Blaikie, 1985). The induced institutional innovation theory (Hayami and Ruttan, 1985) supports the Boserupian's optimism in that it explains the creation of 'efficient' institutions that safeguard scarce resources and allow the use of plentiful ones. Recent studies, however, have doubted such optimism. Speirs and Olsen (1992) argue that inappropriate institutions may evolve as a consequence of population growth and that the mixed farming system characteristic of many parts of the Sahel leads to overgrazing and environmental degradation. Cleaver and Schreiber (1994) maintain that shifting cultivation and transhumant pastoral systems have not been adjusting to rapidly increasing population, resulting in soil degradation and deforestation. In Uganda, Peder, *et al.*, (2001) found that population growth had an insignificant impact on resource conditions and indeterminate impact on welfare indicators. These arguments indicate that the debate on population and environment remains complex and inconclusive. The studies in Nakasongola district reported here will inform the arguments on the contributions of the existing local institutions in influencing environmental trends in the area by investigating their perceptions and adaptations to environmental degradation.

**Inadequate institutional framework**

The absence of (or ineffective) conservation policy and laws regulating land use leads to problems of increased soil erosion. Lele and Stones (1989) argue that public policies are fundamental in shaping the effects that higher population densities have on agricultural change. Without appropriate policies, higher population will inevitably lead to degraded trends. Land tenure is also important as different conventions may offer differential incentives for the land user to invest in long-term improvement of the land. In Uganda, poor land management and land degradation including soil degradation have been attributed to insecure or counter-reproductive land tenure systems (NEAP, 1995). In addition, certain land tenure systems such as the traditional inheritance system sometimes favour fragmentation leading to overuse or inadequate attention in terms of management. In Uganda, there have been reforms to land management policies (e.g. national land tenure policy changes of 1975 and 1998, implementation of the NEAP, the decentralisation of government authority) to address such problems but the impact appears to be negligible or with mixed and/or limited success (Nkonya *et. al.*, 2002).

## 2.4 FACTORS OF SOIL EROSION AND SOIL DEGRADATION

Soil degradation is affected by a number of factors, which, according to Hoosbeek *et al.* (1997) quoting Jenny's equation, are a function of soil formation factors (cl, o, r, p, t...) - where cl represents climate; o is organisms and their abudance; r is topography including certain hydrological features; p is the parent material, defined as the state of soil formation at time zero; t is soil formation time; and ... are additional unspecified factors. Adding a management variable m as the sixth factor yields a qualitative predictive model for soil degradation.

The soil erosion process is affected by related biophysical factors, namely the amount of ground cover, rainfall erosivity, soil erodibility, slope angle and length, and runoff volume and velocity (Hudson, 1995; Morgan, 1995) as discussed below. According to UNEP (1997), the soil erosion problem is basically ecological and socio-economic, while the above variables and their relationships are major factors in understanding the complexity of the soil erosion problem.

## 2.5 ASSESSMENT OF SOIL DEGRADATION

Soil degradation measurement techniques are available for a number of applications ranging from detailed research studies to broad based assessment (Laflen and Roose, 1997). The main types as reviewed by Stocking, (1987) and Laflen and Roose (1997) include laboratory experiments, field measurements, field and catchment-scale experiments and broader scale survey procedures and GLASOD methodology. However, there are challenges inherent in the techniques and sampling, and in the comparablity of the measurements conducted by different methods. This affects the reliability and usefulness of the data (Stocking, 1987). The processes of land and soil degradation occur at varying rates and with varying degrees of severity and yet data are collected on a limited time scale. Another problem is that some data collected are less reliable compared to others. A further limitation is the scale of measurement, which affects the extrapolation and interpolation of data obtained. For instance, extrapolations based on limited data and related to regions outside the ecological limits in which experiments were conducted are often misleading and characterised by errors (Lal, 1994).

Nevertheless, the above methodologies can all be applied depending on the availability of resources and the environmental conditions of the area under consideration. FAO (1979) methods using direct field observation and simple measurements provide a general impression about the nature of land and soil degradation in the watershed. The experimental erosion plots and predictive soil loss equations are suitable for small-scale studies, although they require long-term observations, which may be problematic in dryland environments. The FAO methodology overcomes a number of limitations mentioned above in that it involves actual measurement of the degree to which different parts of the landscape have been eroded using diagnostic criteria e.g. erosion features (pedestals, pavements, rills, gullies, deposition of soil on gentle slopes, reservoirs etc). The FAO approach informed the design of the methodology described in Chapter 4.

### 2.5.1 Experimental And Field Survey Approach

Soil degradation rate can be determined directly by measuring the actual amount of soil loss from fields at different scales (i.e. the plot and catchment level) and extrapolating the results to the entire area. This 'nested' approach has become widely accepted procedure since it permits the sediment production of component units to be related to the overall catchment sediment yield. It is particularly useful in relating the erosion rates and the hydrological responses to the underlying sub-catchment characteristics. Soil degradation by nutrient depletion can be studied using nutrient in- and out-flow (nutrient balances) measurements.

#### *2.5.1.1 Experimental plot level*

Trapping and measuring the quantity of removed soil or estimating the quantity from measurable changes in soil level are the two most common procedures for direct determination of soil loss (El-Swaify *et a.l,* 1982; El-Swaify, 1886).

Hudson (1995) and Morgan (1986, 1995) have described the design and use of experimental plots to monitor erosion loss. This approach is useful in testing the effectiveness of conservation methods at the field scale. It is event-based hence one can relate to the ground conditions, and identify the impact of particular cultivation methods and crop types on the rates of erosion. Laboratory and small field plot experiments are the most expedient way to describe processes important to various types of degradation and to derive parameter values for use in parametric equations or simulation models (West and Bosch, 1997). However, there is a need to be careful with the experimental design in order to minimise errors when extrapolating the findings. The method suffers from a number of shortcomings (Hudson, 1993). It is not possible to obtain evidence on field soil redistribution, as the plots are bound and isolated from the topographical context, which leads to difficulties in applying the results to field situations. Data monitoring should be extended for longer periods, particularly where there is inter-annual variation in rainfall. Associated costs may also be prohibitive.

#### *2.5.1.2 Field survey of erosion features*

Field survey includes the observation, measurement and recording of changes in the soil depth, and visible rills and gullies and estimation of rates of erosion based upon the volume of soil material displaced from these features. The method involves repeated ground observation and may be aided by remotely sensed data. The strength of this method is that it is less demanding in terms of equipment and training experience. Where satellite imagery or aerial photographs are available for a certain length of time, retrospective assessments to study spatial gully distribution can be undertaken. The shortcomings associated with this method are the prohibitive costs for the acquisition of the sequential images. Imagery of appropriate resolution may be lacking and where aerial photographs are used, little control can be exercised over the time employed, as existing records are likely to be limited (Walling and Qwine, 1993). Furthermore, the accuracy of data is questionable when the source of data to explain the erosion problem is limited only to the observable features such as rills and gullies.

Dunne (1978) applied the technique of measuring changes in the soil level, using remnant vegetation and tree root exposure as indicators of surface lowering, to estimate the erosion in the semi-arid rangelands of Kenya. However, simple micro relief measurements are often criticised for being inaccurate in detecting short-term erosion and because of their inherent inability to estimate the runoff. They endure further limitations in that they most frequently account for only local erosion features and it is difficult to apply the results to larger spatial scales.

#### *2.5.1.3 Catchment level*

This is the intermediate scale. Indirectly, soil degradation may be determined by estimating the sediment loads of rivers and reservoirs receiving runoff from the designated basins. This approach has been applied in numerous studies (e.g. Rapp *et al.*, 1972; Ogweny, 1978). There are limitations, however, in the use of sediment delivery data due to the re-deposition of eroded soils on the field slopes. Furthermore, difficulties also arise in sediment sampling; usually the suspended sediment load other than the bed-load is sampled and yet this may be part of the eroded sediment.

### *2.5.1.4 Global/continental level*

Global Assessment of Soil Degradation (GLASOD) methodology by UNEP and its partners (Olderman, *et al.*, 1991; UNEP, 1997) was an initial major international effort to assess soil degradation, to specify the types of degradation and to understand its spatial distribution (Barrow, 1991). The GLASOD work followed on from FAO's *Provisional Methodology* of 1978, which had fundamental errors relating to scale of analysis. Although the GLASOD approach represents a subjective assessment of a complex problem, there have been a number of refinements to provide for higher resolution of regional data and to produce an assessment of the status of human-induced soil degradation, linking degradation with productivity. Small-scale assessments often involve entire river basins and are largely qualitative, hence tend to mask the important contributions of small but seriously degraded areas (El-Swaify, 1986).

### *2.5.1.5 Remote sensing approach*

Satellite remote sensing, as opposed to aerial photography, is the science of deriving data/information about an object from measurements of electromagnetic radiation emitted by that object (Lillesand and Kiefer, 1994). The interpretation of remotely sensed data is based upon the knowledge of properties and behaviour of electromagnetic radiation. Lillesand and Kiefer (1994) provide a detailed description of the various electromagnetic properties.

The spectral reflectance characteristics of the soil are a function of their chemical, physical and mineralogical composition (Curan cited by Nizeyemana and Petersen, 1997). As a result of extensive studies (Stoner and Baumgardner, and Mathew *et al.*, cited in Nizeyamana and Petersen, 1997) the diagnostic absorption bands and portions of the electromagnetic spectrum that are most sensitive in detecting differences in soil properties important to soil mapping have been identified. Soil degradation results in changes in soil properties. The important soil variables in identifying soil degradation at the soil surface, and which have diagnostic absorption features detectable by RS systems are organic matter, soil moisture, texture and iron- oxide (Curan cited by Niyezemana and Petersen, 1997). However, the fact that soil degradation is not measured in terms of quantifiable ranges of soil properties makes the differentiation of reflectance values between undisturbed and degraded soils difficult. Comparing reflectance spectra or data of digital image analyses of degraded and undisturbed soils therefore assesses soil degradation. Niyezemana and Petersen (1997) argued that the determination of soil degradation using RS is thus based on a subjective judgement of the trend of reflectance curves rather than on specific measured ranges of reflectance values.

Aerial photography and satellite imagery have been used for rapid but qualitative observations of erosion sources, relative magnitudes of soil loss and sediment destinations. These techniques can reveal erosion rates when several sets of photographs/imagery are obtained at defined time intervals. However, there are limitations in detecting certain erosion types (e.g. sheet erosion) and hence the technique is more suitable for gully erosion investigation (El-Swaify, 1986).

### 2.5.2 Participatory Rural Appraisal (PRA)

PRA in an important tool in obtaining both the biophysical and socio-economic data at the intermediate scale during field surveys. In recent years 'participation' has become a critical concept in development (Estrella and Gaventa, 1998). Internationally, governments and non-governmental organisations are insisting on participatory approaches in assessing needs and implementing programmes.

Participatory Rural Appraisal (PRA) is a methodological approach that emerged in the 1980s, largely at the initiative of the NGOs, and is an outgrowth from Rapid Rural appraisal (RRA), which emerged from university professionals in the late 1970s. Chambers and Blackburn (1996) describe PRA as a family of approaches, methods and behaviours that enable people to express and analyse the realities of their lives and conditions, to plan what action to take, and monitor and evaluate the results.

Whereas RRA is extractive, PRA and PLA are participatory, empowering, with ownership and analysis more by the rural people themselves; the local people do the mapping, modelling, observation, scoring, interviewing, analysis and planning (Chambers and Blackburn, 1996; IDS, 1996; Chambers, 2004). Outsiders are involved as convenors, learners, catalysts and facilitators in the process thus leading to local ownership of the outcome. Although this may prove difficult, it is more effective if the investigator shows respect, is open and self-critical and can learn not to interrupt (Chambers and Blackburn, 1996). Experiences with PRA in South Asia, East and West Africa and elsewhere (Chambers, 1994) show that local people are more cooperative if this protocol is followed than otherwise.

PRA is not fixed; it is increasingly being adopted and becoming more mainstreamed. According to Pratt (2001), PRA in Pakistan now stands for "Participation Reflection Action" and such a descripter provides better meaning. PRA has grown from a research focus and is now a useful tool for investigative work. The participatory methods are eclectic, borrow from many disciplines, and are adapted to meet the specific jobs at hand. Validity and reliability are achieved through use of multiple methods and including different users and stakeholders in consensus building (Nayaran-Parker, 1999).

There are, however, dangers in scaling up its use too quickly, which puts the method at risk of being discredited and in the process and alienating the local people who participate (Chambers and Blackburn, 1996). The activity of extracting information quickly may prove unethical because local people are brought into a process in which expectations are raised and then frustrated if there is no action or follow-up (Chambers and Blackburn, 1996). The method therefore requires clarifying the researcher's intentions to the local people from the outset, and also remaining commitment on the part of the facilitators to support the actions that local people have decided on.

### 2.5.3 Nutrient Study Approaches

Many methods have been adopted in assessing changes in soil fertility including nutrient balances, soil erosion estimates, rangeland:arable ratios, long term monitoring of yields using different soil amendments, and national level trends in grain (Toulmin and Scoones, 1999). The choice of the method depends on the system being studied, the factors to be monitored and the time frame and baseline against which to assess the trends. To obtain greater understanding of environmental changes, other methods such as farmer's perceptions and assessment of soil changes, documentary evidence and socio-economic data analysis also need to be incorporated (Scoones and Toulmin, 1999).

Several approaches exist for the study of nutrient balances but the appropriate method should be a reflection of the objectives and requirements of the researcher and other users (Smaling and Oenema, 1997). These different approaches are detailed by Smaling and Oenema (1997) and have been applied by researchers in varied temporal and spatial scales. In recent years the nutrient budget and balance approaches have become widely applied in the African context at different spatial scales ranging from plot and catchment studies to regional analyses and continental assessments (Scoones and Toulmin, 1999). A number of these studies point to the widespread processes of nutrient 'mining' and soil fertility decline. Studies on nutrient balances in agricultural systems that were commissioned by FAO on sub Saharan Africa applied a 'black box' approach with many generalisations and simplifications due to limited and uneven data availability. Smaling and Oenema (1997) indicate that such models are mostly used at larger scales, and have 'awareness raising' as their main aim and policy makers as the principal audience.

The scale inherent limitations in the use of these black-box models have triggered related large-scale studies in Africa such as that for Kisii district in Kenya. Nutrient losses of -112 kg N and -3 kg P $ha^{-1}$ $yr^{-1}$ were calculated for the Kiisi district compared to estimated mean continental values of -75 kg N and -5 kg $ha^{-1}$ $yr^{-1}$ (Smaling and Oenema, 1997). Detailed studies on nutrient balances have also been undertaken at the farm (e.g. Wortmann, 1999; Esilaba *et al.*, 2002) and plot level. In this case the farmer is an important controller of nutrient flows and balances, including soil type and climate. The plot-scale and farm-scale balances provide information on directly controllable factors for nutrient flows, and are also very important for the proper understanding of variation in nutrient flows and balances at larger spatial scales (Smaling and Oenema, 1997). Scoones and Toulmin (1999) have assessed the difficulties associated with the use of soil nutrient budget analysis such as dangers of extrapolation from very limited data sets and problems of handling diversity and uncertainty with smallholder farming systems. Soil processes (e.g. gaseous losses, leaching and rock weathering) are difficult to measure accurately in the field, yet they may account for important nutrient losses and errors in their estimation may have significant effects on overall results (Scoones & Toulmin, 1999; Ramisch, 1999). Such variables are often estimated using transfer functions and regression equations standardised across different environments (e.g. Smaling *et al.*, 1993; Stoorvogel & Smaling, 1990). However, such functions may be inappropriate to the local agro-environment and will at best introduce increased uncertainty and error into the calculations.

### 2.5.4 Modeling Approach

Erosion models (Morgan, 1995) vary in form and complexity from empirically derived equations (e.g. USLE, SLEMSA) to distributed process-based models (e.g. WEPP) (Anderson and Rogers cited by Walling and Qwine (1993). The importance of the modeling approach to erosion assessment lies in the near-instant access to wide-scale erosion estimates and the potential for estimating the impact of the changed land use or the introduction of conservation strategies (Walling and Qwine, 1993).

Models, nevertheless, have their shortcomings (Walling and Qwine, 1993; Morgan, 1995). E-swaify and Fowne (1992) note that site specificity, limited transferability, and other limitations of empirical soil loss prediction models have necessitated and encouraged the recent significant efforts in process-based modeling. But the process-based models are too demanding in terms of locally available input data for their operation. Thus, the costs accompanying such data provision often prohibit the wide use of such models, particularly in developing countries such as Uganda.

**The process-based models**

These models explain mathematically each process and then combine the separate effects. They are demanding in terms of data and require powerful computers to undertake the mathematical calculations. Examples of these models include the (i) European Soil Erosion Model (UEROSEM) whose objective is to assess erosion and pollution at field and catchment scales has proved very useful in guiding the selection of protection measures. (ii) Water Erosion Prediction Project (WEPP) was developed as a new generation of erosion prediction technology. It is applicable to different scales and land uses. The soil-based component of WEPP improves on the lumped mean annual K-factor approach of the USLE and distinguishes between rill and interrill erodibility.

**Productive models**

Productive models such as the Erosion Impact Calculator (EPIC) and the Productive Index Model (EPI) estimate the loss of productivity. EPIC is a combination of empirical and physically based components, which requires large amount of data to run. It is capable of estimating changes in production on a term changes basis.

**The empirical or "black-box" models**

These models are derived not from theory but field observations and experiments. They are referred to as "black-box". The USLE, an empirical model derived under temperate humid conditions in the USA (Wischmeier and Smith, 1978), has been widely applied in different parts of the world but with some modifications (e.g. the SLEMSA developed for Southern Africa, see Elwell and Stocking, 1982). The USLE's success in the United States and its relative global popularity have been credited to its simple form (El-Swaify and Fownes, 1992). The USLE equation is presented in the form:

$$A=RKLSCP$$

In which A is the predicted mean annual soil loss (t/acre/yr), and the RKLSCP are the empirically derived factors which linearly and 'independently' quantify the effects on soil loss of rainfall erosivity, soil erodibility, slope length, slope steepness, crop management, and land management practices. Numerous authors have documented the validity limits of the USLE (e.g. Wischmeier and Smith, 1978; El-swaify *et al.*, 1982). For instance, the application of the USLE is limited to the environment and land uses for which it was derived and misleading results are obtained when applied elsewhere.

The most commonly identified constraint is the need for local verification due to site specificity of the values assigned to its factors where the required data are usually unavailable. Long-term historic climatic data are not easily acquired. The model is strictly limited to sheet and rill erosion and is not applicable to short-term soil loss predictions or computations of sediment yields. After reviewing some of the available data on the values of the USLE factors for the temperate and tropical areas, El-Swaify *et al.* (quoted by El-Swaify and Fowne, 1992) concluded that tropical soils are generally less erodible but more susceptible to rainfall erosion compared to temperate soils. In spite of its limitations, the USLE is regarded a robust empirical soil loss prediction equation and has been widelt applied to predicting surface erosion rates in the tropics (El-Swaify and Fowne, 1992).

The Revised Universal Soil Loss Equation (RUSLE), a modified/improved version of the USLE, is also widely applied to estimates of soil erosion (Ouyang and Bartholic, 2001). RUSLE allows more versatility in applying the USLE through refined values of R, K, L, S and methodological estimations of C, the cropping factor, through all of its identifiable factors (El-swaify and Fowne, 1992). This study adopted the RUSLE model in GIS environment to predict the soil loss. Unlike the USLE, the RUSLE/GIS interface is robust and provides a good methodology for analysis of the problem at reconnaissance scale (e.g. district).

**The RUSLE factors**

Soil erosion process may be promoted or retarded depending on the interplaying factors. Rainfall erosivity, soil erodibility, slope (length and gradient) and cover are key factors in the RUSLE and USLE (Wischmeier and Smith, 1978; Renard, *et al.*, 1997) as discussed below.

**Rainfall Erosivity**

Rainfall erosivity is the potential ability of the rain to cause soil erosion and is linked to the physical characteristics of rain namely amount, duration, drop size, drop-size distribution, terminal velocity intensity and kinetic energy (Wischmeier and Smith, 1978; Salako, 2003). Soil loss is closely related to rainfall partly through the detaching power of raindrops and the contribution of rain to runoff (Morgan, 1995). Soil detachment and transport by rainsplash is usually the first step in soil loss (Van Dijk *et al.*, 2002; Legueddois *et al.*, 2005) and can be measured using a variety of approaches including splash cups, trays and boards. The spatial distribution of particles splashed from a point source can be described by an exponential decay function (Van Dijk *et al.*, 2002).

The relationship between rainfall and soil loss, however, is not always simple. The response of the soil to rainfall is influenced by both rainfall intensity and amount including the antecedent soil moisture (Morgan, 1995). Many studies (e.g. Fournier, cited by Morgan, 1995) indicate that the average soil loss per rainfall event increases with the intensity of the storm. However studies elsewhere seem to indicate that this relationship is not always direct.

Rainfall erosivity is best expressed as an index based on the kinetic energy of the rain, which is a function of rainfall intensity and duration, and of the mass, diameter and velocity of the raindrops (Morgan, 1995; Salako, 2003). The general relationship between KE and rainfall intensity is:

$$\mathbf{KE = 11.87 + 8.73 \log_{10} I}$$

Where I is the rainfall intensity (mm/h) and the KE is the kinetic energy (Jm-2mm-1)
For tropical rainfall, based on studies from Zimbabwe, Hudson gives the equation:

$$\mathbf{KE = 29.8 - 127.5/I}$$

The three common indices for rainfall erosivity evaluation are $EI_{30}$ (Wischmeier and Smith, 1978; Renard *et al.*, 1997), KE≥25 (Hudson, 1995), and $AI_m$ (Lal, 1976). The KE is the summation of kinetic energy of rainfall exceeding 25 mm h-1 based on the premise that such rainfall events are the main contributors to soil erosion problem. $AI_m$ is the product of daily rainfall amount and maximum short-term intensity ($I_m$). To qualify as a valid index of potential erosion, an erosivity index must be significantly correlated with soil loss. Wischmeier and Smith (1978) have suggested the index of $EI_{30}$ but this is criticized as not being valid for tropical rains that are characterised by high-energy intensity. It implies that low intensity rains cause erosion but Hudson (1995) found that soil erosion occurs at intensities > 25 mm/h and thus proposed an alternative erosivity index, which uses KE>25. In the absence of appropriate equipment to measure rainfall intensities, the present study attempted to measure rainfall amounts using a non-recording gauge and related it to soil loss. Rainfall amount has been found to be a good indicator of soil loss.

**Runoff generation**

Water infiltration is a major determinant of how much rain will contribute to runoff and cause soil erosion. Under conditions where the rainfall intensity is less than the infiltration capacity of the soil, no surface runoff will occur and the infiltration rate (IR) equals the rainfall intensity (Hudson, 1993). If the rainfall intensity exceeds the infiltration capacity, the IR equals the infiltration capacity and the excess rainfall forms surface runoff (Hortonian overland flow). Overland flow is a major agent of sediment detachment, entrainment and deposition. Horton (1933) was the first to recognize that infiltration is the most important factor in overland flow. However, the other important control for runoff generation is limiting soil moisture content.

When the limiting moisture content is reached and all the pores are full of water, pore pressure equates to atmospheric pressure, suction reduces to zero and surface ponding occurs. Once water starts to pond on the surface it is held in depressions and surface runoff does not start until the storage capacity of the depressions is full. Surface ponding capacity varies according to slope, land use type and the nature of the soils.

**Soil Characteristics**

The properties of a soil are important determinants of resistance to erosion (Morgan, 1995). These properties are combined into soil erodibility factor, which refers to the resistance of the soil to both detachment and transport (Hudson, 1995; Morgan, 1995; Wischmeier and Smith, 1978). Auset *et. al.*, (1990), however, it has been argued that the influence of soil properties cannot be confined to the erodibility concept, as applied in the USLE, because the consequences of a given soil at a given point of a catchment could appear in a completely different part of the catchment.

Infiltration capacity is the maximum sustained rate at which soil can absorb water and is influenced by pore size, pore stability and the form of soil profile. Soils with stable aggregates maintain their pore spaces better while those with swelling clays or minerals that are unstable in water tend to have low infiltration capacities. Dunne and Dietrich (1980) observed a progressive decline in infiltration rates due to swelling colloids in the severely eroded rangelands of Kenya. Soils with deteriorated structures due to over-cultivation or trampling may have reduced porosity and hence low IR (Pietola *et al.*, 2004). Infiltration capacities can be obtained in the field using infiltrometers (Hudson, 1995) but discrepancies are realized between actual capacities during rainstorms and those obtained by field tests. For soils with varied profile depth, the horizon with the lowest infiltration capacity is most critical.

Soil particle size distribution affects infiltration rates and moisture content. For instance, coarse textured soils are usually characterised by high IR (Salako, 2003; Telis, 2001) and hydraulic conductivity (Salako, 2003). Soil moisture content influences soil structural stability by determining the degree to which mechanical forces will cause structural breakdown (Barver, *et al.*, 1972). The organic and chemical constituents of the soil are important due to their influence on aggregate stability. Generally soils with low organic carbon (<2 %), low clay and high in silt content are considered the most erodible. The silt:clay ratio may therefore be an indicator of soil susceptibility to detachment and transport, where an increasing ratio means that the soil is less stable and therefore more prone to erosion (Waruru and Wanjogu, 2003). A threshold value for this ratio of 0.4 is reported for gneiss and ingneious rocks parent material soils (Wanjogu cited in Waruru and Wanjogu, 2003).

Soil erodibility decreases linearly with increasing organic content over the range of 0 to 10 % (Voroney *et al.* cited in Morgan, 1995). However, the role played by organic material depends on its origin and interactions. There is a significant interaction noted between organic matter content and aggregate size in seal formation and final IR (Lado *et al.*, 2004). The high aggregate stability and the low dispersivity of high-organic matter soils seem to limit seal or crust formation.

Chemically, the most important control over erodibility is the proportion of easily dispersible clays in the soils. A high content of exchangeable sodium can cause rapid deterioration of the soil structure on wetting, leading to loss of strength, followed by the formation of a surface crust and decline in infiltration as the detached particles fill the pore spaces in the soil (Shainberg and Letey cited in Morgan, 1995)

Numerous soil erodibility indices have been devised based on soil properties. Morgan (1995) presents a review of these indices for water erosion. Bryan (cited in Morgan, 1995) favours aggregate stability as the most efficient index. However, a more commonly used index is the K value which represents the soil loss per unit of $EI_{30}$as determined in the field on a standard bare plot (22m long on a 5° slope). Estimates of the K value can be obtained from the nomograph based on the particle size distribution, the organic content, structure and permeability of the soil (Wischmeier and Smith, 1978). However, poor predictions are obtained for soils with high organic contents of >4% and swelling clays.

**Vegetation Cover**

Vegetation cover buffers the soil from the erosive effects of raindrops, overland flow and wind, while the roots contribute to its mechanical strength. The importance of vegetative cover in reducing erosion has been widely demonstrated (Hudson, 1981; Hudson and Jackson cited in Morgan, 1995). Increase in vegetation cover reduces soil loss and runoff although the relationship is not linear (Stocking and Elwell, 1976). Wischmeier and Smith (1978) suggested an exponential relationship as applicable to vegetation covers in direct contact with the soil surface. This exponential relationship has been attributed to the ponding rainwater behind or within plant elements, which reduces the effectiveness of raindrop impact (Foster cited in Morgan, 1995). Morgan (1995) argued that the exponential relationship also applies to canopy cover.

The effectiveness of the plant cover in reducing soil erosion by raindrop impact depends upon the type, extent, quantity of cover (Wall, *et al.*, 1987), the height and continuity of the canopy, and the density of the ground cover (Morgan, 1995). Soil erosion potential is increased if the soil has no or very little vegetative cover and or/or crop residue (Wall, *et al.*, 1987).

The vegetative cover also influences the runoff velocity. The greatest reductions in velocity occur with dense, spatially uniform, vegetative covers (Morgan, 1995). Clumpy, tussocky vegetation is less effective and may lead to concentrations in flow with localized high velocities between the clumps. Reid *et al.* (1999) observe that patchy vegetation has an impact on runoff and sediment distribution that affects the ecological processes.

**Slope**

Normally an increase in slope angle is expected to cause an increase in velocity and volume of the surface runoff hence increased in soil erosion. The relationship between erosion and slope is expressed by the equation:

$$E \propto \tan^m \theta \, L^n$$

Where E is soil loss per unit area, θ is the slope angle and L is the slope length.

The value of m was found to be approximately 2.0 in Zimbabwe (Hudson and Jackson cited in Morgan, 1995) and therefore the effect of slope is said to be stronger under tropical conditions where rainfall is heavier. On steeper slopes, however, the value m may decrease further as soil-covered slopes give way to rock surfaces and soil supply becomes limiting.

Surface overland flow causes detachment and transport of the sediment. Zhang *et al.,* (2003) have studied this relationship and indicate that detachment rate increases with slope gradient but the functional relationship between the two variables depends on the flow rate.

There is no simple relationship between slope length and soil loss due to a wide range of conditions (Morgan, 1995). The increasing depth of overland flow downslope may act to protect the soil from raindrop impact (Gilley *et al.* cited in Morgan, 1995). When rills form, soil loss may increase with slope length where rill densities are high (Meyer *et al.* cited in Morgan, 1995) or decrease with slope length where the flow becomes concentrated. Studies by Kinnell (2000) indicate that sediment concentration associated with flows from the side-slopes increases not only with slope gradient but also with slope length, particularly when side-slope gradient exceeds 10%.

### 2.5.5 The Regional Political Ecology Approach

This approach, advanced by Blaikie and Brookfield (1987), attempts to explain the complexity of human-natural resource use relationships encompassing interactive effects operating at different spatial scales and levels of organisation. It takes into consideration 'environmental variability and the spatial variations in the resilience and sensitivity of the land, as different demands are put on the land through time'. They argued that 'the constantly shifting dialectic between society and land-based resources is embraced in this approach through its concerns of ecology and broadly defined political economy'. The understanding of the roles of the international community, the state and the local land managers are derived from the political economy. Thus the approach consciously applies theoretical material from a number of models such as the core-periphery model, applied theories of the state and the ecology of the agricultural systems (Andersen, 1994). In Uganda's situation the local land resource use can be analysed by embracing these kinds of models.

## 2.6 IMPACTS OF SOIL DEGRADATION

Land degradation in fragile areas is one of the key issues of soil resource management and it demands urgent attention (UNCED, 1992). Laflen and Roose (1997:31) note that soil degradation is a serious threat to the quality of the soil, land and water resources. There is no region of the globe where soil erosion by water is not a threat to the long-term sustainability of humankind. Living standards are declining and the environmental situation is of concern in Africa and East Africa in particular (Stähl, 1993). Environmental assessments by the World Bank, the United Nations Environmental Program (UNEP), the World Watch Institute and the World's Conservation Union (IUCN) questioned Africa's capacity to prevent its environmental degradation and to sustain livelihoods by the end of this century. However, discussions on soils in Africa have been replete with overgeneralisations and misinformation, and investigations of land degradation on the continent have been equally prone to mis-measurement, exaggeration and erroneous extrapolation (Farley, 1996). Stocking (1998) observed that the damage traditional herders and pastoralists have done to communal rangeland resources has all too frequently been exaggerated and he proposed a more balanced and objective approach to assess rangeland degradation particularly the rates of erosion and their effect on biomass production, livelihoods and future use or sustainability. Emerging evidence shows that issues of land degradation are contextual (Warren, 2002). Besides, the occurrence of soil degradation is being countered through conservation in different parts of Africa and does not necessary lead only to negative impacts in view of increasing population (Tiffen, *et al.* 1999). Soil degradation leads to winners and losers depending on the nature of the on-site and off-site effects (Stocking and Clark, 1999). FAO (2000) reports widespread on-site and off-site impacts of soil degradation in many countries of Africa including Uganda.

### 2.6.1 Onsite Effects Of Soil Degradation

Soil degradation is a serious constraint to improved agricultural production throughout sub-Saharan Africa (Dregne, 1983; Lal, 1987; UNEP, 1992; Farley, 1996; Nandwa, 2003). Accelerated erosion on agricultural lands affects soil quality and productivity through removal of soil particles and nutrients (Nandwa, 2003; Mills and Fey, 2003). However, the effects are not uniform on all soil types and indeed there may be the same or different soil losses under the identical or similar conditions (Tengberg *et al.,* 1997). Nutrient balance studies show that degradation is evident on arable fields as nutrient depletion, which is the main threat to poor manure reliant farmers (Dougill *et al.,* 2002). For instance, the decline in banana productivity occurring in most of the Great lakes region is partly due to decline in soil fertility caused by nutrient losses through harvests and erosion (Bekunda *et al.,* 2003). Other studies in Uganda (Tukahirwa, 1992 and Zake *et al.,* 1995) indicated that many farmers in different parts of the country experienced a decline in soil productivity due to the soil fertility loss and poor soil management practices. These studies, however, were only based on the humid parts of the country and do not portray the situation in the dry-land areas. Links between environmental processes such as soil erosion and crop or livestock yields are highly complex given variable rainfall, management practices, pest and disease attacks

The environmental and economic losses from soil degradation are, nevertheless, widely thought to be enormous, although it is difficult to estimate without reliable data on the processes involved. Estimates of the economic losses arising from soil erosion cost Uganda between US-$ 132 to 396 million (Slade and Weitz, 1990). The costs of soil degradation to crop yields have been estimated at US $ 129.3 million per annum (Moyini *et al.,* 2002). But the relative magnitude of economic losses due to productivity decline versus environmental deterioration has created debate (Eswaran *et al.,* 2001). Some economists argue that the onsite impact of soil erosion and other degradation processes are not severe enough to warrant implementing any action at national or international level. On the other hand, the agronomists and soil scientists argue that effects on land quality are irreversible; for instance reduction in effective root depth. The masking effect of improved technology may, ofcourse, provide a false sense of security.

The productivity of most of dry-land ecosystems is rather poor (Mann, 1981). Many of these areas are experiencing increasing human and animal populations and changes in the land use due to high resource demand. Practices such as bush burning are very common in such situations. Frequent and uncontrolled bush burning may threaten the sustainable use of these environments particularly where remedial measures are not adopted. However, use of fire in maintaining the benefits of rangeland users is debatable (Roach, 2004). Roach, has argued that the ideal frequency of burning is unknown and would depend on the desired abundance of fire-tolerant versus fire-intolerant species, something that is probably subjective. The intensive utilization of thorny tree/shrub branches (e.g. protecting the crops from wandering livestock) and materials for housing and fuel wood has accentuated the desertification of these lands. Desertification is synonymous with severe degradation of dry-lands and refers to the impoverishment of the terrestrial ecosystems as a result of human impact. It is the process of deterioration in these ecosystems that may be measured by decreased productivity of desirable plants, undesirable alterations in the biomass and the diversity of the micro- and macro-fauna and flora, accelerated soil deterioration and increased hazards for human occupancy (Dregne, 1983). There is a direct link between soil erosion and desertification, which has its greatest impact in Africa (CAZS, 2002). Olsson and Rapp (1988) observed that for degraded land, rehabilitation or restoration is possible but the cost can be prohibitive to a poor resource country. These effects need to be analysed for greater understanding and application of appropriate measures for development of marginal lands.

The soils in the semi-arid areas have limited reserve of nutrients, including nitrogen; low organic matter contents (NRI, 1994). Studies on changes in soil properties due to degradation are still scanty in Africa. However, the few studies undertaken (e.g. Hiernaux *et al.*, 1998) indicate changes in soil properties resulting from grazing pressures.

The semi-arid areas are sensitive to certain developments such as the establishment of water points, which become associated with the sites of animal activity, the outer radius of which depends on the maximum distance the animals can move from the water (Noy-Meir, 1981; Imbamba, 2002). Along the radius of this animal activity there is a gradient of decreasing animal activity from the water point. These gradients are evident in the density of animal tracks and faeces and in the effects of trampling on the soil cover (Lange, 1969; Rogers and Lange, 1971). Rangeland degradation in Namibia has been attributed to positioning and management of water points and boreholes (Imbamba, 2002). The concentration of large cattle herds resulted in intense local overgrazing and degradation that negatively affected cattle population. In northeastern Uganda cattle trek long distances to the water points or dams during the dry resulting in overgrazing of the surrounding areas and soil erosion season (MAAIF, 1994).

### 2.6.2 Offsite Effects Of Soil Degradation

Soil degradation can result in negative and/ or positive offsite socio-economic or environmental effects (Pierzynski, *et al.*, 1997; Gregory, 2000; Ehrlich *et al.*, 2000). There are social related effects of soil degradation but many of them transcend the local areas of occurrence (Ehrlich *et al.*, 2000). Threatened livelihoods and undermined communities can generate border-crossing environmental refugees. These social reverberations of ecological change are felt far from the point of soil degradation and with increasing force (Ehrlich *et al.*, 2000).

Eroded sediment is a major air and water pollutant causing detrimental off-site effects (ASAE, 2001). The potential impacts of soil degradation on water quality include acidification, and enrichment of water with plant nutrients, sediments, pesticides and other organic chemicals, salts and trace elements (Pierzynski, *et al.*, 1997). These changes among others influence human health and enhanced ecological risk. There is widespread evidence of increased siltation and sedimentation of water reservoirs in different parts of Africa (NEMA, 2000; Semalulu, *et al.*, 2003; Ogweny, 1978; Rapp *et al.*, 1972). Accelerated siltation and sedimentation clearly threatens available water quality and quantity. In still other situations, eroded sediments can be a problem downslope when the deposited material buries crops. However, there are some locations, which benefit when the products of erosion are trapped (Gregory, 2000). The transported sediments including the fertile silt and clay may contribute to increased crop yields in areas of sediment deposition. Poudel *et al.* (1999) in the Philippines observed that crop yields downslope were greater by 40% for tomato, 36% for corn and 78% for cabbage than for upslope. In view of these discussions it is important that studies of soil degradation focus on both the positive and negative effects arising from degradation processes, and also the adaptation strategies and knowledge to address it.

## 2.7 LOCAL KNOWLEDGE AND COPING MECHANISMS OF SOIL DEGRADATION

### 2.7.1 Local Knowledge

**Indigenous and hybrid knowledge**

Although modernisation theory has dominated development discourse since 1945, there have been moves to reframe the debate (Briggs *et al.*, 1994). In particular an interest has developed in indigenous knowledge and the importance and value of recognising indigenous knowledge demonstrated. Seely (1998) noted that the importance of indigenous knowledge has been recognised but is usually seen as a source of knowledge to be taken and used by scientists rather than as an input into scientific or decision making processes. Indigenous knowledge systems (IKS) have been given more attention as their importance is addressed in development projects (Materer, *et al.*, 2001). Kloppenburg, (cited in Materer, *et al.*, 2001) distinguishes between scientific and local knowledge. He indicates that scientific knowledge is one in which the ideas, theories and concepts are 'immutable mobiles' i.e. the knowledge is transferable, mobile and not tied to a singular locale, as opposed local knowledge, which is less mobile but more dynamic and thus mutable. However, Materer, *et al.* (2001) disagreed with this distinction set between the two knowledge bases. He argued that, with the advent of globalisation, many subsistence societies are fusing modern technologies with their traditional practices hence knowledge systems in a local area are influenced by 'immutable mobiles' and adapted. Materer, *et al.* prefer to identify IKS as 'LKS' (local knowledge system) since it is unique because of the subject matter it contains, the context and the way in which it is applied and interpreted. It is necessary that it is defined separately or else researchers, scientists and policy makers who work in development will not take extra care in incorporating it into current projects. But Niemeijer and Mazzucato (2003) argued that in order for the local knowledge to be more useful for sustainable development interventions, it is necessary to go beyond the collection of indigenous soil taxonomies and also explore the theories farmers themselves have on soil with respect to formation and degradation processes.

**Perceptions and attitudes to soil degradation**

Acknowledging human perceptions of the environmental problems is an important requirement for better understanding of environmentally damaging forms of production and consumption (WBGU, 1995). Perceptions influence the way we behave or act and therefore an understanding of this concept is crucial in the resolution of environmental problems (Tuan, 1974). Decisions by the local people and the local authority as to whether or not to address the problem of soil degradation are clearly influenced by perceptions and attitudes. The concept of perception is extremely complex (Saarinen 1976). The meanings of perception, attitude and value overlap (Tuan, 1974), although each should be considered in its proper context. Perception is an intuitive recognition or understanding of the ecosystem and its natural resources, often based on human experiences or cultural attitudes or beliefs (EIONET, 2005). But in broad and simple terms, perception is the person's knowledge of, and attitude towards attributes of an area (Lanegran and Palm, 1973). Attitude is primarily a cultural stance; a position one takes vis-à-vis the world (Tuan, 1974). It has greater stability than perception and is formed by a long succession of perceptions or experience. Therefore, perceptions, as opposed to attitudes, are more fluid and change with time as experiences force or cause change.

Perceptions as to the status of resources differ from one community to another (e.g. the scientific and the local land users). What one observer perceives to be an environmental hazard is the normal run of events to another (Stocking, 1987). As emphasised by Blaikie (cited by Brinkcate and Hanvey, 1996), geographers must transcend the barriers between mere physical study of soil erosion to include ideological examinations as to whether all this concern about soil erosion matters and if so, how and to whom. Firey (1961) noted that cultural geographers have long been concerned with perception under the guise of cultural appraisal.

Socio-economic factors such as education, people's needs and their immediate interests govern the way they assess the deterioration of their environment (Tuan, 1974 cited by Brinkcate and Hanvey, 1996). Studies in the Madebe community in South Africa (Brinkcate and Hanvey, 1996) showed large discrepancies between what people perceived as regards soil erosion and what the scientific findings disclosed. Cooke and Doornkamp (1990) agree that within any particular cultural milieu there are often pertinent differences within and between groups such as the scientific personnel, resource users and the general public.

Ervin and Ervin (cited by Hagos *et al.*, 1999) indicated that, although farmers are often well aware of the condition of their land than is sometimes assumed by experts, they might not be fully knowledgeable about the complexity of land degradation, its causes or consequences. In other cases land users may easily relate the decline in crop yields to rainfall deficits but not with the soil moisture deficiency, which may be a consequence of soil degradation (Stocking and Clark, 1999; Hagos *et al.*, 1999). A degrading soil both accepts less rainfall and delivers less plant-available water (Stocking and Clark, 1999) a fact, which may sometimes not be obvious to a land user. Blant (cited in Saarinen, 1966) investigated why farmers in the severely eroded Blue Mountains of Jamaica were unwilling to adopt conservation methods. He observed that farmers failed entirely to perceive or perceived imperfectly the process of soil erosion in cause and effect terms.

Investigation of perceptions and attitudes among local groups can facilitate public involvement and provide critical information, which resource managers can consider together with more scientific and technical data (Brinkcate and Hanvey, 1996; Hagos *et al.*, 1999). Fairhead and Scoones (2005) contend that local experience and knowledge reveals an appreciation of the complex and interacting factors that influence soil fertility. They argue that it tempers any tendency towards reductionism that can be observed e.g. in academic reasoning that gives strong priority to any particular aspect, such as nutrient balance. This study included the investigations of perceptions of the local community as an approach to enhancing their involvement and contribution to an understanding of the soil degradation problem. The aim was also to assess their understanding and supplement with that based on the scientific perspective.

Available literature reveals difficulties in studying perceptions, such as measurement (Saarinen, 1976), since people have difficulty in articulating the conscious or unconscious feelings, attitudes, or ideas associated with perception. In many cases perception must be inferred from behaviour or from other indirect sources.

### 2.7.2 Coping Mechanisms

Environmental adaptation strategies and processes including changes in land use practices, technological innovations and economic diversifications that reduce the impacts local people have on their environment and other natural resources (Batterbury and Forsyth, 1999), is synonymous with the coping strategies as applied in this study.

Research findings are continually being applied to improve soil management and use of water resources. However, the strategies and techniques that involve the intermeshing of livestock and crop production within the farming systems is considered important for the creation of sustainable agricultural production in the semi-arid areas (NRI, 1994). The methods or techniques used by the farmers vary from one area to another depending on existing opportunities and constraints.

According to NRI (1994), research intended to increase production by improving soil and water management in the semi-arid areas should not focus solely on yield and soil water measurements. Rather, integrated research programmes are needed to focus on other factors, which can be crucial for the adoption of a new technology, and the impact that the technology may have on the farmer's household. Problems in the conservation of the soil have sometimes resulted from the gap between farmer perception and scientific knowledge. Peasant farmers often have limited risk capital, seasonal labour constraints, little machinery and restricted access to institutions, therefore they design or adopt outside SWC techniques based upon these local constraints (Millington, 1990).

The traditional approach to overcome nutrient depletion is the use of mineral fertilizer (Sanchez, 2002). But fertilizers in Africa cost 2 –6 times compared to Europe, Asia and North America, and this greatly limits their use. ICRAF and other partners in Africa have developed a soil fertility replenishment approach during the last ten years. The practices include Nitrogen fixing leguminous tree fallows; indigenous rock phosphates in P deficient soils; and biomass transfer of leaves of nutrient accumulating shrubs. Many farm families in eastern and central Africa apply various combinations of these practices with relatively improved results (Sanchez, 2002).

There are a number of adaptive strategies but with mixed results in response to soil degradation in Uganda. Historically, the high productivity of the soils of Uganda resulting from the favourable rainfall and as evidenced by the lush vegetation was misunderstood for inherent natural fertility, leading to some degree of the soil neglect (Zake, 1999). Little attention was given to soil fertility management in the country to an extent that no comprehensive plan was adopted to address the soil degradation problem. Traditionally soils in Uganda were cultivated until exhaustion then the farmer shifted to another area to allow for natural regeneration of soil fertility. High population pressure, however, does not permit this practice.

Application of both organic and inorganic fertilisers as sources of fertilisers is inadequate to cope with the rate of soil degradation (Zake, 1999). The level of inorganic fertiliser use has remained low and inadequate. Increasing efforts are being made to involve various stakeholders in participatory design and planning of soil conservation practices. However, resources to tackle the soil resource degradation problems are still scarce; farmers have little resources to invest in integrated nutrient management in Uganda (Wortmann, 1999).

In Uganda, the Plan for Modernisation of Agriculture (PMA) is a broad framework/policy addressing agricultural productivity for improved livelihood and environmental management (MAAIF and MPED, 2000). Soils are considered an important factor that should be properly managed to ensure high crop productivity. Therefore issues of soil management are targeted in the PMA in general. Achievement of success for such a broad policy depends on the political will and financial resources available.

The most recent efforts dealing with soil degradation in Uganda are broadly outlined in the draft Soils Policy (NEMA, 2004). Due to wide variations in the physical and socio-economic conditions in the country, and the severity and extent of soil degradation (Bagoora, 1997), it is important to formulate appropriate measures for each area.

Soil degradation continues to present a challenge despite the coping strategies adopted at national and local levels including the household as reviewed above. This study contributes to understanding the interplaying factors hence inform the design of appropriate measures. Researchers have pointed to the potentially counter-productive effects of coping strategies on certain sections of society or individuals (Batterbury and Forsyth, 1999). This highlights the need for disaggregating the community under study so that a clear analysis can be made. The approach in this study involved disaggregating the community into herders and crop farmers or both.

## 2.10 SOIL DEGRADATION RESEARCH IN UGANDA

This section reviews soil degradation in Uganda as summarised in Table 2.2. Limited studies on soil degradation undertaken in Uganda largely focus on soil erosion. Research on the dynamics and magnitude of accelerated erosion in Uganda are still in their infancy despite the widespread occurrence of the problem that may even threaten the very survival of peasant farmers (Bagoora, 1997).

**Table 2.2** Summary of soil degradation research in Uganda

| Source | Date | Method/location | Erosion rate(t/ha)/remarks |
|---|---|---|---|
| Rose | 1958 | Simulation, Central Uganda | Erodibility for soils in central Uganda |
| Temple | 1972 | Micro-plots, Namulonge | High erosion in cotton |
| Unep | 1987 | National, Erosion hazard using GIS, Uganda | Spatial erosion hazard |
| Nakileza | 1992 | Plot, Elgon slopes | 6.4 in maize sole crop on 21° |
| Magunda | 1992 | Micro plot, erodibility | Kabanyolo clay more erodible unstable & than Kachwekano |
| Kakuru | 1993 | 93 annual crops, 52 mixed | 56% & 68% reduction in soil loss by calliandra & nappier grass |
| Tenywa | 1993 | Simulation, Elgon, Kabanyolo | Low erodibility on Elgon soils |
| Tukahirwa | 1995 | Plots & WEPP, Kabale, | 1.4, 38 and 29 on 10° 25° and 45° slope respectively in sorghum |
| Bagoora | 1997 | Plots, Kabale, | 10 -14; 14 -129; 23 -107 on lower10 -14; 14 -129; 23 -107 on lower, Middle & upper slope respectively |
| Lufafa | 1999 | Micro-catchment, GIS, in Masaka | 93 annual crops, 52 mixed |
| Magunda | 1999 | Plots, L. Victoria basin | 49.8m³/ha/yr runoff in banana, 1089.6 m³/ha/yr in pastures; 27-126 t/yr soil loss |

The increased concerns about degradation in the 1930s led to the commissioning of surveys on soil degradation (Wayland and Brasnet, 1938). These investigations yielded qualitative data that were used as a basis to plan for the development of the soil and water conservation policies for different regions in Uganda. The qualitative assessments were a first step but were not coupled with quantitative investigations, which could have generated useful data for detailed planning considering the varied physical and socio-economic conditions of the country.

In the 1950s, research on soil erosion at the Namulonge Research Institute, using micro-circular plots of 3 m² on less steep slopes (1°), estimated ten times more runoff on bare plots compared to grass-covered slopes (Temple, 1972). A higher rate of erosion was observed under cotton cropped plots probably due to the bare soils between the rows. Grass mulch was found to be twice as effective in controlling run off compared to the stone mulch. Although limited to runoff plots, the results highlighted the importance of using grass cover/mulch in controlling erosion problem on agricultural lands.

Simulation studies by Rose (1958) involved transporting soil samples from different areas of Uganda to the United Kingdom for laboratory analysis. Data on infiltration and erosion were generated and provided a good index of the soil erodibilities of soils in central Uganda. There are, however, limitations in the application of such data, largely based on artificial or highly disturbed soil samples to wider areas in the field. Caution should therefore be exercised when using this data.

An assessment and mapping of the soil erosion hazard at the national scale using GIS facilities was undertaken in the late 1980s (UNEP, 1987). While providing rough spatial data for national planning purposes, there were inherent shortcomings of the method leading to overestimation in some areas and underestimation in others. High erosion rates were predicted in the central and eastern parts of Uganda although there have been changes over time in, for example, climate, population and soils so the information may not be reflective of the current conditions on the ground, and more particularly, at the district and county scale.

Nevertheless recent studies, even where limited to short term erosion plot studies still indicate that the soil degradation problem remains prevalent in the country in both the lowlands and highland areas. For example, on Mt. Elgon Nakileza (1992), measured runoff and soil loss, on slopes of 8° and 21° under four different representative treatments; maize sole crop, maize with grass strips, maize intercropped with beans and undisturbed pasture. Approximately twice as much soil loss was measured under a maize sole crop on the 21° slope (6.43 t/ha) compared to the less steep slope of 8° (3.03 t/ha). Grass strips and intercropped treatments reduced soil loss by 25% and 16% respectively. These studies were site specific in the humid mountain area and may not reflect the conditions elsewhere e.g. in the drylands.

Other related studies (Tenywa, 1993; Tukahirwa-Bitete, 1995; and Bagoora, 1997) have monitored and found high rates of erosion under different conditions in the humid areas. Tukahirwa-Bitete (1995) applied the WEPP model to assess and predict soil erosion trends in the highlands of Kabale. The model was found to be sensitive to trends of soil erosion dynamics and predicted the loss of soil within the range of observed data. However, the results indicated an overestimation of runoff, and the model was unable to predict non inter-rill erosion processes. Erosion studies such as the current one in the dry lands of Nakasongola are important in providing data for comparison and validation of the model predictions.

Investigations of the cause-effect interrelationships of runoff and soil loss, and environmental implications on upland farms of Rukiga highlands (Bagoora, 1997) have revealed high rates of soil loss with maximum values ranging from 10 - 14, 14 -129 and 23 – 107 t/ha on the lower, middle and upper slopes respectively. All these rates were over and above the recommended tolerance levels (T) of 5, 2.5 and <2.5 t/ha/yr on the lower, middle and upper slopes respectively. These studies were undertaken in a humid steeply sloping area with high population density and intensive agriculture but are relevant to the current investigations in Nakasongola district, although these studies did not emphasise the social related aspects of soil degradation.

Some studies have been dedicated to evaluation of the effectiveness of soil and water conservation technologies in Uganda. Kakuru (1993) investigated the effectiveness of agroforestry practices and grass strips in the control of soil erosion, in the Kabale highlands. Observations indicated 56% and 68% reduction in soil loss by Calliandra and Nappier grass respectively. These findings contrast with those at Lyamungu near Moshi in Tanzania (Temple, 1972b), where widely spaced ridges and hedges were found to be less effective in controlling erosion. The variations in erosion control may be attributed to differences in environmental conditions.

The Lake Victoria basin experiences relatively high rates of erosion. Erosion studies in a predominantly banana based micro-catchment within the basin (Lufafa, 1999) indicate high but varying rates of soil loss. Total annual soil losses were observed to vary; the highest rates of 93 t/ha/yr were predicted (GIS and USLE) for the annual crops, followed by the mixed perennial crops of banana-coffee (52 t/ha/yr). Soil losses of 48 t/ha/yr and 42 t/ha/yr were predicted for the back slope and summit respectively. In another catchment of L. Victoria, in Rakai district, Magunda *et al.* (1999) measured runoff and soil loss under experimental plots (10 m x 15 m). Preliminary results indicated high rates of both runoff and soil loss; runoff ranged from 49.8 $m^3$/ha/yr for bananas to 1089.6 $m^3$/ha/yr for pastures while soil loss ranged from 27 - 126 t/ha/yr. The high rate of erosion threatens the sustainable resource utilisation in the lake basin. Subsequent studies on sediment and nutrient loading in two micro-catchments in predominantly agro-pastoral areas of Rakai in Lake Victoria (Semalulu *et al.*, 2003) revealed higher total sediment loads ranging from 61.7 to 355 Mg/l t 105$^o$C. These findings provide an indicator of the off-site impacts of soil degradation but require further studies from related agro-pastoral ecosystems so as to improve on the information database for the country.

Majaliwa *et al.*, (2003) studied the interrill erodibility of selected soils in Kifamba area of the Lake Victoria basin using portable rainfall simulator. Soil erodibility was observed to vary across the soil types and topo-sequences. It ranged from 0.31 to 4.13 X $10^6$ $kgm^{-4}$ s and the most highly eroded and less eroded soils were the Haplic luvisols on the lower slopes and Ferri rhodic acrisols on the midslopes under coffee. These studies suggest great variability in interrill erodibility.

The erosion data as reviewed above point to the continued but varied prevalence of soil degradation in different parts of the country. More studies, particularly where there has been scanty research, are needed to build a clear view of the local and national degradation conditions.

There are no long-term studies monitoring the status of soil nutrient balances and crop productivity in Uganda. However, evidence from various limited sources (Zake, 1993; Bekunda and Woomer, 1996; Wortmann and Kaizi, 1998) indicates that soil fertility is declining as demonstrated by studies on farmers' perception of soil fertility change, nutrient balance and on-station fertilizer trials. Various factors affect soil fertility including the political ones that need to be underpinned so as to understand the trends and dynamics of agroecosystems. Studies by Walaga *et al.* (1999) in the districts of Palisa and Kabalore demonstrated that government policies impact on soil fertility through promotion of certain cropping and management practices.

In 1995, CIAT and the Soils and Soil Fertility Programme at the Kawanda Agricultural Research Institute estimated nitrogen, phosphorous and potasium nutrient balances and flows at field level, land use type and farm level under existing farming practices in eastern and central Uganda (Wortmann, 1999). The study provided information for prediction of the effects of alternative management practices on nutrient balances. Small land parcel size, diversity of the systems, rough seedbeds and the generally poor weed control reduced soil erosion but losses were still significant. Nutrient losses to soil erosion were greater in Pallisa with 13, 5 and 26 kg ha-1 for N, P and K, while losses for the other three locations in central Uganda were 7, 2 and 7 kg ha-1 for N, P and K respectively. Extrapolation of nutrient budget information to larger area is fraught with inaccuracy but can be informative, and may be done for exploratory purposes.

The influence of clay mineralogy was investigated by Magunda (1992). Kabanyolo clay was found to be more unstable and erodable compared to Kachwekano clay These results particularly from Kabanyolo clay have a bearing on soil degradation studies in Nakasongola area; where the soils are low in organic matter and with similar clays.

Okwakol, (1980 and 1987) studied the effect of termites on soil and organic matter, and the influence of land use change on soil macro-fauna in and around Mabira forest. The effect of degradation levels on population distribution of soil macro-fauna and the extent to which macro-fauna contribute to soil degradation in relation to other interplaying factors are less understood. The current study attempted to explain the role of soil fauna in soil degradation in Nakasongola.

As revealed in this review, soil degradation is a complex problem that has been studied using different methods. A case study approach was used and an experimental design adopted to measure the changes in soil physical attributes (e.g. soil loss, nutrients). This was, however, supported by inquiries (social survey) into farmers' perception on degradation of the soil resources in the area. Details of the methods are described in Chapter 4.

## 2.12 SUMMARY

The review in this chapter reveals important knowledge gaps and issues in the soil degradation processes. Particularly important are the following:

- Soil degradation is very complex and involving a number of interacting variables and impacts on biophysical and socio-economic and political conditions.
- The problem and the extent of surface soil degradation processes (sheet and rill erosion) and dimensions are less understood in the dry land environments of Uganda.
- The extent and degree of gully erosion are not well known
- Soil degradation has both spatially and temporally varied implications that are not adequately documented or analysed.
- The perceptions of the affected communities need to be considered since they are the ones who eventually have to bear the burden of implementing any remedial plans or measures advanced by the government or scientists.
- A number of studies have been confined to soil erosion and conservation research on the plot scale, particularly in the highlands in Uganda and no comprehensive mapping of soil degradation has been undertaken beyond the plot level. The research undertaken in Nakasongola district involved plot measurements and field mapping of soil degradation features outside the plots for purposes of providing a comprehensive understanding of the problem.
- There are many methods used in assessing soil degradation and each has its own advantages and disadvantages. There is a need to take into consideration factors such as the standardisation, costs and data reliability. This research applied an integrated but simple approach without compromising on data reliability.

This review has therefore informed the design of the objectives (Chapter 1) and methodological approach adopted by this study as elaborated in Chapter 4. The next chapter provides details of the study area.

# CHAPTER 3

# GEOGRAPHY OF THE CENTRAL UGANDA DRYLANDS

## 3.1 INTRODUCTION

This chapter is intended to familiarise the reader with the study area in Uganda. It provides a broad description of the major ecological and socio-economic background of the dryland areas in Uganda and particularly the central drylands in Nakasongola district. The reader who is familiar with the geography of the area could turn directly to the Chapter 4.

The central dryland incorporates the study area *sensu stricto*, which in turn includes the study of the sub-catchments and two experimental sites. A detailed description of the sub-catchments and experimental sites is given in the later part of this chapter.

## 3.2 DRY LAND ENVIRONMENTS IN UGANDA

### 3.2.1 Concept

Dryland ecosystems, or simply drylands, cover a complex set of ecosystems; the arid, semi-arid and sub-humid (with marked dry season) (Mainguet, 1994). The semi-arid and sub-humid dominates in Nakasongola district.

The term dryland has been used to designate those areas subject to periodic drought stress, which are most liable to desertification (Mabbut cited in Mainguet, 1994). Nevertheless, the occurrence of droughts and related phenomena in the drylands raises major questions about the climatic norms and the delimitation of dryland regions, which have both academic and practical implications (Thomas and Middleton, 1994). Drylands may be delimited based on features such as drainage systems, vegetation and soils. However, it has become usual to apply the aridity index based on climatic data (Thomas and Middleton, 1994). Different schemes incorporating the measurement of evapotranspiration (e.g. using Thornwaite or Penman method) rely on the principle of defining drylands in a manner that reflects deficits in available moisture (Thomas and Middleton, 1994; UNEP, 1997).

Three categories of dryland areas can be identified (Table 3.1). The areas receiving 1000mm are considered dry in Uganda, even though this amount of annual rainfall would appear equitable in drier countries (Kabera, 1985). The 700-mm isohyet, however, is considered the lowest limit of permanent runoff, hence the hydrological limit of drylands (UNEP, 1997).

**Table 3.1** General characteristics of dryland areas

| Dryland area | Aridity index (P/PET) | Comments |
|---|---|---|
| Arid | 0.05 to <0.20 | Mean annual ppt is approx. 200 mm, with high interannual variability (50 -100%) |
| Semi-arid | 0.20 to <0.50 | Distinctive seasonal rainfall regimes mean annual ppt is approx. 500 - 800 mm. Interannual variability is 20-50% |
| Dry sub-humid | 0.50 to <0.65 | Highly seasonal rainfall regimes, <25% interannual variability |

*After UNEP (1997)*

### 3.2.2 Distribution Of The Drylands In Uganda

The location and distribution of dryland areas is shown in Figure 3.1. Approximately a third of Uganda's land surface area comprises dryland. But the area susceptible to drylands is estimated at 60,739 $km^2$ (UNEP, 1997), which expressed, as percentage of all land available for agriculture and pastoralism is 25%.

The distribution occurs in four main blocks, which can be distinguished as zones A, B, C and D.

**Zone A**: is a semi-arid livestock belt that stretches from the borders of Rwanda and Tanzania in the south, northwards through parts of Mbarara, Rakai, Masaka, Mpigi, Mubende, Kiboga, Luwero and Nakasongola districts. The details on this zone are provided in a later sub-section 3.2.11.

**Zone B**: is located in the northeast and stretches through the districts of Katakwi, Moroto and Kotido (Karamoja) and part of Kitgum district.

**Zone C:** is a small patch in western Uganda located in the Rwenzori and Kazinga area. It covers parts of Kasese and Kabarole districts.

**Zone D:** is a narrow stretch located in the Rift Valley in the Lake Albert/River Nile belt. It stretches northwards from the districts of Bundibugyo, through Hoima, Masindi, Nebbi, Moyo and Adjuman districts towards the Uganda-Sudan border.

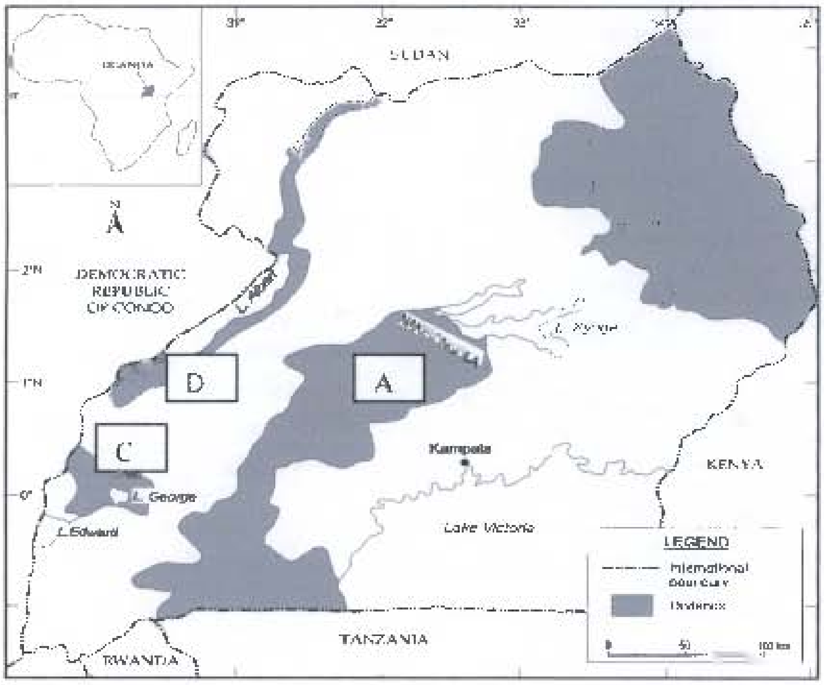



**Figure 3.1** Location of the dryland areas in Uganda (After MAAIF, 1989)

### 3.2.3 Characteristics Of The Drylands In Uganda

The areas are characterised by low and erratic rainfall with short rainy seasons, severe long dry seasons, high temperatures and evaporation rates (Langlands, 1974; Kabera, 1985). They also have water scarcity problem particularly in the dry season, poor soils and scanty pastures, which deteriorate markedly during dry seasons. The unfavourable climatic fluctuations affect the socio-economic and ecological conditions (Kabera, 1985). The soils of the dryland areas of Uganda are varied in terms of fertility and productivity (Kabera, 1985).

Climax vegetation cover types include dry combretum; dry acacias and grass savannas (Langdale-Brown et *al.*, 1963; Langlands, 1974). The only exceptions are the drier eastern areas of Karamoja and along Lake Albert where bush lands and dry thickets are pronounced. More sparse vegetation is dominant in drier areas. The vegetation in most of these areas is also greatly affected by human practices.

The population of the dryland areas has been low since the start of the last century due to low rainfall and diseases such as sleeping sickness and Nagana. However, as revealed by the various population censuses (1959, 1969, 1980, 1991 and 2002) there has been an increasing trend in population numbers and densities in these areas (Figure 3.2). This is partly attributed to immigration, tsetse fly eradication and improvements in the infrastructure. Increase in population leads to land pressure and eventually land degradation incase there is inadequate management.

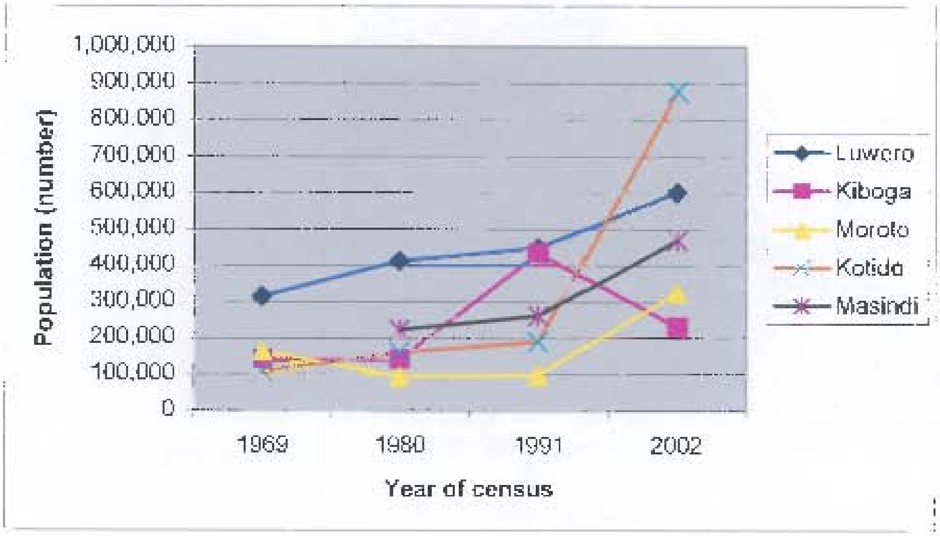



**Figure 3.2** Population changes in the dryland areas by district (1960 2002) (After MPED 1991 and UBS, 2002)

The choice of the central dryland area and in particular the Nakasongola district was based on numerous considerations including (i) approximate central location between the northern and southwestern dryland blocks (ii) relatively dense and growing rural and urban population (iii) varied soil types and geomorphic units and (iv) pilot area for desertification control or intervention mainly by the government as part of the CCD programme. The local community in Nalukonge village initiated a tree planting and soil conservation (using trenches) project to rehabilitate the degraded area and was funded by UNDP. This provided vital information on the analysis of the local community attitude to soil degradation and the capacity to address desertification challenges.

## 3.3 ECOLOGICAL BACKGROUND OF NAKASONGOLA

### 3.3.1 Location

The area of study is located approximately between 1° 10' N and 1° 40' N and 32° 5' E and 32° 50' E (Figure 3.3). It is situated in the central part of the country about 120 km northwest of Kampala City.

### 3.3.2 Geology And Geomorphology

The geology of the area consists of mobilised and intrusive granites derived from the 'basement complex' (GOU, 1967). Geology has an important influence on erosion. The physical and chemical characteristics of soils are influenced by the geology of the area of origin. Rock type influences the slope factors (slope angle and form), which are important controlls in erosion processes.

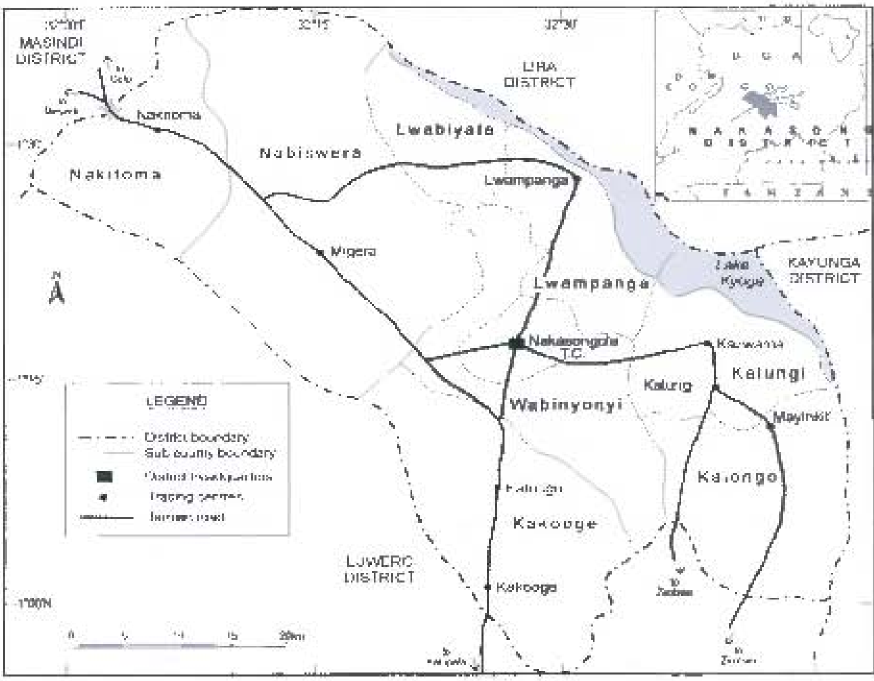



Figure 1: Location of the study area in Uganda

**Figure 3.3** Location of the study area in Uganda (After Lands and Survey Department, 1992)

The geomorphology of the area consists of the Tanganyika and Acholi surfaces but the most dominant is the Tanganyika surface, which belongs to the end-Tertiary and covers much of the hills and hill slopes. It is a peneplain, earlier described by Wayland (Langlands, 1974) as peneplain III and consisting of pediments that have undergone varying amount of degradation and slopes of <5° are common (Pallister, 1960). Much of the land, therefore, consists of gently subdued relief (Figure 3.4) and limited massive granitic rock out-crops (inselbergs) particularly within 10 – 20 km of Nakasongola town.

Lateritic ironstone is frequently encountered on this Tanganyika surface though it is not prominent as that on the remnants of the Buganda peneplain. The laterite is overlain by soils and encountered in pits on the crests and sides of hills. However, on the lower slopes at the pediments the lateritic crust frequently emerges from under the soils and increases the sensitivity of these areas to heavy runoff and soil loss.

McConnel, cited in Pallister (1960), described and termed the Acholi surface as valley-floor peneplain. It is a surface of accumulation attributed to the lower Pleistocene. In the north, along the shores of lake Kyoga and the valley of river Kafu, there are extensive areas of alluvium and a series of terraces (Figure 3.4). Geomorphology and related geomorphological processes have a significant influence on soil formation and vulnerability to erosion.


**Figure 3.4** A cross section of the geomorphology of the north Mengo (Luwero & Nakasongola) (After Pallister, 1960)

3.3.3 Soils

Yost and Eswaran (1990) classified the soils based on the soil taxonomy soil survey staff 1990. Details of data on soil properties and classification are scanty. The six main soil types found in Nakasongola district are shown in Figure 3.5.

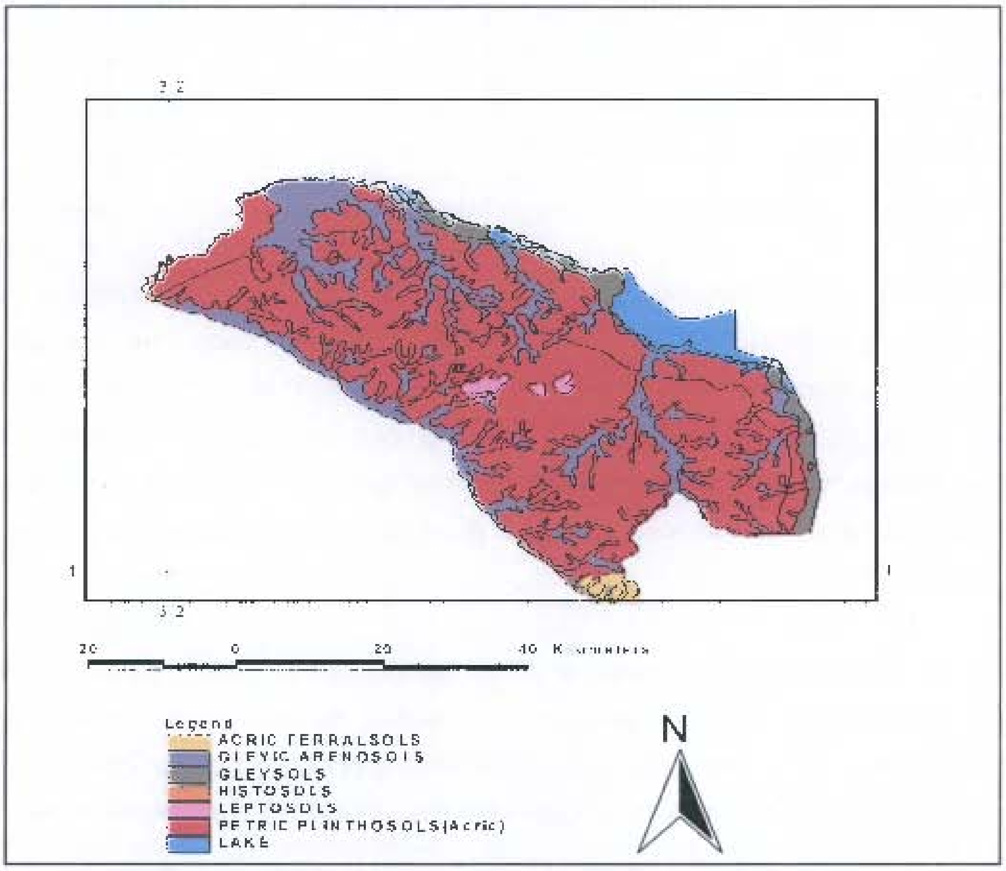



**Figure 3.5** Soils of the Nakasongola district, according to FAO system (adapted and modified using data from Soils Unit, Kawanda Research Institute)

A large part of the area is dominated by the petric plinthosols (red ferrallitic soils) of sandy loam and sandy clay loam type, which belong to the Buruli catena. These soils have little reserve of weatherable minerals, deep horizons not clearly differentiated and Kaolinite (1:1) as the main clay mineral associated with Fe and Al oxides. Langlands (1974) categorised them as fair productivity soils, which also occupies a great part of Uganda (43%), and particularly the cattle corridor. The extensive laterisation of the unit suggests a high degree of leaching and maturity of the soil profile, probably confirming their 'old age'. Laterisation has taken place in the subsoil of both the lower and upper pediments (Harrop, 1970). Patches of 'murram' are often found on the hill ridges/crests and shoulders.

Soils of the acric ferralsol type are largely deep red clay loams over laterites and have developed from the basement complex gneisses and amphibolites. The unit belongs to the Buyaga catena and occupies a small area to the south. The Leptosols are shallow skeletal loam that often occur on steep slopes and belong to the metu complex.

The gleyic arenosols (hydromorphic soils) are pale yellow fine sands derived from recent alluvium and categorised under Mulembo series. The unit occurs in depressions connecting to L. Kyoga and occupies much of the R. Lugogo low-lying swampy areas. Seasonal or permanent water logging largely influences their development and the texture varies from sandy to loamy type. The pH ranges from acidic to neutral.

Gleysols are peat or peaty sands and clays derived from the papyrus residues and river alluvium. The mapping unit belongs to Kaku series, occupying a large area bordering L. Kyoga in the north and east. Closely related to this unit is the histosols derived from the papyrus peats and occurring in small areas to the west and northwest.

The soil erodibility is largely described as low, and the soils especially in the northwest part harden on drying. Soil productivity is high (UNEP, 1987) based on texture, depth, pH, fertility, drainage, organic matter, workability and water holding. However, nutrients and water are known to constrain crop productivity (Wortmann and Eledu, 1999).

### 3.3.4 Climate And Drainage

The climate of the area is warm and dry. The southern part is relatively moist but the conditions are drier toward the north and northwest of the district as evidenced further by the change to drier vegetation type (section 3.2.6). The mean monthly rainfall (Figure 3.4) is about 169 mm. However, there is great variation in that parts of the district particularly to the northwest receive lower rainfall.

The mean annual rainfall of 800 mm to 1000 mm (Figure 3.6) is typical of the dry land conditions. Droughts are frequent and affect soil cover and agricultural productivity. During the dry period, the soils (dry and hardened) cause the vegetation to wilt thus exposing the ground to the early rains of the wet season. This phenomenon coupled with overgrazing and clearance of vegetation worsens the exposure of the ground to erosive agents. Murray-Rust (1973), in a related environment in Tanzania, noted that alternating dry and wet seasons affect soil erosion; soils dry out thoroughly in the long dry season (May - October), leaving the ground exposed and forming deep cracks. Except for some soils with vertisol characteristics in the low-lying areas (see Appendix 3), there are generally no observed deep cracks of this kind in the Nakasongola district.

Rainfall erosivity is moderate (Wortmann and Eledu, 1999). The rainfall erosivity computed using the modified Fournier Index ranges from 100 to 200 (UNEP, 1987; Yost and Eswaran, 1990), and is thus within the range of what prevails in other dry land areas in the country.

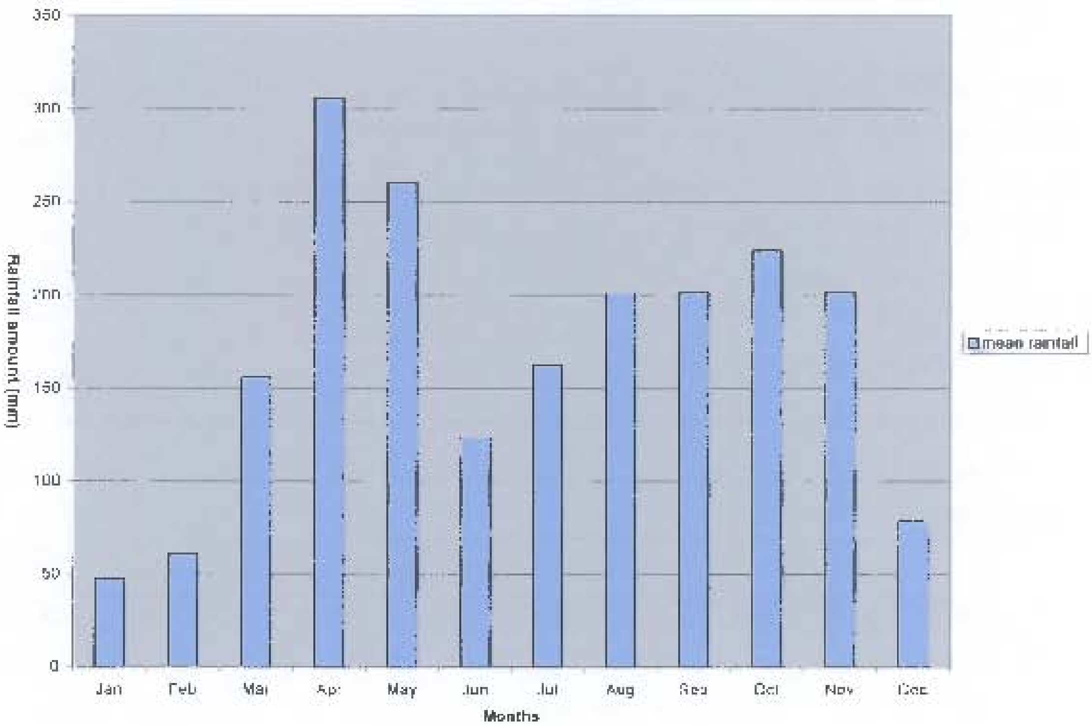



**Figure 3.6** Mean monthly rainfalls for the Nakasongola district (Based on data from the Meteorology department, Entebbe, Uganda)

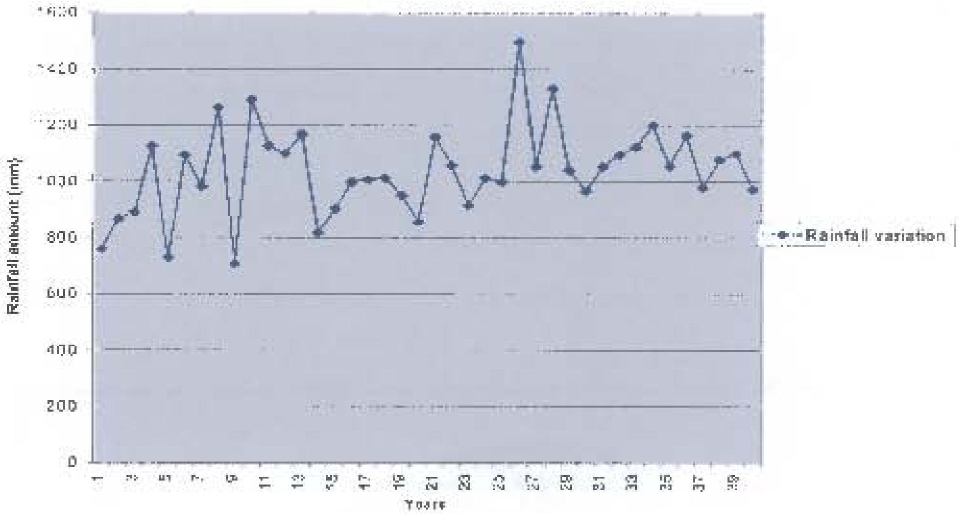



**Figure 3.7** Mean annual rainfall (mm) for the Nakasongola district (Based on data from the Meteorology department, Entebbe, Uganda)

The mean annual maximum temperature is ~30°C while the mean minimum temperature is ~17.5° C. During the dry season, the cloud cover is very low or absent thus high temperatures and excessive evapo-transpiration are experienced. The mean monthly evaporation during December to March varies between 150 – 200 mm (GOU, 1967) and may exceed the mean monthly rainfall. The mean monthly evaporation of 125 mm for April to August and 150 mm for September to October are quite high, and reduce the rainfall effectiveness.

Winds under limited soil and vegetation cover, can be a very effective medium for the transport of sediment (Wiggs, 1997, cited by Holmes, 1998, p49). The area receives low - moderate speed winds, varying according to season. High-speed winds, which are more destructive to property and soils, are experienced during the drier months of December to February and at the start of the wet season in March.

Small ephemeral rivers and streams mainly drain the area. Most of these rivers/streams empty into seasonal swamps, including Lugogo to the south and Lake Kyoga to the north. The limited network of tributaries is an index of relatively drier conditions and typical of subdued relief area (Holmes, pers. Comm., 2002). The degraded sloping lands in the catchments increase incidences of flooding whenever it rains.

3.3.5 Vegetation

The vegetation of the area (Figure 3.6), though greatly modified by human activities, is a function of drainage, soils and geomorphology. Vegetation serves as a control on surface processes and as an indicator of prevailing climatic conditions (Holmes, 1998). Changes in vegetation cover can be used as an indicator in estimating the rates of soil degradation.

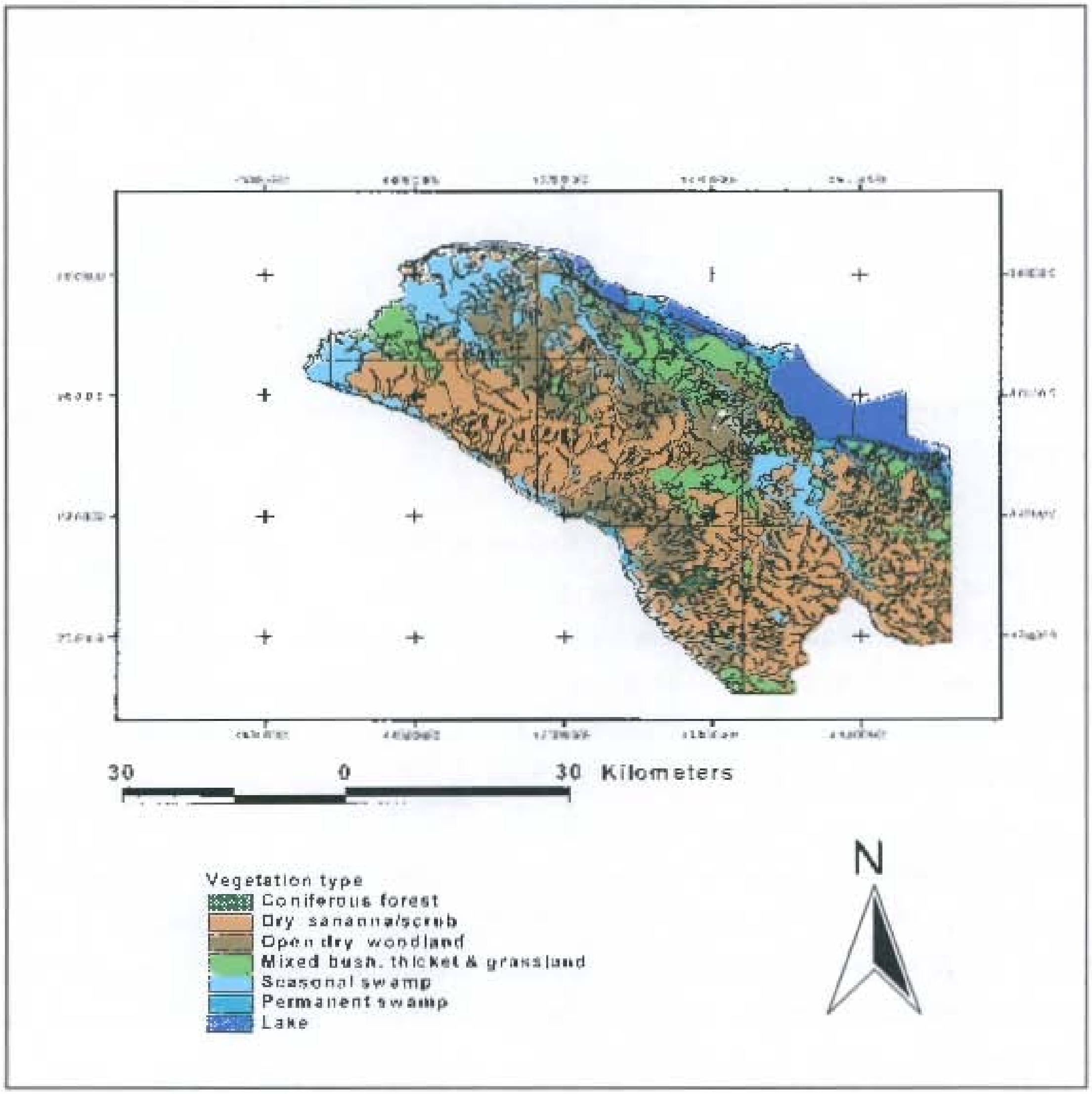



**Figure 3.8** Vegetation types of the Nakasongola district (Manipulated from the National Biomass Study remote sensing data)

Langdale-Brown *et al.* (1963) provide a detailed account of the vegetation of the area. The dominant vegetation types occupying the hillsides and hilltops include the dry acacia and moist combretum savannahs and moist thickets. Examples of common tree species include *Combretum collinum, Combretum guenzii, Combretum mole, Terminalia dawei, Terminalia mollis, Accia hockii,* *acacia sieberian, Acacia senegal, Albizia coriaria, Albizia grandibracteata*. The less dominant ones include *Euphorbia candelabrum, Ficus sycomorus and Margaritria discodeus* commonly found growing on termite mounds. Tree species such as Combretum, Albizia and Erythrina, which are fire tolerant, provide evidence of the role of long-term effect of fires in influencing the ecology of this ecosystem.

The grassland savannahs are also common in open but relatively flat areas. However, the seasonal swamps dominate the broad valley bottoms and the main grass species include *Themeda triadra, Brachoria ruziziensis and Hyperrhenia rufa*. The papyrus swamps are limited to the few permanent swamps occurring on the outskirts of the district but mostly around Lake Kyoga.

Overall the vegetation cover has changed as a result of human interference reflected in intensive grazing, bush burning and cultivation. Collection of firewood and building materials and soil degradation contributes to vegetation changes. There are few remnants of woodland forests. Most of them have been cleared for fuel wood and charcoal burning, which has become a dominant alternative income activity in the area. Bare patches, caused by overgrazing and other factors are common on grazing lands. This is further explained in Chapters 5 through 7 in relation to soil degradation.

## 3.4 SOCIO-ECONOMIC BACKGROUND

### 3.4.1 Administration

Nakasongola district was granted district status in March 1997. It covers an area of 3424.47 km² and consists of only one county, Buruli, subdivided into five sub- counties and 28 parishes. Nabiswera is the largest sub-county (1363.86 km²) while Lwampanga is the smallest in area (441.44 km²).

The Chief Administrative Officer (CAO) is the overall head of the technical section and has an assistant who is also in charge of the county. As stipulated in the Decentralisation Statute of 1997, sub-county chiefs and parish chiefs head the sub-counties and parishes respectively.

The local council committees at each administrative level (LC IV, LC III, LC II and LC I) oversee the implementation of the government policies by the technocrats. Under this set up, the Local Council V (LC V) Chairman is the supreme political head in the district and takes precedence over all functions and everybody in the district. This set-up has implications for the management of the natural resources, including the soils; for instance in the settling of land conflicts, making bylaws and in the implementation of the natural resource policies formulated by the central government.

**Table 3.2** Administrative units and distribution by sub-counties and parishes

| County | Sub-county | Parish | Area ($km^2$) |
|---|---|---|---|
| Buruli | Nabiswera | 6 | 1363.86 |
| | Lwampanga | 4 | 441.44 |
| | Kalungi | 8 | 671.71 |
| | Kakooge | 5 | 511.09 |
| | Wabinyonyi | 5 | 436.37 |
| Total | | 28 | 3424.47 |

Adapted from Population office, Luwero

## 3.4.2 Human Population

### *3.4.2.1 Ethnic composition*

The largest ethnic group is the Baruli followed by the Banyarwanda, Barundi, Baganda and Bahima respectively. The Baruli, Banyarwanda and Bahima are mainly cattle keepers while the Barundi and Baganda are cultivators. Despite the presence of ranches in the district the majority of the cattle keepers still practise some form of nomadic pastoralism. Apart from the Baganda and Baruli, the rest of the groups are recent migrants in search of casual labour or pasture for the animals but decided to settle permanently.

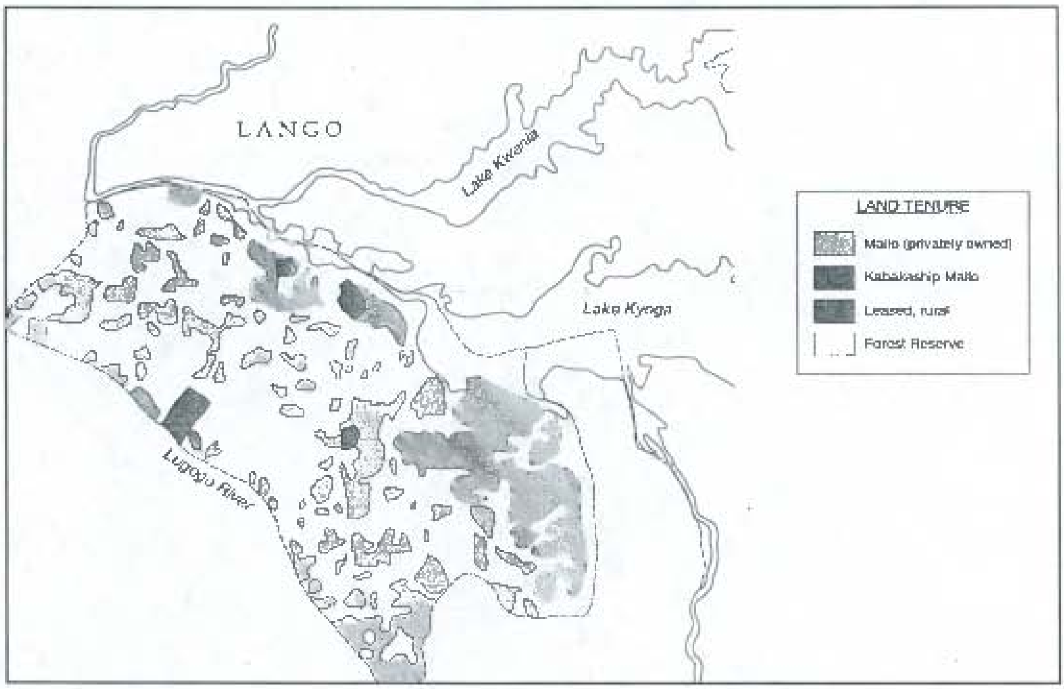
### *3.4.2.2 Population density, structure and growth*

**a. Population growth and density**

The population in 2000 was estimated to be 141,639 people. The national census of 2002 report indicated a slightly lower number of 125,297. The general trend, as revealed by the recent population statistics, shows a declining growth. The population growth rate between the years 1969 to 1980 was 2.6%; 1980 to 1991 was 0.8%, but from 1991 to 2002 it showed a decline (1.89). However, a few sub-counties in 1991 (e.g. Lwampanga) had experienced population increase due to immigration largely from the surrounding districts.

The population density approximated 32 persons $km^{-2}$ in 1991 (inclusive of reserve forestland) (MPED, 1991) but it is unevenly distributed (Table 3.3). It ranges from 13 - 73 persons $km^{-2}$ with the most densely populated sub county being Lwampanga probably due to the recent migration by

customary, mailo, leasehold and freehold. Figure 3.9 shows the general distribution of these land tenure (West, 1972), which are further deliborated on below. There are certainly recent changes with respect to acquisition of more leaseholds but the mailo ownership pattern has not changed greatly.




*(The tenure class forest reserve here includes the unalienated public land)*

**Figure 3.9** Distribution of the land ownership in the Nakasongola district (After West, 1972 land tenure system in Uganda).

**a. Mailo tenure**

This tenure system resulted from the 1900 Agreement between the Protectorate government and the king of Buganda (West, 1972). In this tenure system, interest in land goes on in perpetuity and it is recognised and protected by the state. The holder has the freedom to transfer his rights (whole or part) to a second party without restrictions by the controlling authority, the Uganda Land Commission (West, 1972). This has culminated in a majority of the people being squatters with little incentive to develop the land, let alone being able to use it to access funds for development.

In the 1975 Decree all forms of land tenure were replaced with one system referred to as leasehold. But the constitutional changes of 1995 restored the mailo tenure with few modifications. The mailo tenure system is negatively criticised for not being developmental in that the nature of ownership does not permit squatters to engage in meaningful lucrative activities or long-term investments (e.g. soil water conservation) on the land.

**b. Customary**

This tenure system, occurring on mailo and public land, is the most common/widespread and oldest in the area. The right of land is regulated by the local customs but the individual household(s) has the rights to cultivate and graze his/her stock on the land, construct a house and to pass his ownership to an heir of his/her choice. It is important to note that in practical terms these rights do not amount to a permanent, indefensible right to a specific piece of land but are held conditional on productive occupation and acceptable behaviour.

**c. Leasehold**

Leasehold is based on an agreement between the lessor and the lessee where land is granted for a specified period of time (45 for rural and 99 years) for urban areas) and for developmental purpose. All the land presently occupied by civic centres (e.g. town council, government schools, resettlement schemes and district headquarters) falls under this category. Notwithstanding the high costs and other difficulties in obtaining a lease, this system is considered flexible for the government to intervene in effecting desirable developments on the land (NEMA, 1997).

**d. Freehold**

Land is owned in perpetuity at no cost of acquisition and a certificate is given, taxes are levied and there is adherence to proper land use control in the interest of the public. The Protectorate government, following the 1903 Crown Land Ordinance, granted land to some special interest groups such as the protestant (e.g. Nakasongola church of Uganda) and catholic churches to cater for both their religious and commercial interests.

**e. Public land**

The enactment of the Public Lands Acts in 1962, after independence, reverted all land hitherto designated as crown land, to public land. For example forest reserves, wetlands and any other outside mailo land constitute public land. However, according to NEMA (1999), of all the tenure systems, the leasehold tenure seems to be the best for enhancement of both conservation and development.

The most common method of land accessibility in the area is through inheritance. Other forms of inheritance are allocation by local authorities, borrowing and outright purchase. The different social groups don't have the same access to land. The widening income gaps and unwillingness of the landlords to dispose of their land has aggravated the situation.

The operation of the tenure systems and their recent evolution under the influence of demographic growth and climatic factors can thus represent real stumbling blocks to attempts to set up natural resource management arrangements with the population.

### 3.4.4 Land Use

Agriculture is the main land use in the area and largely includes traditional pastoralism and ranching, and cultivation. Annual crops cultivated are sorghum, cotton, groundnuts and cassava are possible. A few perrenial crops are grown.

The government designated Nakasongola mainly for ranching. There are 85 commercial ranches in the district but nearly all have sub-level management and are either overstocked and/or diseased (NEMA, 1996). Communal grazers have often encroached on these ranches searching for both pasture and water thus, accentuating pressures on the carrying capacity of the ranches.

The area is experiencing medium land use pressure (UNEP, 1987) that can be attributed to the increasing population caused by natural increase and immigration. Table 3.4 illustrates the changes in population in relation to the cultivable land. Though the statistics on cultivatable land are not available after 1959 population census, there is clear evidence of growing pressure on the cultivatable land based on the increasing population density.

**Table 3.4 Population changes and cultivable area in Nakasongola district**

| Year | Rural Population growth | Density persons $km^{-2}$ | Cultivatable area | Remarks |
|---|---|---|---|---|
| 1959 | 22792 | 8 | 2746 | Low pressure on land |
| 1969 | 47165 | 17 | - | - |
| 1980 | - | - | - | - |
| 1991 | 90,300 | 28 | - | - |
| 2001 | 118,707 | 37 | - | - |

*(Adapted from Langlands and the National Population censuses reports1980-2001)*

The population is mainly dependent on both crops and livestock, and mixed farming, but a small proportion is engaged in fishing. Crops become progressively more important towards the north as compared to livestock. The farming population per square kilometre of arable land ranges from 48 - 111 but the commonest was 62 - 68. On the other hand, grazing land ranges from 3.8 - 13.7 ha per household. Though described at one time in the past as the main pastoral area, pastoralism is declining in importance, and giving way to settled livestock farming and cultivation.

## 3.5 STUDY LOCALITIES AND EXPERIMENTAL SITES

### 3.5.1 Introduction

This section provides the details of two selected study localities and experimental sites in this dryland area. The two study areas are Migera (Nalukonge and Singya-Wamukende) and Wibisi, which lies within the selected transects that runs from SE to NW and N to S direction (see Figure 3.10).

### 3.5.2 The Migera Study Locality

This is situated about 120 km from Kampala city along the Kampala to Gulu road. Migera consists of Migera Town council, the villages of Nalukonge, Sigya and Wamukende.
The population in Migera town council is between 500 to 1000 people mainly engaged in trade and some form of agriculture; both crop farming and livestock keeping. The population is increasing rapidly due to easy access to major Towns in the south and north of the country. There are thus available opportunities in high way business including sale of milk products and animals. The rural population especially to the south of Migera town is very sparse and largely composed of sedimentary pastoralists (ranchers). A few of them, however, combine livestock with crop growing on a subsistence scale. The rest are subsistence small-scale crop farmers growing mainly cassava, sweet potatoes, maize and ground nuts. The crop farmers are also engaged in off- farm activities such as trade to boost their incomes.

### 3.5.3 The Wibisi Study Locality

This is situated about 10 km from Nakasongola town. It consists of the villages of Sikye, Machum and Sasira. The population density is moderate and the population is largely involved in agricultural activity; sole crop and mixed farming are dominant. The main agricultural implements used include a hoe but some ploughing is also carried out.

The topography is undulating with some moderately steep slopes on the inselbergs and broad seasonally impeded valleys. Soils include the sandy and sandy loams in the valleys and red ferralsols on the hill slopes. Shallow soils with protrusions of ironstones are common in some parts on both the grazing and crop lands. Young black soils are found towards the steep and rocky parts of the inselbergs. Though recently invaded for crop growing, the inselbergs are dominantly used for grazing. There is evidence of intensive grazing from the bare degraded patches and rill erosion on the slopes of these inselbergs.

### 3.5.4 Erosion Catchments And Experimental Sites

The two experimental sub-catchments where permanent erosion plots were established are Bizibitukula and Lubega (see Figure 3.10).

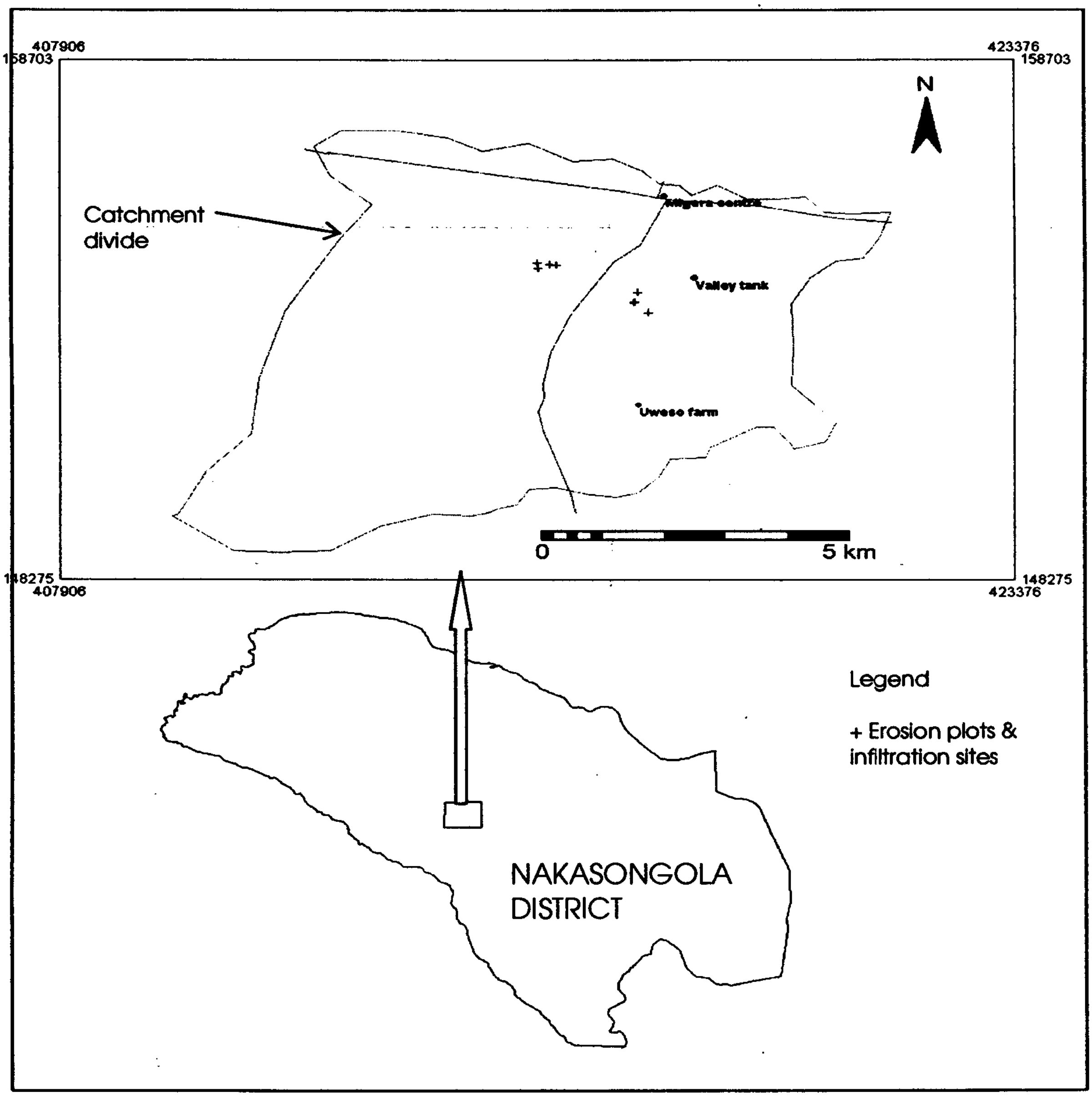



**Figure 3.10** Location of the experimental sites in the selected sub-catchment of the Nakasongola district (Based on GIS analysis of imagery from National biomass and GPS data collected from the field in the year 2001/2)

*3.5.4.1 Bizibitukula sub catchment*

**Location and area**- This catchment covers an area of about 5 $km^2$. It is located roughly 32° 15'15" East to 32° 15'18" East and 1° 22' North to 1° 24' North.

**Geology, soils and topography**- The catchment is underlain by gneiss and granites. There are a number of protrusions of these rocks observable in the catchment. On the sloping areas, the active geomorphic processes have exposed the laterites, which lead to high runoff generation.

The soils are mainly red ferralitic (ferralsols) sandy clay loams and clay loams. They are shallow in some places but relatively deep in others (1 - 2 m deep). In the valleys are mainly sandy loam underlain by clays and sandy soils.

Generally the catchment slopes toward the SW but with the hillslopes facing SE, S and NW. The hillslopes are long; some stretch up to about 1.5 km but the gradient generally ranges from 5% to 15%. The slope shapes are generally convex (from mid-slope to upper) and concave (from mid-slope to valley bottom). The altitude ranges from 1040 m to 1080 m a.s.l.

**Population**- there are very few scattered homesteads as would be expected in such an area largely devoted to livestock keeping. However, the animals constitute the largest population numbering over 2000.

**Land use and cover**- the main land use activity is grazing, which occupies 99%. There are few crops grown around the homesteads. Cattle form the major livestock though a few homesteads rear goats and sheep. Most if not all the grazing lands are fenced and there are clear boundary demarcation lines (tracks). The fences are poorly maintained and animals easily encroach on the neighbouring ranches. The catchment has been degraded and a number of bare patches are observed especially on the hill-slopes and –ridge tops. A few scattered trees, shrubs and thicket remain on the hillslopes but grades into a dense thicket and woodland on the lower slopes. A mixture of grasses and woodland or open grassland occupies most of the valleys.

*3.5.4.2 Lubega sub-catchment*

**Location and area**- This catchment covers an area of approximately 8 $km^2$. It is located about 32 ° 13' East to 32° 15'15" East and 1° 22' North to 1° 24' North.

**Geology, soils and topography**- rocks of similar gneiss and granite type underlie the catchment. There are also protrusions of these rocks, and mainly the lateritic stones/boulders, exposed in the catchment due to active geomorphic processes of water erosion.

The soils are mainly red ferralitic sandy loams and sandy clay loams. They are relatively deep (1 - 2 m) in some places and shallow in others; some places have truncated B horizon. The valleys are occupied mainly by sandy loam underlain by clays and sandy soils.

Generally the catchment slopes toward the SW but with the hillslopes facing SE, S and NW. The hillslopes are also long and may stretch up to about 2 km but the gradients are low generally ranging from 5% to 10%. The slopes are generally convex in shape. The altitude ranges from 1050 m to 1090 m a.s.l.

**Population**- the area is very sparsely populated with only two homesteads whose livelihood is largely dependent on livestock rearing.

**Land use and cover**- the main land use activity is grazing, which occupies 100% of the land. Cattle constitutes the major livestock population; there are about 500 head of cattle and less than 20 goats. The land is fenced but poorly maintained. However boundary demarcation lines (tracks) are clear.

About half of the sub-catchment has been seriously degraded and a number of bare patches are observed especially on the hill-slopes and hill-tops stretching hundreds of metres. A few scattered trees, shrubs and thicket remain on the more degraded slopes. A dense thicket and woodland especially on the lower hill slopes cover the areas that are not seriously affected by degradation. A mixture of grasses and woodland occupies most of the valleys.

#### *3.5.4.3 Machum sub-catchment*

**Location:** This catchment covers an area of approximately 6 Km². It is located about 32° 13' East to 32° 15'15" East and 1° 22' North to 1° 24' North.

**Geology, soils and topography**- rocks of gneiss and granite type underlie the catchment. The granites dominate the higher slopes on the inselbergs on the southern part. There are also protrusions of mainly the lateritic concretions exposed on the upper and mid/lower sections of the catchment due to probably due to active geomorphic processes of water erosion.

the soils are mainly red ferralitic sandy clay loams on the hill slopes and sandy loams in the valleys. The soils vary greatly in depth (1 - 2 m) in some places but shallow in others; with truncated B horizon.

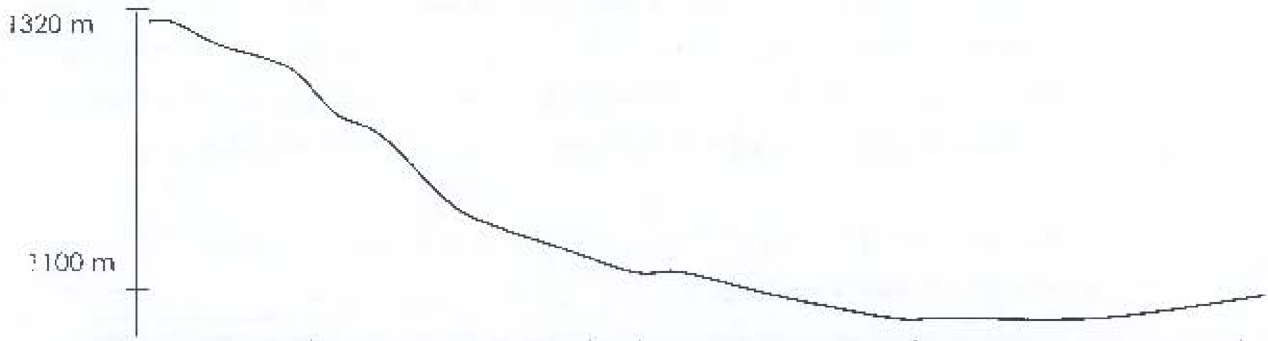
Generally the catchment slopes toward the northeast but with the hillslopes facing east and west, S and NW. The hillslopes stretch up to about 2 - 3 km in some places but the gradients are low generally ranging from 5% to 10%. Steeper slopes of >15% are found on the inselbergs. The slopes are generally convex in shape. The altitude ranges from 1050 m to 1320 m a.s.l.

**Population**- the area is moderately settled and the main livelihood is largely dependent both crop growing and livestock keeping.

**Land use and cover**- the main land use activity is crop growing, occupying about 60% of the land (see plate 3.1). The rest of the land and the fallow fields are used for livestock grazing. A few degraded bare patches were observed on intensively grazed lands. The tree cover is 60% on the grazing land but approximately 10 - 20% on the croplands.

**Plate 3.1** A typical land use/cover type in Machum sub-catchment; note the scanty vegetation cover & exposed rock on Sikye inselberg and scattered farm plots on lower pediment (Photo by author, 2002)

Figure 3.11 shows details of vegetation, land use/cover and topographic features along transect 3 in Machum sub-catchment. The steep areas are associated with inselbergs. They accelerate runoff generation hence soil loss particularly when degraded of vegetation cover through human activities such as burning and grazing.




| | | | | |
|---|---|---|---|---|
| Slope & form | 3 - 5° convex & concave | 8 - 15° convex | 4 – 6° concave | <1°, relatively flat, valley |
| Length (m) | 70 | 150 | 200 | >100 |
| Vegetation & land use/cover | Sparse vegetation, 40% bare exposed rock, 20% trees & thicket, 20-30 grass cover, grazing | Sparse tree vegetation (e.g. combretum, albizia,) ~20%, basal cover scanty (15 - 20%), 20 -30% bare land, cultivated (30% of land area), charcoal burning and settlements | Cultivated (e.g. cassava) and fallow plots (40 – 50%), Scattered trees 10 - 20% (e.g. mango, acacia and ficus) and thicket, 15 - 20% bare land | Thick cover, 70% basal grass cover, 20% woodland & bush, Seasonal cultivation (sweet potatoes) |
| Erosion features | Sheet wash, few rills & exposed boulders | Rills common, exposed boulders/rock, cattle tracks running downslope. | Major rills along former cattle tracks, sheet wash on cropped land | Deposition, limited sheet wash, water logging |

**Figure 3.11** Details of topography, landuse/cover and erosion features along Transect 3 from Sikye hill to Wabiguyo depression (Based on field data by author)

### 3.5.5 Experimental Sites

The location of the erosion plots in the two sub-catchments described above is shown in Figure 3.9. Appendix 17 provides a summary of the description of plots at the time of installation in April 2001. The plots are intended to simulate the major land use/cover conditions existing in much of the rangeland i.e. bare and compacted soil surfaces on virtually all the slope positions, the effects of grass and wood/grassland. Earlier surveys in the area by the researcher in 1997 had shown that bare patches were experiencing intensive erosion compared to well-vegetated grass and woodland areas, hence the need for this design to attempt and quantify the rates of soil and runoff losses.

The details of the soil profile characterisation at each experimental site are provided in Appendix 3. Suffice to report here is that the dominant soil type is the red ferralsol of sandy clay or clay loam texture, varying greatly in depth on the hillslopes and ridges/hilltops. Shallow gravely sandy clays with more than 50% ironstones cover the lower midslopes.

## 3.6 SYNTHESIS

The diverse ecological and socio-economic conditions prevailing in this dryland have been reviewed in this Chapter. These factors have an important bearing on the processes and consequences of soil degradation. Important to note is that these factors do not operate in isolation but rather in a complex and intricate manner, leading to different rates and magnitude of degradation observed in this environment, as discussed further in subsequent Chapters 5 - 8.

In view of the physical and human factors presented including the susceptibility of the area to problems of soil degradation by soil erosion and nutrient decline, the dryland area of central Uganda qualifies for consideration in monitoring of degradation processes to provide information for planning and rural development.

Having provided the reader with the background information thus setting the context of the study, Chapter 4 details the rationale for selection of the study area and the methods.

# CHAPTER 4

# RESEARCH STRATEGY AND METHODS

## 4.1 INTRODUCTION

This chapter provides a description of the research strategy and approach followed by an explanation or rationale and procedures used in the study area. It details the methods and materials used in attempting to find answers to the principal objectives as outlined in Chapter 1. The analytical tools applied in data processing are then presented.

Soil degradation is a multifaceted socio-economic and environmental problem that requires a holistic approach if it is to be clearly understood and managed. A methodological triangulation approach involving documentary review, personal field observations, field measurements, aerial photo interpretation and image analysis, soil sampling and laboratory analysis, questionnaires and interviews was used, and the problem addressed at different spatial scales. The various methods used in this study complement each other in data acquisition to explain a complex phenomenon. Analysis of multi-temporal remotely sensed data is potentially important for monitoring vegetation and land dynamics, geomorphological processes and the links between them (Millington & Pye, 1994). The detailed field investigations were preceded by reconnaissance survey.

Initial visits were made to the research area so as to identify the sites for detailed work, and the potential respondents and institutions. During these visits research/field assistants were identified, based on criteria, involving consideration of the level of education, willingness to work under taxing field conditions, honesty and ability to work as a team. The field/research assistants helped to identify key informants, mobilise focus groups and were trained to assist in administering the questionnaires and interviews. To ensure the subsequent success of the operation of the questionnaire, a pilot pre-test was carried out on a small population outside the selected study area in Ngoma county, Luwero district, and adjustments made in the final questionnaire.

The general approach aimed at obtaining the data from the scientific view ("outsider") and interpreting it in view of the understanding by local people ("insider" view). The multimethodological approach covering both the natural and social sciences is a reflection of the underlying complexity of the soil degradation problem and the need to underpin the study with appropriate theory so as to yield meaningful results.

## 4.2 RESEARCH STRATEGY

A comprehensive literature review informed the design of the research objectives and choice of methods used. A workshop on desertification in Mukono by MAAIF and a subsequent field visit with Makerere University Environmental Management students also informed the choice and selection of the case study area. However, the two phases of fieldwork in year 2000 and 2001 to 2002 formed the fundamental basis for the overall study. The research progressed in a flexible and exploratory manner. The preliminary field visits and data analysis, and subsequent literature review shaped the subsequent research ideas. Table 4.1 provides a summary of the research strategy.

**Table 4.1** Summary of research strategy

| **Project stage** | **Time frame** | **Purpose and activities** |
|---|---|---|
| Preliminary | 2000 | Review of literature, Selection of a case study and experimental design combined with social survey, Field preparations, selection of field assistants, refinement of objectives, |
| Fieldwork, Phase 1 | 2001 | Setup field experiments- runoff plots, runoff sample analysis, rainfall simulation, soil sampling, Household survey, questionnaire data analysis, GIS interpretation |
| Fieldwork Phase 2 | 2002-2003 | Complete with field data collection for erosion |
| Writeup | 2004 | Continued refinement, analysis and write up |

In order to fulfil the objectives, as outlined in Chapter 1, data were collected through field observations and measurements, laboratory analyses (soil chemical and physical properties) and study of available maps and other secondary data sources (e.g. soils, topography, climate and land use). Therefore, the research strategy consisted of selection of a case study area and multi-spatial scale approach (experimental design) where the data on runoff and soil loss were collected at micro-and field runoff plots and erosion features at watershed levels.

The micro-level studies were intended to capture with greater accuracy those erosion processes (e.g. runoff generation, ponding time and splash erosion) not easily discernible or measured at plot and watershed levels. The small plots also allow the sediment sources and output to be determined. Thus micro-plots provide the basic concepts and knowledge necessary for efficient development research. Numerous researchers (e.g. Bagoora, 1997, Mwanjalolo, 2003; Rose, 1958; Boardman, *et al.*, 2002) have conducted related investigations on micro-plots ranging in size from 0.5 $m^2$ to 1 $m^2$. However, the micro-plots can lead to over- or under-estimation of erosion measurements (Stocking, 2000) depending on the conditions at the experimental site. The sites in this research were therefore carefully evaluated before final selection.

The available data on soil degradation factors (i.e. climate, topography, soils, landcover and management) were integrated in a GIS environment to obtain the spatial variation or susceptibility of the area in terms of soil erosion. The spatial information is important in designing strategies for soil conservation and rehabilitating degraded areas.

Interviews and questionnaires were administered so as to capture the opinions of the local community as regards soil degradation issues, in and outside the areas where the biophysical measurements (soils, runoff plots) were made in the Nakasongola district.

## 4.3 STUDY AREA AND SITES

As noted earlier, much of Uganda and more particularly the drylands, is reported to suffer from varying intensities of soil degradation (NEMA, 2000), reflecting differences in environmental and socio-economic conditions. In view of the constraints imposed by time and financial resources, this study focused on a specific area and particular variables. The first decision was to focus on the dryland areas; these areas are clearly fragile (see Chapter 3) but have witnessed limited research on soil degradation in Uganda. The dryland area of central Uganda, which covers a greater part of Nakasongola district and lying barely 120 km north of the more humid Victoria basin, was selected for investigation. Livestock remains the dominant economic activity here despite the increasing trend elsewhere towards crop farming. The area has also witnessed population immigrations, resource use conflicts, climatic irregularities and displays obvious manifestations of land degradation. Soil degradation is reported to be rampant and yet, as indicated earlier in Chapters 1 and 2, there are few systematic studies of the problem. Moreover, in terms of development, much of the area is isolated and lags behind others in the country. Therefore, studies of this nature constitute an important approach to understanding the constraints to sustainable development.

A multistage sampling design was used in selecting the areas for preliminary assessment and those for more detailed investigations, as described below. In order to have a detailed assessment of soil degradation in this dryland area, it was necessary to ensure the study sites selected were representative in terms of a range of factors, including population density (human and livestock), soil types, land use, topography, culture and climatic conditions. Thus, the dryland area in central Uganda (Nakasongola) was divided along the watersheds and sub-watersheds. Then, two representative sub-catchments namely Bizibitukula and Machum were selected for detailed analyses; their selection was based upon accessibility and the cooperation of the local communities. The Bizibitula sub-catchment is largely devoted to grazing and is obviously highly degraded area, whereas Machum is characterised by mixed farming (crop growing and animal rearing). Three representative transects (Figure 7.1) were established for detailed observation of erosion features, landuse/cover and slope. GIS analysis (Bernhardsen, 1999) and aerial photo/image interpretation aided the selection of the areas for detailed studies, as described below.

## 4.4 RESEARCH METHODS

The six research objectives and the methods used to address these are summarized in Table 4.2. Details of the methods applied per objective are discussed thereafter.

**Table 4.2.** Summary of research methods per respective objective

| | **Objective** | **Methods** |
|---|---|---|
| Objective 1 | Identify forms of soil degradation and assess their distribution | Field survey, field measurements and mapping, |
| Objective 2 | Assess magnitude of soil loss under dominant land use | Field runoff plots, rainfall simulation |
| Objective 3 | Examine the environmental and socio-economic factors influencing soil degradation processes | Field survey, field infiltration, soil sampling, image analysis, GIS manipulations |
| Objective 4 | Assess effects of soil erosion on biodiversity, nutrient status, soil depth | Field observations, soil sampling, secondary data |
| Objective 5 | Assess perceptions of local people about soil degradation | Household survey, informal discussions, participant observations and assessment of degradation, semi-structured interviews, soil sampling |
| Objective 6 | Evaluate coping mechanisms adopted by the local people | Semi structured interviews of government and NGO personnel, Household survey, participatory observations, analysis of relevant documents/reports of district |

### 4.4.1 Identification Of Nature And Extent Of Soil Degradation

#### *4.4.1.1 Field survey/assessment of soil degradation status*

The complex interplay of soil degradation processes and their spatial variability needs to be assessed according to local conditions and forms of land use (UNEP, 1997). Soil degradation processes and features and soil conservation practices were identified through personal observations in the field along randomly selected transects in the study catchments. According to Stocking and Clark (1999), techniques such as measuring the armour layer of small stones, soil pedestal and sedimentation in drains are useful indications of erosion rates. The data were related to information on slope and land use types and used for spatial analysis in an appropriate GIS environment.

Indicators (see Table 4.3) were developed and applied in this study to identify and map soil degradation processes. Interpretation of image data, in combination with intensive field investigations, formed the basis for determining the status of the degradation processes.

**Table 4.3** Biophysical indicators used in this study

Physical indicators

- Sheet wash
- Soil deposition & accumulation of litter/organic matter on slopes
- Exposed subsoil
- Exposed stones (rock out crops, increased no. of stone concretions & boulders)
- Compaction & crusting
- Bare ground (after vegetation denudation)
- Rill density
- Gully density
- Deterioration of soil structure

Biological indicators

- Exposed tree roots
- Decline in diversity/abundance of organisms
- New plant spp encroachment (e.g. thorny acacia)

Soil degradation was categorised with respect to its degree or intensity and extent as defined in the GLASOD methodology (UNEP, 1997). The code system for the soil degradation processes and categories is given in Tables 4.4 and 4.5. The code system for identifying the degree and intensity of soil degradation in the field is depicted in Tables 4.6 & 4.7a &b.

**Table 4.4** Codes for soil degradation processes

| Code | | Process |
|---|---|---|
| E | | **Erosion by water** |
| | *Es* | *sheet erosion* |
| | *Er* | *rill erosion* |
| | *Eg* | *gully erosion* |
| W | | Wind erosion |
| C | | Chemical degradation |
| | Co | *loss of organic matter* |
| | **Cn** | **decline in nutrients** |
| P | | Physical degradation |
| | *Pc* | *Soil compaction* |

**Table 4.5** Code system for magnitude of soil degradation

| | | |
|---|---|---|
| ***(a) Degree*** | | |
| Code | | |
| 0 | Absence of significant soil degradation (none) | |
| 1 | Slight | |
| 2 | Moderate | |
| 3 | Severe | |
| 4 | Very severe | |
| ***(b) Extent*** | | |
| 1 | Infrequent | (0 - 5% of the unit is affected) |
| 2 | Common | (6 - 10% " ) |
| 3 | Frequent | (11 - 25% " ) |
| 4 | Very frequent | (26 - 50% " ) |
| 5 | Dominant | (>50% " ) |

**Table 4.6** Code for degree of soil degradation processes

| **Code** | **Definition** | **Criteria/indicators** |
|---|---|---|
| 0 | None | No sign of degradation stable land >70% plant cover (ground and canopy) |
| 1 | Slight/light | Part of soil removed, shallow rills, perennial vegetation cover 70% biology intact, restoration possible |
| 2 | Moderate | Soil lost part of topsoil, rills 20 m apart. Greatly reduced productivity, major improvement for restoration, gully development 20 - 50m spacing, perennial vegetation cover reduced to 30 - 70% |
| 3 | Strong | all topsoil and part of subsoil removed, moderate deep gullies <20m apart. Perennial vegetation cover <30%, major engineering works needed for restoration |
| 4 | Extreme | Impossible to restore land, biologically fully destroyed beyond restoration |

The area in each of the selected catchments was divided into landform mapping units and three slope transects demarcated (Dent and Young, 1972; 105-6). The landform sub-unit is in essence a geomorphological unit (e.g. hill slope, hill-top, and drainage lines). In each of these transects, three quadrants of 20 X 20 m were established on the upper, mid and lower slope positions for determining - soil degradation parameters noted above. The slope traverses included observations of slope angles, vegetation cover, soils, land use/cover, forms and degree/extent of degradation. Quadrants were randomly located on the slope positions and their positions taken with GPS.

The extent and degree were combined in a cross-matrix tabulation to obtain the severity of soil degradation in the area under study as shown in Table 4.7a. A summary of the parameters and layout for status of soil degradation in the study area is presented in Table 4.7b below. The results are presented in Chapter 5.

**Table 4.7a** The severity of soil degradation by cross-matrix tabulation

| | **Extent (%)** | | | | |
|---|---|---|---|---|---|
| **Degree** | **0 - 5** | **6 - 10** | **11- 25** | **26 - 50** | **>50** |
| Light<br>Moderate<br>Strong<br>Extreme | | | | | |

**Table 4.7b** Severity of soil degradation in the study area

| Unit/area | Type/process | Degree | Extent | Severity |
|---|---|---|---|---|
| | | | | |

*4.4.1.2 Gully erosion*

To obtain the spatial pattern, distribution and impacts of gullies, field survey and mapping activities were undertaken and the position of all gullies recorded using a GPS. Determining the distribution pattern of gullies is not only important in analysing the problem of degradation but also in developing strategies for soil and land management.

The main parameters related to gullies, notably slope form, land use intensity and soil type were recorded. Although, sequential aerial photos and images are reported to be useful in mapping gully erosion (Laflen and Roose, 1997), they were not helpful in mapping gully erosion in this area except for general land cover mapping; this is because the aerial photos available dating to the 1960s are indistinct and it seems probable that gully erosion was not yet prominent in that area by that time.

Lal and Roose (1997) argue that channel erosion (gullies and rills) is best measured volumetrically if rates are such that sufficient precision can be gained. Three-dimensional field measurements of gully width, depth and length were obtained in order to estimate the affected area and the contribution of gullies to sediment production. Bulk density of eroded material was assumed to be 1.5.

The local community, including pastoralists and cultivators in the area, was interviewed to establish the age of the identified gullies and also to determine their perception as regards soil degradation by gully erosion and how to overcome it. An estimate of the annual rate of gully ($Ar_g$) advancement was computed, based on the year when the gully started to develop (gully age) and the current measured length of the respective gullies. A further attempt was made to estimate gully expansion during the two years (2001-2002) using erosion pins (2.5 mm diameter and 250 mm length) driven into the soil at the head of two selected prominent gullies. The pins were set up in April 2001 to monitor the rate of head ward erosion and measurements taken after every month during the wet season (2001 to 2002). The small diameter (2.5mm) of the pins was assumed to cause negligible soil disturbance that would have induced erosion as cautioned by Hudson (1993).

## 4.5 ASSESSING THE MAGNITUDE OF SOIL LOSS

### 4.5.1 Erosion Measurements

In order to assess the variation of water erosion, which is one of the main soil degradation processes, sediment traps were applied. The traps were used to measure sediment and runoff losses under natural rainfall and simulated/artificial rainfall. Wash traps have been used widely by geomorphologists and provide a simple rapid technique for measuring surface wash (Morgan, 1995).

The erosion pins were installed to measure changes in soil depth over time. Also monitored were data on rainfall, infiltration capacity and land cover, which are important parameters affecting soil erosion. The infiltration capacity of the soil was measured by use of the 'double ring method' (Morgan, 1995). The details of the experimental procedures and layout are as described below. The erosion measurement methods are described each for natural and artificial rainfall. This is followed by description of the infiltration measurement methods.

*4.5.1.1 Erosion measurements under natural rainfall*

Eight plots were established in an *en echelon* manner on the upper-, mid- and lower- slopes in Apri 2001, in two representative sub-catchments (Chapter 5) of Nalukonge village, Migera parish in Nabiswera sub-county. These plots were laid on different slopes, under different land cover/use types. Eight simple, locally constructed Gerlach troughs (each 50 cm x 20 cm, and connected to two collection tanks each 100 litre capacity) were then installed at the lower end of each plot for collecting runoff and sediment (Plate 4.1 and Appendix 2). The erosion collection system design was based upon Gerlach troughs as described by Morgan (1995). The unbound plots were modified, following consultation with R.P.C Morgan in April 2001 (Pers. Comm., 2001); to include a barrier located 15 m upslope. This made it possible to determine and express the runoff and sediment in tonnes per unit area. Estimates of soil loss using these soil traps and the more conventional methodologies have been found to produce comparable results (Feldman *et al.* cited by Lewis *et al.*, 1988).

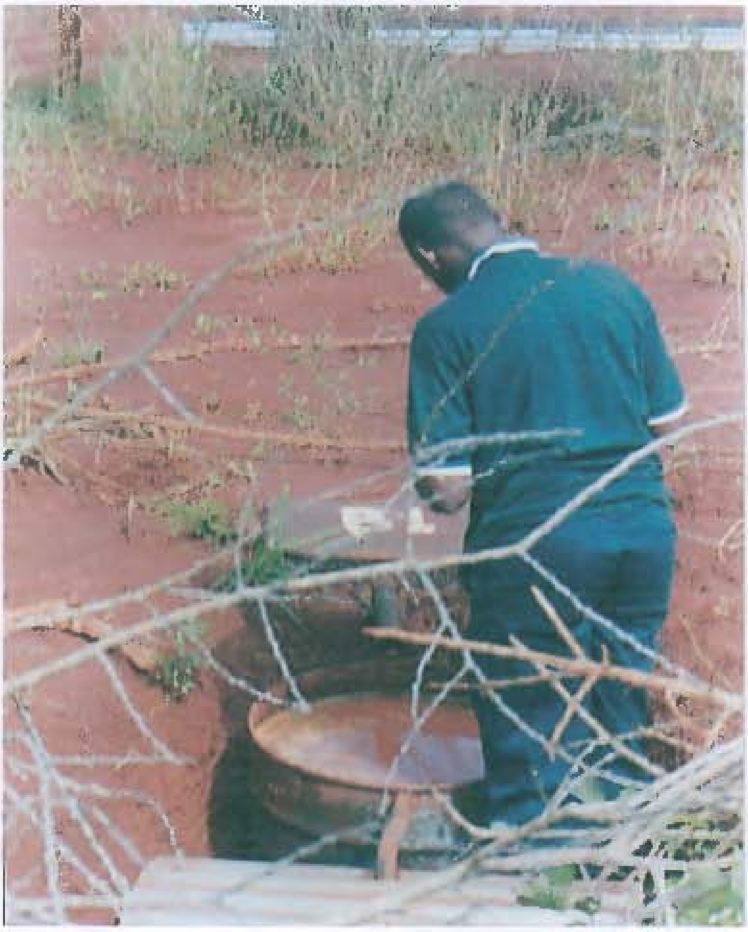


**Plate 4.1** Lay out of the erosion plot; a sheet barrier bound the upper section. The field assistant is sampling and recording runoff (Photo by author, 2001).

Immediately after each storm event, total runoff and soil volumes were recorded. Thereafter, a one-litre sample was collected from each of the plot collection tanks after thorough mixing of the runoff. The equipment was then cleaned for the next event. The sediment and runoff samples were transported to the laboratory for filtering and weighing. The total soil loss was computed, based on the laboratory sample weight data and the amount of storm runoff measured. This provided required data on the magnitude and frequency of surface wash and denudation.

**Rainfall measurement**: Two simple manual rain gauges were installed at different sites in the close vicinity of the experimental sites in the two study catchment areas to estimate rainfall amount. Readings were taken immediately following a storm event that contributed to runoff. That is only effective rain storms that generated runoff and soil loss were measured. Although the semi-arid area experiences rainfall scarcity, some significant rainstorms occurred during the wet season that needed to be sampled and related to soil erosion. Limitations of financial resources did not allow the purchase of an automatic recording rain gauge for placement near each plot.

#### *4.5.1.2 Rainfall simulation experiments*

- **Introduction**

Simulation experiments were conducted to supplement studies characterising the current soil degradation processes, particularly runoff and sediment loss, under different cover, gradient and soils, using rainfall conditions that closely match natural conditions. The details of the merits and demerits of this technique are well documented by Hudson (1993) and Morgan (1995). The rainfall simulation is associated with limitations including the inability to simulate actual natural rainfall conditions and short experiment times that do not adequately simulate the high runoff rates causing rill erosion. However, in general, the rainfall simulation technique offers rapid generation of results unlike under natural rainfall conditions where the appropriate rainfall event has to be awaited. The technique also increases the efficiency of the research through control of the important variable of rainfall. The simulation studies also permitted the determination of soil infiltration and erodibility, which constitute important factors influencing erosion. The equipment used was simple and portable and has been applied by other researchers in Uganda (Bagoora, 1998 and Tenywa *et al.*, 2003). Related simulation studies have been undertaken in southern Africa by Boardman *et al.* (2001) and found to be instrumental in aiding the interpretations of land degradation processes in this type of environment.

- **Experimental design and layout**

The simulation was undertaken on plots measuring 0.5 m by 2 m; this plot dimension was covered by the sprinkling unit and assumed sufficient to allow for the generation of the main processes of interill and rill erosion being monitored in the area. A metal sheet driven 10 cm into the ground, leaving 15 cm protruding above the ground enclosed the plot; this was high enough to stop any interference from outside the plot. However, the inner part of the plot between the replicates was open. The collection system was similar to that used for measurement under natural rainfall conditions for the sake of maintaining uniformity. For purposes of maintaining environmental conditions similar to those for natural rainfall plots, the simulation plots were set up in close proximity; upper, mid and lower slope. Surface microtopography representing typical conditions in the study area was simulated, that is, bare soil surface with 0 – 20% basal cover (severely degraded areas), surface with grass/basal cover of >20<60% (moderately degraded) and surface with grass/basal cover of >60% (non-degraded areas).

- **Rainfall simulator**

The choice of this simulator (Plate 4.2) was largely governed by its availability, portability and inexpensiveness. Its applicability had already been demonstrated to the author for erosion studies on Mt. Elgon slopes (Tenywa, *et al.* 2003) and was therefore very familiar. The simulator has a Sprayco core jet nozzle and the details of its design are described by Bagoora (1997). It consists of a stand-alone unit, which irrigates an annular area from a downward spraying nozzle. The unit consists of a 4.57m high, 19mm galvanised vertical standpipe, a 90 cm extension pipe and a nozzle attached to the end of the extension pipe. Water was pumped to the sprinkler unit from a 200 litre tank using a portable 2.2 h.p capacity water pump (Honda model WB15C), which has the capacity to deliver up to 200 litres per minute. Simulation experiments were conducted at a constant pressure of approximately 138 KPa (20psi) for 45 minutes. At a fall height of 4.75 m and with sufficient pressure applied during water pumping, the unit has the capacity to deliver high intensity rainfall that is spatially uniform and with a kinetic energy approximating that of natural rainfall.

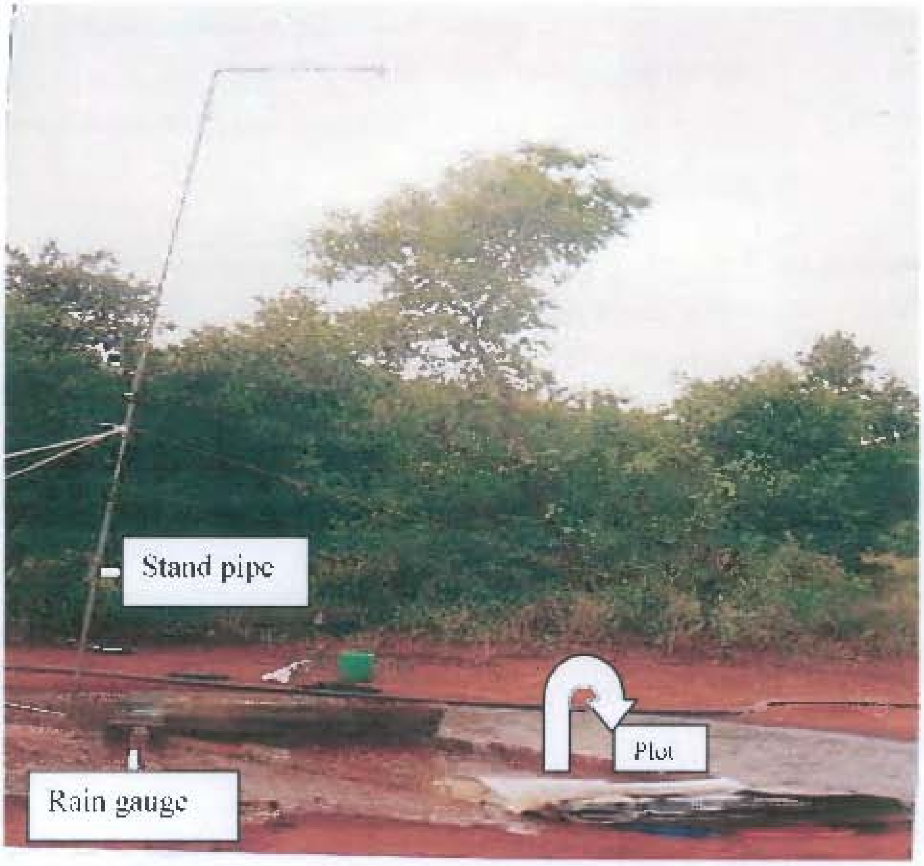



**Plate 4.2** Simulation experiment in the field in the Nakasongola district (Photo by author, 2002)

- **Calibration**

Calibration experiments carried out (Bagoora, 1997) indicate that the erosion sprinkler plots of 3 m by 4 m can be sufficiently covered by single nozzle sprinkling. Before running the experiments, an analysis of available climatic data (long term rainfall data) for Masindi and several stations in Nakasongola was conducted. Based on the analysed data calibration of the simulator was done. Potential limitations of the simulation were then assessed.

The Rainfall co-efficient on the erosion plot was determined prior to field experimental runs. This is very necessary in harmonising the erosion plot dimensions with respect to raindrop coverage from the simulator nozzle. Coefficient of uniformity range from 0.78 to 0.95, but increases with decreasing application pressure from 270 Kpa to 103 Kpa (Bagoora, 1997).

- **Experimental runs and measurement of parameters**

Each simulation test involved a dry run followed by a wet run after 30 minutes' interval. The dry run simulated soil surface conditions at field capacity or after the dry season. The main parameters monitored include runoff discharge and sediment loss. These were measured by trapping and collecting all the runoff from the enclosed plot by using a Gerlach trough, which is similar to the one under natural rainfall. The details of the simulation plot layout are provided in Appendix 1.

Samples were collected after 5 minutes interval so as to compute the rate of runoff discharge and sediment loss. Total sediment loss (per storm) from the plots was determined by sampling 1 litre of runoff collected after stirring to ensure uniform mixture in the tank. The samples were filtered, air dried and weighed and total sediment mass calculated by taking into consideration the total volume of runoff that was collected.

Observations were also made elapsed time to saturation and infiltration capacity, ponding and runoff initiation on the plots. These are important parameters in characterising the magnitude of degradation processes. To estimate the antecedent soil moisture, soil samples (five) were taken in the vicinity of each plot prior to the experimental run and the moisture determined using standard laboratory procedures.

## 4.6 METHODS TO DETERMINE ENVIRONMENTAL AND SOCIO-ECONOMIC CONDITIONS

### 4.6.1 Remote Sensing (Rs) Image Interpretation And GIS Manipulations

A reconnaissance assessment of natural resources (using the land systems approach) was conducted by visual analysis of aerial photographs and SPOT images aided by field surveys (ground truthing). Mapping and analysis of landform units (as defined by Dent and Young, 1981), land use changes and soil degradation were made. The spatial variation in the tone representing different landforms and degradation units formed the basis for selecting representative sample areas and transects in the catchments for further investigations. The RS image interpretations were supported by GIS operations.

### 4.6.2 GIS Manipulations And Erosion Prediction

As indicated in Chapter 2, the Revised Universal Soil Loss Equation (RUSLE) (Renard, et al, 1997) was chosen to model the effects of climate, soil, topography, land use/cover and management (Wischmeier and Smith, 1978, Morgan, 1995) on soil loss. The procedures are described below.

In the modeling procedure, the values for the different RUSLE factors are assigned to their respective mapping units (Blaszczynski, 2001). Therefore, the initial maps/layers were developed from the existing analog and digital maps for each factor and input in GIS (ILWIS 3.1 and ARC VIEW 3.2). The digital land use/cover data were obtained from the National Biomass Studies at Nakawa. Verification of the data was undertaken prior to any further operations. The land use/cover map was interpreted using the RS images (XS SPOT and LANDSAT), field surveys and topographic map sheets at a scale of 1: 50,000, series Y732 (Uganda Government, 1971). The C-factor map was developed from the land use/cover map for each unit, using values based on the USLE guide tables (Morgan, 1995; Wischmeier and Smith, 1978).

The district soil map was obtained from the Kawanda Agricultural Research Institute (KARI) and edited. For each soil-mapping unit, the soil property values of organic matter, clay, silt and sand were recorded from the memoirs (Rwandasnki, 1960). This was combined with the available recent field survey data to compute the mean values. Based on these values, the K factor was determined from the nomograph (Wischmeier and Smith, 1978) and an erodibility map (K- factor layer) was produced for the district. Due to inadequate financial resources, it was not possible to further improve on the K-factor computations, e.g. through more soil sample sites in each mapping unit, and applying a correction factor for the soils with gravel and boulders/stones.

The average rainfall amount for three synoptic stations, namely Kakooge, Nabiswera and Nakasongola town, was used to obtain the rainfall erosivity. The annual erosivity (R-factor) was computed for each station according to Moore (1979a), using the equation:

$R = 0.029 * (3.96 * P + 3122) - 26.0$

Where:

R = erosivity ($J\ mm^{-1}\ yr^{-1}$); P = annual precipitation (mm)

The erosivity point map was interpolated, using ILWIS 3.1, to generate the R factor layer covering the entire study area.

The LS-factor was estimated from the digital elevation data, using a technique (Moore and Burch, 1986 a, b) that requires computation of the flow accumulation, as expressed in the following formula:

LS = (Flow Accumulation * Cell size/22.13)^0.4 * (Sin slope/0.0896)^1.3

The flow accumulation, computed using the Ann AGNPS program integrated in GIS Arc View, was used to estimate slope length. The slope steepness was computed from the DEM. A resolution/grid cell size of 30 m was used, considering the available computer processing capacity. The cell size (30 m) is far less than the maximum slope length estimated of 200 – 300 m, in the field. There are limitations when determining the LS factor from grid based DEM. However, it was assumed that each factor was relevant for runoff-producing sections of the hillslopes, and each slope unit is covered by homogeneous vegetation and soil.

The P-factor was given a maximum and constant value of unity. The respective input factor maps/layers are shown in Appendix 10.

The RUSLE model only estimates erosion from a single plane and does not take into account the deposition. In this study, an attempt was made to incorporate the Unit Stream Power – based Erosion Deposition (USPED) model (Milasova, et. al., 1996; Mitasova and Mitas, 1999) to compute the erosion, including deposition, from surface planes (oxy). The assumption is that sediment flow can be estimated at sediment transport capacity as:

$T = RKCPA^{m} (\sin b)^{n}$

Where:

$R \sim i^{m}$, $KCP \sim Kt$ and $LS = A^{m} \sin b^{n}$, and $m = 1.6$, $n = 1.3$ for prevailing rill erosion while $m = n = 1$ for prevailing sheet erosion.

The net erosion/deposition (ED) is estimated using the formula below.

$$ED = \text{div} (T . s) = d(T^{*}\cos a)/dy + d(T^{*}\sin a)/dy$$

Where:

a (degrees) is an aspect of the terrain surface.

Based on the output factor values, determined above for each of the mapping units, the factor maps/layers were overlaid in GIS Arc View to produce a visualization of predicted soil loss (Chapter 6). Onscreen digitising of clusters/erosion hotspots was done. Computations and overlay analysis were undertaken in Arc View, to produce various maps depicting potential soil loss/degradation variation with respect to different parameters. Supported by ground truthing, the areas of high, moderate and low degradation risk were identified for further investigation. The choice of the final areas and sampling sites for further studies, however, depended additionally upon their accessibility as discussed below.

### 4.6.3 Infiltration Capacity

The infiltration capacity ($f_c$) is noted to be an important indicator of the susceptibility of the soil to erosion. A double ring infiltrometer (Plate 4.3) (Bouwer quoted by Pierzynski, et al., 1997) was used to determine the $f_c$ under varied degrees of soil degradation surfaces. The infiltrometer consists of two cylinders that were driven into the soil about 10 to 15 cm deep. The outer cylinder was filled with water up to a height of 30 cm. The effect of wetting the soil outside of the cylinder is eliminated hence it is superior to the single ring infiltrometer (Pierzynski, *et al.*, 1997). A record of the height at specific time intervals of 1 minute for 5 minutes; 5 minutes for 55 minutes and 10 minutes for 70 to 80 minutes was taken until a steady state was reached. Water in the outer and inner rings had to be balanced whenever the level went down to 15 cm. The measurements were conducted in the vicinity of the soil profile pits and natural erosion plots so that the outcomes could be related and interpreted in proper context. Two replications of the experiments were conducted simultaneously at each site. The results of infiltration capacity measurements are presented and discussed in Chapter 7.

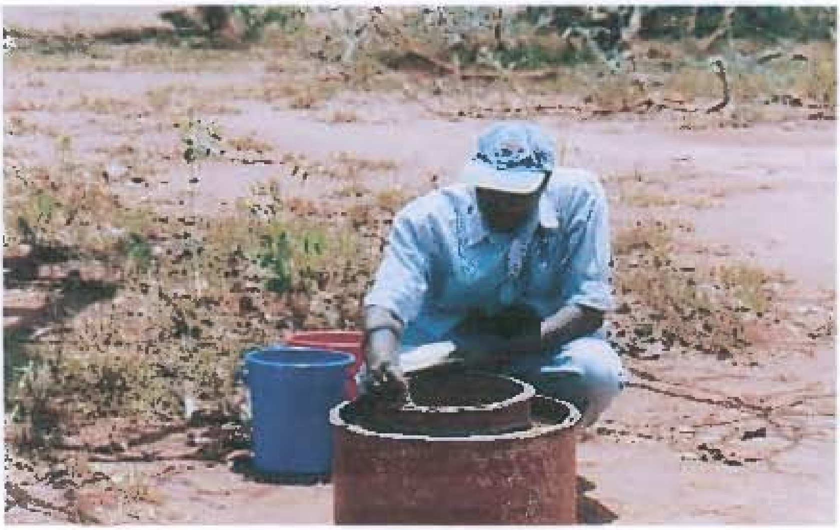


**Plate 4.3** Double ring infiltrometre; the researcher recording changes in water level with respect to time

The double ring method is, however, criticised for over estimating $f_c$ when compared to natural rainstorms, where the interactions with the soil lead to the lateral spread of the headwater. Nevertheless, the results provide important information for comparing the degraded rangeland surfaces (Zebhe, 1995).

## 4.7 METHODS TO ASSESS EFFECTS OF SOIL EROSION ON BIODIVERSITY, NUTRIENT STATUS AND SOIL DEPTH

### 4.7.1 Soil Sampling And Analysis

Sampling of soils was undertaken in order to (i) establish and compare the changes in the biophysical and chemical characteristics due to degradation processes (e.g. organic matter, nitrogen, infiltration capacity, bulk density and porosity, water retention), and (ii) analyse the implications of these changes on soil quality for agro-production.

#### 4.7.1.1 Soil sampling for analysis of physical and chemical properties

Longitudinal and spatial analogue methods (Tiffen et al., 1994) were adopted. Landform units in the study catchments were identified and mapped using aerial photo interpretation supported by ground truthing. These were used as bases for determining transect lines for soil sampling and profile descriptions. The landform units identified in the area include hilltops, hill slopes and valley bottoms.

Soil sample sites were randomly established along representative transect(s) traversing major delineated soil mapping units in the selected catchment(s). Soils were sampled from degraded and non-degraded areas on hilltops, upper-, mid- and lower- slopes and valley bottom. Samples were collected from the topsoil (0 – 20 cm) and the main soil horizons of selected soil profile for laboratory analysis. Random observations allow estimates of mean and variance of properties, but a large number of observations are necessary for the estimate of the variance to be within narrow limits desired for accurate assessment of degradation (West and Bosch, 1997).

Information on soil profile characteristics is useful in supplementing qualitative information, and drawing conclusions about the effects of erosion on crop performance and soil properties (Lal, 1994). Observations and recording of the soil profile characteristics at each site was based on FAO guidelines (FAO, 1979). These observations were supplemented by those made at existing soil exposures (e.g. road cuts and gullies). The details of the results are presented in Chapter 6 and tabulated in Appendix 3.

The soils survey data of 1960s for Buruli was used as baseline and proxy data in the comparison with the newly sampled data set. It was hoped this would reveal the changes that have occurred in the physical and chemical properties from a temporal perspective. However, while recognising some deficiencies arising in the longitudinal approach (Tiffen et al., 1994), it was necessary to consider adopting a spatial analogue method that compares changes in soil properties for the non-degraded soils with the undegraded ones. Brief remarks are made relating the current observations to the old data set in Chapter 6.

Soil sample analyses were conducted at Soil Science Department at Makerere University based on standard procedures (Okalebo et al., 1996, 2002). Parameters analysed include CEC, aggregate stability (using an indicator of mean weight diameter), particle size distribution, organic carbon, five macronutrients (total N, Available P, Ca, Mg and K). These parameters are very important in influencing plant performance hence the need to analyse their status in the soil and in the sediment. Appendix 4 presents the details of the data on soil parameters analysed and the results are given in Chapter 6.

*4.7.1.2 Soil moisture*

Soil water can be measured in terms of water content or as soil water potential. These two are related to each other and the soil water retention characteristic curve provides a graphical representation of this relationship (Eijkelkamp, 2004). The nature of the soil moisture retention characteristic depends on the physical properties of the soil (texture and structure), which are also affected by the degradative processes. The logarithmic relationship (pF-curve) is soil specific and applied in plotting the moisture retention characteristic.

Soil samples were collected within the 0-15 cm depth at different slope positions (upper, lower and middle) and in the non-degraded and degraded areas for determination of water retention, permanent wilting point and field capacity using standard procedures.

**Water retention** - To determine the moisture retention characteristic or the pF-curve of a specific soil, undisturbed core samples were collected. Four core samples (two replicates) were collected from each slope position in the cultivated and grazing land yielding a total sample size of 32. The cores were transported to the Makerere University soil science laboratory and Kawanda Agricultural Research Institute (KARI) for analysis. The sample weight was determined and the samples saturated with water. After saturation and when each sunction was ready, all the samples were weighed again. The soils were oven-dried (105°c) and weighed.
The water retention curves were determined for each of the soils in the three slope positions and degraded areas, using a sand box (Eijkelkamp, 2004). The suction pump was used for relatively low suctions (pF 1.0, 1.3 and 2.0 ie. 0.1, 0.2 and 1.0 m wc respectively).

**Permanent wilting point**- This was determined using the plant water-method (Wiklert, 1964); sunflower was planted and used as an indicator. Three soil samples from each slope position were used. The plants were confined in an environment where they received sunshine but not exposed to wind or rain. Water was added to the plants until the point at which they had developed four leaves. When the plants wilted they were placed in a moisture chamber to observe whether they had experienced permanent or temporary wilting. If wilting was determined to be permanent, the soil samples were weighed and oven dried for two days after which another weighing was done. If temporary wilting, the plants were further exposed to drought conditions. Computations of volumetric water content at permanent wilting point were done. The average volumetric water content for the wilting point is shown in the pF curves for the respective field soil conditions.

#### *4.7.1.3 Assessing changes in soil level*

The direct measurement of changes in soil level is appropriate in the case of localized erosion where rates are high and the distribution of erosion can be predicted (Hudson, 1993). The ground loss or gain on grazing lands was determined using erosion pins without washers. Hudson (1993) notes that this technique is not suitable for arable lands due to surface disturbance by cultivation and settlement. Erosion pins represent an effective and simples method for monitoring the minute changes in depth of ground surface due to erosion and deposition (Hudson, 1993; Morgan, 1995).

The iron pins (nails) measuring 4 mm diameter and 110 mm length were driven into the soil at carefully selected positions on the upper, mid and lower slopes in the Bizibitukula subcatchment predominantly used for grazing. A small diameter of 4 mm was assumed to cause minimum interference with surface flow, hence reducing scour. The pins were arranged in a rectangular grid at a spacing of 0.5 M on 4 plots. The top of the pin provided a datum from which changes in the soil surface were monitored from 2001 to 2002. Measurements in pin height were made every month for two years. Livestock disturbed some of the pins and unknown people also removed others. However, the few that remained were used to estimate the rate of change in soil depth.

#### *4.7.1.4 Soil sampling to determine the effect of degradation on soil biota*

Soil degradation has a wide range of effects on the edaphic system, and yet often more attention is paid to chemical and physical changes as opposed to the biological component. Soil macro-fauna has many vital roles in the soil and their dynamics have serious repercussions in terms of soil functions. This study attempted to analyse the changes in the abundance and diversity of soil invertebrates (arthropods) in relation to changes due to soil degradation.

Three sites (degraded, moderately degraded and non-degraded) in each selected sub-catchments (Bizibitukula, Lubega and Machum), were identified and soil samples, corresponding to dimensions 20 cm x 20 cm x 30 cm deep, collected from five points. A bottomless steel box of 20 cm x 20 cm x 30 cm deep was driven into the ground up to a depth of 30 cm. The macro-fauna were then hand sorted and counted for the three successive strata of 0 - 10 cm, 10 - 20 cm and 20 - 30 cm to determine their abudance and diversity. The individual organisms were counted based on their order (taxonomic unit) and weighed in the laboratory using an analytical balance, and results expressed as biomass per unit area. The animals collected for identification were preserved using 4% formalin. The results are presented in Chapter 6.

#### *4.7.1.5 Measurement of land cover*

Land use cover was measured for the area in the watersheds under study by detailed analyses of the available aerial photos and Spot XS images. This was aided by field checks and topographic map sheets (1:50,000) of the area. The vegetative cover type and major species composition of woody species was sampled (using the stratified random sampling technique) and identified. These data were correlated with the soil surface condition, to ascertain the spatial extent of the degradation problem.

## 4.8 METHODS USED TO DETERMINE PERCEPTIONS OF LOCAL PEOPLE

### 4.8.1 Introduction

The main techniques adopted to obtain the knowledge and perceptions of the local people and the managers as regards soil degradation were a questionnaire and interviews. The background information including that from the earlier interviews with district personnel and secondary sources, guided the design of the household survey. The survey method and design of the collection tools is largely based on the standard social survey techniques advanced by a number of authorities (e.g. Sudman and Bradburn, 1983; Bailey, 1994; Dewar *pers. Comm.,*. 2001; Oppenheim, 2000). In this text, the pastoralists and farmers, including both the crop only and mixed farmers, are also referred to as resource users.

### 4.8.2 Survey Design

This study adopted a cross-sectional analysis of the perceptions of local farmers/pastoralists and local authorities/managers towards soil degradation problem in the area. Both qualitative and quantitative approaches were applied in the analyses.

#### *4.8.2.1 Household survey*

The household was selected as a basic unit of analysis in this research. This is explained by the fact that the household constitutes a major avenue for individuals to access important livelihood assets such as income, labour and land.

Five out of seven sub-counties of the district were selected for scrutiny in regard to soil degradation. These included Kakooge, Wabinyonyi, Lwapanga, Nabiswera and Nakitoma. The first two sub-counties are more humid and dominated by mixed farming. Nabiswera and Nakitoma are drier and mainly pastoral areas, whereas Lwampanga is relatively dry and the dominating activities include fishing, cattle keeping and crop farming. In each of these sub-counties two parishes were randomly selected, and from each parish a random selection of two villages was made. One village was found to be inaccessible and hence not sampled.

The total number of interviews conducted during the household survey including the number of households for each sub-county based on the district population statistics and the LC records are shown in Table 4.8.

**Table 4.8** Survey sample sizes and settlement population

| | **Sub county** | | | |
|---|---|---|---|---|
| | Nabiswera & Nakitoma | Wabiyonyi | Kakooge | Lwampanga |
| Total population (Census 2002) | 14,447 | 6,902 | 20,615 | 19,007 |
| Total households | 1444 | 690 | 2,061 | 1900 |
| Total Interviews | 164 | 10 | 61 | 20 |
| Percentage of households represented in survey | 11 | 2 | 3 | 1 |

The selection of the households was based on the available lists of registered households in each of the selected villages. Appendix 5 provides the location and distribution of the villages sampled. The villages of Sija and Nalukonge including Migera in Nabiswera sub-county were selected for detailed soil degradation mapping and soil sampling, with the intention of gaining a better understanding of environmental conditions in relation to local people's local knowledge and perceptions. Because of the greater focus on Nabiswera sub-county, a relatively higher percentage of households (11%) were sampled. Due to financial constraints it was not possible to undertake soil sampling in all the villages where the questionnaires were administered. This creates a weakness in analysis of the respondents' views and the existing conditions on their land. The categories of respondents that were randomly sampled included the crop only farmers, the mixed farmers, and herders. On average, 17 households (hence resource users) were sampled from each of the 19 villages. However, it is important to note that due to constraints in accessing certain households in some villages, only a small sample size was used. It should be noted that larger sample sizes would have provided more precise estimates of population characteristics but these would have also necessitated more time and effort spent in interviewing and analysis (see McLafferty, 2003). The homesteads are widely distributed and the paths/tracks were often inaccessible. Sampling of the population in all the villages selected was constrained by lack of reliable lists identifying all the residents in the households. Another problem was that 45 respondents could not complete the questionnaire for various reasons, thus leaving a sample size of only 282. In other instances the respondents declined to answer certain questions. This explains why there is a variation of the total number of respondents used for the statistical analysis (Chapters 8 and 9). These missing responses are assumed to be insignificant in affecting the final results.

#### *4.8.2.2 Survey of local authorities*

Twelve people selected from the local authorities included various decision-makers involved in resource management and planning at the district and lower levels (county and sub-county) for both government and non-governmental institutions. Personal semi-structured interviews as well as self-administered questionnaires because of their significance in stimulating face-to-face interactions. However, unstructured interviews with elders were held to establish information on land use changes and land management for the last 50 years. A list of elders present in each village was obtained with the help of the local council authorities. At least one elder was subjectively selected and interviewed in each village, based on the simple criterion of accessibility, ability to recall the past and ability to communicate effectively.

#### *4.8.2.3 Household survey procedure*

Personal interviews, rather than a mail survey, were deemed appropriate to ensure adequate control over actual respondent identity, high response rate and the likely problem of "public relations" answers. "Public relations" response usually occurs when the non-targeted respondents participate in providing answers for targeted respondent(s). The interviews were conducted in one of the widely spoken local languages (Luganda, sometimes mixed with Runyankole) and English depending on the respondent's preference. For purposes of not biasing the respondent(s), consistency and to avoid problems of respondents unable to write, the researcher/trained research assistants administered the questionnaires. All the questions were read aloud and clearly to the respondent and the interviewer filled in the responses. This gave the respondent an adequate opportunity to reflect on the questions and for a smooth flow of the responses. Above all, this technique, although a variation of the self-administered questionnaire approach, retains the advantages noted (Bailey, 1994). It ensures systematic completion of the items in the questionnaire, accurate sampling, higher response rate and guards against "public relations" responses. The interviewer also has the opportunity to create good rapport, obtain successful responses and corroborate the answers. This is not to say that there are no disadvantages such as time and high costs incurred and the possibility of inconveniencing the respondent or even influencing his behaviour. Attempts were made to downplay such a likely tendency through pre-testing of the questionnaire to check on the questions likely to elicit "public relations" answers and emphasis on the fact that the research findings reflecting their views were to be published and a copy of the report given to them. An advance letter, indicating the nature of the research and expected co-operation, was compiled and delivered to the local authorities (see Appendix 9).

#### *4.8.2.4 Questionnaire/interview design*

The questionnaire design drew largely from procedures recommended in the literature (Sudman and Bradburn, 1983; and Bailey, 1994; Fowler, 1995; Wiggins, 1998; Oppenheim, 2000;); Best practice is characterised and emphasis on simplicity, appropriateness, clarity and consistency. The questionnaires were pre-tested for accuracy. The completed questionnaires in English are attached (Appendices 6, 7 and 8). There were two main sets of questionnaire targeting the farmers/pastoralists and officials involved in resource management at various local authority levels.

Part of the cover page was devoted to the letter outlining the intentions and expectations of the study in reference to the earlier communications. This part also points to the importance of the confidentiality of the respondents' answers and indicates the procedure of the questionnaire administration.

The questionnaires developed for this research include both open and closed response forms through unstructured and general questions with structured items. Each set of questionnaires was divided into sections that consisted of, initially, general background and socio-demographic characteristics of individual respondents, followed by other sections and sub-sections concerning data/information on the perceptions on awareness, causes, severity, effects and those related to management of resources, including the soils. Thus, the items included in the questionnaire on perceptions sought to find out the general understanding of soil degradation in the area and the level at which it is considered a problem by the local people.

Adjustments were made during the designing of the questionnaires and pre-testing. A few of the additional but pertinent questions that came up during the surveys were also included after conducting the interviews, where and when time allowed.

#### *4.8.2.5 Pilot study and implementation of the survey*

The initial drafts of the questionnaires were developed as a result of wide consultation of relevant literature and discussions with the supervisor and colleagues in this field. Pre-testing was conducted on a relatively small sample of students at Makerere University and thereafter, pilot studies conducted in a related dryland area of Luwero district (Ngoma county) to ensure that unforeseen problems would not occur in the questionnaire. An open format approach was used for questions during this stage.

Letters of intention to undertake research on soil degradation and seeking the participation of the local community were submitted to the local leaders who then informed their respective community members during social or other fora and through personal delivery. This is a workable and fast communication channel in the rural villages. The communities agreed unanimously, as informed by the leaders.

## 4.9 EVALUATE COPING MECHANISMS ADOPTED BY LOCAL PEOPLE

### 4.9.1 Semi-Structured Interviews

The semi-structured interviews involved use of a standardised checklist of predetermined questions, although interviews were performed in a flexible manner that allowed respondents to discuss freely any issues of importance at hand.

### 4.9.2 Questionnaire And PRA

#### *4.9.2.1 Household questionnaire survey*

The questions concerning the local knowledge and coping practices were embedded in the main household questionnaire and administered to the respondents as described above.

#### *4.9.2.2 Participatory Rural Appraisal (PRA)*

Group discussions, matrix tables for ranking problems (e.g. causes and severity of soil degradation), diagrammatic representation (e.g. rainfall changes over time) and resource maps were the PRA techniques employed in this study obtain the general background information on the problems, including soil degradation, faced by the people in the area. Note that it is very difficult to obtain background information of the area when administering individual questionnaires/interviews. The PRA was useful in supplementing and validating the findings obtained from individual respondents through the questionnaires and interviews. During the PRA, the interviews and discussions were centred on topical issues such as changes in climatic conditions, degree of soil degradation, past changes in land use, population migration effects as relates to the soil resource and impacts of soil degradation.

### 4.9.3 Secondary Sources

Analysis of secondary data from governmental and non-governmental reports and documents complemented the use of qualitative and quantitative fieldwork methods. The secondary data sources (e.g. on rainfall, livestock trends, demography and livelihood) were used to provide un-available data in other forms and or to enable corroboration of primary data. Note that the secondary data, where employed, where applicable, in relation to all the six research objectives.

## 4.10 DATA ANALYSES AND SPATIAL MODELING

### 4.10.1 Analysis Of Questionnaires

Data were captured in MS Excel and imported in SPSS/MINTAB/STATISTICA 5.5 software programs for analyses of different aspects in the survey questionnaires. Since most of the responses were categorical, non-parametric (i.e. Chi square, Pearson product moment correlation) methods of statistical analysis had to be applied. Cross-tabulation procedures were carried out in an attempt to establish association among the variables. Descriptive analysis was carried out on aspects related to the socio-economic profile of the respondents. The results of these analyses are presented in Chapters 7 and 8, while tables displaying basic data of the responses from administered questionnaires are given in Appendix 16.

### 4.10.2 Data Analyses On Soils, Land Use And Erosion

STATISTICA 6 and GENSTAT 5 release 3.2 programs were applied in most of the analyses related to erosion and soils. The multi-correlation and regression analysis were used to find out the relationship between rainfall amount, runoff and soil loss. ANOVA was used to establish the differences between the means of soil parameters with respect to slope positions and degradation levels; runoff and soil loss with respect to slope position, land use, and season. The univariate test of significance for the means was applied in establishing the effect of degradation status, the slope position and catchment on soil properties. Spatial data analyses (on georeferenced and attribute data such as gullies, land use/cover) were achieved by using analytical tools in the ILWIS and Arc View GIS software (see section 4.6.2).

## 4.11 SUMMARY

This research adopted a multi-pronged methodological approach in addressing the six objectives outlined in Chapter 1. The methods involved the use of field experiments and soil sampling supplemented by household surveys and interviews plus participatory methods and image interpretation. The theoretical perspectives and literature review informed the choice of the methods and the focus of the study on biophysical and social issues. The findings from this research constitute the rest of the chapters that follow. The next Chapter presents and discusses the nature of soil degradation in Nakasongola district.

# CHAPTER 5

# THE NATURE OF SOIL DEGRADATION IN NAKASONGOLA DISTRICT

## 5.1 INTRODUCTION

The various forms of soil degradation and their spatial distribution in the study region are presented and discussed in this chapter. Sheet erosion is the dominant form of soil degradation, although, the presence of gully erosion is an indication that degradation has reached serious dimensions in some parts of the Nakasongola district. After exploring the forms and distribution of soil erosion, the chapter presents the findings and discussion regarding the magnitude and extent of the problem. The chapter demonstrates that soil erosion is a major form of soil and land degradation and is a result of interplaying factors, involving mainly changes in land use/cover due to the influence of increasing human and livestock population or pressure, inappropriate land use practices and increasingly drier conditions probably, due to both natural and human causes. Finally, the chapter addresses the environmental and socio-economic factors underlying the prevalence and distribution of soil erosion and degradation problem in this area.

## 5.2 FORMS AND DISTRIBUTION OF SOIL DEGRADATION IN NAKASONGOLA

The forms of soil degradation were identified in the field based largely on their typology. In Nakasongola district, soil degradation manifests itself in many forms, including erosion by water such as sheet erosion, rill and gully erosion; and non-erosive forms like compaction, sealing and crusting. These forms are presented and discussed respectively in this section.

### 5.2.1 Forms And Distribution Of Erosive Degradation

#### *5.2.1.1 Sheet erosion*

Sheet wash is a dominant and active form of erosion in the area. It is particularly intensive on bare hill slopes (Plate 5.1) as shown by observed surface flow patterns of sand, truncated topsoil and soil pedestals. The bare patches are degraded spots characterized by reduced infiltration rates, hence promoting the generation of high surface runoff that leads to sheet wash. The widely observed bare patches in this area appear to have been formed as a result of intensive grazing and over trampling by livestock. However, termites, deforestation and drought have compounded this phenomenon leading to further expansion of the problem on the areas originally unaffected.

**Plate 5.1** Sheet erosion on rangelands in Bizibitukula sub catchment in Migera; note the eroded bare land, poor vegetation growth & patterns of eroded sediment

Sheet erosion was identified from the linear and dendritic sediment deposition patterns on the bare patches on grazing lands, and intensive patterns of sand depositions on the lower pediments and hill slopes as Plate 5.1 as shows. At the time of observation, areas under cultivation were mainly experiencing sheet wash as further explained later. The general distribution of soil degradation types along a slope profile is shown in Figure 5.1. Soil degradation processes and forms tend to vary along the slopes depending upon interrelated factors including vegetation cover, rainfall and topography as discussed in section 6.3.

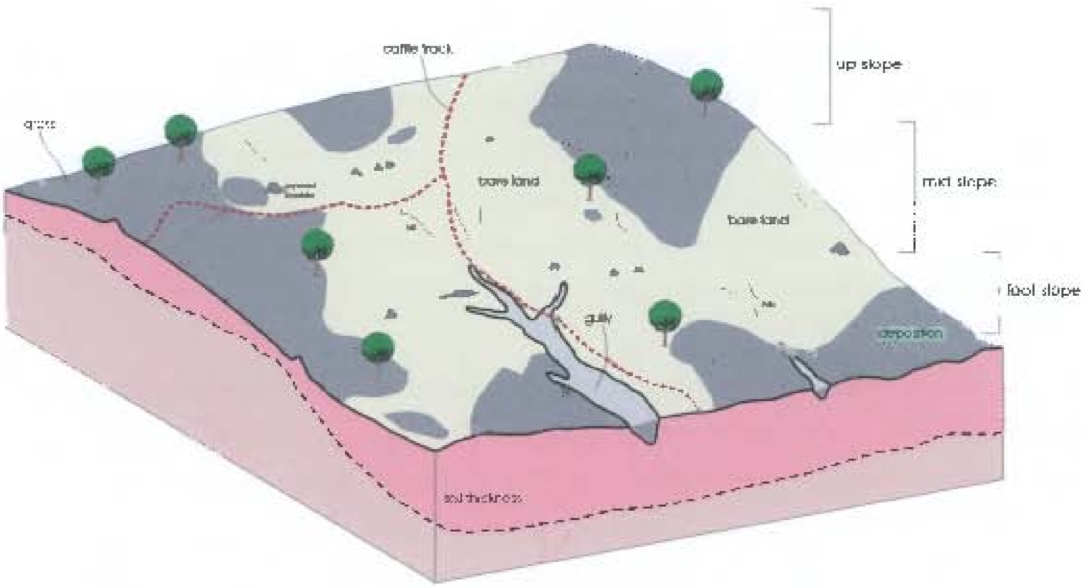



**Figure 5.1** Distribution of soil degradation forms along a typical slope profile in transect 1; the short lines running downslope depict the rill erosion.

#### 5.2.1.2 *Rill and Gully erosion*

Rill and gully erosion refers to the process of detachment and transport of soil due to flowing water (Laflen and Roose, 1997) in confined channels. Rills and gullies are the most conspicuous forms of soil erosion observed in the area, particularly on the degraded grazing lands. As will become apparent, their occurrence and extent are influenced by both social and natural factors.

**a. Rill erosion**

This consists of incised flow lines, which occur as runoff concentrated in channels on hillslopes, on both grazing and crop lands. However, it was observed to be evident as ephemeral features after pronounced rainstorms on the cultivated hillslopes. Rill erosion is usually masked by the farming operations during weeding and cultivation. However, on poorly managed grazing lands the rills remain and may subsequently develop into gullies.

**b. Gullies**

Areas depleted in or devoid of plant cover and compacted by large numbers of livestock experience high runoff generation, which on sloping lands concentrates into enlarged channels or gullies. Further discussion of gullies is presented in section 5.3. However, it is important to indicate here is that the formation of gullies in this dryland suggests the transition to a critical phase of instability. Laflen and Roose (1997) argued that gullies are a major source of land degradation and their presence is a strong indicator that erosion is out of control and that the land is entering a critical phase that threatens its productivity. Morgan (1995) also noted that gullies are almost always associated with accelerated erosion and, therefore, with landscape instability. Change in vegetation cover and /or soil erodibility caused by agricultural practices induces geomorphic processes such as gullies (Vanacker *et al.*, 2003).

The initiation and development of gullies is very complex (Leopold, Wolman and Miller cited in Morgan, 1995). In the Nakasongola district, gullies have developed mainly as a result of surface erosion by overland flow in the degraded catchments. However, in other areas such as Lesotho Nordström, 1989) and western Kenya (Waruru and Wanjongu, 2000), piping (or tunnel erosion) due to sub-surface flow processes is reported to be the main erosional process in gully formation. A further discussion of the types and distribution of gullies in the Nakasongola dryland is provided below.

**Plate 5.2** Gully erosion; gullies are discontinuous in the degraded catchments and pose problems. Note the sand fan on the lower end of the slope in the foreground of the photo.

The main factors influencing the formation and distribution of gullies in the study catchments include slope form and angle, geology, vegetation cover, footpaths and livestock tracks. Nordström, (1989) in Lesotho observed that a decrease in rainfall (drought) would lead to deterioration in vegetation cover although grazing also negatively impacts vegetation. Absence of or reduced plant cover appears to be the main factor responsible for the increased runoff generation in the drylands of the Nakasongola district. The increased runoff concentrates along the compacted and depressed lines (e.g. tracks and paths) running down slope towards the valley and often to watering points. As explained by Morgan (1995) gullying will occur if tractive forces exceed a critical or threshold value. In other words, as observed by Poesen *et al.* (2002), gully erosion is clearly a threshold phenomenon, a geomorphic process occurring only when a threshold in terms of flow hydraulics, rainfall, pedology and land use has been exceeded. More details on these factors as regards gullying are given in section 6.3. Once the gully channel is established, the resulting concentration of flow is sufficient to sustain gully erosion (FAO, 1986:126). The scouring action by runoff causes gully expansion downward whereas headward erosion contributes to its extension upslope. Subsequent headward erosion and widening will continue until the gully is adjusted to a new set of equilibrium conditions and becomes relatively stable (FAO, 1986:126). Other observed processes that induce gully development in this area are cracking, slumping and collapsing of undercut gully walls.

Table 5.2 provides a summary of the gully measurements in the area. The details of the results on the main gully measurements are given in Appendix 11. Gully depth varied greatly but rarely exceeded 2.5 m, whereas the width varied from 0.5 to 3 m. An estimate of soil loss (Table 5.2), based on the average cross-section area and depth of gullies, provides an insight into the contribution of gullies as a soil degradation feature in the area, and the dangers posed due to the on-site effects such as siltation of water sources (see Chapter 6). High soil loss estimate of 686 $m^3$ from the Uweso road gully is attributed to the high runoff generation from the road and the devegetated grazing land on the upper section of the landscape. The observed active rill network connected to the gullies and continued interplay of the factors alluded to, are likely to result into gully extension. Gully density is generally low, approximating to one gully $km^{-2}$.

**Table 5.2** Average measurements of prominent gullies on grazing lands in Nakasongola

| Gully No. | Location | Date of formation in years | Length (m) | Width (m) | Depth (m) | Soil loss M3 | Advancement m/yr | General pattern |
|---|---|---|---|---|---|---|---|---|
| 1 | Bizibitukula | 10 - 15 | 150 | 1.5 | 0.5 - | 86.8 | 10 - 15 | Dendritic |
| 2 | Bizibitukula | 10 | 80 | 2 | 0.45 | | 8 | Linear |
| 3 | Kabojja | >15 | 80 | 2 | 1.5 | 80.5 | 5 | Linear/dendritic |
| 4 | Kyamukama | >10 | 140 | 3 | 2.5 | 306.6 | 14 | Linear |
| 5 | Bujumbura | 5 - 10 | 80 | 1 | 0.5<br>0.8 | 40-64 | 8 - 16 | Linear |
| 6 | Sebwato | <5 | 65 | 0.7 | 1 | 16.3 | 10 | Linear |
| 7 | Uweso Road | 20 | 900 | 3 | 0.9 | 687.3 | 45 | Linear |

**(ii) Development and distribution of gullies in other parts of Nakasongola**

Gullies assessed in areas outside the Bizibitukula sub-catchment (Table 5.2) show variation in distribution and magnitude that is linked to human and animal tracks, plant cover, soil and slope angle. The areas where gullies were observed include Kaboja, Kyamukama, Bujumbura and Kyalapande villages. Observations in these areas showed that soils (colluvial deposition) on the sloping land are sandy and sandy loam. The loose texture, and hence reduced cohesiveness in the sandy soils combined with the concave slopes and changes in slope gradient, was likely to have affected the development of the gullies. Waruru and Wanjongu (2000) have highlighted the contribution of human and animal tracks in gully erosion in Kenya. In other areas natural factors play significant part in influencing gully erosion. Research in Swaziland has also shown that large-scale gully formation and activities are linked to cyclonic rainfall episodes and thus are climate driven rather than human-induced.

### 5.2.2 Non-Erosive Degradation Forms And its Distribution

Field observations shows clearly that the area suffers from serious soil compaction problems (Table 6.2), including crusting and sealing. Soil extraction for brickmaking is another form of degradation problem identified in the area.

Cattle mainly cause compaction on the rangeland due to trampling. The weak soil structure and high evaporation rate probably compound this. Bezkorowanjynj et al. (1993) report that mature cattle can exert a ground pressure of some 1.7 kg/cm² of hoof bearing area. They argue further that this may be comparable to the force exerted by heavy-wheeled tractors, which may affect soil densities to a depth of 1 m and cause a decline in crop yields of 30 - 40%. High bulk densities of >1.45 g/cm³ were measured on the degraded rangelands in Nakasongola. Further consideration of the measured bulk densities in this area is to be found in section 6.1.2.

Degradation forms such as crusting/sealing, are common particularly on the exposed/bare soils, as evidenced by darker c surfaces. The soils are susceptible to crusting and sealing due to the fine texture (relatively high clay and silt content). Clay content ranges as high as 68% and the silt content is 28% in some places. Compaction, crusting and sealing of soils contribute to elevated surface runoff due to reduced infiltration capacity. This is supported by the results on measurement of infiltration capacity on these surfaces (see Chapter 6).

Soil extraction is another form of soil degradation that here mainly associated with brick making (Plate 5.3) and quarrying for road construction. The main areas affected by brick making are the low-lying areas (wetlands) especially those that are close to the urban centres. The form of land use is likely to increase as the demand for the building constructions rises due to demographic pressure in the urban centres. Problems consequent upon accelerating urbanisation arise not only on-site due to physical removal of soils but also due to the growing demand for fuel wood, which contributes to reduction in plant cover and exposure of soils to erosive forces. A kiln (~6,000 – 10,000 bricks) consumes on average of one truck of fuel wood in the form of logs. This is equivalent to felling down three entire trees, which exposes ~75 - 300 m² of soil. Any subsequent increased demand for fuel wood will thus be a major potential problem in terms of soil degradation in the future. This suggests that integrated planning is required to achieve a balance in soil use for brick making while correspondingly attending to strategies towards ensuring a sustainable source of fuel wood or adopting alternative energy technologies to fuel the kilns and/or improving on the efficiency of energy utilisation in kilns.

**Plate 5.3** Soil extraction for brickmaking near Migera town; note the degraded area in the middle & foreground and the number of kilns, which highlights the fuel wood demand.

It is not the intention of this study to undertake a detailed assessment of soil extraction as a degradation process. However, soil extraction or quarrying is commonly observed on landing the study area, especially along the major roads. There is approximately one quarry per every 2 km along the main Gulu – Kampala road. Some of the quarries cover as much as 0.5ha and are abandoned without any rehabilitation of the land. In addition, rills and gullies were observed in and around these sites, although these gullies rarely exceeded 20m in length and 1m in width. The quarrying usually leaves behind exposed sub-soils with poor structure and low infiltration capacity that leads to surface runoff whenever high magnitude rainfall events are experienced. Accelerated runoff and soil loss can be a potential factor in causing off site damage, including silting of channels and flooding in other areas.

## 5.3 THE EXTENT AND SEVERITY OF SOIL DEGRADATION IN THE DISTRICT

Soil erosion prediction was done in order to provide an index on the assessment of the extent and magnitude of soil degradation processes in the Nakasongola district. The soil erosion severity is based on the FAO classification of 1979.

5.3.1 Soil Erosion Prediction

The RUSLE erosion model, an improved version of the USLE (Wischmeier and Smith, 1978) was applied in a GIS environment (see Chapter 4) to predict the spatial distribution and severity of soil erosion at a reconnaissance scale in the Nakasongola district. Predicted soil loss can be a reasonably good indicator of other soil degradation processes such as physical deterioration, exposed soils and reduced organic matter. Areas of severe soil erosion are characterised by exposed and physically deteriorated soils with poor organic matter. Figure 5. 2, shows the predicted average annual soil loss in t/ha/yr.

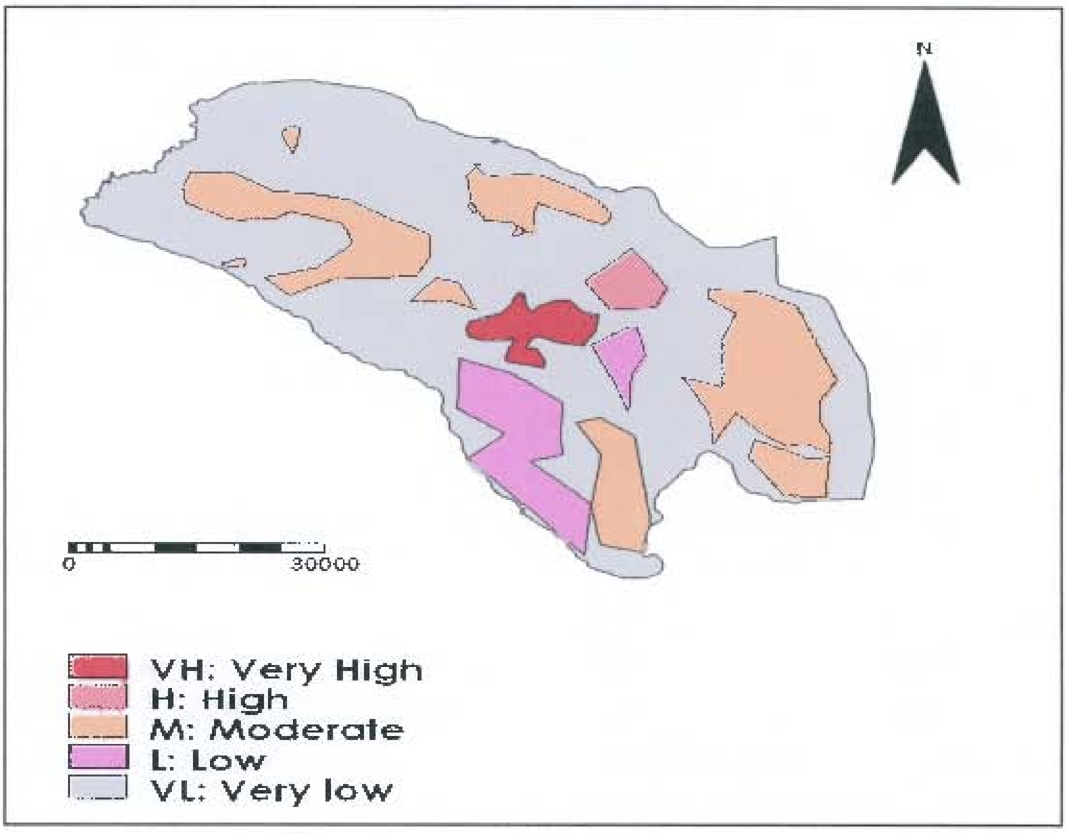



**Figure 5.2** Magnitude and distribution of soil loss in the Nakasongola district.

The results of application of RUSLE in Nakasongola district (Figure 5.2) reveal that areas with serious soil erosion (hot spots) occur in a patchy/cluster pattern mainly in the central, northwest, north and eastern part. In general, the greater parts of the area (67%) are modelled as experiencing a low rate (<2 t/ha/yr) of sheet and rill erosion (Figure 5.3). Some areas corresponding to relatively steeper, long slopes and low plant cover, experience moderate (10 - 50 t/ha/yr) to very high soil loss (>90 t/ha/yr). The area experiencing moderate soil loss covers ~ 22% and that with high to very high soil loss constitutes 9% of the district area. The areas, which are covered by steep and long slopes combined with reduced cover, may generate high surface runoff and hence are predicted to have higher rate of soil erosion.

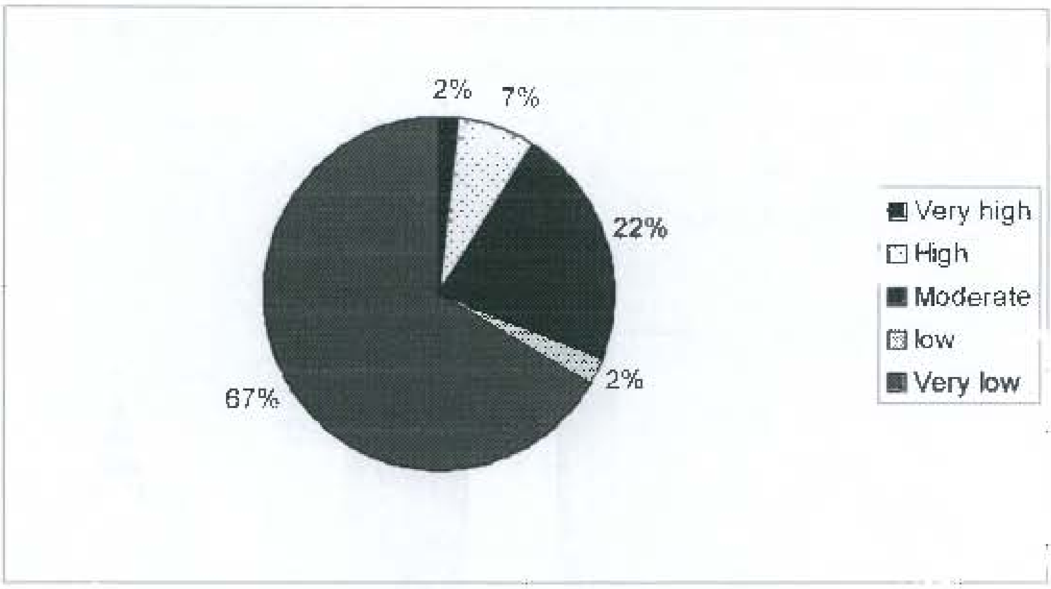



**Figure 5.3** Percentage area of the Nakasongola district affected by different types of soil erosion based on RUSLE severity classes

Field observations by the author have revealed that low-lying areas mainly experience very low levels of degradation in the form of sheet erosion, and compaction limited to places around watering points and tracks. Heavy grazing and trampling was observed around these watering points. Nonetheless, the reasonably high moisture content in this low-lying area ensures quick recovery of vegetation cover. This explains why soil degradation by erosion is not prominent even when such areas are heavily grazed. The thick bush and woodland forests fringing the low-lying/valley areas provide adequate cover against the raindrop impact, and the interception and therefore infiltration rate is promoted by the leaf-littered soil surface.

The gentle slopes, particularly the cultivated and moderately grazed parts, largely experience moderate soil degradation in the form of sheet wash and rill erosion. The relatively steeper slopes suffer from severe degradation by sheet wash, compaction and rilling. Gullies were observed to be associated with such areas of intensive or severe degradation. The areas of severe soil degradation in general coincide with bare patches on sloping grazing land (Plate 5.4).

**Plate 5.4** Severe sheet erosion on the grazing land of Mr. Lubega's ranch in Migera; plant roots and boulders in the fore/mid-ground are exposed due to removal of soil.

Based on the level of severity of soil degradation (Lal, 1983), three distinct phases of degradation were distinguished in this study area;

- The first phase is where there is minimal soil degradation processes, such as sheet wash and the plant cover is high (>60%). The soil organic matter content is above the critical level (3%). Thus, the low-lying areas and dense woodland/forest areas are categorised under this phase.
- The second phase is characterised by presence of sheet wash, scattered rills and low degree of compaction. Areas under this category occur anywhere on hill-crests and – hill-sides on crop or grazing lands.
- The third phase is characterised by a high intensity of sheet wash, rilling including gullying; the plant cover is low (<20%); the degree of compaction of soils is high and sub-soils are usually exposed as a result of truncation by erosion. Patches experiencing severe to very severe erosion (Figure 5.2) (occupying ~ 9% of the land area) belong to this third phase. Steeper sections of the slopes with little or no proper land husbandry are vulnerable to the second and third phase level of degradation. In terms of conservation, the areas under the second and third phase require urgent attention.

## 5.4 PATTERN AND MAGNITUDE OF SOIL EROSION ON GRAZING LAND

Runoff and soil loss were measured under natural and simulated rainfall conditions on experimental plots (Appendix 2 and Plate 4.1) established on a sample of typical grazing land. The runoff plots measuring 1.5 m wide by 15 m long, for conditions under natural rainfall, were positioned on a representative area of grazing land in Migera parish, about 20 km north west of Nakasongola town. The plots included 2 replicates and 2 treatments (degraded and non degraded) positioned on the upperslope (L1 and B1), midslope (L2 and B2) and backslope or lower pediment (B3 and L3). Plots B3 and L4 were non-degraded and acted as a control. The rainfall simulation plots of 0.5 m wide by 2 m long were meant to simulate the existing erosion processes under grazing land, which is one of the main land cover/use in this area. Furthermore, rainfall simulation experiments were undertaken to supplement the field erosion plots and were particularly meant to help in obtaining data on erodibility, infiltration rate and provide a further understanding of the erosion processes. Due to limited financial resources, it was not possible to set up erosion plots under other land use types. The results for both the natural and simulated rainfall plots are presented and discussed below.

### 5.4.1 Rangeland Erosion Plots Under Natural Rainfall

The rangeland plot studies were designed to help in quantifying runoff and soil losses from different environmental conditions, namely the non-degraded, severely degraded, and moderately degraded areas (see Chapters 3 and 4) under the currently practised traditional perimeter fenced grazing system, on the leased land. This grazing system involves free range and daily movement of livestock under the guidance of a herder (locally called *mularo*). It is the most commonly used grazing method in this area following the recent 1993 ranch restructuring. Results on runoff and soil losses are presented and discussed below on the basis of annual and seasonal trends. Full details as to actual measurements of runoff are provided in Appendix 12.

#### 5.4.1.1 *Annual runoff losses on different degradation surfaces*

The average annual runoff losses from different degraded surface conditions for the years 2001 and 2002 are given in Figure 5.4.

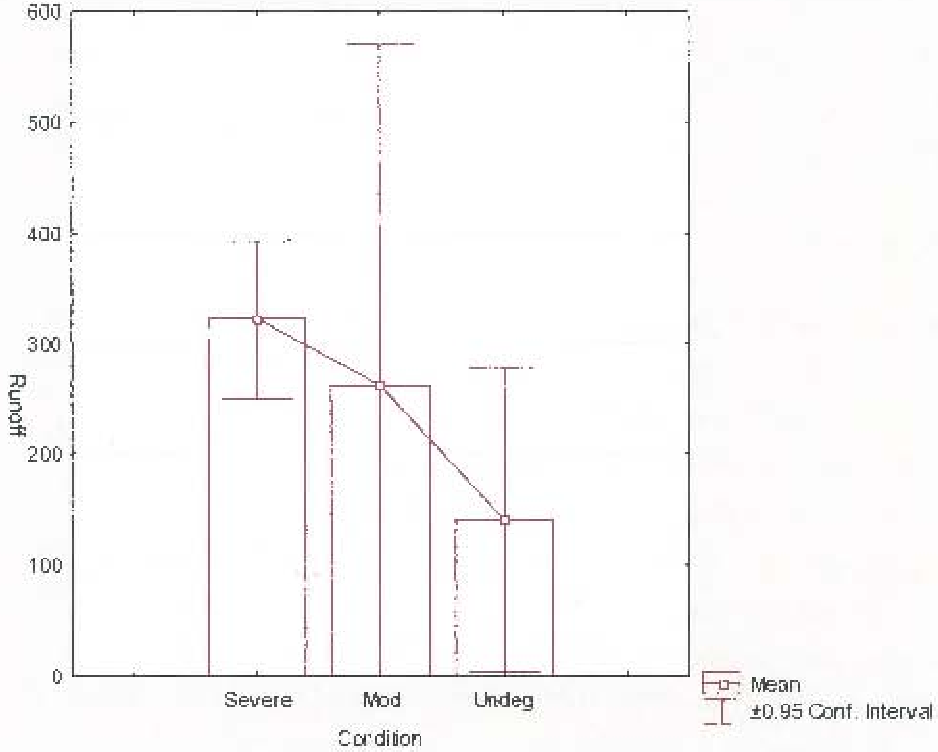



**Figure 5.4** Average runoff losses from different degraded surfaces for two years

The average runoff losses (Figure 5.4) reveal an interesting but expected trend. In general the pattern of runoff losses indicates relatively higher losses of surface runoff from the severely degraded plots (321 mm) compared to the moderately degraded ones (261 mm). Severely degraded plots recorded approximately twice the runoff of the non-degraded plots. The high losses from severely degraded plots can be accounted for by low infiltration rates caused by surface crusting and compaction of soils by animal trampling. The results on infiltration rate in Chapter 6 reinforce this explanation; low infiltration was obtained from severely degraded areas as opposed to the non-degraded ones.

There were no significant variations in the runoff losses between the two years except for the different degradation conditions (p=0.018) as shown in Table 5.3.

**Table 5.3** Variation of runoff loss for the degraded surfaces for the 2 years

| Range condition | Runoff loss (mm) Year 2001 | Year 2002 |
|---|---|---|
| Severely degraded | 147.8 | 181.8 |
| Moderately degraded | 77.4 | 114.4 |
| Non-degraded | 20.4 | 57.4 |
| LSD 0.05 Year | | 70.1 |
| LSD 0.05 status of degradation | | 85.8 |

Figures 5.5 – 5.7 show the annual runoff loss for the individual years 2001 and 2002, as expected, the data indicate that the non-degraded plots, B4 and L4, recorded the lowest runoff losses (Figures 5.4 5.6). The relatively higher losses for B4 and L4 in year 2002 compared to 2001 can be attributed to greater effective rainfall storms. Year 2002 received 622 mm of rainfall, which was substantially more than that of 2001 (340 mm). The increase in runoff was observed at all the other plots during the year 2002, and shows the important role that rainfall amount can play in runoff generation. The relationship between rainfall amount and runoff is addressed in sub-section 5.4.1.4. The severely degraded Plot L3 recorded the highest amount of runoff (290 mm) during the year 2001 although in year 2002 the loss only increased to 431 mm. High runoff loss has implications in terms of increased potential for soil loss and desiccation of land under such degraded condition. As shown in Figure 5.6, on average the loss of runoff for plot L3 was still higher than the other plots. It is not clear what could have caused this variation but most probably it is because of the observed increase of surface crust and higher rainfall amount received.

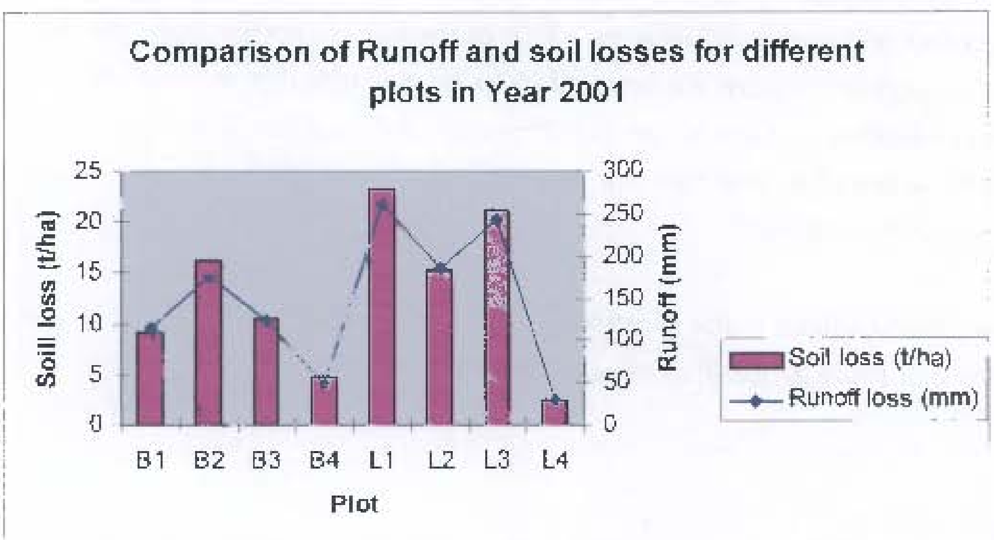



**Figure 5.5** Runoff and soil losses for the year 2001

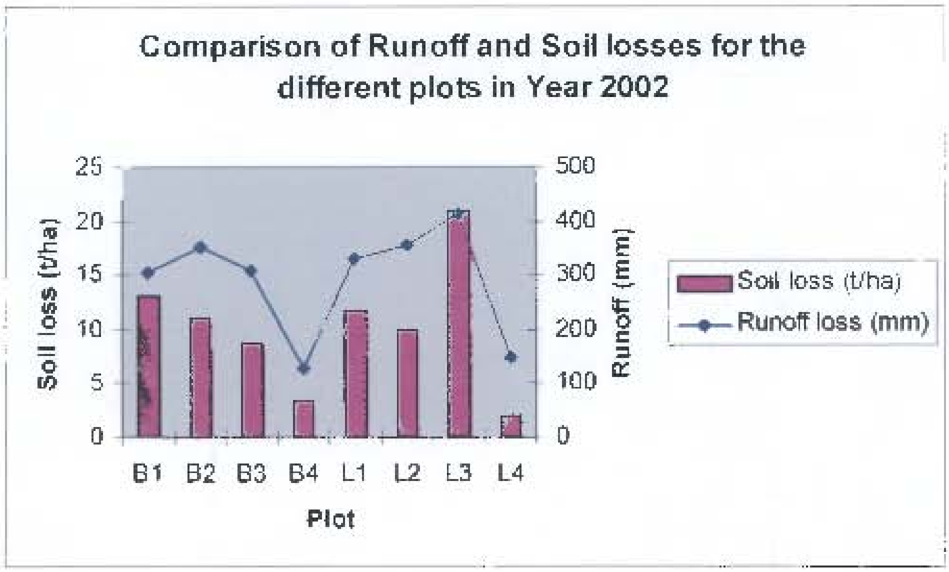



**Figure 5.6** Runoff and soil losses for different plots in the year 2002

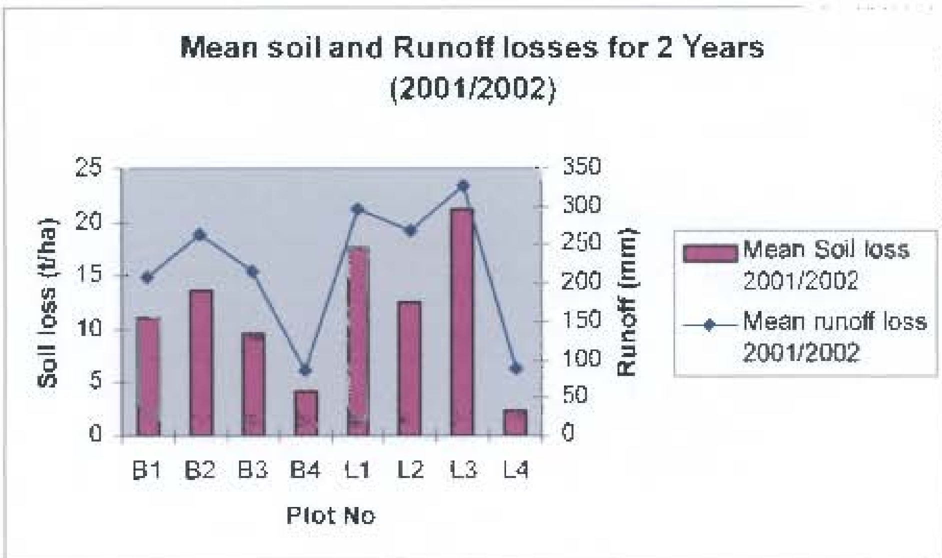



**Figure 5.7** Average total runoff and soil losses for two years 2001/2002

### *5.4.1.2. Annual soil loss on different degradation surfaces*

The average soil losses on the different rangeland surfaces are summarised in Figure 5.8, Table 5.4 and appendix 18B. In general the severely degraded areas, experienced a significantly ($p < 0.001$) higher average soil loss (20 t/ha) compared to the moderately- and non-degraded plots over the two monitored years ($p = 0.034$).

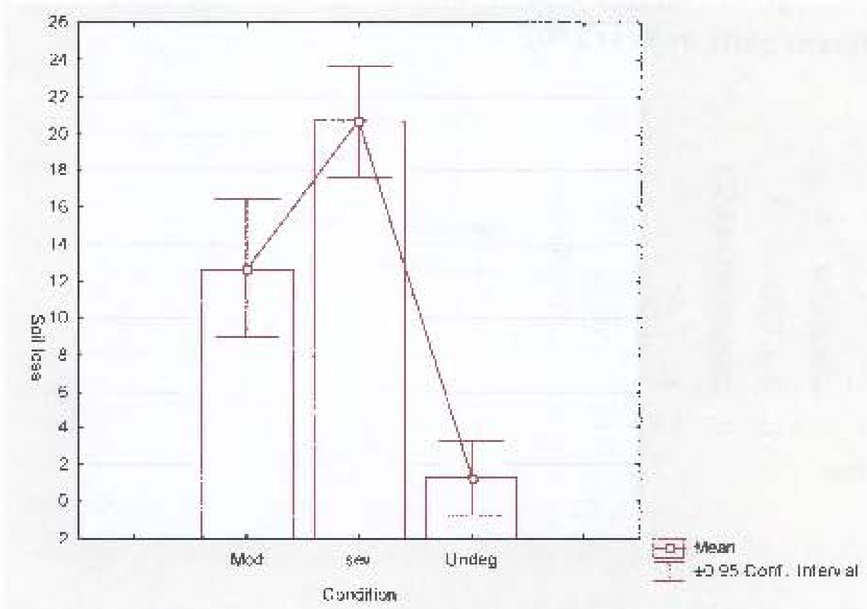



**Figure 5.8** Comparison of soil loss on different degraded surfaces; mod = moderately degraded. Sev = severely degraded, Undeg = non-degraded

**Table 5.4** A comparison of average soil loss on different range condition for 2001/2002 for Each individual plot replica

| | Soil loss (t/ha) | | |
|---|---|---|---|
| **Range condition** | **2001** | **2002** | **Average (t/ha)** |
| Severely degraded | 18.05 | 23.4 | 21 |
| Moderately degraded | 11.75 | 14.2 | 12.8 |
| Non-degraded | 0.7 | 2.95 | 1.8 |
| LSD 0.05 Status | 5.04 | | |
| LSD 0.05 Year | 3.84 | | |

The severely degraded area (Plot L3) experienced the highest soil loss averaging 25 t/ha, which is explained by the relatively steep slope (7%) and the observed development of rills during heavy storms. Rills are known to concentrate runoff leading to increased detachment and entrainment of soils. Christiansson (1981) in Tanzania observed similar patterns and indicates bare soils are particularly vulnerable to loss of soil and water. The moderately degraded plots (L2 and B1) had an average soil loss of 13 t/ha, which is lower than the severely degraded plots. This can be attributed to the relatively lower runoff amount caused by the higher infiltration rate as indicated above. In general, the non-degraded plots experienced the least soil loss, which averaged 2 t/ha for the two years in question. This underpins the importance of plant cover in reducing the impact of raindrops and retarding the runoff velocity that would otherwise cause more detachment and entrainment of soil particles. As shown in Figure 5.9, 2002 experienced higher albeit statistically insignificant soil loss. High soil loss is a result of the relatively higher rainfall compared to 2001.

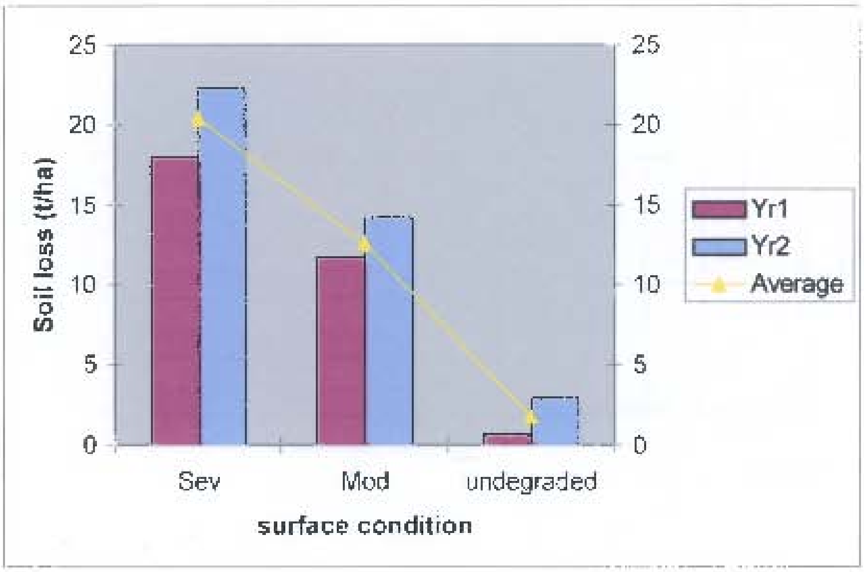



**Figure 5.9** A comparison of average soil loss on different rangeland surface condition for 2001/2002: sev = severely degraded, mod = moderately degraded, undegraded = non-degraded.

### *5.4.1.3 Annual runoff and soil losses on different slope positions*

**Runoff loss**

The average runoff losses (mm) on the various slope positions are shown in Figure 5.10. Note that the lower slope position experienced higher average runoff loss (327 mm) compared to the upper and middle slope plots, which had similar runoff losses. As expected, the control plot experienced the lowest average runoff loss of 141 mm, which, as alluded to, is thought to be due to the higher infiltration rates promoted by the basal cover.

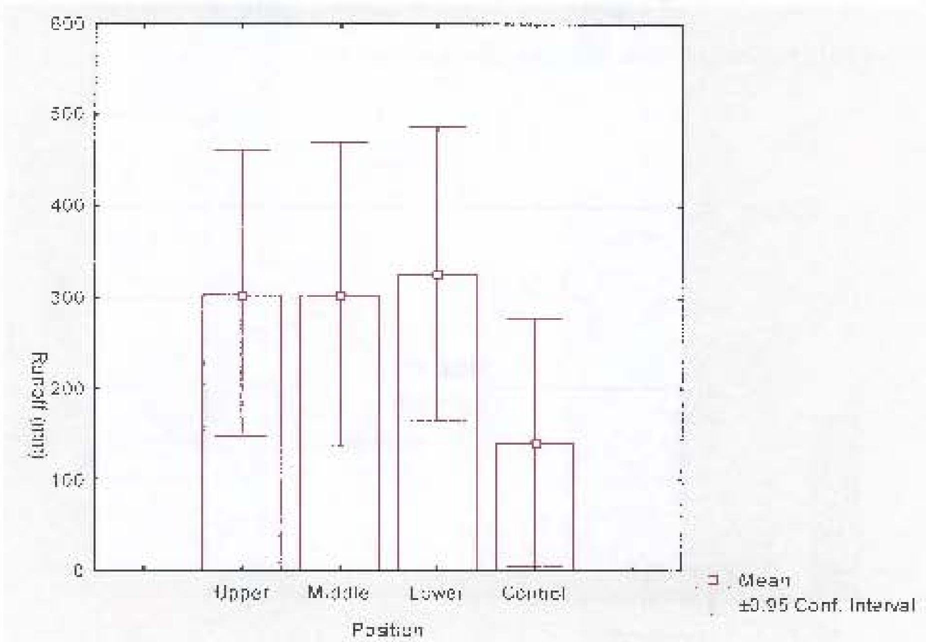



**Figure 5.10** Runoff loss (mm) according to slope position

**Soil loss**

As shown in Figure 5.11, high average soil losses (22 t/ha) were experienced on the lower slope position followed by the upper slope (18 t/ha). The middle slope registered the lowest amount (15 t/ha) of soil loss. It would be expected that the loss of sediment on the middle slope position should be more than that on the upper slope position, but this was not the case observed in this study. This can be explained by the fact that the slopes are long (ranging up to >200 m) and the morphology is such that the middle slopes are gentle. The gentle slopes reduce the velocity and transport capacity of the runoff and hence the resultant lower soil loss. Another reason for the observed lower soil loss on the middle slope was that one of the plot (I 2) had a basal grass cover of >20<40% and a tree cover of about 20%. This was considered to have intercepted the rainfall leading to greater infiltration rate, hence less surface runoff flow. Furthermore, the reduced transport capacity of runoff flow by the basal cover slowed down the rate of soil detachment.

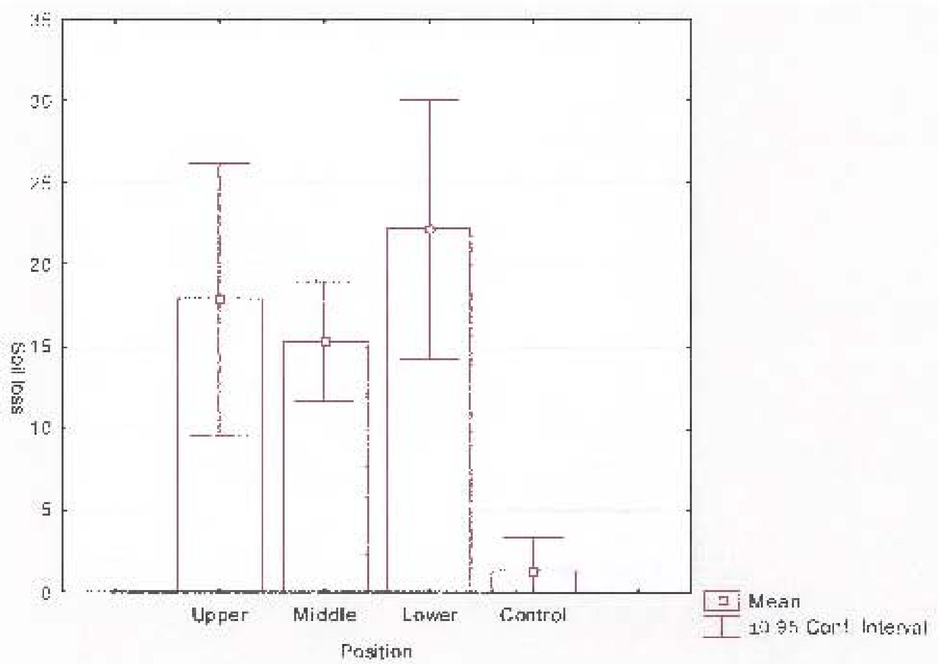



**Figure 5.11** Average soil losses on different landscape positions for 2001/2002; upper = upper slope, middle = middle slope, lower = lower slope, control = on lower slope

The data on soil loss, for the years 2001 and 2002, are shown in Figures 5.8 and 5.9. In 2001 the lowest soil losses were observed on the non-degraded plot L4, whereas the highest loss was from the severely degraded plot L3. In 2002 the same plot L4 experienced the least soil loss and plot L3 again recorded the highest loss.

*5.4.1.4 The relationship between rainfall, runoff and soil losses*

The relationship between rainfall amount, runoff and soil losses was computed using the data sets for the two years and the results are shown in Figure 5.12. A significant relationship ($p < 0.05$) was observed between rainfall amount and runoff and soil loss. The highest correlation was between rainfall amount and runoff as shown by high values of 0.79 for $r^2$. However, the correlation between rainfall amount and soil loss was moderate as shown by the computed $r^2$ value of 0.27. The relatively weaker correlation can be attributed to the fact that rainfall amount (as opposed to rainfall intensity) may reveal little about its effectiveness of contributing to soil loss by raindrop detachment of soil particles. Rain splash erosion was not monitored separately, although as shown in Table 5.5, rainstorms with high intensity are associated with high soil loss. Soil loss also depends on antecedent conditions. The detached soil particles are not wholly transported on the slope profile. Partial deposition occurs whenever the runoff transportation capacity becomes inadequate until the next rainstorm transports it downslope. Thus, rainstorms of lower amount (e.g. for 2nd and 6th June 2002, Table 5.5) lead to more soil loss depending on the pre-existing conditions.

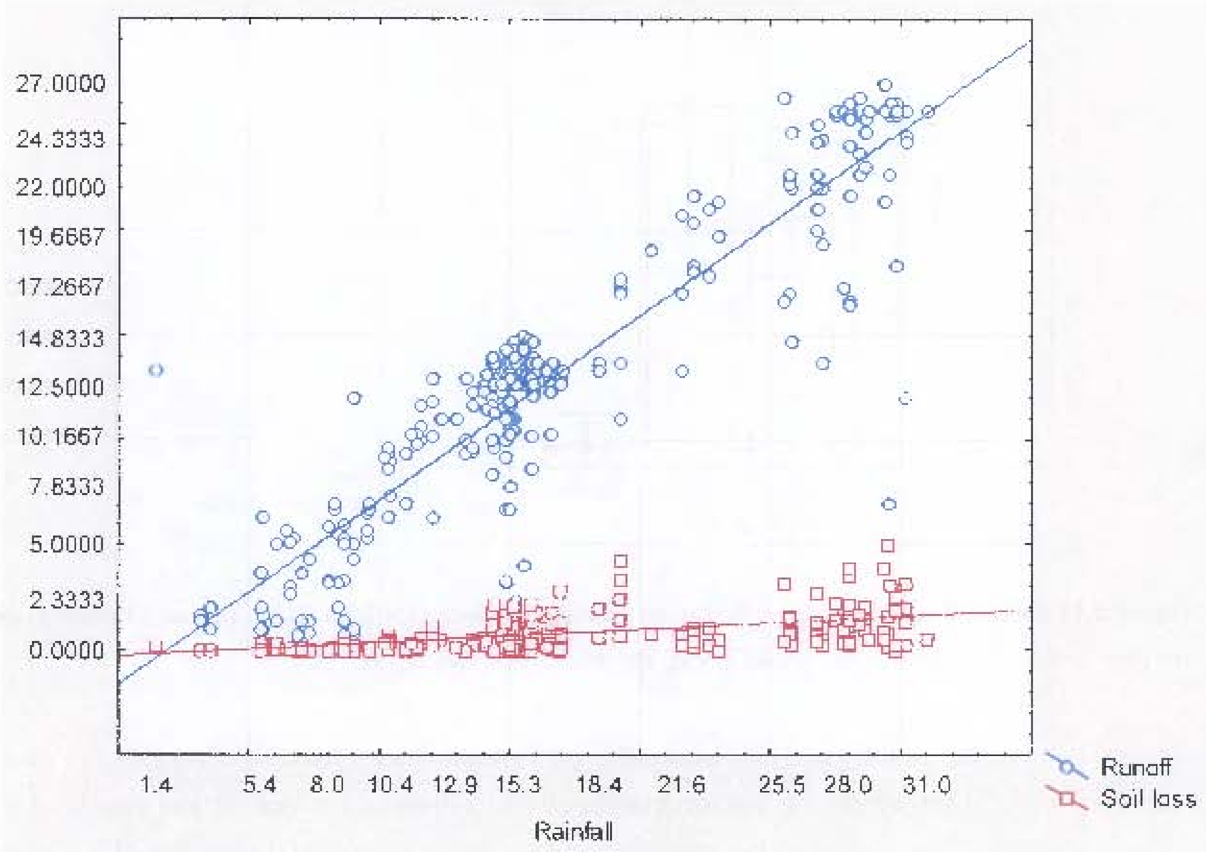



**Figure 5.12** Relationship between Rainfall, runoff and soil losses for the two experimental years

**Table 5.5** Runoff and soil loss for some monitored rainfall storms on upper slope in Bizibitukula sub-catchment

| Date | Rainfall amount (mm) | Rainfall intensity (mm/hr) | Runoff amount (l) | Soil loss t/ha |
|---|---|---|---|---|
| 190402 | 15.5 | 36.9 | 112.5 | 0.74 |
| 200402 | 27 | 36.0 | 182.5 | 1.02 |
| 230402 | 26.8 | 29.5 | 181.25 | 1.28 |
| 020502 | 30.2 | 45.1 | 183.75 | 1.96 |
| 060502 | 29.5 | 50.9 | 191.25 | 5.00 |

Further analysis of the relationship between erosion and rains was investigated using the so-called aggressive coefficient of the erosional rains (FRa). This coefficient shows how much soil loss (t/ha) was eroded per erosive storm. Only the erosional rains were used for calculation based on the formula:

$$ERa = \frac{\text{Erosional loss (t/ha)}}{\text{Erosional rain (mm)}}$$

The statistical values of the analysis are shown in Table 5.5

**Table 5.6** Statistical analyses of the ERa values for the years 2001/2002

| Cover type | No. of observations | Mean t/ha/mm | Range Minimum | Range Maximum |
|---|---|---|---|---|
| Non-degraded | 34 | 0.01 | 0.00 | 0.03 |
| Moderately degraded | 43 | 0.04 | 0.00 | 0.17 |
| Highly degraded | 175 | 0.05 | 0.00 | 0.23 |
| LSD0.05 | | | | 0.015 |

ERa varied considerably with maximum values in the highly degraded plots of 0.23 ($p<0.001$). This implies that 1 mm of excessive rain can erode > 0.23 t/ha of soil on a bare or highly degraded land. The non-degraded areas had low maximum value, which can be attributed to protective plant cover.

### *5.4.1.5 Seasonal runoff and soil loss for different surface conditions*

**Runoff**

Tables 5.6 and 5.7 show the seasonal total runoff loss from different rangeland conditions characterised by the non-degraded, moderately degraded and severely degraded plots. There were no significant differences in the seasonal runoff losses except for different degraded surfaces or treatments ($P< 0.018$; df =2). Significant differences ($p=0.008$) were noted between the seasonal runoff losses between the two years attributable to the higher amount of rainfall received in the second year.

For the first season, the months of May and June in 2001 recorded high loss for nearly all the plots apart from the non-degraded plots (B4 and L4). In the second season, the months of September - November had high runoff loss. The months of July and August recorded no loss for the non-degraded plots. This variation is closely related to the variation in the rainfall but also the condition of the surface plant cover. In 2002, the months of March – May experienced higher runoff compared to the months of January and February. The month of November in the second season of 2002 recorded reasonably high runoff loss for all the plots. In general, the second season of the year 2002 registered significantly (p=0.002) lower runoff loss compared to the first season. Variation in runoff corresponds to the rainfall amount and its distribution, and also the condition of the soil surface as indicated (see also Figure 5.13).

**Table 5.7** Average seasonal runoff (mm) for different degraded areas in the year 2001

| | Non-degraded | Moderately degraded | Severely degraded | |
|---|---|---|---|---|
| Season1 | 0.2 | 48.2 | 48.4 | |
| Season2 | 40.2 | 106.2 | 246.4 | |
| LSD (0.05) | | | | 84 |

**Table 5.8** Average seasonal runoff (mm) for different degraded areas in the year 2002

| | Non-degraded | Moderately degraded | Severely degraded | |
|---|---|---|---|---|
| Season1 | 90.2 | 125.2 | 271.4 | |
| Season2 | 24.2 | 103.2 | 90.4 | |
| LSD (0.05) | | | | 61.8 |

As shown in Figure 5.13, the mean seasonal runoff loss also varied according to the soil surface condition. The severely degraded areas (e.g. plots L3 and B3) have little or no basal cover to intercept the raintall impact that contributes to soil compaction hence lowering of the infiltration. Under such conditions higher runoff is generated when compared to the surface with high basal cover (e.g. plots B4, L4).

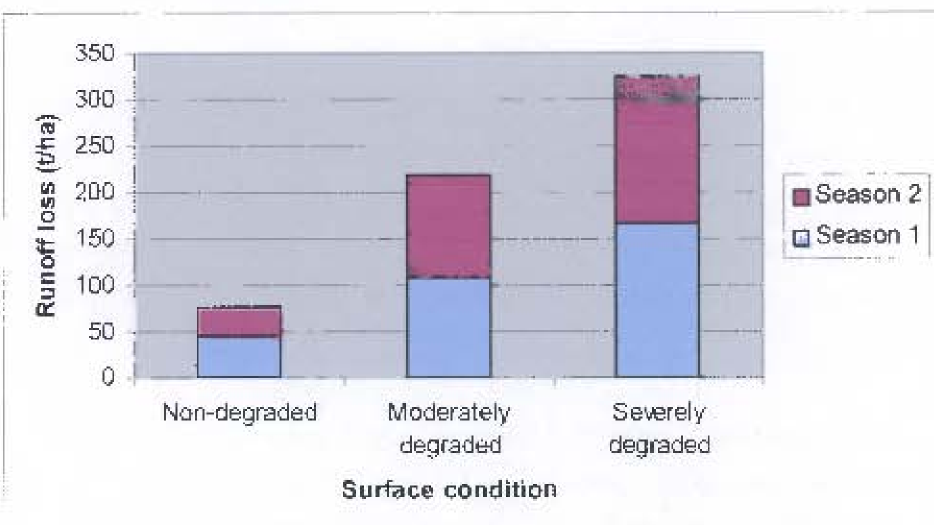



**Figure 5.13** Mean runoff loss under different surface conditions for the two experimental years

**Soil loss**

Tables 5.7 and 5.8 summarise the results concerning soil loss under different treatments for the two monitored years. Figure 5.14 illustrates mean seasonal soil loss for 2001 and 2002. The seasonal pattern for soil loss was inconsistent due to the variable rainfall amount and consequently the runoff distribution as indicated above. In 2001, soil loss in the second season was greater than the first season, but in 2002, the second season recorded significantly less soil loss ($p=0.008$). The ANOVA test revealed no significant ($p<0.05$) difference between the mean seasonal soil loss, in the first and second season for the first and second year (see Figure 5.14). Variations in soil loss ($p=0.002$) were noted for the different degraded conditions in all the seasons in the two years. In general, however, for the two years, higher soil loss was recorded in April and May and September November (Appendix 17). These months experienced peak rainfall values and hence generated higher runoff. The observed seasonal and monthly variation in soil loss reveals that rainfall and consequently runoff are obviously important factors that should be planned for in terms of soil and water conservation, in this dryland environment.

**Table 5.9** Average sseasonal soil loss (t/ha) for different degraded areas in the year 2001

| | Non-degraded | Moderately degraded | Severely degraded |
|---|---|---|---|
| Seasonal 1 | 0.0 | 2.5 | 4.1 |
| Season 2 | 1.06 | 8.56 | 13.23 |
| LSD 0.05 | | | |

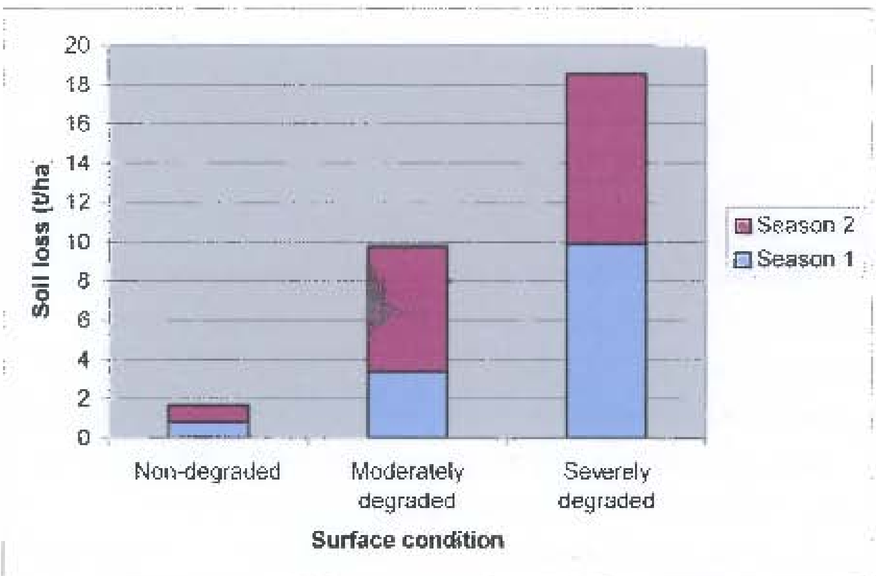



**Figure** 5.14 Mean seasonal soil loss under different surface conditions for the two years

**Table 5.10** Average seasonal soil loss (t/ha) for different degraded areas in the year 2002

| | Non-degraded | Moderately degraded | Severely degraded |
|---|---|---|---|
| Season1 | 1.62 | 10.46 | 14.15 |
| Season2 | 0.71 | 4.12 | 5.81 |
| LSD (0.05) | | | 4.0 |

### 5.4.2 Runoff And Soil Losses From Rainfall Simulation

Artificial rainfall experiments were conducted adjacent to the erosion plots under natural rainfall, so as to provide more information about the pattern of degradation processes on grazing land and soil erodibility. Rainfall was applied using a spray cone jet nozzle simulator and the total runoff and soil loss measured for the dry and wet experimental runs, as described in Chapter 4. Note that the wet run on the mid slope was conducted late in the evening to avoid wind disturbance. This monitored period was not ideal but was considered reasonable time for meaningful interpretation of the runoff and soil loss. The dry run refers to conditions when the soils are dry or at the field moisture capacity; it was meant to simulate conditions during the dry season or just before the wet season, whereas, the wet run refers to experimental conditions when the soils are having moisture above the field capacity, and was meant to simulate the processes on initially wet soils or storms occurring following each other. Overall five and four storms were simulated for dry and wet runs respectively. Results on soil erodibility obtained from the simulation experiments are reported in the next section 5.5. The simulation results on runoff and soil loss are presented and discussed in the sub-section below. Appendix 13 provides details on the simulation measurements.

#### *5.4.2.1 Runoff and soil losses*

Table 5.10 summarises the runoff and soil losses according to the slope positions namely the upper, middle and lower slopes. In terms of soil loss, higher measurements were observed for the dry run (0.83 to 1.02 t/ha) compared to the wet run (≤0.88 t/ha) on all the slope positions. It is not confirmed but the loose soils and sediments existing on the surface before the experiment could have caused the high rate of soil loss under the dry run. If this is the case, then this finding points to the significance of the soil surface condition during the dry season. Surface soil disturbances during dry periods by the actions of livestock trampling (hooves), termites, ants and moles can play a significant role in loosening the soil and promoting erodibility. This can thus lead to high soil loss especially at the start of the wet season. As expected, the lowest soil loss values (<0.5 t/ha) were observed under the control, which included basal grass cover of >90%. The low runoff and soil loss under the control experimental plots can thus be attributed to the effect of the protective vegetation cover against the rainfall impact and entrainment by surface runoff, as well as increased infiltration rate hence less runoff. Among others, Hudson (1995) has demonstrated the significance of vegetative cover in reducing soil loss and runoff in Zimbabwe.

**Table 5.11** Runoff and soil losses for the different slope positions for the dry and wet simulation runs (n = 7)

| Status | Slope position | Runoff (mm) | | Soil loss (t/ha) | |
|---|---|---|---|---|---|
| | | Dry run | Wet run | Dry run | Wet run |
| Degraded | Upper | 25.01 | 28.88 | 1.00 | 0.88 |
| Degraded | Middle | 24.83 | 25 | 0.83 | NA |
| Degraded | Lower | 29.9 | 24.13 | 1.02 | 0.80 |
| Non-degraded | Lower (control) | 24.48 | NA | 0.43 | NA |

NA = data not available, reasons given in text.

In general, the runoff loss as indicated in Table 5.11 proved to be slightly higher on the lower slope compared to upper slopes for the dry run. The observed algae surface coating and the steep slope (8 - 9%) account for this high runoff loss. This coated (armoured) surface is likely to have contributed to the reduced infiltration of rainwater into the soil. The algae coated surfaces were observed to be common on the soils that have remained exposed or de-vegetated for a number of years. The runoff loss on the upper slope was higher than that for the lower slope plots for the wet run. There is no specific explanation to account for this reversed trend in runoff generation. The vegetated (90% plant cover) treatment, referred to as the control, on the lower slope recorded the least runoff loss as expected no doubt due to high infiltration rate enhanced by plant cover. Generally high infiltration rates are typical of areas with ample vegetation cover i.e. presumably non-degraded, as demonstrated Chapter 6.

The relationship between runoff and soil loss was also explored. Correlations between runoff and soil loss for the upper, lower and mid slope positions are shown in Figures 5.15 – 5.17. Generally the data indicate that runoff and soil loss are not strongly correlated as revealed by the low $r^2$ and r-values for both the dry and wet runs. The dry runs, however, generally had higher correlation coefficients (e.g. $r^2$ values of 0.61 and 0.54 on the upper and mid slopes) compared with the wet runs, for which most values were below 0.10. It is expected that an increase in runoff amount causes more entrainment of the soil particles and hence higher sediment loss due to increased erosive and transport capacity. The results show that this relationship is not always predictable as the entrainment may be influenced by the soil conditions such as erodibility. The erodibility measurements were low for the compacted rangeland soils in this area (see section 5.5.1.2).

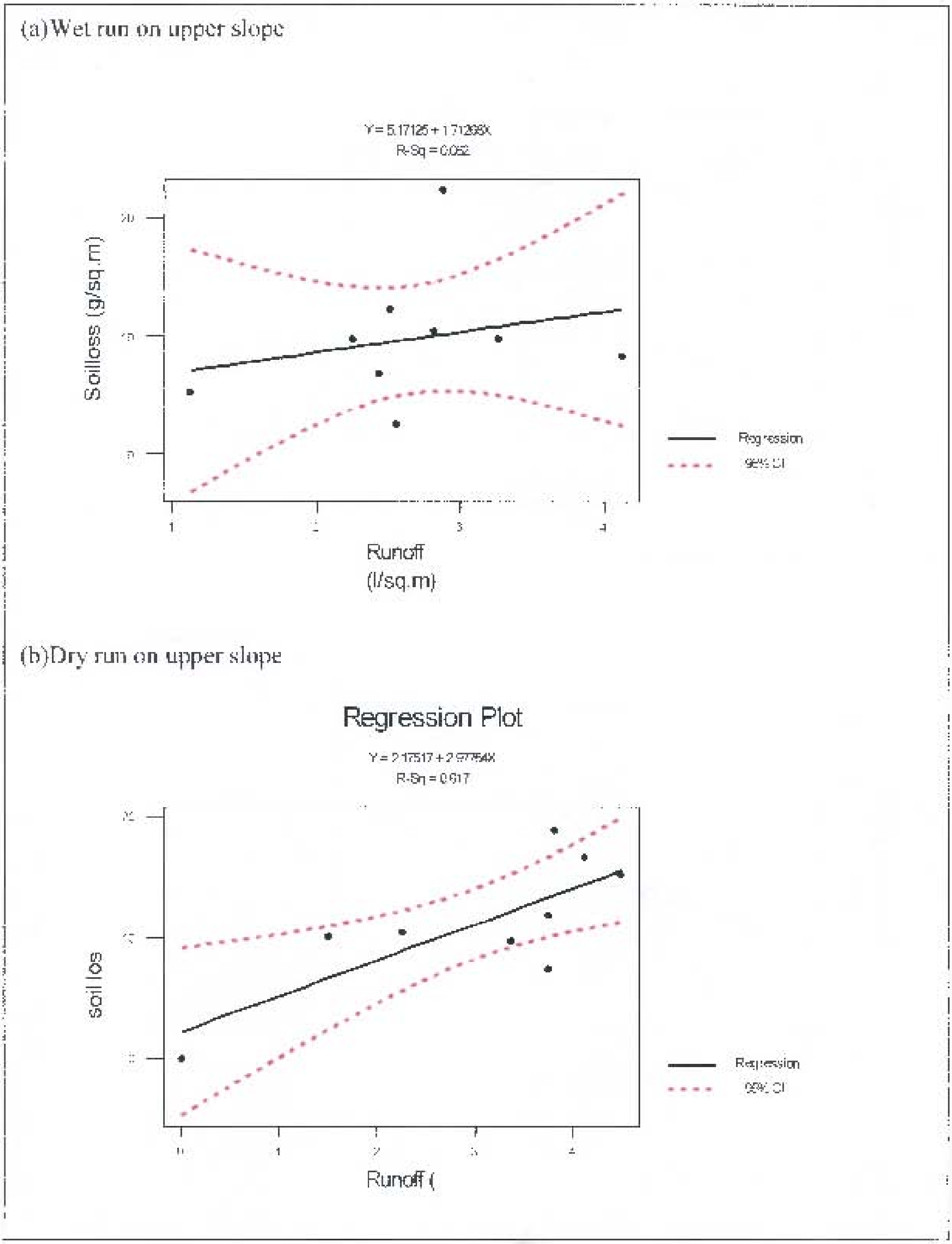
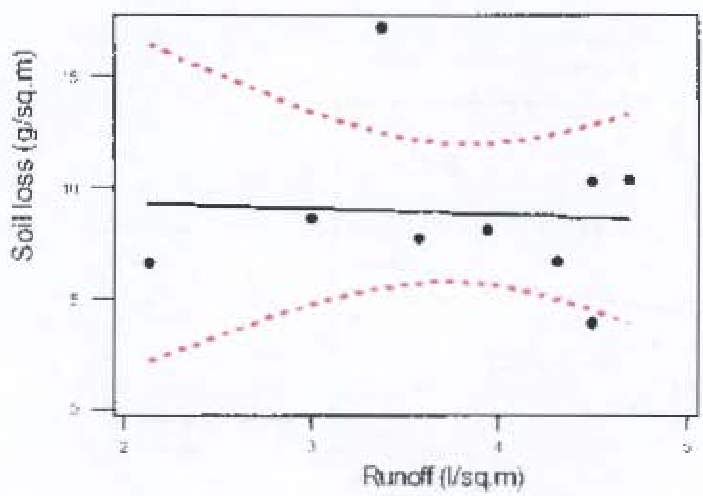
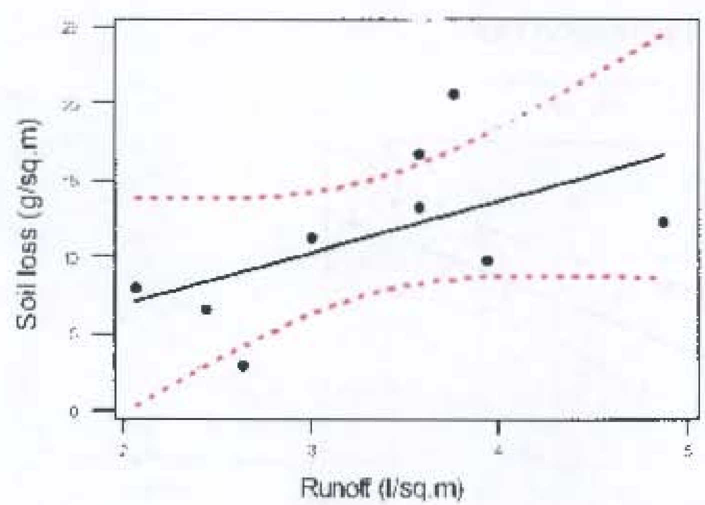



**Figure 5.15** Relationship between runoff and soil loss under constant rainfall intensity on the upper slope position

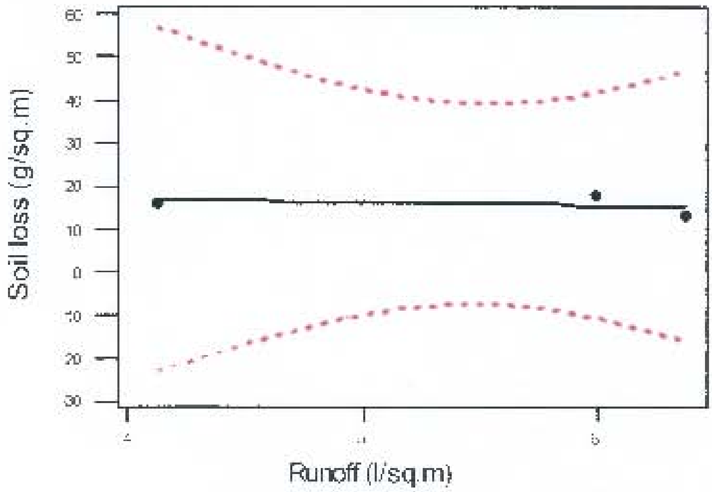



Wet run on lower slope position




Dry run on lower slope position

**Figure 5.16** Relationship between runoff and soil loss under constant rainfall intensity on the lower slope position




Wet (above) and Dry (below) runs on midslope position

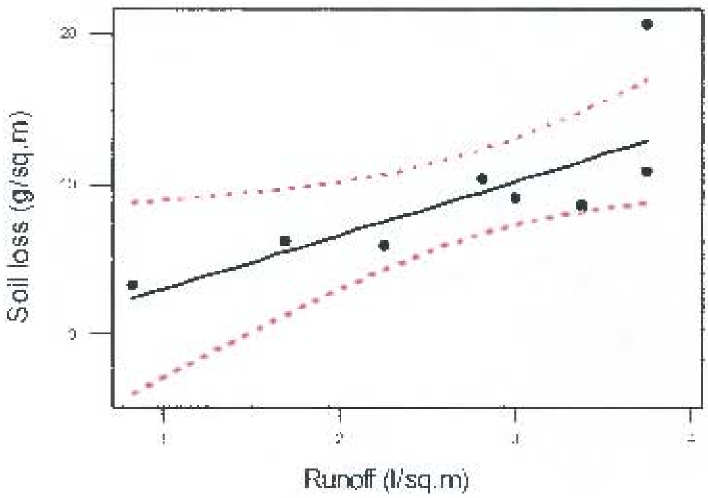



**Figure 5.17** Relationship between runoff and soil loss under constant rainfall intensity on the mid slope position

The simulation experiments, as demonstrated here, provide an opportunity to analyse the temporal relationship between runoff and soil loss. As shown in Figures 5.18 – 5.19 and 5.20 – 5.21, soil and runoff losses respectively varied over time. This temporal variation in runoff and soil loss showed an increase in general, for both the wet and dry runs.

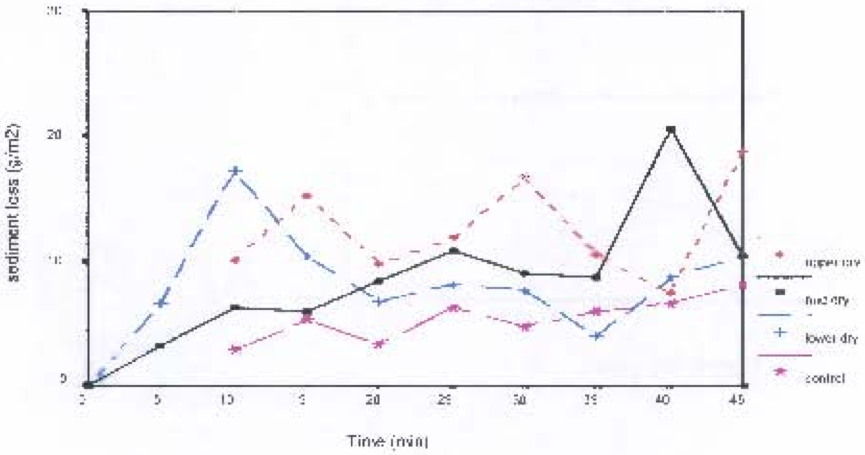



**Figure 5.18** Dry run soil loss for the different slope positions

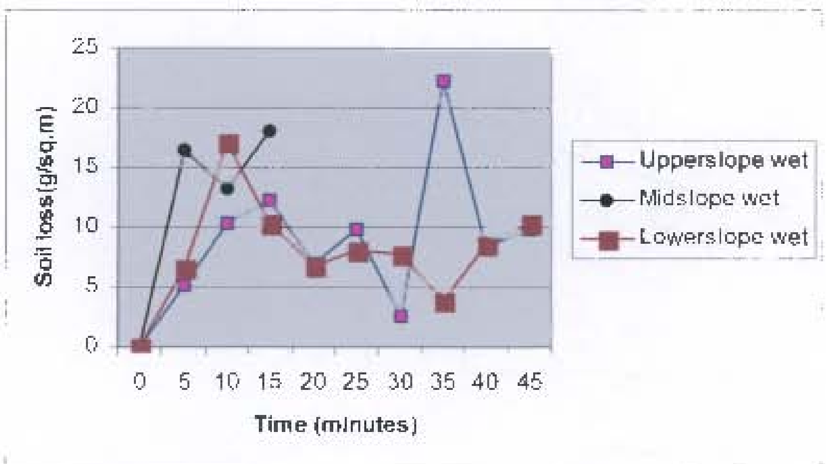



**Figure 5.19** Wet run soil loss for the upper, mid and lower slope positions

Generally, the results were characterised by normal fluctuation. There was a moderately gradual increase in the soil loss for both the entire dry and wet simulation. All the dry runs on the mid and upper slopes showed a sharp increase in soil loss in the first 15 minutes, then a more or less steady state up to about 30 minutes, after which there was an increase again in the final 10 minutes of the run. The wet run recorded a similar increase in the first 20 minutes, then a slight decline followed by a sharp rise to a peak for the upper and lower runs. The last 5 minutes recorded another decline. The dry run for the control on the lower slope recorded no soil loss until after about 10 minutes because of lack of runoff, and compared to other runs it had the lowest overall soil loss, which can be attributed to relatively high basal cover (90% cover). High percentage of basal cover retarded the runoff thus promoting infiltration rate.

Runoff discharges during the wet and dry experimental runs are depicted in Figures 5.20 and 5.21. All the runs showed a consistent dramatic increase in runoff within the first 10 - 15 minutes, then a decline and subsequent fluctuation for the rest of the experimental time. The decline and fluctuation in runoff cannot easily be explained but this was probably a natural random occurrence. The abrupt increase in runoff, after 30 minutes, for the dry run on the lower slope can be attributed to unanticipated increase in rainfall intensity caused by the observed slight deflection of the rains onto the plot due to the wind. Fluctuations in infiltration rate, appear to have been in part caused by the occasional destruction of the surface crust by the runoff and rainfall impact. As the original crust is destroyed a new one may form with time due to the raindrop impact, and again as would be expected, the runoff increased due to reduced infiltration rate.

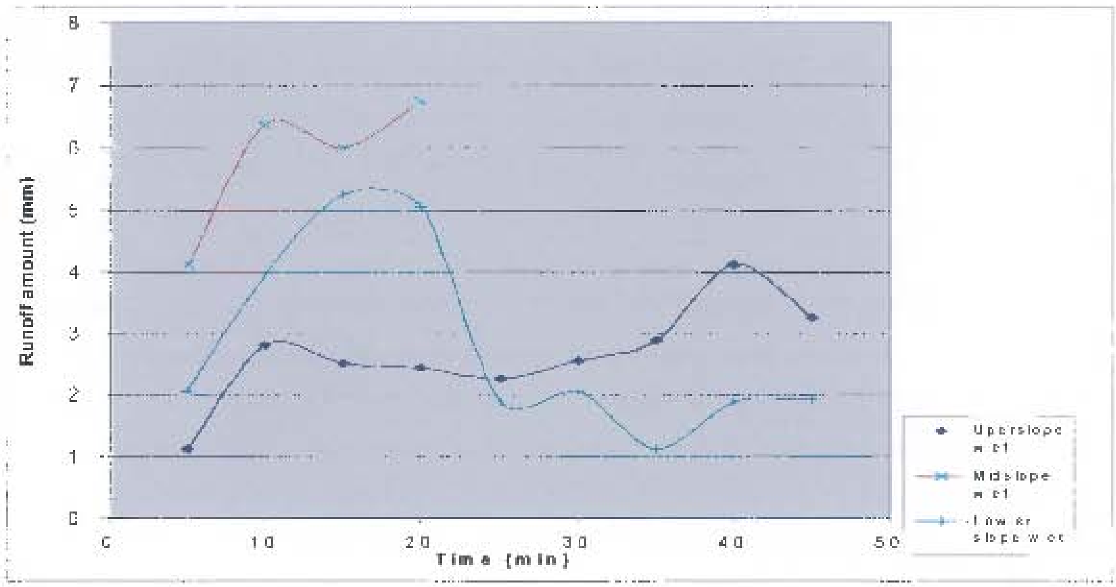



**Figure 5.20** Runoff discharge for the wet run simulation on different slope positions

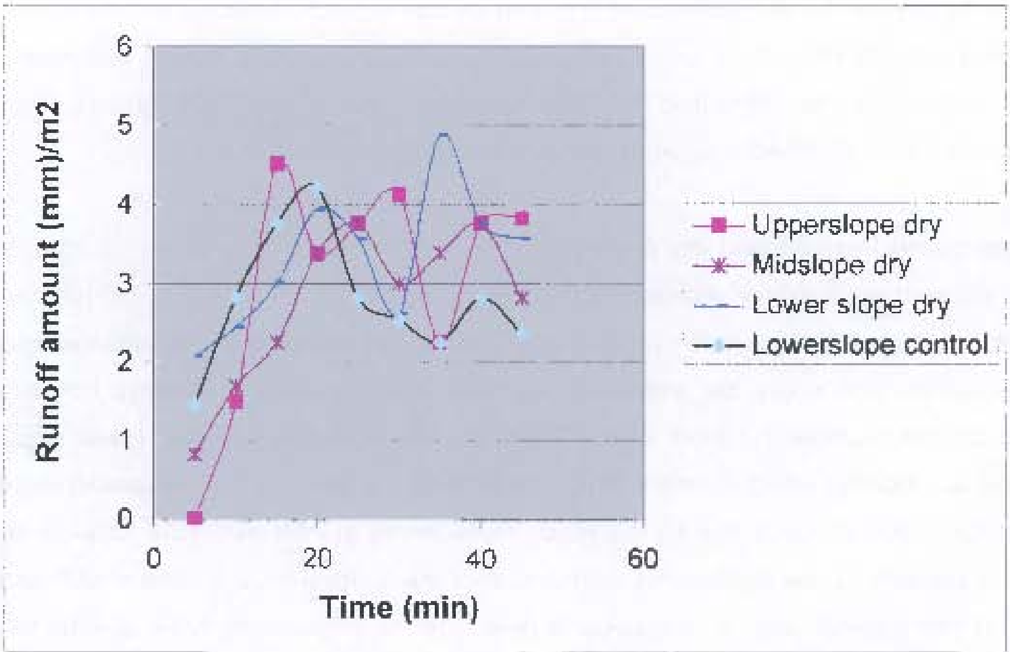



**Figure 5.21** Runoff discharge for the dry run simulation on different slope positions

The time for ponding and runoff initiation varied from one experiment to another as illustrated in Table 5.12. The ponding time for the dry run ranged from 34 seconds to 3 minutes, whereas that for the wet runs was the shorter and ranged from less than a second to almost two minutes. As expected, the runoff initiation time was relatively short for the wet runs compared to the dry runs i.e. the average difference in time between ponding and runoff for the dry run (1.76 minutes) was twice that of the wet run (0.71 minutes). It ranged from as low as 0.56 minutes on the lower slope for the wet run to 2 minutes on the upper slope position. For the dry run, it ranged from 1.30 minutes on the mid slopes to 6 minutes on the lower slope (control) dry run experiment. Interesting to note is the relatively short time for ponding and runoff initiation time for the bare lower slope. This is partly explained by the observed presence of algae coating and soil crusts, which are a common characteristic on bare patches that have been in existence for a number of years as earlier hinted on in this section. The short time for ponding and runoff initiation has negative implications for this rangeland in that the soils have inadequate time to absorb water hence much of it is lost as surface runoff causing either or both increased erosion and aridity. Further variations in ponding and runoff initiation may be a function of antecedent moisture conditions as described below.

**Table 5.12** Ponding and runoff initiation time during the dry and wet experimental runs

| Time | Upper slope | | Mid slope | | Lower slope | | Lower slope Control | |
|---|---|---|---|---|---|---|---|---|
| | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet |
| Ponding | 3 | 1 | 1.48 | 0.52 | 0.56 | 0.31 | 2 | 0.5 |
| Runoff initiation | 4.20 | 2 | 2.56 | 0.6 | 1.30 | 0.56 | 6 | 2 |

The antecedent soil moisture (Table 5.13) played a role in influencing both the ponding and runoff time. The average antecedent moisture was 10.0% prior to the dry simulation but it doubled (20.5%) after the rainfall. Higher antecedent moisture conditions, i.e. conditions closer to saturation, led to a shorter time for the ponding and runoff initiation. When the soils are relatively dry, the infiltration rate is high, thus delaying the ponding and the runoff initiation. Similar observations have been made elsewhere (e.g. Boardman, *et al.*, 2001).

**Table 5.13** Antecedent soil moisture during simulation experiments

| **Plot position** | **% Moisture** | |
|---|---|---|
| | Before dry run | Before wet run |
| Upper slope | 11.32 | 24.01 |
| Mid slope | 10.18 | 21.11 |
| Lower slope | 8.63 | 16.46 |
| Lower slope (control) | 10.20 | * |

** Data not available since wet run was left out*

## 5.5 ROLE OF FACTORS CONTROLLING SPATIAL VARIATION IN SOIL DEGRADATION

Environmental change in general and soil degradation in particular is influenced by various factors, although it is difficult to isolate the contribution of each (Goudie, 1977).

A complex of interdepentent factors relating to soil type, slope form, climate and land cover or land management determines the occurrence and spatial or temporal distribution of soil degradation. Faunal activity mainly by termites also compounds the problem especially on grazinglands. These factors are presented and their contribution to soil degradation discussed below. The environmental factors are dealt with first followed by the socio-economic factors.

### 5.5.1 Environmental Factors

Climate, soil type (erodibility), slope and macro-fauna were identified as the important environmental factors affecting soil degradation in the Nakasogola district. Each factor is examined and evaluated as to its contribution to the problem of degradation as follows.

#### *5.5.1.1 Climate*

Analysis of both historical and current climatic variability can help to account for the observed phenomena of soil degradation in this dryland. Pertinent to note, however, is that there is a dearth of long-term quantitative climatic records in Uganda, and in particular, for the Nakasongola district. Available rainfall records stretch back to the 1940s but the data are inconsistent; records are available for some years only and characterised by missing data for some months of particular years. Rainfall data in and around Nakasongola district for selected years with full records were used to compute the mean values and these are presented to support the arguments in this section. However, any further evidence of change has to rely on proxy data in the form of lake mean level (depth) changes in the region as analysed below.

One of the most marked examples of historical environmental change has been the fluctuating level of lakes in the tropics (Goudie, 1977, p149). The lakes of East Africa are known to be important indicators of environmental and climatic change on a long time scale (Nicholson and Yin, 2000). According to Nicholson and Yin (2000), the lakes have registered the pulse of rainfall variability in the equatorial tropics, hence historical records of their fluctuations can potentially provide a spatially and temporally detailed picture of this variability prior to the availability of actual rainfall measurements. As a starting point in reconstructing the climate in the 19th and 20th century, Lamb, cited by Zhebe (1995: 64), describes the temporal climatic fluctuation in East Africa as a proxy for rainfall fluctuations, by referring to fluctuations in the levels of Lakes Victoria and Tanganyika. The mean depth of Lake Victoria was approximately 13.5 m in 1880 but declined to 10.5 m in about 1902. It fluctuated from that time with a maximum depth of approximately 12 m. Lake Victoria's lowest level was reached in 1922 (Goudie, 1977, p149). Dramatic fluctuations were also noted to have occurred during this period, with Nicholson and Yin (2000) suggesting a period of continent-wide desiccation in the first decades and markedly wetter conditions in the last few decades (see Figure 6.13). Using a water balance model, these authors interpret the record of lake Victoria in terms of rainfall over the lake and its catchment.

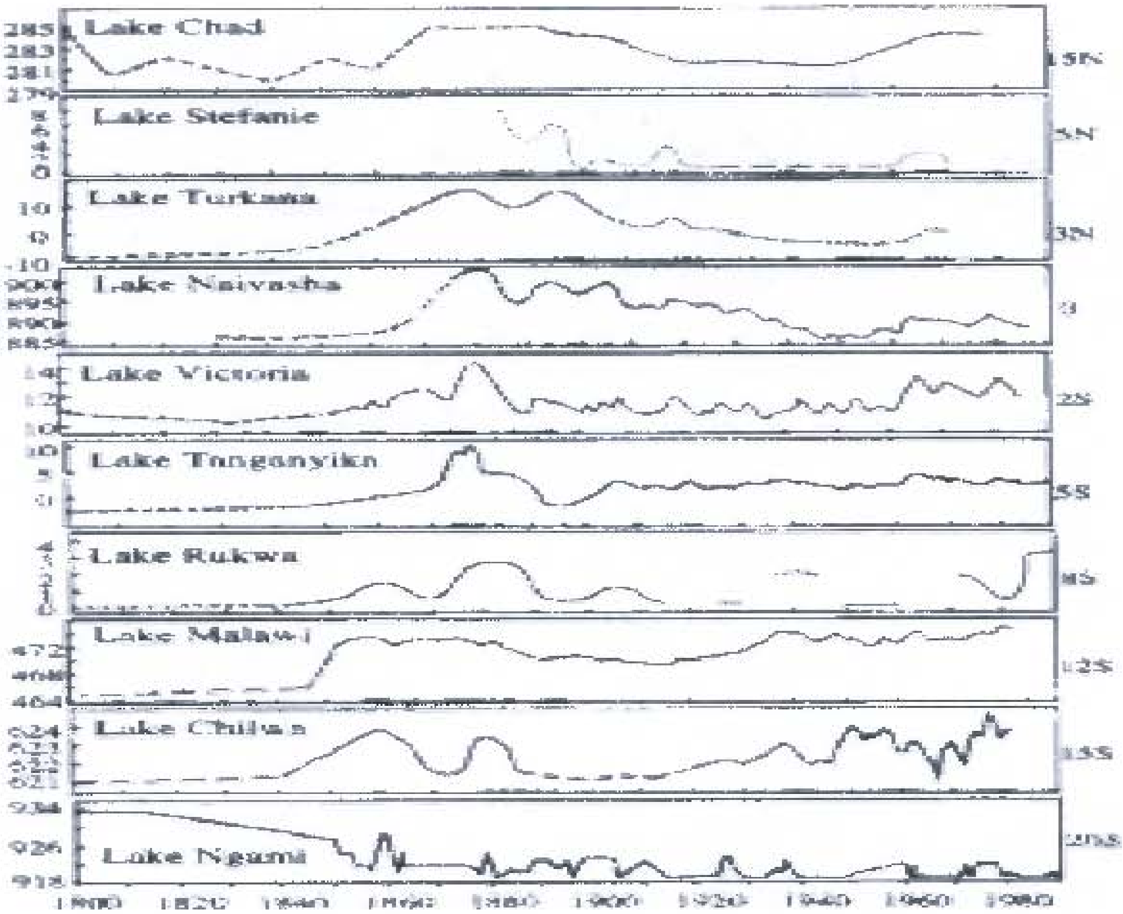



**Figure 5.22** A historical climatic fluctuation in African lakes (After Nicholson and Yin (2000)). The solid lines indicate modern measurements, short dashed lines show historical information and long dashed lines indicate general trends. Where indicated, the dots on the x – axis represent years with actual historical reference. The y – axis on the right shows latitudinal position and on the left, apart from Lake Naivasha, the values refer to mean lake levels (metres).

The level is noted to have increased in 1962 to about 13.5 m due to high rainfall at that time. Generally, the variation in the rainfall amount is closely related to the changes in the lake Victoria levels. The raised level of Lake Victoria (Figure 5.22) is correlated with the relatively high rainfall during that time for Nakasongola (Figure 5.23). According to Nicholson (1989), the trend in climatic conditions since the 1970s has been towards drier conditions at a continental level. The drier conditions were prominent in the early 1980s and late 1990s. The rainfall quantity received is lower than the evapotranspiration rate, which ranges from 1600 – 1750 mm per annum (NEMA, 1998), resulting in an annual water deficit accentuated by human activities such as deforestation that lead to soil exposure (see sub section 5.5.2).

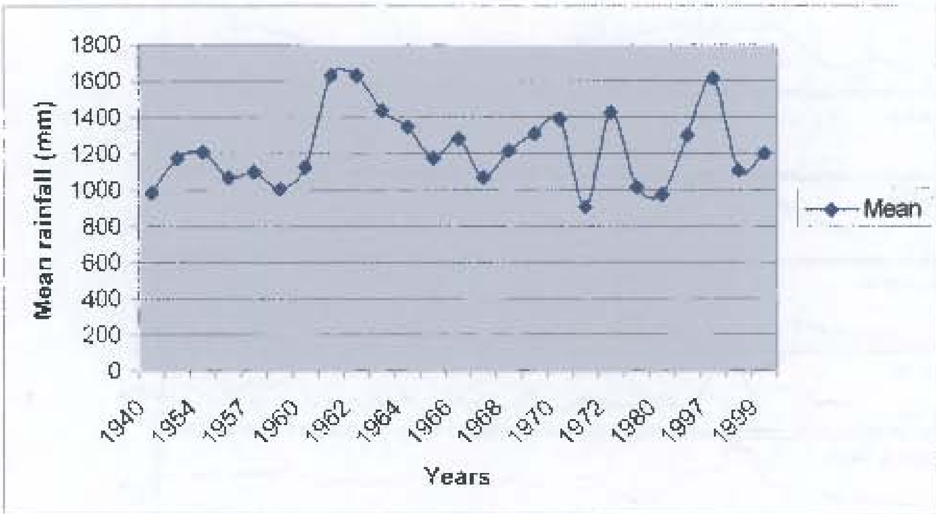



**Figure 5.23** Mean annual rainfall variations for the stations within and nearby Nakasongola district (Extrapolated from the Statistical records of Meteorological department, Entebbe, Uganda, 1960-1999)

The occurrence of drier periods leads to scarcity of resources, particularly water and pasture for livestock, and also poor vegetation performance and reduced vegetation cover. This contributes to structural deterioration of exposed soils through scorching. Overgrazing is usually apparent during such dry times in the Nakasongola dryland and, combined with bush burning, trampling and termite activity, this has contributed to the emergence of bare patches, which rarely recover over the short or medium term, even when the rains return to normal. The 'hotspot' sites are those with relatively shallow and poorer soils e.g. the plinthic type of soils (underlain by ironstone hard pan), particularly on the grazing lands.

### *5.5.1.2 Soil type and erodibility*

Soil degradation forms and processes are affected by soil physical properties including depth, texture, structure and chemical properties. These soil properties define soil erodibility (Stocking, 1994). Erodibility is defined as the resistance of the soil to both detachment and transport (Hudson, 1993; Morgan, 1995) by water or wind. It is a property that determines the vulnerability of a soil to erosion process. Its characterisation forms an important step in planning for sustainable agricultural landuse, implementation of effective management and conservation policies (Macharia, *et al.*, 1996).

The dominant soil types in this area are ferralsols on the hillsides and hilltops and hydromorphic soils in the seasonally wet and dry broad depressions. Some of the ferralsols can be categorised as plinthic ferralsols, which are underlain by a shallow hard pan within a metre depth especially on the crests and lower mid hill slopes. The rampant truncation of the topsoil and part of the subsoil by intensive water erosion (see Chapter 6) has exposed more friable and poorly structured soils; sometimes with iron concretions. In other places, the hard iron pans or boulders have been exposed or brought closer to the surface. The influence of the hard pan on water penetration is more significant when it is closer to the surface (sub-section 6.1 Chapter 6).

The exposure of hardpan or quartzite concretions on the surface as a result of soil erosion (Plate 5.5) not only influences infiltration, but also diverts surface runoff. This leads to concentrated linear flows that develop into rills. Water percolation is usually hindered on such surfaces leading to higher overland flow that accelerates erosion down slope. The hardpan layer has also played an important part, therefore, in influencing the development of erosion features such as gullies. Evidence from field observations indicates that gullies developing on such soils are shallower (<1m deep) due to the local base level formed by the hard surface. This contrasts sharply with the areas down slope on lower pediments where relatively deep U-shaped gullies (up to 2.5 m) have developed due to deep and loose sandy or sandy loam soils.

**Plate 5.5** Quartzite concretions exposed as a result of removal of topsoil by erosion on the grazing land in Bizibitukula sub catchment, Migera parish

The plinthic ferralsol in this area have a fine to medium texture and weak structured subsoil, which therefore leads to a high susceptibility to erosion and compaction and crusting when exposed to the surface. Such soils are easily saturated and thus, usually suffer from intensive sheet wash.

The erodibility of the soils on different degradation surface conditions along the slopes was measured (Chapter 4) and the results are shown in Table 5.14. Generally, the erodibility was found to be low for both moisture regimes i.e. the dry and wet before and after the first simulation respectively. However, the lower- and middle slope degraded areas tended to have lower erodibility compared to the upper slope. The same pattern was observed for the wet run except on the middle slope position. The wet run resulted in relatively higher values for the upper (0.94) and middle slope (0.72). These results contrast with those by Majaliwa, et al. (2003) who obtained higher values on the lower footslopes compared to upperslopes in Rakai district in Uganda. Elsewhere in the tropics values of erodibility have been reported to be as high as 0.72 Mg/ha/metric R units by El-Swaify et *al.* quoted by El-Swaify and Fowne (1992) and the highest global value is 0.89 Mg/ha/metric R units. Erodibility is known to vary with soil texture, infiltration capacity and organic matter (Morgan, 1995). Though the soils in this area, particularly on the hill sides, were observed to have moderately high values of clay content (40% - 60%), the organic matter was quite low (<3%). As Evans (cited in Morgan, 1995) observed, soils with <3.5% organic matter are considered erodible. The observed tendency for the increase in the erodibility with time during the experimental runs, can be attributed to the weakening of the aggregates, which as explained further by Morgan (1995) lowers their cohesiveness, softens the cements and causes swelling as the water is adsorbed on to the clay particles. This reveals that soil erodibility is dynamic; varying with moisture content, texture and other properties. This has implication in terms of management of these soils calling for better protection of the surface to reduce soil loss by using mulching. Though not investigated in this study, the activities of insects such as termites, which were commonly observed in Nakasongola area, bring the soil to the surface especially during the dry season and this also is probably instrumental in altering the soil erodibility.

**Table 5.14** Soil erodibility (Ki) on different soil and degraded slope positions (n = 6) in Migera, Nakongola district

| Position & moisture condition | Soil type | Ki (kg $m^{-4}$ $s^{-2}$) |
|---|---|---|
| Upper slope | Moderately shallow ferralsol, | |
| Dry | degraded | 0.27- 0.62 |
| Wet | | 0.11 – 0.94 |
| Mid slope | Moderately deep ferralsol, | |
| Dry | degraded | 0.07 0.47 |
| Wet | | 0.53 – 0.72 |
| Lower slope | Shallow hard pan underlain | |
| Dry | ferralsol, degraded | 0.07 0.50 |
| Wet | | 0.09 –0.36 |

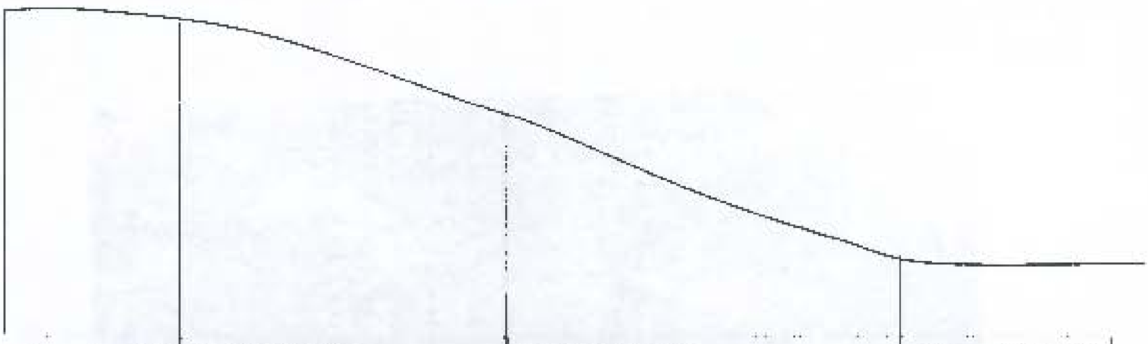
The soils in this area are prone to hardening when exposed to dry conditions. This coupled with low moisture holding capacity, probably as a result of degradation, leads to poor plant growth. Intensive grazing, particularly during the dry season, contributes to low plant basal cover that characterizes much of the rangeland. Bare soil patches are widespread on virtually all the 'poorly' managed rangelands (Plate 5.6)

**Plate 5.6** Bare soil patches in an a grazing land in Sija village after UWESO; note the intensively grazed area in the front and middle of the photograph. Bare patches have affected the surrounding grazing areas even underneatn the trees.

Soils in the low-lying areas have a high clay content, hence poor infiltration, and are thus susceptible to flooding during the wet season. They also experience inundation by sediments eroded from the surrounding degraded hill slopes.

### *5.5.1.3 Slope*

Slope length and form influence the rate and type of soil degradation processes. Steep slopes increase the volume and velocity of surface runoff, which causes detachment and transportation of soils (Morgan, 1995). As shown in Figure 5.24, low-lying areas experience water logging and soil deposition, whereas, the steeper slopes experience all forms of degradation including gully erosion, intensive sheet wash and rill erosion. Sites of very intensive erosion, especially on steeper hill slopes have truncated A and B horizons or exposed hardpan layer of quartzite rocks. Areas on hillcrests are mainly dominated by sheet erosion due to the pronounced effect of rainsplash and the inability of the runoff to effectively detach/entrain the sediment on such a gentle/flat landscape unit.



| | | | | |
|---|---|---|---|---|
| Slope gradient & form | 1 - 2° convex | 3 - 4° convex | 4 – 6° concave | <1°, relatively flat |
| Length (m) | 60 | 100 | 150 | 80 |
| Vegetation cover | Sparse vegetation, 30% bare, 30% trees & thicket | Sparse tree vegetation (e.g. combretum, albizia, euphorbia) ~30%, basal cover scanty (10 – 20%), 30–40% bare land. | Scattered tree (e.g. acacia and combretum) and thicket, 30-50% bare land partly covered by crust & coated by algae (15%), basal grass cover limited in patches (10 – 50%) | Thick cover, 60% basal grass cover, 30% woodland & bush, 10% bare |
| Erosion features | Sheet wash, few rills & exposed boulders | Sheet wash, rill prominent, exposed boulders, truncated A horizons, gully headcuts, cattle tracks running downslope. | Gullies (7 m deep) & ramified, gullies partly along former cattle tracks, intense rills and sheet wash, exposed hard pan and boulders, truncated A horizons | Deposition, limited sheet wash, water logging |

**Figure 5.24** Variation of soil degradation processes with topography along transect 1 in Bizibitukulo sub-catchment.

The morphology of the basin(s) plays an important role in the development of gullies. Based on studies in Lesotho, Nordstrom (1989) states that gullying does not require steep slopes. He observed gullies and gully heads on very low angle slopes of <2%. Slope length is an important factor affecting gullying mainly by causing a build up of runoff, hence increasing the erosivity. It was not part of the objective of this study to investigate the effect of slope length in the study catchments. However, though difficult to assess, it is expected that long slopes lead to generation and concentration of surface runoff, which increases the scouring action down slope. Deeper sections of the gullies were thus observed on lower pediments. Close observations also showed that apart from human and cattle tracks, runoff flow concentration lines were significantly influenced by surface morphology; areas of concave surfaces concentrated runoff compared to the convex ones, which diverged it. The local bedrock topography, as noted earlier in section 5.1, also affects gullying in a catchment more directly. For example, gullies were discontinuous due to bedrock outcrops as observed in many areas on the grazing lands in Nakasongola district. The rock out-crops (boulders), apart from obstructing runoff, also diverts and concentrates the flow on the land surface. This affects the development of sheet and rill erosion.

#### *5.5.1.4 Macro-faunal activity*

Termites, black ants and moles are biological factors that contribute to soil disturbance through increasing soil exposure. This occurs most commonly on the grazing lands. Earthworm activity is also very influential in mobilizing the soil for transportation by water/wind. This is achieved largely during the wet season. Earthworm activity-enhanced infiltration rate is known to greatly reduce water runoff and soil erosion (FAO, 2001; Edwards *et al.*, 1979 cited by Nilantha and Ezumah, 1992). They observed that earthworm activity increases transmissivity and hence infiltration rate by increasing the proportion of transmission pores (pore diameter >50 μm) through increasing the number of earthworm burrows in a given area.

The activities of macro-organisms also include soil exposure as a result of destruction of the vegetation and litter. Particularly important are the activities of termites as observed in the field and also based on the narratives of the local population. Sampling was undertaken to identify the termite genera and their level of activity. Table 5. 15 shows the main termite genera in the area and related intensity of activity observed in this area. The main genera identified include the *macrotermes, microtermes, cubitermes* and *trinervitermes*. However, the most dominant genera, as evidenced even by the mound distributions, are *macro-* and *micro-termes*. The mound population density ranged as high as 125 mounds per ha and 1000 mounds per ha for the macrotermes and microtermes respectively. This provides an indicator of the potential destruction of vegetation by these termites in this area.

**Table 5.15** Main termite genera and intensity of activity related to degradation

| Species | Population frequency | Intensity of activity | Remarks |
|---|---|---|---|
| Macrotermes | High | High | Commonly occurs anywhere, feeds intensively on dry matter |
| Microtermes | Moderate | Moderate to high | Occurs anywhere plus low-lying areas |
| Cubitermes | Low | Low | |
| Trinervitermes | Low | Very low | On trees |

The local people interviewed indicate that not all termites are destructive. The *empawu* (local name for macrotermes) is recognised particularly by the herders to be the most deleterious. The macrotermes were observed to be active and widely distributed in the area. They feed on almost all types of organic matter but most particularly drier plant material such as grass. Thus, their activities are amplified during the dry season when they graze intensively on dry matter. This contributes to exposure of soils to erosive agents like rain and surface water runoff. The grasses fringing bare patches are susceptible to wilting and drying whenever dry conditions set in, and this too makes them highly palatable to termite. Many bare patches, ranging from $1m^2$ to $10\ m^2$ in diameter, were observed particularly around termite mounds, and where conditions permit, these patches coalesce creating enlarged bare patches (Plate 5.6). Bare patches are sites of increased runoff generation due to reduced infiltration caused by clay rich soils from termite mounds. The role of the termites in contributing to the acceleration of soil erosion and expansion of bare patches has been recognised elsewhere in tropical Africa. For example, in Tanzania, Christianstiansson (1981) reported considerable amounts of material from termite terrain due to splash erosion and overland flow.

### 5.5.2 Socio-Economic Factors

Soil degradation is influenced by both natural and socio-economic factors (Blaikie, 1985; Morgan, 1995). The major socio-economic factors considered here are those that contribute to changes in landuse/cover such as grazing, cultivation, tracks, built area and settlement.

*5.5.2.1 Land use/cover and practices*

Land use and vegetation cover in general are the major input in defining actual risk to erosion. The land use/cover types in the study area (Table 5.16 and Figure 5.25) were identified as described in Chapter 4. Grazing land, which includes bush land, grasslands, trees and shrubs (woodland) and wetland, occupies around 77% of the total land area; cropland occupies about 16%, built up areas covers a small percentage area (0.2 %) and the rest of the land area is occupied by water bodies (6.8%).

**Table 5.16** Land use types identified in the Nakasongola district

| Landuse/cover | | Area (km²) | % Area |
|---|---|---|---|
| **Grazing land** | Bare rocks/soils | 0.0 | 0.0 |
| | Bush land | 495.8 | 14.1 |
| | Deciduous trees | 0.0 | 0.0 |
| | Grassland | 769.7 | 21.9 |
| | Trees and shrubs | 1281.2 | 36.4 |
| | Wetland | 157.4 | 4.5 |
| **Cropland** | Commercial farmland | 0.7 | 0.0 |
| | Mixed farmland | 548.1 | 15.6 |
| **Forest** | Coniferous trees | 17.1 | 0.5 |
| **Other** | Built up area | 7.6 | 0.2 |
| | Open water | 240.4 | 6.8 |
| **Total area** | | **3518.1** | **100.0** |

Grazing and crop farming, which are the main landuse practices in this area, have a great influence on the nature of land degradation in general and soil degradation in particular, as discussed below.

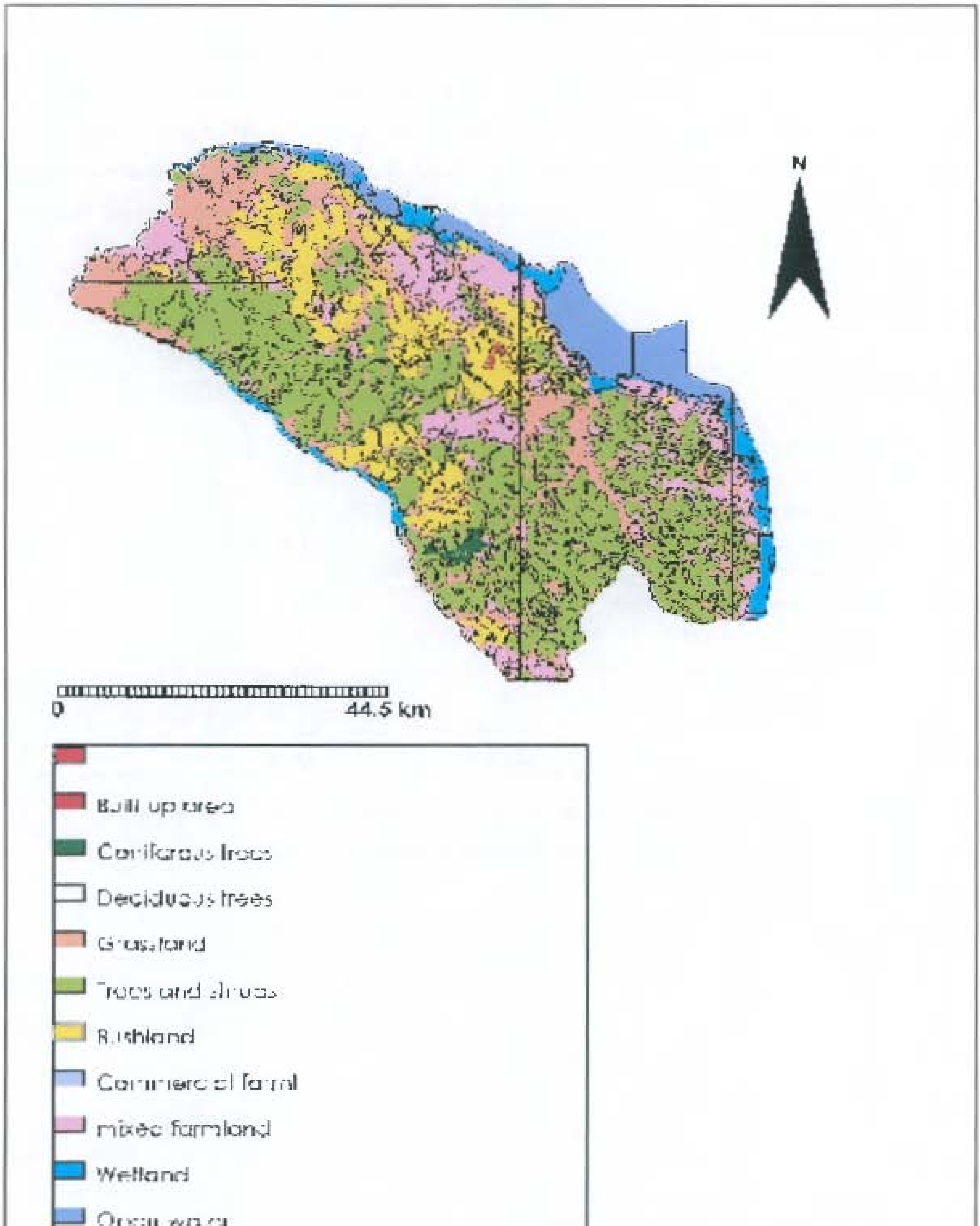



**Figure 5.25** Land use map of Nakasongola district based on Remote Sensing image interpretation (Data source from Kawanda Research Institute and National Biomass, Uganda)

**1. Grazing land use**

The present land use and the problem of soil degradation are due to the interplay of several factors including human population pressure, government policy and civil conflict particularly in the 1980s. Soil degradation on the grazing lands cannot be fully understood without placing it in an appropriate historical context. The historical profile (Figure 5.26) derived from PRA discussions shows the complexity of soil and land degradation as involving the interplay of both human and natural factors. It is impossible therefore to attribute the present degradation problem in Nakasongola district to a single cause.

In the 1960s, the human and livestock population was relatively small (estimated at <50,000) and communal grazing was widely practised. No problems of soil degradation were observed or reported in the 1960s as revealed by the informal interviews with the local people. Subsequent events, however, are likely to have contributed to the susceptibility of the area to soil degradation. In the 1970s, numerous changes were observed including increase in the human and cattle population, overgrazing, appearance of *biwalamata* (local word for bare patches) and increased termite activity. The civil war (*Museveni war*) in the early 1980s displaced many people but most of them appear to have returned after the war in 1987 and no doubt the human population and associated livestock population increased, although there are no formal population statistics to confirm this. Drought conditions, experienced in late 1980s and compounded by termite activity, undermined the vegetation cover hence the growth of *biwalamata* escalated again. In the 1990s, charcoal burning became widespread and many areas particularly on grazing lands around Migera town were devegetated thus, exposing the soils to erosion.

The government ranches that were established in the 1960s were restructured and distributed among the nomadic pastoralists in 1993. The district officials interviewed indicated that there were many pastoralists during that time (in relation to the available land) that had migrated from Rwanda and the districts of Masindi and Luwero. Therefore, due to land shortage, most of them were confined to smaller sized ranches in relation to their actual herd size. Consequently the grazing practice adopted was unconstrained within the perimeter fenced land. Intensive grazing on grazing lands of small unit size coupled with limited access to non-degraded grazing land elsewhere additionally contributed to problems of localised overstocking and overgrazing, which was widely experienced on the rangelands. The deterioration in vegetation cover on the localised overstocked and overgrazed areas contributed to bare patches, which are presently sites of intensive soil erosion as observed in the field.

The local initiatives (Nalukonge Pilot Project) to deal with the problem of soil degradation and water scarcity were supported by UNDP and the national under the umbrella of CCD. The local people were sensitised and trees planted on one farmer's land. The drought conditions of the time destroyed some of the trees and grass planted along the bunds. At the time of these field studies there was an estimated 10 pine trees and 15 acacia trees planted in 1998. There are no actual records on the number of trees planted though the farmer claims over 100 trees were planted. The grass bunds and water diversion channels were ineffective probably due to poor planning and lack of maintenance.

According to the interviews with some herders the increasing land degradation particularly on grazing lands has bewildered them and yet they are inadequately oriented to other alternative land husbandry practices. This is discussed in more detail in Chapters 7 and 8.

**2. Livestock tracks and paths**

Human influence on soil degradation is also clearly manifested through livestock keeping that has created a number of tracks traversing the grazing land. Erosion features such as rills and gullies have developed in close association with these tracks and paths. Figure 5.27 shows the distribution of gullies in relation to the main cattle tracks and paths.

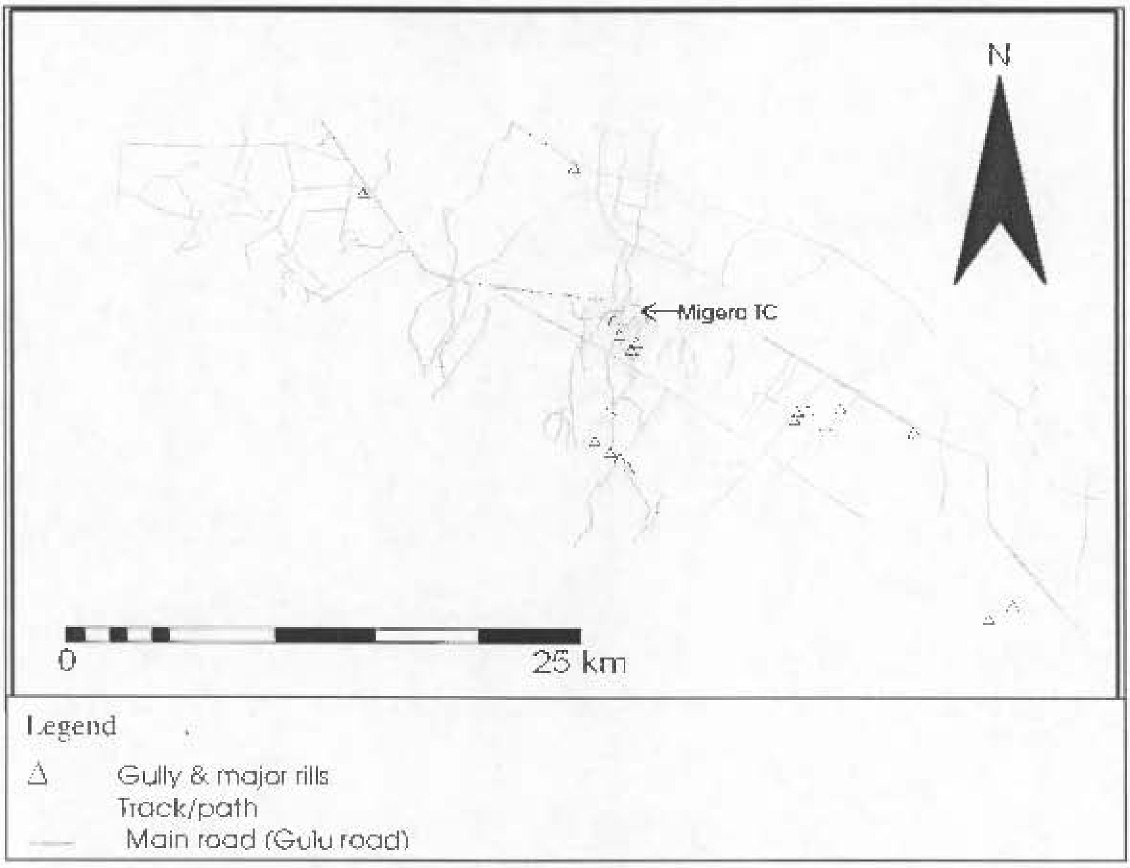



**Figure 5.27** Spatial distribution of gullies in relation to livestock tracks and paths

Gullies initiated by human activities have a characteristic pattern e.g. located along cattle tracks, road ditches or human tracks running down and upslope (Nordström, 1989). As observed in the Nakasongola district, an increase in infrastructure such as roads and tracks (*locally called ebihandagazi*) is likely to have contributed to an increase in runoff from the compacted surfaces that constitute a potential for gully development, especially along the poorly maintained road diversion channels. Increase in livestock population, probably due to the corresponding increase in human population in the area, has also led directly to a general reduction in vegetation cover and the development of stock routes or tracks and associated accelerated soil degradation including gullies. Stock routes traversing the slopes appear to be less susceptible to gully development. In a related environment in Tanzania, Kangalawe *et al.* (1999) observed extensive gullies on the hill slopes formed along the former cattle tracks aligned down slope.

**3. Livestock population on grazing land**

Although difficulties were encountered in obtaining absolute livestock numbers from herders and even the official statistics were unclear, the general impression as expressed by the district veterinary officer, is that the population has increased over time due to improved veterinary services, increase in human population and a positive attitude to livestock keeping. Based on the informal interviews, it was noted that in contrast to the past, herders are now willing to meet the costs of veterinary treatment. The herders are currently more knowledgeable about the dangers of diseases posed to their animals and the benefit of having health livestock. Veterinary services have therefore been utilised more frequently and animal mortality has declined. The estimates of livestock total population and densities by sub-counties are shown in Table 5.17. Nabiswera and Wabinyonyi sub-counties had high livestock population densities (>50 cattle per km$^2$) in the district.

**Table 5.17** Livestock population in Nakasongola district

| Sub-county | Area (km$^2$) | Livestock population | Density (Cattle per km$^2$) |
|---|---|---|---|
| Nabiswera, Nakitoma | 1363.86 | 86,591 | 63.5 |
| Lwampanga | 441.44 | 20,709 | 46.9 |
| Kalungi | 671.71 | 36,319 | 54.0 |
| Kakooge | 511.09 | 25,459 | 49.8 |
| Wabinyonyi | 436.37 | 19,140 | 58.44 |
| Total | 3424.47 | 151,600 | 44.27 |

*Source: Veterinary department, Nakasongola, 2004/5, and Livestock and animal industry, Entebbe. The data was corroborated with field observations and interviews during this study.*

Livestock in this area is viewed as wealth in both social and economic terms. Therefore, each household strives to own some animals even if it does not own land; opportunities for renting land for such purpose are usually available and the practise is common. This however, has augmented increased densities of livestock on grazing land and associated problems of vegetation destruction and trampling. Destruction of vegetation induces degradation of soils, particularly along the stock routes and around the kraals or camping sites. Patches of intensive grazing and bare soils were commonly observed in the sub-counties of Wabinyoyi and Nabiswera/Nakitoma where population densities are high and Figure 5.2 reveals that these two sub-counties are severely affected by soil degradation. Interviews with local herders revealed that some ranches support densities as high as 10 LU per ha at the expense of the range condition. Under such conditions, the rangeland is bound to degrade further. There is urgent need to address the issue of overstocking and overgrazing on the affected rangelands through integrated campaigns aimed at e.g. rehabilitation or replanting of suitable pastures and de-stocking.

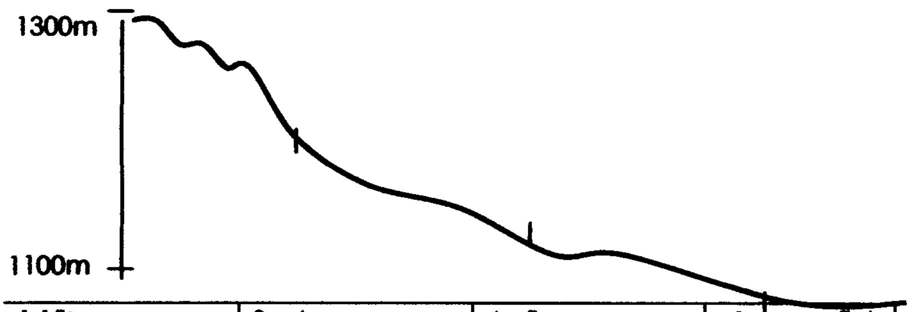
**4. Cultivation**

Cultivated land is the second most important type of land use in the study area. Figure 5.28 shows a typical cultivated sub-catchment and related erosion features along transect 3. A variety of crops are grown mainly on the mid and lower pediments below the steep parts of the inselbergs. The major crops grown are cassava, sweet potatoes, maize, finger millet, cotton, groundnuts and beans. The main cropping system is intercropping for purposes of maximising the land and minimising risks of crop loss. The fields are cleared in February and March ready for planting in April to May when the rains are received. Preparations for crops like groundnuts involve clean weeding; weeds and plant residues are removed and/ or burned. The soils are thus, exposed to erosive rainstorms at the beginning of the wet season (Plate 5.7). Sheet erosion is experienced during this time although the rate may decline as crop cover increases with time.

Soils on selectively sampled cultivated lands were observed to be weakly structured (friable) probably as a result of over cultivation. Continuous cultivation destroys the soil aggregates leading to low aggregate stability (Robertson, 2001). Poor soil structural stability often leads to puddling, crusting and formation of indurated surface horizons (FizPatrick, 1986; Magunda, 1992). The critical nutrient levels for soils in Uganda (Tenywa, 1998) are 2.28% for OM; pH of 5.5; 0.12 for N; available P of 5 ppm; 0.88 Cmol/kg for Ca and K of < 0.38 Cmol/kg. Many of the cultivated fields sampled (40%) had nutrient levels below the critical level and showed signs of nutrient deficiency; stunted crops with yellowish leaves indicating nitrogen deficiency. Poor crop performance is often associated with poor cover, which implies a higher potential rate of erosion (Elwell and Stocking, 1982).

The tree cover on most cultivated fields sampled is low ranging from 5 % to 30%. The main trees grown are mangoes, pawpaw and Ficus spp. Trees are known to play an important role in intercepting rainfall impact (Meunier, 1996; Morgan, 1995) and contributing to soil fertility improvement (FizPatrick, 1986; Sanchez, *et al*., 1997) so that reduced trees or tree cover on the farms points to the high potential of soil erosion in this area.

Height a.s.l (m)




| | | | | |
|---|---|---|---|---|
| Slope gradient & form | 1-15° convex, inselberg | 3 - 4° convex | 4 – 5° concave | <1°, flat, valley |
| Length (m) | 80 | 200 | 250 | 70 |
| Agricultural land use/ cover | Grazing, sparse vegetation, 30% barerock, 40% shrubs & thicket. | Grazing and cultivation, sparse tree vegetation (e.g. ficus spp, albizia, mangoes) ~30%, basal cover scanty (10 – 20%), 30-40% bare land. | Few trees (e.g. acacia and combretum) and thicket, crops grown e.g. cassava, beans, & groundnuts. 10-20% bareland | Thick cover, 60% basal grass cover, 30% woodland & bush, 10% bareland |
| Erosion features | Sheet wash, few rills along tracks, exposed boulders | Sheet wash, truncated A horizons, few cattle tracks running downslope. | Intense rills and sheet wash, exposed hard pan (10%) and boulders, truncated A horizons | Deposition, limited sheet wash, water logging |

**Figure 5.28** Erosional features and associated land use along transect 3 (Sikye hill to Machum valley)

**Plate 5.7** Intensive erosion on cropland at the start of the wet season in Machum village: note the sheetwash and rills developing in the foreground of the photo taken along transect 3 on lower slope section (see Figure 5.78).

**5. Built area, settlements and roads**

The influence of the built areas (e.g. Migera town council) and settlements on soil degradation is reflected in the generation of surface runoff. This study did not address this issue through direct field measurements but based on field observations, the surface in the built up areas and the surrounding of settlements was usually compacted and therefore the infiltration of the rainwater is reduced. Roads form another impermeable surface that generates high surface runoff. Under inadequately controlled or poorly maintained disposal systems these developments are likely to augment the dangers of erosion on crop and grazing lands located down slope.

## 5.6 CONCLUSION

This chapter suggests, that based on western scientific methods of assessment, soil degradation is a problem in the Nakasongola district. Soil degradation in this area manifests itself in various forms including erosive types such as sheet wash, rill and gully erosion; the non-erosive types include crust, sealing and soil extraction for brick making. The dominant form identified was sheet wash, which occurs on grazing lands and croplands. Gullies were more localised mainly on hill slopes of poorly managed grazing lands. The development of gullies was observed to have triggered other soil degradation processes particularly in the inter- and within- gully areas; active sheet and rill erosion and soil topple were observed. The nature and distribution of these various forms is mainly governed by interacting factors of topography, soil type and land cover. The different erosion forms prevailing in this area imply that different kinds of risks and the technical measures to redress these are not necessarily the same.

Soil erosion by water, which is the dominant soil degradation process in this area, was measured. The findings indicated high runoff and soil losses, particularly on bare lands, on the rangelands. Runoff from degraded areas was twice that of the non-degraded plots. The soil loss on severely degraded plots was ten times more than that from non-degraded plots. However, as observed by Stocking and Clark (1999), soil eroded upslope may not necessary be lost but redistributed on the lower slope. These studies were not designed to determine the net soil loss. High runoff was mainly attributed to the compacted soils with low infiltration rates and development of crusts. Low infiltration is also promoted by the shallow nature of the soils, which are underlain by iron hardpan (iron concretions) in quite a number of places. The iron hard pan is an impervious layer, which when exposed contributes to high surface runoff generation. The soil erodibility in the area is generally varying from low to moderate but tends to be higher on the upper slopes and generally increases with soil moisture. The high runoff generation coupled with disturbances of soils by livestock and termites contributes to susceptibility of the soils to erosion especially on grazing lands. Therefore, better management techniques are required for the protection of the soils, particularly on the upper slopes.

The rainfall simulation experiments on the grazing lands have further demonstrated that erosion is high on bare soils but comparatively low in areas with relatively high percentage basal plant cover. As expected this emphasises the role of maintaining ample basal cover to counter problems of soil degradation. The simulation also revealed that surfaces coated with algae and crust generates high surface runoff. This has got a conservation implication in that lose of water through surface runoff exacerbates problems of water deficit in an already drier area. It was also observed that soil disturbances such as over trampling by livestock during the dry season leads to high sediment loss during the first rains of the wet season.

Soil degradation is an increasing problem in the central drylands due to a number of interplaying factors notably climatic fluctuations (uncertainties), overstocking and overgrazing in some areas and lack of application of proper land husbandry practices. Erosion by surface runoff is dominant especially on the hill slopes and upper slopes. Higher runoff and soil losses were measured on the grazing lands and mainly attributed to the reduction or degradation of plant basal cover. Similar observations of high erosion have been noted in related environments in Lake Victoria (Majaliwa, 2005) and largely attributed to poor management of agricultural lands (Majaliwa and Magunda, 2000). Many areas on grazing lands with bare and compacted soils are particularly susceptible to high runoff due to low infiltration capacity. It would normally be expected that an area of such less steep terrain with low soil erodibility ranging from 0.72 to 0.94 on grazing land should experience low erosion rates. However, considering the observations in the field, the situation is likely to worsen with more increasing degradation of vegetation cover compounded by termite activity and drier climatic conditions.

As further shown in this chapter the process of soil and land degradation has been greatly accelerated by land use/cover changes; intensive grazing reflected in increasing livestock numbers; deforestation for farming and charcoal burning that lead to vegetation degradation, soil compaction and other forms of degradation. Overgrazing of this marginal and climatically sensitive area coupled with unplanned bush fires constitutes a degradation promoting land use, which further depletes the available land resources.

Gullies are slowly but increasingly becoming a dominant phenomenon in the degraded areas of Nakasongola district. The major factors for its growth and development include cattle and human tracks aligned up and down the slopes and changes in land use cover that leads to rapid concentration of the runoff. The main strategies in the control of these gullies in this area should be directed to reducing stock to appropriate numbers particularly in the seriously affected areas and practising prudent livestock management techniques, including desisting to move the stock up and down slope from the watering points. Related to this may be the need to install more watering points (dams) to lessen the pressure along the current tracks. Efforts should also be made to commit the land users to the rehabilitation of the degraded land, be it cropland or grazing land. The maintenance of dense cover seems to be important, considering that areas with ample vegetation cover were little affected by gully erosion. This technique has been recommended in Swaziland Morgan and Mugomezuzulu (2003), where the main cause of the gully development was the Hortonian overland flow. The issue of gully erosion is picked up in the concluding Chapter 8.

In this chapter, the forms, extent, magnitude and factors influencing soil degradation processes have been addressed. Soil degradation processes as addressed in this chapter are associated with various impacts, and part of the objective of this study was to investigate it. In the following chapter, both the physical and selected socio-ecological impacts associated with soil degradation processes, are presented and discussed.

# CHAPTER 6

# IMPACTS OF SOIL DEGRADATION PROCESSES

## 6.1 INTRODUCTION

Soil degradation has a wide range of impacts transcending the biophysical-chemical, socio-economic and political dimensions. The impacts of soil degradation may be positive or negative hence presenting 'winner' and 'loser' situation (Stocking, 1995). This chapter presents and discusses results from a scientific perspective and relates this to the indigenous or local peoples' perspective. Emphasis is placed on changes in selected physical and chemical soil properties largely caused by degradation processes such as erosion in the Nakasongola district. The chapter also addresses some aspects of the implications of degradation on the soil macro-fauna and general productivity of the area.

Soil erosion causes loss of nutrients through rain splash and overland flow, which remove the most fertile, lightest and smallest particles of clay and organic matter (Stocking, 1998; Morgan, 1995). Most semi-arid soils have low organic matter (om) of <0.2% and correspondingly low nitrogen (N), phosphorous (P) and sulphur (S). Nutrient availability is typically more evenly distributed throughout the soil profile so there are no profound changes when the surface layers are removed by erosion, as is the case in the humid or temperate soils (Moore, 1981); the Nakasongola area is a dry sub humid area (Chapter 3). However, loss of surface soil is accompanied by loss of water and may also lead to exposure of stony or rocky infertile sub-soil horizons. During erosion, as observed by Moore (1981), the water passing across the soil surface is unavailable to plants at that site for transpiration. This water loss can amount to 5% of the total annual rainfall or to more than half the water in intense rainstorms (Baber *et al.*, cited in Moore, 1981). Loss of soil nutrients, water and sediments from upslope, however, may benefit the areas downslope where deposition occurs. In some cases deposition of eroded soils can be destructive when it covers the crops in low-lying areas.

As outlined in Chapter 4, sampling of soils was undertaken in order (i) to establish and compare the changes in selected biophysical and chemical properties due to degradation processes (e.g. erosion, vegetation) on grazing and farmlands, and (ii) to analyse the implications of these changes on soil quality for agro-production in a typical dryland of Nakasongola. Soil properties that may influence productivity, such as infiltration capacity, porosity, bulk density, texture, nutrient balance, rooting depth and profile development were analysed.

Primarily, the chapter presents and discusses the soil physical aspects (i.e. infiltration capacity, bulk density, texture and truncation of top soil horizons). Secondly, it addresses the chemical-related effects where a focus is placed on the major nutrients affecting plant performance. The analysis covers the implication of movement of nutrients, water and sediments across the landscape positions. Finally, the effects of gullying and changes in soil faunal distribution are dealt with.

## 6.2 CHANGES IN SOIL PHYSICAL PROPERTIES

Degradation by water and wind erosion removes the topsoil exposing the underlying sub-soil horizons whose infiltration rate and water-holding capacity are lower than the original surface horizons (Moore, 1981). This coupled with compaction by raindrops and trampling by animals, negatively impacts on infiltration rates, porosity and bulk densities of the soil as explained below. The changes in the physical properties have implications in terms of altering the soil's capacity to support plant growth and organisms living in it.

### 6.2.1 Infiltration Capacity

Infiltration capacity is defined as the maximum sustained rate at which water can enter the soil surface. The concept is often inadvertently used synonymously with infiltration rate, which is the actual rate at which water passes into the soil. Data on infiltration values under varying environmental conditions are an essential part of process investigation (Kirkby, 1978). According to Lal, cited in Zebhe (1995), infiltration capacity is dependent on the nature of the soil surface and structure within the soil horizons. Soil surfaces with reduced/low infiltration rates generate high runoff, hence increased soil loss down-slope as discussed in the previous chapter. The data on infiltration characteristics were derived from experimental field measurements as described in Chapter 4. The location of the experimental infiltration sites is given in Figure 3.10.

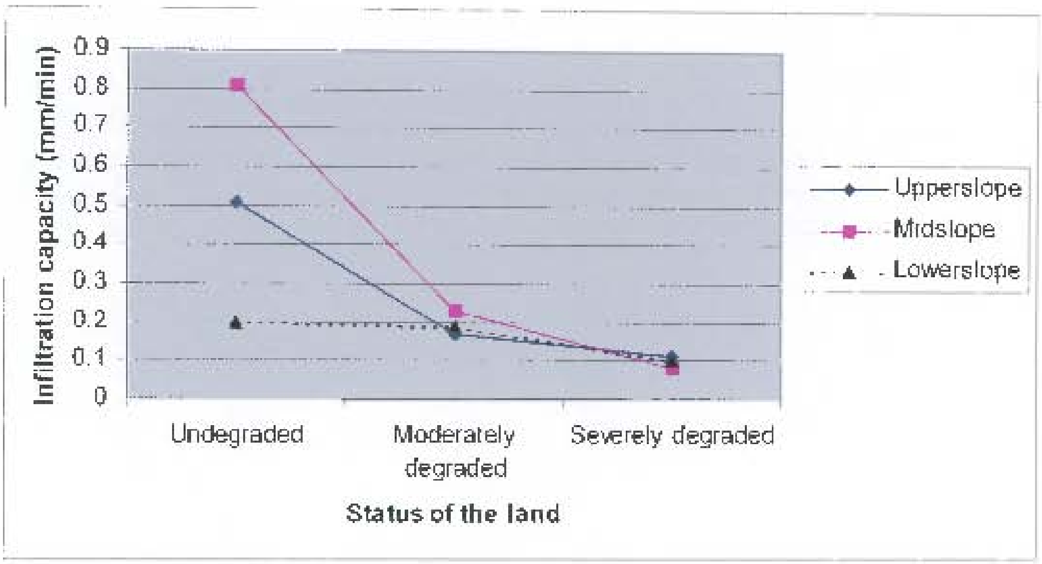
Table 6.1 presents data on the initial and final infiltration measurements for different degraded surfaces identified, namely non-degraded, moderately degraded and severely degraded. The data on detailed infiltration rates for different surfaces are provided subsequent to this analysis.

**Table 6.1** infiltration measurements on different levels of degradation soil surfaces

| Location | | Nature of surface HD="highly degraded MD=Moderately degraded LD=Moderately degraded | Infiltration rate (mm/min | | | |
|---|---|---|---|---|---|---|
| | | | Initial | Final | Mean | SD |
| Site 1 | (a) | MD | 0.8 | 0.1 | 0.45 | 0.49 |
| | (b) | | 0.7 | 0.15 | 0.43 | 0.39 |
| Site 2 | (a) | HD | 0.3 | 0.08 | 0.19 | 0.16 |
| | © | | 0.8 | 0.16 | 0.48 | 0.45 |
| Site 3 | (a) | HD | 0.9 | 0.13 | 0.52 | 0.54 |
| | (b) | | 0.3 | 0.1 | 0.2 | 0.14 |
| Site 4 | (a) | LD | 0.6 | 0.04 | 0.32 | 0.40 |
| | (b) | | 0.6 | 0.15 | 0.38 | 0.32 |
| Site 5 | (a) | HD | 0.2 | 0.08 | 0.14 | 0.08 |
| | (b) | | 0.5 | 0.08 | 0.29 | 0.30 |
| Site 6 | (a) | MD | 0.5 | 0.2 | 0.35 | 0.21 |
| | (b) | | 0.7 | 0.34 | 0.52 | 0.25 |
| Site 7 | (a) | HD | 0.2 | 0.04 | 0.12 | 0.11 |
| | (b) | | 0.2 | 0.12 | 0.16 | 0.06 |

** Highly degraded is used synonymously with severely degraded*

In general the results (Table 6.1) show that the severely or highly degraded surfaces are associated with lower initial and final infiltration rates compared to the moderately- and non degraded ones. Among other factors, this can be attributed to the compacted and crusted soil surfaces on degraded land. With a few exceptions, the final and initial infiltration capacities ($f_c$) are higher for most of the non degraded and moderately degraded surfaces than for highly degraded surfaces. High $f_c$ values are promoted by high sorptivity and maintained by relatively good soil structure with higher porosity associated with the less/non degraded soils (see Table 6.2). Figure 6.1 compares the $f_c$ values for the different slope positions and levels of degradation. A significant ($p<0.05$) difference in the $f_c$ value was observed between the different degraded surfaces, irrespective of the slope position and location of the catchment. Slope position had no significant effect on the variation of the fc in the catchments studied.




($F=22.5$; $df=2$; $p<0.05$)

**Figure 6.1** Mean infiltration capacities for different slope positions on different degradation soil surfaces

Details of the infiltration pattern and trend of different soil surface are depicted in the best-fit curves in Figure 6.2. These results compare with those of Zebhe (1995) in the semi-arid areas of Tanzania. He observed higher infiltration rates in the less degraded areas compared with the highly degraded areas of the same soil type.

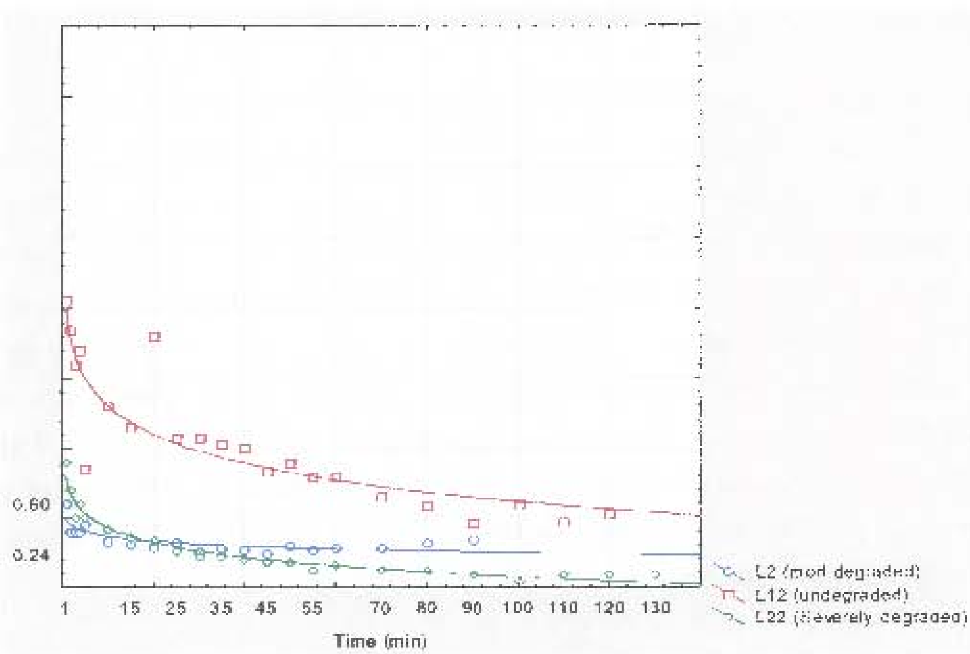



**Figure 6.2** Comparison of infiltration curves for different degradation levels in Nakasongola

In the severely degraded areas, the infiltration reaches equilibrium, ranging from 0.08 - 0.2 mm/min, in less than 15 minutes. The moderately degraded areas associated with infiltration equilibria, ranging from 0.3 - 0.5 mm/min after about 20 minutes. However, the non degraded area (patchy forest/woodland) had a much higher initial infiltration rate and there was a longer time lag to equilibrium. The infiltration capacity attained was greater than the severely and moderately degraded areas. These findings have implications in terms of surface runoff generation and accelerated soil loss. The degraded soil surfaces tend to generate higher surface runoff that leads to increased sheet wash down-slope as explained in the previous chapter. Lundgren and Lundgren (1972) in Tanzania similarly observed low infiltration rates in a heavily grazed and degraded rangeland, compared with the forest ecosystem but mainly attributed the differences to the hard unbroken duripan.

Differences in the infiltration rates were observed for soils of the same type and degraded condition on the same topo-sequence, as shown by the less degraded surfaces at site B4 (Figure 6.3); with grass and bush vegetation type on the lower slopes in Bizibitukula catchment. This was attributed to the presence of an underlying shallow impermeable layer of quartzite and laterite (barely 40 cm depth), which impeded water transmisivity. As shown by the best fit method, there is a possibility of no infiltration at all when the soils are fully saturated above the underlying hard pan. Under such circumstances, there is likely to be a reversed flow of water from this impervious layer towards the surface, thus causing increased surface runoff generation.
No observation of reversed flow was recorded in this study.

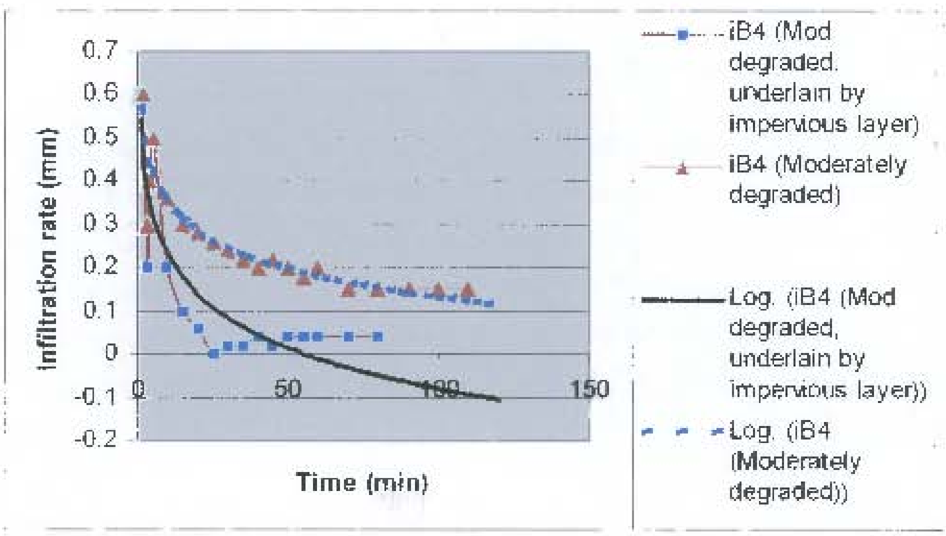



**Figure 6.3** Comparison of infiltration rate curves for the soils under degraded conditions on the lower slope.

Infiltration measurements were carried out in order to compare a highly degraded surface and a similar surface broken by cultivation using a hoe, on the same mid slope segment (Figure 6.4). The cultivated surface yielded a higher infiltration capacity compared with the uncultivated severely degraded surface. This could be explained by the broken crust at the surface as a result of cultivation, therefore implying that this technique can be applied to improve on the water penetration and hence reduce rapid surface runoff especially on the grazing land.

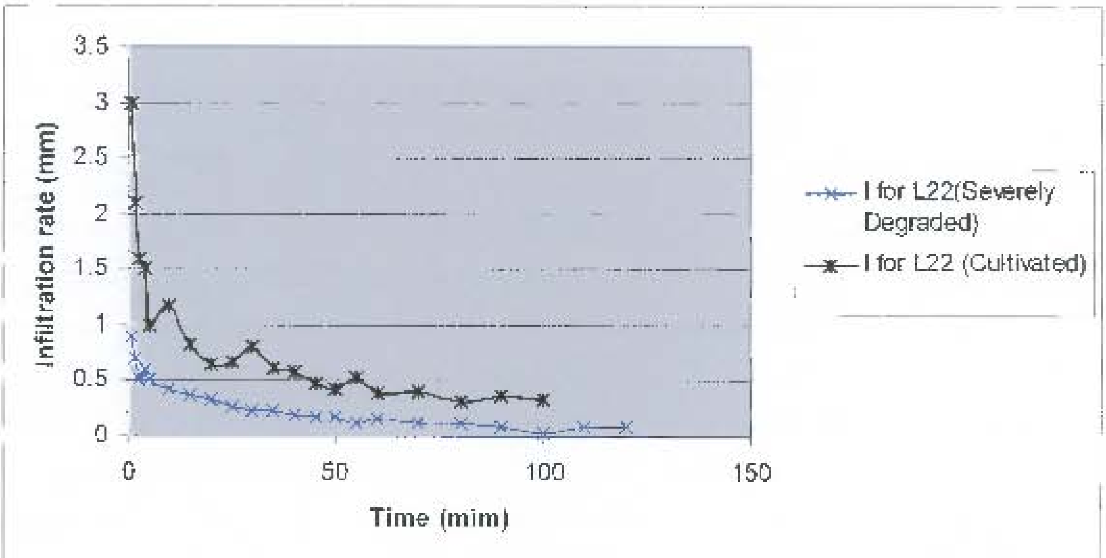



**Figure 6.4** Comparing the infiltration curves for the highly degraded and cultivated area

### 6.2.2 Bulk Density, Porosity And Mean Weight Diameter

Soil structural degradation can be characterised using bulk density, porosity and mean weight diameter (MWD) diameters. The assessment of soil degradation through compaction was limited to the topsoil because, as noted by Hakansson and Voorhees (1997), sub-soil compaction is not easily assessed. A good measure of soil compaction is bulk density (Hakansson and Voorhees, 1997). The major agent identified in contributing to compaction in the Nakasongola district was livestock trampling. Compaction by tractors was only observed on UWESO farm and a limited number of individual farmlands.

Table 6.2 shows the data on bulk density and porosity measured by sampling soils under different degraded conditions (severely, moderately and non-degraded) using the core method (Chapter 4).

**Table 6.2** Bulk density for soils under different degradation conditions in Bizibitukula and Machum catchments in Nakasongola district (n=16)

| Landuse | Surface condition | Bulk density (Mg/mg³) | Total porosity |
|---|---|---|---|
| Grazing | Non-degraded | 1.31 | 0.51 |
| | Degraded | 1.44 | 0.46 |
| | Severely degraded | 1.55 | 0.41 |
| Cultivated (ploughed) | Degraded | 1.39 | |
| | Non-degraded | 1.25 | |

The results reveal that severely degraded soils have higher bulk density, which could be attributed to the exposed and compacted sub-soils. The exposed sub-soils have high levels of clay (Figures 6.7 d - e) and low organic matter. Soils with higher levels of organic matter also display physical properties that make them less susceptible to compaction (Sali, 2002). Bulk densities of >1.45 mg $m^{-3}$ are considered high and were observed mainly on overgrazed lands. This is explained by the trampling effect due to grazing herbivores. Trampling is especially pronounced along the animal tracks and around kraals as compared with the rest of the grazing land. This has hydrological implications, such as reduced infiltration that contributes to increased runoff generation. High bulk densities may also result in high soil resistance to root elongation, hence affecting plant performance. Sali (2002), among others, also observed that compacted soil layers have high bulk density that restricts water and air movement and prevents penetration of plant roots, and that compacted layers are very hard and difficult to till. Although not a major object study here, observation showed low rates of plant regeneration especially on the more degraded areas on the rangeland (Plate 6.1). Based on the interview with the landowner, the area in Plate 6.1 was initially under *Themeda* grass cover with a few scattered shrubs and was not degraded. The invasion by thorny acacia shrubs could have discouraged livestock grazing on the lower slopes hence the dense plant growth. The area outside these thickets upslope remained under intensive grazing that reduced the grass cover, compacting and exposing the soil. The eroded soils including nutrients were deposited downslope contributing to the observed luxuriant plant growth.

**Plate 6.1** Variation in plant growth on the severely degraded and compacted area; note the poor regeneration in the foreground compared with the luxuriant growth in the background.

Non-degraded areas, including areas recovering from degradation and now under grass cover, have lower bulk density. Among other factors, this could be attributed to improved soil structure as a result of accumulated organic matter and increased plant roots and soil macro fauna activity.

The total soil porosity was computed, based on the bulk density (Db) and particle size density ($P_s$) using the formula $f = 1 - D_b / P_s$. Most of the degraded soils registered total porosity of ≤46% (Table 6.5). Degraded soils have less pore space mainly due to compaction, hence poor aeration and, as indicated in section 6.1, are associated with low infiltration, a factor that impacts negatively on root growth. These results are similar to those of Styzen (1992) in Nigeria. He observed that erosion caused changes in soil consistence and structure. Soil in the upper soil horizon had changed from granular structure in the non-eroded to porous massive in the eroded soil, and that at all sites the eroded soils seemed to be susceptible to crusting.

The structure of the soils under different degraded conditions was characterised using the mean weight diameter (MWD) as shown in Figure 6.5. The MWD of soil aggregates is an indication of the stable fraction of the aggregates in the soil system (Tenywa, *et al.*, 2001). A higher MWD indicates better structure (for plant growth) hence more stable aggregates. The soil samples from the non degraded areas had the highest MWD (p=0.003) compared with those from the degraded parts. Soils with low mean weight diameter coupled with low porosity (high bulk densities) are therefore likely to impact negatively on the water infiltration, water retention and root penetration hence plant performance.

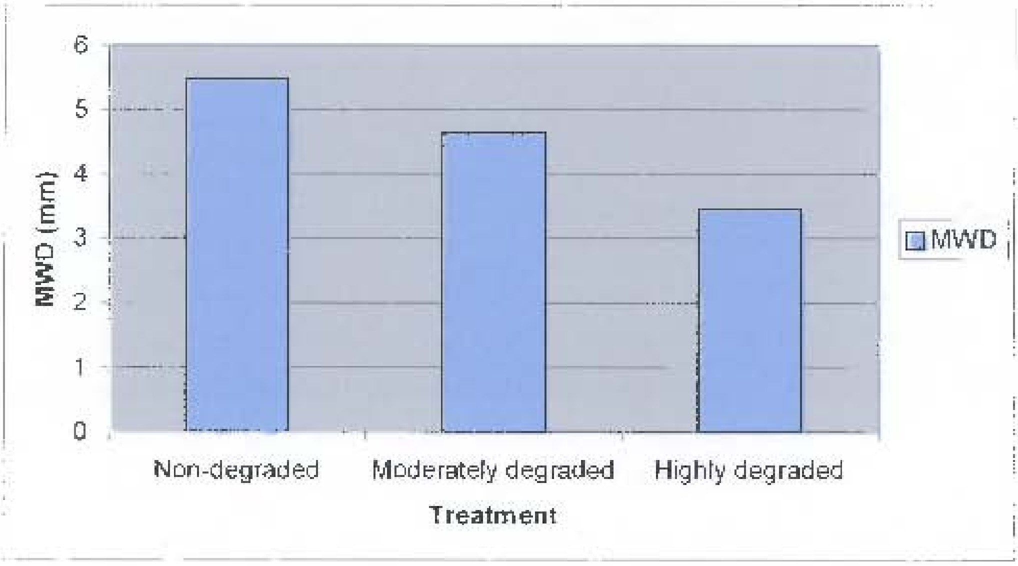



**Figure 6.5** Variation of mean weight diameter under different soil degraded conditions (LSD0.05 0.86)

6.2.3 Effect Of Erosion On Texture

The data on texture, as presented in Table 6.3, indicate effect of degradation on texture. The percentage sand, however, tended to be higher (51.04%) in the severely degraded areas, compared with the moderately degraded (46.57%) and non-degroded areas (46.83%). The local community, as revealed by the informal interviews, recognise the change to sandy soil texture (locally called *iusenyi*) in the degraded soils in Nabiswera Sub County. They expressed their concern for the exposed gravel soils (locally referred to as *ettaka lyo luyinja*) particularly on the degraded grazing lands as a result of intense sheet erosion. The changes in soil texture affect organic matter distribution. Studies in Uganda by Sali (2002) show that soil organic matter (SOM) depends on soil texture; where silt plus clay exceed 20%, the SOM ranged from 3.0% - 6.7% but where the silt plus clay were less than 26%, the range was 1.0% - 3.0%.

Field observations of soil profiles also indicated that clay content increased with depth within 25 - 50 cm, after which there was a decline (Figure 6.7 d - e). This trend may be largely attributed to the transport clay-sized particles downwards through the profile. Removal of the uppermost soil largely by intensive erosion processes has exposed the underlying, clayey soil sub-horizons to the surface in some areas that are severely degraded. As discussed in Chapter 5, there is stark evidence of intensive sheet erosion from the appearance of a multitude of ironstone boulders, which are largely of limonite and magnetite type. Related findings by Styzen (1992) showed that erosion brought a clay-enriched textural B-horizon closer to the surface and the clay content of the 'new' surface layer was greater than that of the removed surface layer soils in the Samaru and Jos in Nigeria. However, Styzen (1992) argues that the effect of erosion on texture is dependent upon hydrological conditions.

6.2.4 Truncation Of Topsoil Horizons By Erosion

Another important on-site effect that was commonly observed in areas of intense erosion was the truncation of the topsoil horizons A and B. In some areas, where serious erosion has occurred, the underlying sub-horizons consisting of iron concretions or iron hard pan have been exposed or brought closer to the surface, hence the 'transition' of the soil type from ferralsol to plinthic ferralsol (Figure 6.6), and evidenced by the truncated soils (Plate 6.7). Truncation of topsoil undermines the foothold for plant roots and water holding capacity.

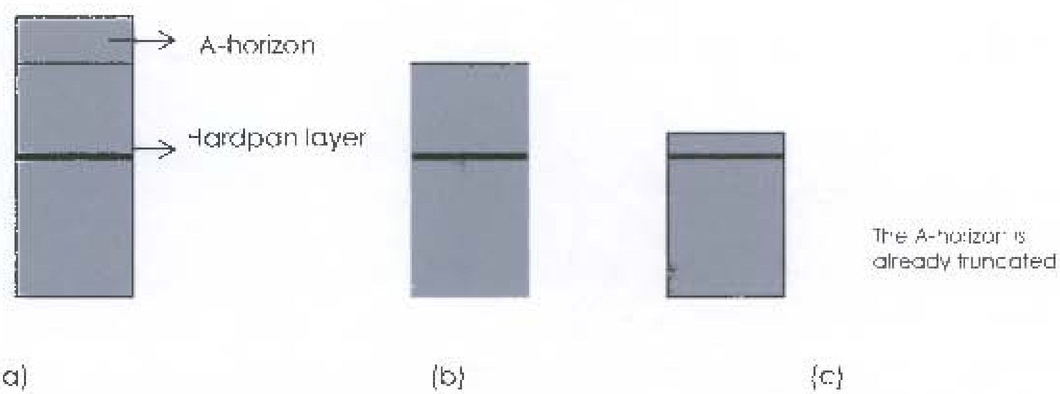



**Figure 6.6** A hypothetical soil profile transition from a typical ferralsol (a) to plinthic ferralsol (c) (Source: Based on research field observations of soil profiles)


**Plate 6.2 Typical** soil profile of a terralsol: topsoil truncated by erosion on the grazing land in Bizibitukula sub catchment in Migera parish

Changes in soil depth were corroborated with erosion pin assessments. Point measurements were taken using erosion pins and observations of the paint collars on boulders (Plate 6.3) to estimate changes in the soil depth (see Chapter 4). Soil pedestals were also observed for general assessment of denudation on the grazing land. The observations of the pins and paint collar on the boulder showed an average annual decline of 15.4 mm and 20 mm respectively, on the bare land. This change is considerable, taking into account the slow rate of soil formation in this area. Soil formation rate is known to range from 0.001 – 7.7 mm/year (Morgan, 1995). In Kenya, Dunne *et al.* (1978) estimated the rate in a semi-arid area to be ≤0.01mm/yr, which is not likely to be much different from that in the Nakasongola district.

Such changes in soil depth, as already explained, can lead to undermining the plant performance in various ways. The exposed soil patches observed particularly on the grazing lands are generally infertile, with low water-holding capacity and insufficient foothold for the plants especially with deep root penetration. Sediments or eroded soils plus nutrients and moisture are transported across the landscape. Areas down-slope benefit when eroded soils including nutrients and moisture are deposited thus leading to luxuriant plant growth. It may be argued that eroded soil from one area may benefit another area down-slope, hence no total loss to the overall productivity in the area or to an individual land user. However, in terms of individual land user(s) there is differential benefit where the land down-slope belongs to another person or is flooded at certain times of the year. Where such land in low-lying areas is susceptible to flooding, it is usually not available for grazing or crop production other than though cultivating water tolerant crops such as rice.

**Plate 6.3** Erosion pins and collar painting on a boulder to measure the changes in soil depth. The soil pedestals also reveal the changes in soil depth on the hillslopes.

## 6.3 CHANGES IN SELECTED SOIL CHEMICAL PROPERTIES

Table 6.3 shows data on organic matter and nutrient content for the different degradation surfaces identified on grazing lands. Generally, those nutrients associated with organic matter (N and P) and the cation exchanges of the soil colloids (K and Ca) are most at risk (Stocking, 1995). The details of the soil data and analysis are provided in Appendix 4.

**Table 6.3** Variation in soil properties for the different degraded soil surfaces on rangelands in comparison with the critical levels for Uganda agricultural soils

| | PH | Om | N | P | K | Ca | Na | Sand | Silt | Clay |
|---|---|---|---|---|---|---|---|---|---|---|
| Non-deg | 4.470 | 3.31 | 0.10 | 4.47 | 12.60 | 11.80 | 0.52 | 46.83 | 11.23 | 41.97 |
| Less deg | 4.38 | 2.35 | 0.07 | 2.73 | 5.60 | 10.50 | 0.42 | 46.57 | 7.52 | 45.97 |
| Highly deg | 3.80 | 2.06 | 0.03 | 2.07 | 8.25 | 8.01 | 0.66 | 51.04 | 6.51 | 42.53 |
| Fp | <0.001 | <0.001 | <0.001 | 0.115 | 0.017 | 0.058 | 0.188 | 0.673 | 0.020 | 0.773 |
| SED | 0.1920 | 0.2363 | 0.0111 | 1.208 | 2.16 | 4.59 | 0.1270 | 6.06 | 1.10 | 5.57 |
| LSD | 0.3982 | 0.4901 | 0.0238 | 2.50 | 4.4.86 | 9.52 | 0.2634 | 12.57 | 3.36 | 11.56 |
| CV% | 8.9 | 18.4 | 34 | 79.4 | 47.3 | 88.0 | 45 | 24.6 | 40.9 | 25.4 |

Soil organic carbon is a reliable measure of overall soil quality. As shown in Table 6.3, the mean ± SE% organic matter in the severely degraded soils (2.06 ± 0.47%) was not significantly (P<0.05, error df = 22) different from that in the non-degraded areas (3.31 ± 0.47%), although the organic matter level is below the critical level for both the highly and moderately degraded areas. The low levels of organic matter in the moderately and severely degraded areas are largely attributed to rapid oxidation and mineralisation due to exposure to aeration and high temperatures. Elsewhere, many researchers have observed similar declines in organic matter (e.g. Shukla and Lal, 2004). The low levels of organic matter suggest unstable structural aggregates that may collapse on impact of raindrops, enhancing runoff and erosion (Waruru and Wanjogu, 2000).

Ward et al. (1998) noted that organic matter is frequently highly and positively correlated with two of the most important soil nutrients, N and P, in African soils. Nitrogen and available phosphorous were relatively low and below the critical levels in all the different soils in this study area. Langlands (1974), based on work in the 1960s, pointed out the nutrient deficiency in this area. However, the mean + SE% nitrogen level in the severely degraded areas (0.03 ± 0.02%) was not significantly (P<0.05; df = 16) different from those in the less (0.07 ± 0.02%) and non-degraded areas (0.01 ± 0.02%).

The mean pH was more acidic in the highly degraded areas (3.80 ± 0.38) compared with the less degraded (4.38 ± 0.38) and non degraded area (4.70 ± 0.38), although statistical analysis showed no significant difference (p<0.05). The marked acidity in the degraded areas may cause P to be strongly adsorbed to soil colloids, thus rendering it unavailable for plant use (Ng'anga and Ekiripa, 2000).

The distribution of nutrients in the soil profile is very important in evaluating the possible effects of degradation processes such as erosion. Nutrients tend to concentrate in the upper soil horizons especially for the humid areas although this is not necessarily the case for the dryland areas as already noted above. The distribution of the nutrients was analysed for the soil pits under different conditions (Figures 6.7), with a view to evaluating the likely effects of continued degradation and truncation of topsoil by erosion processes.

In general, there is a tendency towards nutrient decline with increasing soil depth for all selected nutrient elements (Figure 6.7). This is particularly the case for organic matter and Nitrogen. However, the pH levels tended to increase with depth. The variation in texture is not clear or consistent though higher clay content was noted at 30 – 50 m depth probably due to leaching and illuviation. Therefore, continued removal of the top-soil by erosion will probably lead to more acidic and less fertile soils with greater deficiency in organic matter and nutrients such as nitrogen. The problem of low nutrient levels combined with low water-holding capacity, shallow underlying plinthite layer and reduced plant root depth (especially for the annual grasses), is likely to cause accelerated declines in soil quality for pasture production and crop farming. To a farmer this may also have implications for increased cost of rehabilitation of the degraded land. Also important is the reduced economic value of such a degraded land.

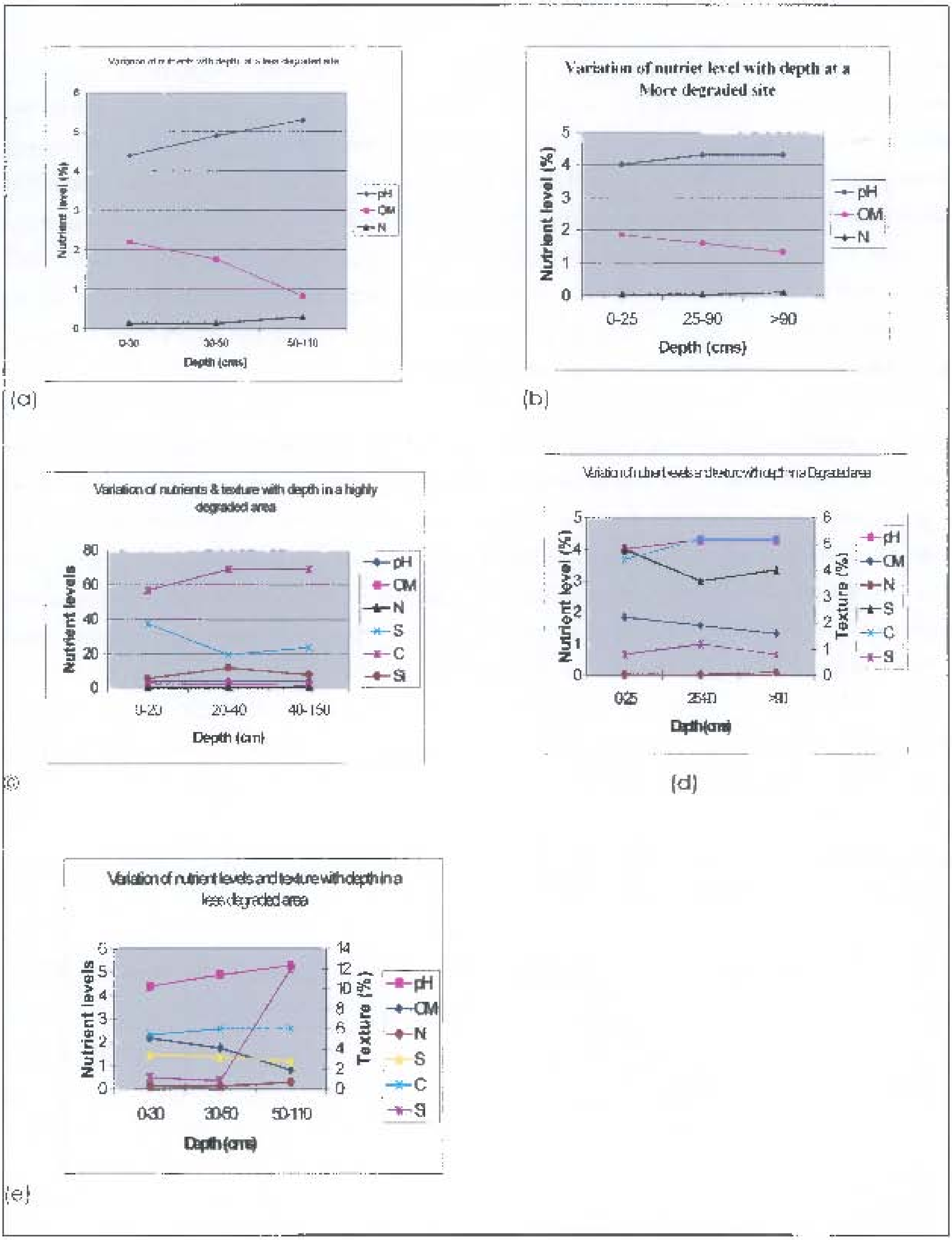



**Figure 6.7** Variation of nutrients and texture with depth for different levels of degraded soils; where S = sand, C = clay, Si = silt; OM = organic matter, N = nitrogen

## 6.4 CHANGES IN SOIL PROPERTIES WITH SLOPE POSITION

Soil moisture storage and availability vary with soil type, management, vegetation cover and position along the slope (Ekirapa and Muya, 2003). Soil properties, particularly particle size distribution, clay mineralogy, organic carbon and bulk density, influences water retention and release characteristics (Williams, et al., 1983). Soil structure, which influences pore size distribution is strongly related to the soil water characteristics of a soil. Soil water conservation requires data on water storage and its availability to plants. To investigate the relationship between soil moisture and topographic positions, soils were sampled along a transect running from the upper, the middle and lower slope segments (Chapter 4). These were analysed for their hydraulic properties i.e. water retention curves and available moisture.

Soil degradation not only leads to negative on-site and off-site effects but can have beneficial effects particularly downslope. The eroded soils including nutrients and water from upperslopes are transported and redistributed on the lower parts of the backslope and footslopes. Table 6.4 shows the average soil moisture and nutrients variation with slope position on grazing and croplands. The lower slope had significantly higher organic matter content. The water retention capacity was significantly higher (p=0.025) for the low-lying areas compared to the upper slope position (Table 6.4 and Appendix 19). The data also reveal that more water is held in micropores at high suction pressure in low-lying areas compared to the other slope positions. This may be attributed to relatively high organic matter. This variation in organic matter and water storage has implications for plant performance.

**Table 6.4** Variation of physical and chemical soil properties with the slope position in Bizibitukula and Machum sub cathments in Nakasogola

| Position | Depth | pH | om | N | P | Sand | Silt | Clay | Volumetric water content % at different water tensions* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 5cm | 20cm | 30cm | 40cm | 50cm |
| Upperslope | 0-16 | 4.0 | 2.2 | 0.03 | 4.5 | 37.8 | 7.8 | 54.5 | 53.93 | 38.40 | 32.83 | 27.93 | 30.53 |
| Midslope | 0-16 | 4.0 | 2.8 | 1.0 | 5.2 | 35.8 | 8.8 | 55.5 | 49.24 | 40.80 | 36.08 | 32.08 | 30.00 |
| Lower (bottom) | 0-15 | 4.3 | 4.4 | 0.18 | 3.5 | 46 | 9 | 45 | 50.83 | 46.83 | 43.8 | 40.73 | 39.43 |
| LSD (0.05) position | | | | | | | | | | | | | 0.027 |

* *Relates to level of sunction pressure*

The deposited soils on the low lying grazing lands support more luxuriant growth of vegetation, which was reportedly used by herders for grazing particularly in the dry season. During the dry periods, the pasture on the upper and mid backslopes becomes scanty or absent in a number of places, whereas the areas on the lowerslopes are characterised by relatively abundant growth. The observed retention of higher moisture on lower slopes (Table 6.4), can be corroborated by the observations that grass grows for longer periods in the lower parts compared to the upper (Ekirapa and Muya, 2003). Similarly the croplands on the lower backslopes and footslopes were used for growing various crops (including the high value crops such as Cabbages) supported by soil moisture. A few farmers on the lower slopes also grew moisture-demanding crops such as bananas to a greater advantage.

## 6.5 OTHER EFFECTS OF SOIL DEGRADATION

### 6.5.1 Effects Of Soil Degradation Caused By Gullies

The on- and off-site problems associated with gullies were identified and are summarised in Table 6.4. Gullies are localised in a few sub-catchments, particularly in Bizibitukula and Kabojja (see Chapter 5), which incidentally have numerous bare patches and experience intense degradation by sheet erosion. The effects of the gullies are also localised in these sub-catchments. The gullies directly concentrate runoff and therefore, compared with sheet erosion, they may well contribute to heavy sediment loss deposited down-slope and in valley water tanks (Plate 6.4). The concentration of the sediment in the sampled runoff from a gully in the Bizibitukula sub-catchment ranged from 40 – 85g/l. An estimated 14 $m^3$ deposited silt and sediments, which is ~1% of the total volume of the water reservoir, was measured in a single season in 2002. This provides an indication of the potential threats to water reservoirs due to degradation of the catchments in this area. Mainly coarse sand and gravel (iron concretions) eroded from the deepened gully walls and floor are deposited downslope. Field observations revealed that soil loss from sheet wash is trapped in depressions or by barriers such as vegetation on the slopes. Thus, gullies constitute major sources of sediment and silt deposited directly in the water cources in low-lying areas. According to the respondents interviewed during the focus group discussions, presently the local community is required to de-silt the Bizibitukula water storage dam at least twice a year, whereas in the past the practice was required rarely.

**Table 6.5** Summary of the observed effects of gully erosion in the Nakasongola district

| Effects | Comments |
| --- | --- |
| • Increased siltation/sedimentation of water sources | Valley dams in degraded catchments susceptible |
| • Reduced land value (land value depreciation)<br>• Obstacle & hazard to free human and livestock movement has led to injury or death of some livestock (see photo 3)<br>• Land surface disfiguration<br>• Lowering of water level that may undermine land productivity especially in the vicinity of gullies<br>• Increased difficulty and costs in land rehabilitation | Grazing lands prone |
| • Road impairment | Localised along the roads |


**Plate 6.4** Dangers of gully erosion: (i) to livestock (ii) siltation of water sources located in Bizibitukula sub catchment in Migera, see the piled sediment in mid-upper part of photo on the right.

Gullies were reported to be a great danger to livestock this has not been quantified. Large livestock on the ranches (Plate 6.4) are particularly prone to injuries. Interactions with the affected livestock keepers indicated they were particularly concerned about the presence of gullies on their ranches. This is because animals trapped in the depressions are either injured or killed in the process. '*It sometimes happens that even no one easily discovers the carcass until after a long time. This is a big loss indeed!*' lamented one of them. Calves and old animals are particularly vulnerable.

Field observations showed that the areas surrounding the gullies on grazing lands, especially on the lower to middle slopes, experienced heavy soil loss. This was further revealed by intense rill formations, estimated at 1.6 m of rills per $m^2$ and 10 - 30 cm depth. In Lesotho, Rydgren (1993) has made similar observations and reported that gullies contributed to locally lowered base levels; an effect that has a great impact on the intensity of other erosion processes in the adjacent areas.

The respondents in the sub county of Nabiswera remarked that not only is the cost of rehabilitation of the land prohibitive to most pastoralists, but they also have inadequate time and/or labour to spend on gullies when their animals need to be moved around for grazing and watering. Thus, most gullies in the area are unattended and they continue to proliferate. Urgent action is required to address degradation by gully erosion before it becomes even more problematic.

### 6.5.2 Effects Of Soil Degradation On Soil Macro-Fauna

When soil is degraded e.g. as a result of overgrazing or over-cultivation, the effect on the soil ecosystem is manifested as a loss of both biomass and biodiversity. It loses species in the same way that species are lost from forest ecosystem when trees are cut. Once the top layer of the soil is removed by erosion, soil formation slows to significantly low rates because the key soil-forming organisms have disappeared (Ecoforum, 1993).

Changes in soil conditions affect the distribution and abundance of soil fauna. Soils were sampled (n = 30) under different degradation conditions (non-degraded, moderately and severely degraded) and the macro-fauna hand sorted and counted according to their orders, as detailed in Chapter 4. The data on the population distribution of soil macro organisms under different soil degradation conditions is presented in Tables 6.5 and 6.6 and Figure 6.8 for the grazing- and crop land, respectively. Details of the sampled data are provided in Appendix 15.

**Table 6.6** Population (mean counts/m²) of soil macro-fauna under different degradation conditions on grazing lands

| Order | Status of land | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Non-degraded | | | Moderately degraded | | | Degraded | | |
| | 0 - 10 | 20 - Oct | 20 - 30 | 0 - 10 | 20 - Oct | 20 - 30 | 0 - 10 | 20 Oct | 20 - 30 |
| Arachnida | 3 | 1.5 | 1.5 | 4 | 2 | 1 | 7 | 4 | 1 |
| Isoptera | 510 | 72.5 | 26 | 125 | 45 | 25.5 | 665 | 60 | 29 |
| Hymenoptera | 75 | 40.5 | 10 | 300 | 46.5 | 12 | 15 | 13 | 9 |
| Oligocheta | 13 | 7.5 | 2 | 3.5 | 1 | 2 | 1.5 | 3.5 | 1 |
| Coleoptera | 4 | 3.5 | 1.5 | 6.5 | 3 | 1.5 | 0 | 2 | 1 |
| Diplopoda | 26 | 14.5 | 3 | 7 | 3.5 | 0.5 | 0.5 | 1 | 0 |
| Chilopoda | 1.5 | 3 | 2 | 2.5 | 2 | 1 | 0 | 1 | 0.5 |

**Table 6.7** Population (Mean counts/m²) and distribution of soil macro-fauna under different management practices and degradation conditions on croplands

| | Non-degraded | | | Moderately Degraded | | | Degraded | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 - 10 | 10 - 20 | 20 - 30 | 0 - 10 | 10 - 20 | 20 - 30 | 0 - 10 | 10 20 | 20 - 30 |
| Arachnida | 5.5 | 3.5 | 1 | 4.5 | 2.5 | 0.5 | 2 | 0.5 | 0 |
| Isoptera | 79 | 87 | 39 | 148 | 67 | 17.5 | 23.5 | 6.5 | 3.5 |
| Hymenoptera | 24 | 7.5 | 2.5 | 18 | 15.5 | 5 | 14 | 6.5 | 2.5 |
| Oligocheta | 8.5 | 4 | 4 | 15.5 | 5 | 1.5 | 2.5 | 0.5 | 0 |
| Coleoptera | 4.5 | 1.5 | 0.5 | 4.5 | 2 | 2 | 4 | 1.5 | 1 |
| Diplopoda | 6 | 2.5 | 1 | 4 | 2 | 1.5 | 2 | 1.5 | 0.5 |
| Chilopoda | 2.5 | 2 | 0 | 3.5 | 1 | 1 | 1.5 | 0.5 | 0 |

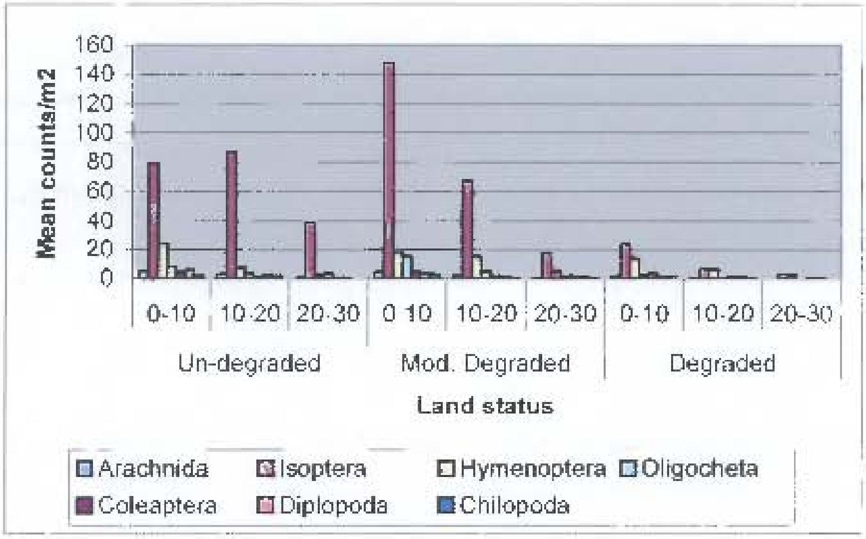



**Figure 6.8** Population (Mean counts/m²) and distribution of soil macro-fauna under different management practices and degradation conditions for croplands

There are differences in the distribution of soil macro-fauna (Tables 6.6 and 6.7). The non-degraded areas tend to have higher populations and uniform distribution of macro-fauna. This is particularly the case for the earthworms and millipedes at all soil depths sampled. Earthworms are more favourable indicators because of their greater sensitivity to changes in soil conditions; they prefer moist and organic rich soils prevalent in non degraded areas. However, termite distribution varied greatly and showed irregular frequency at all levels in the soil.

The diversity of soil macro-fauna based on their order under different degraded conditions is shown in Table 6.8.

**Table 6.8** Diversity of soil fauna under different degraded conditions

| Order | Soil state | | |
|---|---|---|---|
| | Non-degraded | Moderately degraded | Highly degraded |
| Arachida | + | + | - |
| Isaptera | +++ | ++ | + |
| Hymnoptera | ++ | + | + |
| Oligocheata | +++ | ++ | - |
| Coleaptera | ++ | + | |
| Diplopoda | ++ | + | - |

- Not present
+ Low frequency
++ High frequency
+++ Very high frequency

There is a significant difference in the diversity of soil fauna for different degradation levels. The diversity of soil fauna is much higher in the non-degraded soils compared with the moderately and severely degraded soils. The generally high organic matter and moisture but low temperature conditions prevalent in non-degraded areas can explain this. In terms of soil management, this has significant implications and points to the need to adopt practices that will promote the increase in organic matter, hence moisture, if benefit is to be realised from the free ecological services, such as improved porosity, offered to the soils by these animals.

## 6.6 SYNTHESIS

Soil degradation as discussed in this chapter has associated on- and off-site effects, which directly or indirectly affect the resource users in this area.

Studies on infiltration, in general, have revealed that the severely degraded soil surfaces experience lower infiltration rates compared with the less/non-degraded areas. This has the implication of high surface runoff generation that leads to reduced soil moisture and increased soil erosion down-slope. Chorley, cited by Strunk (2001) similarly observed that the infiltration rate of water into a soil indicates the hazard of erosion during excessive rainfall event. It is, however, possible to improve on the infiltration into the soil by breaking the ground, particularly on grazing lands. This was investigated in the field through tillage, to break the soil surface crust, and a higher infiltration was recorded. Improvement of soil structure through use of appropriate conservation measures that maintain sufficient plant cover is also vital in promoting water infiltration for improved range conditions. This is revealed by the data in Figure 6.4 for cultivated and non-degraded forest/bush soils.

In a number of places, the severely degraded ferralsols were observedly characterised by truncated A-horizons and sometimes exposed B-horizons, which are associated with a weak structure and less stable aggregates. These truncated soils compact quickly on exposure to the surface and also crumble easily when soaked with water (Sali, C.K. pers. comm. 2003). With such an unstable structure the soils have low erodibility and are prone to erosion by water.

Truncation of soils through intensive sheet erosion also exposes sub-soils, which are relatively poor in nutrients. Although the soil nutrients in this area show little variation with depth, loss of topsoil leads to a reduced root depth or foothold for plants and can therefore affect their performance in the long term. Under such conditions of reduced root depth and fertility plus water-holding capacity, the vegetation is usually xerophytised. Similar observations by Fraga and Salcedo (2004), indicate that losses of C and N in low P status soils, in addition to limited water availability and unsuitable land management techniques, are likely to restrict the recovery of degraded soils by traditional bush fallow techniques. Related observations by Snyman and du Preez (2005) also demonstrate that rangeland degradation lengthened time for the replacement of the root system to about a year and decomposition time of litter to eight months.

As revealed in this chapter, soil degradation has off-site effects such as siltation of the water sources. Water is a very scarce commodity in this area, especially during the dry periods, when people have to move long distances, covering over 10 km, in search of water for domestic consumption and animals. Thus, degradation of surrounding watersheds is a great worry to the local communities. De-siltation is costly in terms of wasting valuable time, which should be utilised for taking care of the livestock. Rehabilitation of the degraded hill slopes is also very expensive and the land requires more time to recover since it has low resilience. There are often uncertainties with the rains and termites are very active. These factors compound problems of recovery whenever the land is degraded.

Soil degradation, especially by erosion processes, affects the nutrient dynamics as a result of accelerated loss of soil particles and organic matter. Soil degradation, and particularly loss of organic matter, affects the distribution of soil macro-fauna that play an important role in nutrient cycling and improvement of physical properties. The severely degraded areas are associated with unfavourable conditions such as low organic matter, hence the low abundance of macro-fauna.

This chapter has discussed the impacts caused by soil degradation largely from a scientific perspective. The next chapter analyses the existing knowledge and understanding of soil degradation from the local peoples' perspective.

# CHAPTER 7

# LOCAL KNOWLEDGE AND UNDERSTANDING OF SOIL PROCESSES

## 7.1 INTRODUCTION

Chapters 5 and 6 are based largely on the scientific approaches to the assessment of soil degradation in selected areas of the Nakasongola district. This chapter provides a stakeholder analysis of the local people's perspective of soil degradation in the same area. The farmers and herders who are the main local resource users, and therefore, stakeholders were assumed to be a valuable source of knowledgeable issues relating to soil processes and natural resources in general. The other stakeholders, the resource use planners, including the agricultural, veterinary and environmental officers and extension staff, deal with the concerns and management of soil related issues were selected accordingly. Investigations into local knowledge and understanding, in addition to the scientific observations and measurements, offer a holistic approach to the understanding of soil processes viz. soil erosion, fertility dynamics and rangeland change. This local perspective is discussed with respect to the classification, general awareness, causes, severity, concerns and control of soil erosion in the study area.

A total of 295 respondents (household resource users) were interviewed. The sampling ratio was 1:4:6 for herders, mixed farmers and sole crop farmers, respectively. This ratio approximates the actual distribution of households for these resource users in the Nakasongola district. It was impossible to cover the entire target population as initially planned due to resource constraints (Chapter 4). This, however, does not significantly affect the results since a representative sample from each resource user type was obtained in all the important geographical areas covered i.e. the relatively drier and largely pastoral/grazing land, the relatively wet crop land and mixed cropping land.

Perspectives on the issue of soil degradation from the two groups of respondents (stakeholders), namely household resource users (the herders, mixed and sole crop farmers), and resource planners and managers are here presented and analysed. The critical issues of causalities, severity and effects/concerns of soil degradation are of critical concern and have been highlighted at the international level (GLASOD, see UNEP, 1997). GLASOD relied on data collected by 'experts' from each country. However, these data are too generalised and detailed investigations such as reported on here are required to enhance the usefulness of such an approach in planning and management of the soil degradation problem. The Man and Biosphere (MAB) Programme is a UN intergovernmental programme, in which the project 'Perception of environmental quality' addresses various aspects of environmental perception studies, thus, indicating the increasing recognition and awareness of the relevance of local knowledge to be included in ecological studies (Soroons cited in Kikula, 1997).

A content analysis approach was used to analyse the data. A data set of responses, classifica under each group of issues, was analysed through cross tabulation and statistical testing (e.g. Chi-square). There are, of course, non-responses and missing data, but these relatively insignificant and do not affect the conclusions. The data from the relatively small number of respondents (12), for the resource planners and managers, was unsuited to statistical analysis and only summaries of their views are presented and discussed. The details of the questionnaire and the summary from the respondents are provided in Appendices 6 - 8 and Appendix 16 respectively.

## 7.2 RESOURCE USERS

### 7.2.1 General Socio-Economic Profile Of The Respondents

The percentage distribution of the respondents in the five sub-counties is shown in Figure 7.1. Most of the respondents were from the two sub-counties of Kakooge and Nabiswera, which are the largest in area. The selected socio-economic characteristics of the respondents, which included age, gender, education level, household size, land acreage, vary greatly and, as discussed below, affect the perceptions of soil degradation.

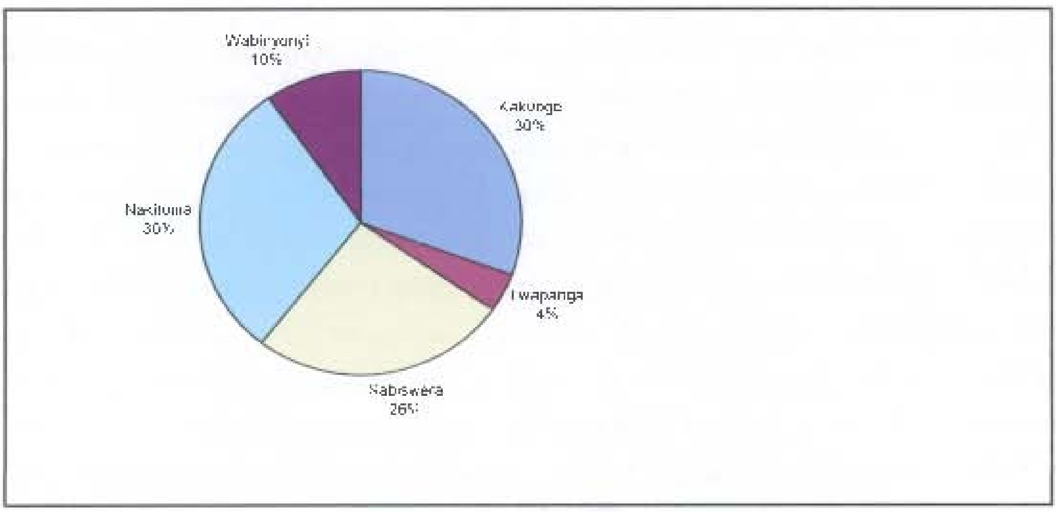



**Figure 7.1** Percentage distribution of respondents in the sub-counties of Nakasongola district

An almost equal number of male (51%) and female (49%) respondents was interviewed. Most of the respondents (69%) interviewed indicated they have had primary education. However, about 20% had no formal education and a relatively a small percentage have tertiary education. The analysis of the relationship between educational level and soil degradation is dealt with in subsequent sections of this chapter. 56% of interviewees were below the age of 35 years and 27% were 50 years or older, while 31% were attribute to the middle age group (35 - 45 years). Thus, the sample population was mainly constituted of young/middle-aged people, which is fair reflection of the population of Nakasongola district. The average household size of the respondents interviewed was below four.

Land ownership (see Chapter 3) is an important variable influencing decisions, particularly those concerning soil and water conservation (SWC). (Hatibu *et al.*, 2002). Land ownership types vary between resource users (Table 7.1). The majority of respondents were *Bibanja* owners (64%). *Bibanja* is a commonly used local term meaning squatters on mailo land. This mode of land tenure partly accounts for the low investment in SWC practices. For as explained below, such squatters are often hesitant to adopt practices where they are uncertain of sharing the long-term benefits. Nevertheless, studies elsewhere indicate that land tenure insecurity does not necessarily affect investment in SWC practices. Only 20% of the respondents were leasehold owners. About 15% of the herders interviewed own their land on a leasehold basis largely due to the recent land restructuring developments by the government through the Land Restructuring Board. The large population of crop farmers, who are mainly *Bibanja* owners (38%), is explained by the recent migration of the farmers from the Luwero district and those that were dispossessed of livestock and displaced during the 1980s' civil war in central Uganda. Few of the resource users interviewed indicated they were renting land or using communal areas. However, it became apparent through detailed interviews that a number of respondents were reluctant to indicate they were renting or using communal land. This was probably due to expectations that they would be considered for land allocation in any future developments in landform. The land restructuring was effected mainly in the so called 'cattle corridor' and, as noted by Kisamba-Mugerwa (1995), most of the former communal lands in these areas have been individualised as part of the government's cover policy to settle the pastoralists. As reported during formal discussions, back in the 1960s, much of the land in Nakasongola was allocated for ranch developments but later, in the 1970s and 1980s, mainly nomadic pastoralists used these ranches. In 1993/4 there was land redistribution to accommodate and settle the landless nomadic pastoralists.

**Table 7.1** Land ownership according to different resource users in Nakasongola district

| n=295 | Resource user | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Land ownership | Crop farmer | | Herder | | Both | | Grand Total | |
| | N | % | N | % | N | % | | |
| | | | | | | | N | % |
| Communal | 27 | 9 | 3 | 1 | 13 | 4 | 43 | 15 |
| Leasehold | 19 | 6 | 15 | 5 | 28 | 10 | 62 | 21 |
| Kibanja | 111 | 38 | 9 | 3 | 70 | 24 | 190 | 64 |
| Total | 157 | 53 | 27 | 9 | 111 | 38 | 295 | 100 |

The household incomes range from less than one US dollar to one hundred US dollars per month. The majority of the respondents earn less than 20 US $. There is a significant difference ($P<0.03$) in the level of income between the male and female. Most of the women respondents earn barely five US dollars a month and this is largely attributed to limited control of household resources and low incomes from farming in which a majority are involved. As also shown by studies elsewhere (e.g. PRB, 2002) women have additional responsibilities (e.g. childcare, food preparation, fuelwood and water collection), which require substantial effort and financial resources. Interviews with women revealed that such additional responsibilities affect their level of investment in farm resource improvement.

The respondents are engaged in various activities including farming, herding and trading. A significant difference ($P<0.002$) was noted between male and female respondents in resource utilisation. Few women participate in herding; the majority of them are involved in either crop farming or domestic tasks, which incidentally consume a lot of their time and yet fetches little income. Therefore, degradation of soils and other natural resources are bound to seriously impact on women workload in this dryland.

The following sections provide the details on the various understandings and perceptions of local people concerning different aspects of soil degradation.

### 7.2.2 Local Understanding Of Soil Processes And Change

The concept of soil degradation and change from the local peoples' perspective was explored during the PRA discussions. The local people were able to describe the concepts of soil degradation and change, which are also embedded in their local vocabulary. Soil change is locally referred to as *ekyuka kyuka eyekyisela mu takka*. Soil degradation is referred to as *okusisikara* and is described as being more permanent change in the soil. According to their understanding, the soil changes and degradation are all attributed to continuous cultivation, runoff (locally called *mukkoka*), reduced plant cover as a result of overgrazing and deforestation. The recognition of these processes at the local level made it easier to describe the soil conditions on the farmlands during interviews with the local people.

Respondents were asked whether or not they experienced soil changes on their land. Figure 7.2 shows the percentage number of respondents experiencing soil changes that constrain agricultural production in the respective sub-counties. Most respondents reported experiencing soil changes on their farmland (Figure 7.2). No significant differences were noted between the male and female in their perception of change in soil quality. This implies that both women and men are knowledgeable is assessing soil conditions and should be targeted in conservation work. The main soil changes identified included soil fertility decline, reduction in crop yields, changes in soil fauna, changes in soil colour, exposure of stones and tree roots, occurrence of sandy soils and deposition of soils in depressions. Removal of crop residues was not specifically mentioned but was raised as another factor contributing to soil changes after probing during the discussions. Overall, in the sampled sub counties, less than 5% reported no soil changes, which is most likely to be the case for those occupying gently sloping land and applying good land management practices, although inadequate observation/assessment of the problem on their farmlands is a possibility. As reported in the literature (Chapter 2), soil changes or processes such as sheet erosion may occur very slowly and inconspicuously so that some resource users fail to detect it on their land.

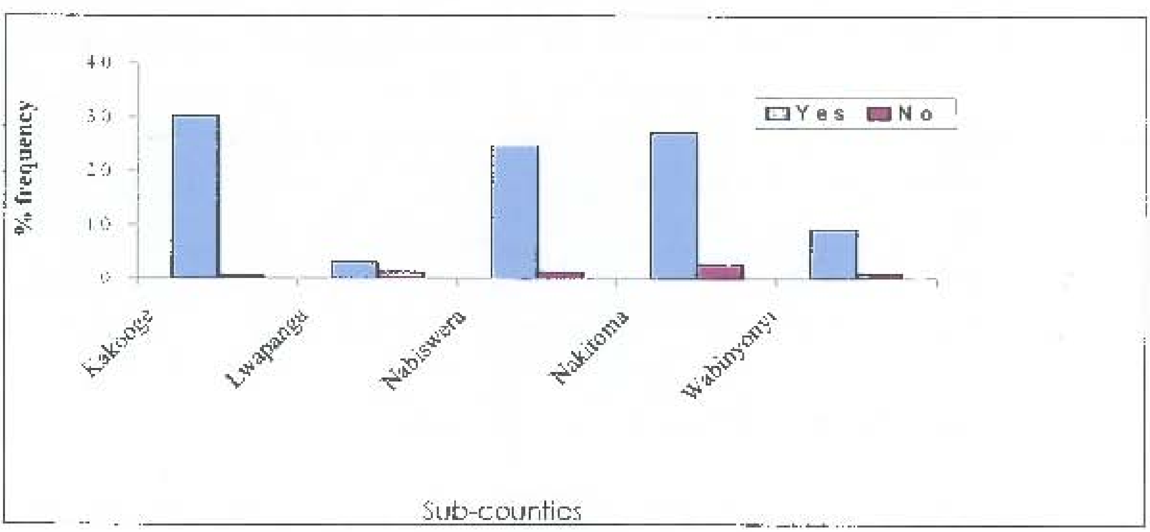



**Figure 7.2** Percentage of respondents that experienced soil changes in the different sub counties of Nakasongola district

Resource users' views on soil changes in all sub-counties were analysed and results are presented in Table 7.2. Overall, the majority of resource users indicated that they have observed soil changes. However, a large percentage (51%) of the sole crop farmers reported soil changes, followed by those engaged in both crop and livestock farming (34%) and followed by the sole herders (9%). A Chi-square test showed that perception of the presence or absence of a soil change is not significantly different between the different types of resource users.

**Table 7.2** Resource user type and perception of a soil change

| **Resource user type n = 281** | **Changes in soils** | | | |
|---|---|---|---|---|
| | Yes | | No | |
| | N | % | N | % |
| Sole crop farmer | 143 | 51 | 7 | 2 |
| Herder/livestock | 25 | 9 | 1 | 0 |
| Both crop & livestock | 96 | 34 | 9 | 3 |
| Total | 264 | 94 | 17 | 6 |

The changes in soil due to wind erosion were perceived to be a problem mainly by the sole crop farmers (28%) as shown in Table 7.3. About 4% of the livestock farmers reported wind to be a problem. However, no significant difference in the perceptions was observed between the different groups of resource users.

**Table 7.3** Resource users' perception of wind as an erosive problem

| **n=279** | **Wind problem to soils** | | | | | |
|---|---|---|---|---|---|---|
| Resource user type | Yes | | No | | Grand Total | |
| | N | % | N | % | N | % |
| Sole crop farmer | 78 | 28 | 71 | 25 | 149 | 53 |
| Herder/livestock | 12 | 4 | 14 | 5 | 26 | 9 |
| Both crop & livestock | 57 | 20 | 47 | 17 | 104 | 37 |
| Grand Total | 147 | 53 | 132 | 47 | 279 | 100 |

$X^2 = 0.640$ DF = 2, P-Value = 0.726

Respondents were asked whether they experienced, or were aware of negative changes in their soils. Figure 7.3 provides a summary of various problems advanced by resource users as being associated with soil processes on their land. Reduced fertility (29%), followed by moisture deficiencies (18%) and compacted soils (13%) was perceived to be the major problems by all the respondents. Soil erosion was recognised as a problem by all resource users interviewed in the district, although it was not highly regarded as a problem except by the herders. Water logging and exposed soils are the least highlighted problems, especially as perceived by respondents in Lwampanga sub-county. However, soil micro/macro-related diseases, were least mentioned as a problem by mixed farmers. It cannot be ascertained whether diseases commonly mentioned as problematic were a result of soil changes or other factor(s). One possible biological explanation is that, when natural ecosystems are simplified, the organisms initially dependent on natural prey will turn to new varieties in this case the introduced crops- for their survival.

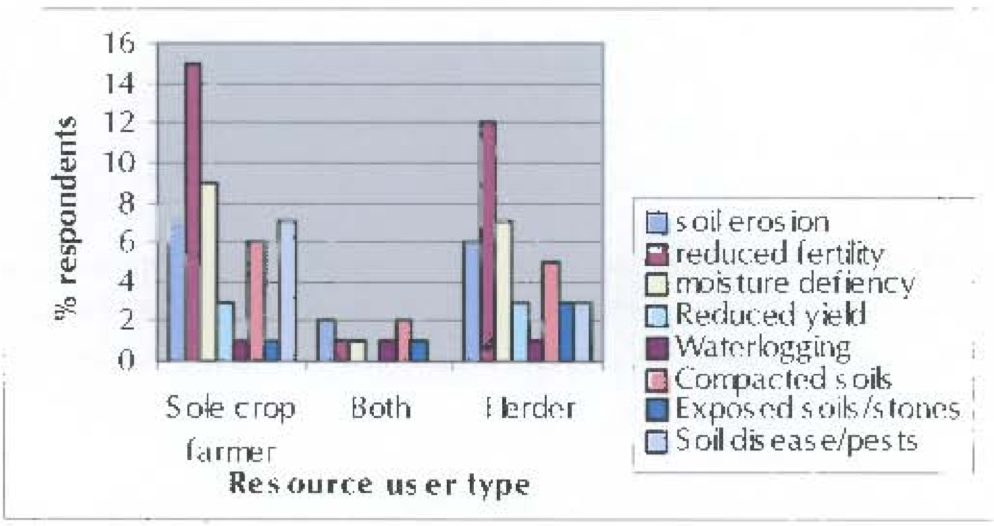



**Figure 7.3** Soil degradation problems by different resource user type in the Nakasongola district

Further investigations of soil changes leading to degradation problems were conducted for soil quality and productivity (Table 7.4). While the perceptions of the respondents were not significantly different between sub-counties, a substantial proportion of them (82%) indicated that they have detected changes in the quality and productivity of the soils. A Chi-square ($X^2$) test revealed no significant difference in the perception of soil degradation problems but a higher percentage (43%) of the sole crop farmers, followed by mixed farmers (32%) recognised the change in soil quality as a problem on their land. The change in soil quality was largely attributable to over cultivation. Evidence of change in soil quality was perceived to have occurred through a number of other causes. These include the observed loss of valuable plant nutrients, reduced water-holding capacity and change to a less dark/brown and more sandy soil texture (Table 7.6). These changes were perceived to be more prominent in the sub-counties of Kakooge and Nakitoma.

**Table 7.4** Change in soil quality and productivity according to resource user type

| n=276 | Resource user type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Change in soil quality | Sole crop farmer | | Livestock (herder) | | Mixed | | Total | |
| | N | % | N | % | N | % | | |
| Yes | 118 | 43 | 22 | 8 | 89 | 32 | 229 | 82 |
| No | 31 | 11 | 3 | 1 | 16 | 6 | 50 | 18 |
| Grand Total | 149 | 54 | 25 | 9 | 105 | 38 | 276 | 100 |

The respondents identified and ranked the main soil degradation processes/types in the area as shown in Table 7.5. Sheet erosion, fertility decline and compaction by animals were perceived to be the most important processes of soil degradation. Gully erosion was ranked least to moderately important, no doubt because gullies are only localised occurrences particularly along the cattle tracks on grazing lands and poorly maintained roads on sloping lands. A few respondents ranked rill erosion to be moderately important to important. Rills are ephemeral features especially on the croplands and are destroyed during cultivation so their importance is never realised, which is probably why it is not highly ranked by resource users.

Exposure of sub-soil through loss of topsoil was mainly ranked as not being important. Quite a number of respondents, however, ranked it from moderately important to most important. Exposure of sub-soils is sometimes hard to visualise or conceptualise especially where the soil horizons are almost similar in colour throughout the profile. However, where the laterite (stone concretion layer) is close to the surface and is exposed by removal of topsoil, it is very easy to perceive the magnitude of the erosion process.

**Table 7.5** Responses on the identification and ranking of soil degradation type in Nakasongola district

| Rank | Soil degradation type | | | | | |
|---|---|---|---|---|---|---|
| | **Sheet erosion** | **Rill erosion** | **Gully erosion** | **Compaction** | **Exposed patches** | **Fertility loss** |
| Most important | 106 | 5 | 4 | 60 | 9 | 77 |
| Important | 45 | 37 | 4 | 73 | 24 | 59 |
| Moderately important | 28 | 29 | 16 | 29 | 42 | 29 |
| Less important | 8 | 21 | 11 | 24 | 28 | 17 |
| Least important | 2 | 17 | 16 | 9 | 6 | 10 |
| Not important | - | 1 | 3 | 2 | 109 | 1 |

## 7.2.3 Local Understandings Of The Causes Of Soil Degradation

Tables 7.6 and 7.7 depict the response to the question posed to resource users: '*What causes soil degradation on your farmlands?*'

**Table 7.6** Percentage responses on the causes of soil degradation by the different resource users

| | **Sole crop farmer** | | **Both** | | **Livestock** | | **Total** | |
|---|---|---|---|---|---|---|---|---|
| | **N** | **%** | **N** | **%** | **N** | **%** | **N** | **%** |
| Cannot tell | 34 | 10 | 5 | 1 | 24 | 7 | 63 | 18 |
| Over cultivation | 57 | 17 | 1 | 0 | 32 | 9 | 90 | 26 |
| Soil erosion | 12 | 3 | 3 | 1 | 20 | 6 | 35 | 10 |
| Overstocking | 22 | 6 | 12 | 3 | 13 | 4 | 47 | 14 |
| Disease/pests | 5 | 1 | 2 | 1 | 8 | 2 | 15 | 4 |
| Deforestation | 8 | 2 | 2 | 1 | 6 | 2 | 16 | 5 |
| No fertility inputs | 5 | 1 | 1 | 0 | 4 | 1 | 10 | 3 |
| Long drought | 23 | 7 | 9 | 3 | 30 | 9 | 62 | 18 |
| Poor cultivation | 1 | 0 | 0 | 0 | 4 | 1 | 5 | 1 |
| Grand total | 167 | 49 | 35 | 10 | 141 | 41 | 343 | 100 |

The factors or causes identified are embedded within the broader political-economic, historical processes, gender relations and are indivisible. Most respondents (58%) attribute accelerated degradation to the key factors of overstocking, overgrazing, drought and over cultivation. Confinement of large stock on inadequate grazing land leads to deterioration of the rangeland due to trampling and reduced plant cover. The interviews showed that many herders have greater than 100 head of cattle, although actual figures on livestock population are difficult to establish, as pointed out in Chapter 6. The DVO indicated that, based on their field observations, quite a number of herders in the area have in excess of the recommended number (2 LU/ha). A number of respondents (18%) were unable to explain the cause of soil degradation; some attributed it to natural forces beyond their understanding, possibly attributable to unwillingness to appear responsible for degradation or simply mere apathy. Interestingly, the sole crop farmers attributed the cause to overstocking but the herders pinpointed over cultivation. No significant differences were noted between the male and female in the perception of the causes of soil degradation. However, a number of women mentioned overcultivation and erosive rains as the major cause. This is attributed to their greater involvement in crop farming activity other than herding, which as noted before is a male dominated enterprise.

Respondents in all the sub-counties identified wind as a significant problem ($P<0.05$) to the soils. Wind is recognised as a recent problem contributing to the removal of loose sediments (Appendix 16) from exposed surfaces around the homesteads and on the grazing and croplands. It was indicated that wind is more of a problem in Nabiswera and Nakitoma which, are incidentally, drier and dominated by grazing activity. The resource users also perceived so-called secondary activities as contributing to soil degradation (Table 7.7). The relationship between soil degradation and other activities was found to be significant ($P < 0.05$). Paths and tracks (26%) as a land use type pose the greatest threat, followed by activities of charcoal burning and fire wood collection. Paths and tracks running down-and up-slope particularly around watering points form compacted and highly disturbed linear zones for accelerated runoff and soil loss. As already explained (Chapter 6), the linear zones running down slope develop into gullies incase of no control measures.

Charcoal burning contributes to localised removal of vegetation cover and hence exposes the soil to erosive forces, as pointed out in Chapter 6. Besides, charcoal-burning activity may not be sustainable in the medium to long term considering the current reported high rate of tree harvest. This is elaborated upon below in discussing the coping strategies and in the conclusions. The least important factor was perceived to be fishing activity (10%). The significance of fishing activity, which involves fish-smoking using fuel wood, was a problem in the early 1990s particularly around Lake Kyoga in Lwampanga sub-county but it is now reported to be under control following awareness campaigns and monitoring by the local authority. Strict measures involving impounding smoked fish have been applied and therefore discouraged the potential culprits.

**Table 7.7** Resource users' responses on secondary activity/land use contribution to soil degradation

| | **Contribution rating** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Activity | Insignificant | | Significant | | Highly significant | | Total | |
| | N | % | N | % | N | % | N | % |
| Brick making | 146 | 16 | 19 | 2 | 3 | 0 | 168 | 18 |
| Charcoal burning | 110 | 12 | 74 | 8 | 29 | 3 | 213 | 23 |
| Firewood collection | 174 | 19 | 27 | 3 | 8 | 1 | 209 | 23 |
| Fishing | 88 | 10 | 1 | 0 | 0 | 0 | 89 | 10 |
| Paths & tracks | 93 | 10 | 115 | 13 | 33 | 4 | 241 | 26 |
| Grand Total | 611 | 66 | 236 | 26 | 73 | 8 | 920 | 100 |

Charcoal burning, brick making, fishing including crop growing and livestock keeping are part of the livelihood activities whose intensity is dependent upon the demand in the market economy ranging from local to international level. Higher demand of the products can lead to over exploitation of the resource and consequently resource degradation where there are inadequate management practices.

### 7.2.4 Soil Degradation Severity Rating

Resource users were asked to rate the severity of soil degradation in the different sub-counties and the results are shown in Figures 7.4 and 7.5. The severity ratings ranged from very low to severe. Overall, degradation by water erosion was rated as very low, but varying from moderate to severe (high) in the sub-counties of Kakooge, Nabiswera and Nakitoma. Wind degradation was rated as being very low in all the sub-counties except Nabiswera, where it was rated moderate.

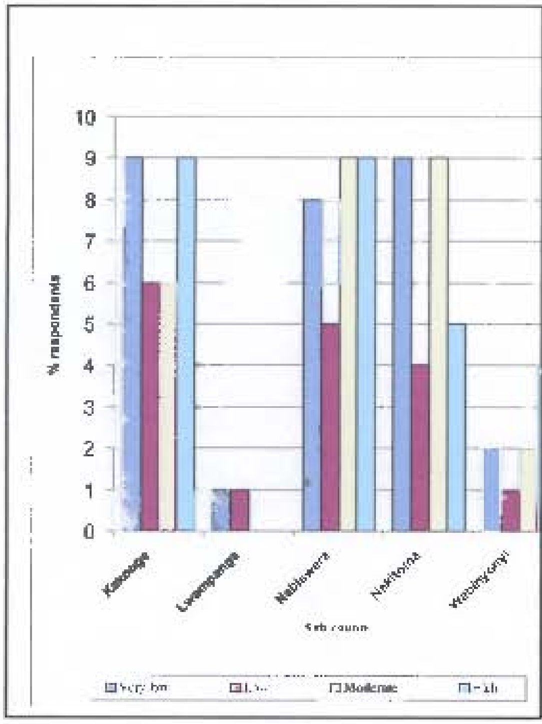



Figure 7.4 Severity rating of soil degradation by water erosion

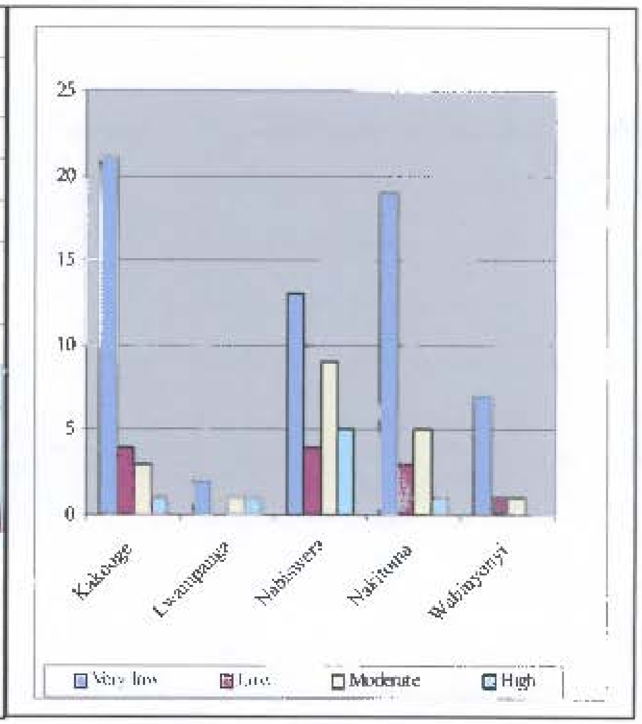



Figure 7.5 Severity rating of soil degradation by wind erosion

The severity of soil degradation (water and wind), as rated according to the resource users, is shown in Tables 7.8 and 7.9. The severity ratings were not significantly ($P = 0.074$) different among the resource users. Water erosion severity was rated very low to low (47%) by all resource users. However, all respondents (51%) rated it as being almost equally moderate and severe. Compared to livestock keepers and mixed farmers (11%), the sole crop farmers (15%) rated water erosion to be severe.

**Table 7.8** Water erosion severity rating by type of resource users

| n=278 | Resource user type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Water erosion severity | Sole crop farmer N | | Herder | | Mixed | | Grand Total | |
| | | % | N | % | N | % | N | % |
| Very low | 42 | 15 | 9 | 3 | 31 | 11 | 82 | 29 |
| Low | 31 | 11 | 7 | 3 | 12 | 4 | 50 | 18 |
| Moderate | 34 | 12 | 8 | 3 | 30 | 11 | 72 | 26 |
| Severe | 42 | 15 | 1 | 0 | 31 | 11 | 74 | 27 |
| Grand Total | 149 | 54 | 25 | 9 | 104 | 37 | 278 | 100 |

$X^2$=11.499, Df = 6, P-Value = 0.074

The majority of different resource users (74%) rated wind severity as very low to low (Table 7.9). However, 18% rated it as moderate and 8% of the respondents as severe. Windstorms occur for a limited time during the dry season and at the start of the wet season. Loose soil particles are eroded from the exposed soil surfaces in farmlands, grazing lands and around homesteads. The very low ratings by resource users are realistic considering that there are presently no clear visible depositional or erosional features associated with severe wind erosion in the district.

**Table 7.9** Wind erosion severity rating by type of resource users

| n = 273 | Resource user type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Wind erosion severity | Sole crop farmer | | Both | | Livestock | | Total | |
| | N | % | | % | N | % | N | % |
| Very low | 89 | 33 | 15 | 5 | 66 | 24 | 170 | 62 |
| Low | 20 | 7 | 2 | 1 | 11 | 4 | 33 | 12 |
| Moderate | 23 | 8 | 6 | 2 | 20 | 7 | 49 | 18 |
| Severe | 16 | 6 | 1 | 0 | 4 | 1 | 21 | 8 |
| Total | 148 | 54 | 24 | 9 | 101 | 37 | 273 | 100 |

$X^2$=6.334, DF = 6, P-Value = 0.387

The respondents were asked to rate the seriousness of change in soil quality (Table 7.10). The term seriousness, as applied here, also implies severity. All the respondents (48%) indicated the change in soil quality to be a serious problem. A few (9%) reported the problem as very serious and of these the majority (6%) were sole crop farmers. Only 4% indicated they were not aware of the change in soil quality.

**Table 7.10** Resource users rating of the seriousness of change in soil quality (n = 276)

| Seriousness of quality change | Sole crop farmer N | % | Herder N | % | Mixed N | % | Total N | % |
|---|---|---|---|---|---|---|---|---|
| Not aware | 5 | 2 | 2 | 1 | 5 | 2 | 12 | 4 |
| Not serious | 46 | 17 | 6 | 2 | 27 | 10 | 79 | 29 |
| Serious | 65 | 24 | 12 | 4 | 55 | 20 | 132 | 48 |
| Moderate | 16 | 6 | 4 | 1 | 8 | 3 | 28 | 10 |
| Very serious | 17 | 6 | 1 | 0 | 7 | 3 | 25 | 9 |
| Grand Total | 149 | 54 | 25 | 9 | 102 | 37 | 276 | 100 |

The change in soil quality was reported to have mostly affected the land on hilltops (28%) and hillslope (19%) (Table 7.11). Crop farmers (15%) perceived this problem to be more serious on these land facets i.e. the hillslopes and hillstops. Land on hillslopes and upper slopes is more susceptible to accelerated runoff and erosion processes, which selectively remove the more fertile nutrients including organic matter.

**Table 7.11** Resource users' observation of soil quality change on critical positions (n = 268)

| Position on land | Sole crop farmer N | % | Herders N | % | Both N | % | Grand Total N | % |
|---|---|---|---|---|---|---|---|---|
| Valley land | 15 | 6 | 6 | 2 | 7 | 3 | 28 | 10 |
| Sloping land | 33 | 12 | 3 | 1 | 16 | 6 | 52 | 19 |
| Hill tops | 41 | 15 | 3 | 1 | 30 | 11 | 74 | 28 |
| Valley/slope/Hilltop | 18 | 7 | 7 | 3 | 11 | 4 | 36 | 13 |
| Valley /slope | 2 | 1 | | 0 | | 0 | 2 | 1 |
| Slope/hill top | 20 | 7 | 5 | 2 | 27 | 10 | 52 | 19 |
| Can't tell | 12 | 4 | 2 | 1 | 8 | 3 | 22 | 8 |
| Grand Total | 143 | 53 | 26 | 10 | 99 | 37 | 268 | 100 |

### 7.2.5 Concerns About Soil Degradation

Soil degradation was viewed to be associated with various physical and socio-ecological effects or problems as identified by the resource users. The percentage responses for the livestock keepers, mixed and sole crop farmers are shown in Tables 7.12 and 7.13. In general, both the sole crop farmers and mixed farmers perceived reduced moisture (37%) and loss of nutrients (33%) to be the most crucial threats to farming by soil degradation. Loss of organic matter was perceived as an effect by both the sole crop and mixed farmers (16%). A small percentage of the respondents indicated problems of increased acidity and loss of fauna. This tallies with the field observations and measurements presented in Chapter 6 as marked changes were observed in organic matter, increased acidity and reduction of soil biodiversity particularly in the degraded areas in Migera. The low perception of increased acidity and loss of fauna may be attributed to the fact that these properties are not so easily observed or detected without keen observation of the soil beyond the surface. This could form an entry point for intervention to promote greater understanding about changes in soil biodiversity associated with degradation.

**Table 7.12** Problems perceived to be affecting crops in Nakasongola district

| Problem | Resource user | | | | | |
|---|---|---|---|---|---|---|
| | **Sole crop farmer** | | **Mixed farmer** | | **Total** | |
| | **N** | **%** | **N** | **%** | **N** | **%** |
| Loss of nutrients | 103 | 19 | 79 | 14 | 182 | 33 |
| Water /moisture reduction | 115 | 21 | 88 | 16 | 203 | 37 |
| Loss om | 44 | 8 | 43 | 8 | 87 | 16 |
| Acidity | 21 | 4 | 13 | 2 | 34 | 6 |
| Fauna loss | 26 | 5 | 13 | 2 | 39 | 7 |
| Nothing | 3 | 1 | 2 | 0 | 5 | 1 |

The responses (Table 7.13) showed that the perceived reduction in grazing land, followed by poor quality pastures and silting of water valley dams were the main problems posed by soil degradation, and therefore, affecting the livestock. It is interesting to note that the livestock keepers are aware of conspicuous problems directly affecting them, probably because they are more seriously impacted. During the PRA group discussions, the local people pointed out that scarcity of water and pastures is compounded by reduced grazing land due to eroded bare patches, encroachment by thorny bushes (e.g. *Acacia senegalensis*) and poor quality pastures. Resource conflict, while not featuring as a major problem, is an indirect challenge that frequently escalates during times of scarcity in the dry season as reported by some respondents during in- depth discussions.

**Table 7.13** Responses on perceived soil degradation related problems affecting livestock

| n=312 | Resource user | | | | | |
|---|---|---|---|---|---|---|
| **Problem** | **Herder** | | **Mixed farmer** | | **Total** | |
| | **N** | **%** | **N** | **%** | **N** | **%** |
| Poor pasture | 15 | 5 | 64 | 21 | 79 | 26 |
| Reduced grazing land | 14 | 4 | 75 | 24 | 89 | 28 |
| Silting | 20 | 6 | 56 | 18 | 76 | 24 |
| Resource conflict | 15 | 5 | 49 | 16 | 64 | 21 |
| Nothing | 0 | 0 | 4 | 1 | 4 | 1 |
| Total | 64 | 20 | 248 | 80 | 312 | 100 |

### 7.2.6 Relationship Between Soil Degradation Problem And Respondents Characteristics

Resource users' socio-demographic characteristics are important factors influencing environmental perceptions and understandings. Thus, the age, gender, educational level and length of time stayed in the area, were analysed with respect to the perceptions regarding the awareness of the problem of soil degradation, soil quality changes (Table 7.14) and severity rating of the problem (Table 7.15)

Both respondents with tertiary education perceived a change in soil quality to be a problem (Table 7.14). The change in soil quality was recognised as a problem by a high percentage (56%) of those who had acquired primary education, followed by those with no formal education (16%). However, a Chi-square test showed that the level of education did not significantly influence the perception of soil quality.

**Table 7.14** Perception of soil quality change by educational level in Nakasongola district

| N=262 | Change in soil quality | | | | | |
|---|---|---|---|---|---|---|
| **Educational level** | **Yes** | | **No** | | **Grand Total** | |
| | **N** | **%** | **N** | **%** | **N** | **%** |
| Primary | 148 | 56 | 31 | 12 | 179 | 68 |
| Secondary | 20 | 8 | 8 | 3 | 28 | 11 |
| Tertiary | 2 | 1 | 0 | 0 | 2 | 1 |
| Non-formal | 43 | 16 | 10 | 4 | 53 | 20 |
| Grand Total | 213 | 81 | 49 | 19 | 262 | 100 |

Most resource users (47%) rated the change in soil quality as serious (Table 7.15). Both those with tertiary education rated the problem as serious and the majority (34%) of those who rated it as serious had attained primary education. Interesting to note is that only those who had attained primary education and with no formal education reported they were unaware of change in soil quality. However, there was none with secondary or tertiary education that indicated lack of awareness. There is no specific reason to explain this difference. There is need for further investigations to explore the influence of level of education on environmental perceptions. The small sample size of those educated upto secondary or tertiary level may have not provided sufficient proof.

**Table 7.15** Influence of educational level on perception of change in soil quality

| | Seriousness of quality change | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Educational level** | **Not aware** | | **Not serious** | | **Serious** | | **Mod serious** | | **Very serious** | |
| | **N** | **%** | **N** | **%** | **N** | **%** | **N** | **%** | **N** | **%** |
| Primary | 8 | 3 | 46 | 18 | 88 | 34 | 18 | 7 | 19 | 7 |
| Secondary | 0 | 0 | 11 | 4 | 13 | 5 | 2 | 1 | 2 | 1 |
| Tertiary | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 |
| Non-formal | 4 | 2 | 16 | 6 | 19 | 7 | 6 | 2 | 4 | 2 |
| Grand Total | 12 | 5 | 73 | 28 | 122 | 47 | 26 | 10 | 25 | 10 |

Figures 7.6 a - f summarises the results of the analysis of the relationship between the perceptions of the severity of soil degradation and the socio-demographic characteristics of respondents. The statistical test showed no significant ($p < 0.05$) relationship between the perceptions on severity of the problem and the socio-demographic characteristics. However, there are interesting patterns revealed by the data. There were differences in gender perception of the

severity of soil degradation (Figure 7.6a). The percentage response of males (~27%) categorised the problem as very low or low while a higher percentage of females (16%) categorised soil degradation as severe. This is attributed to the fact that women are key players in farming activities and therefore likely to be knowledgeable and more observant.

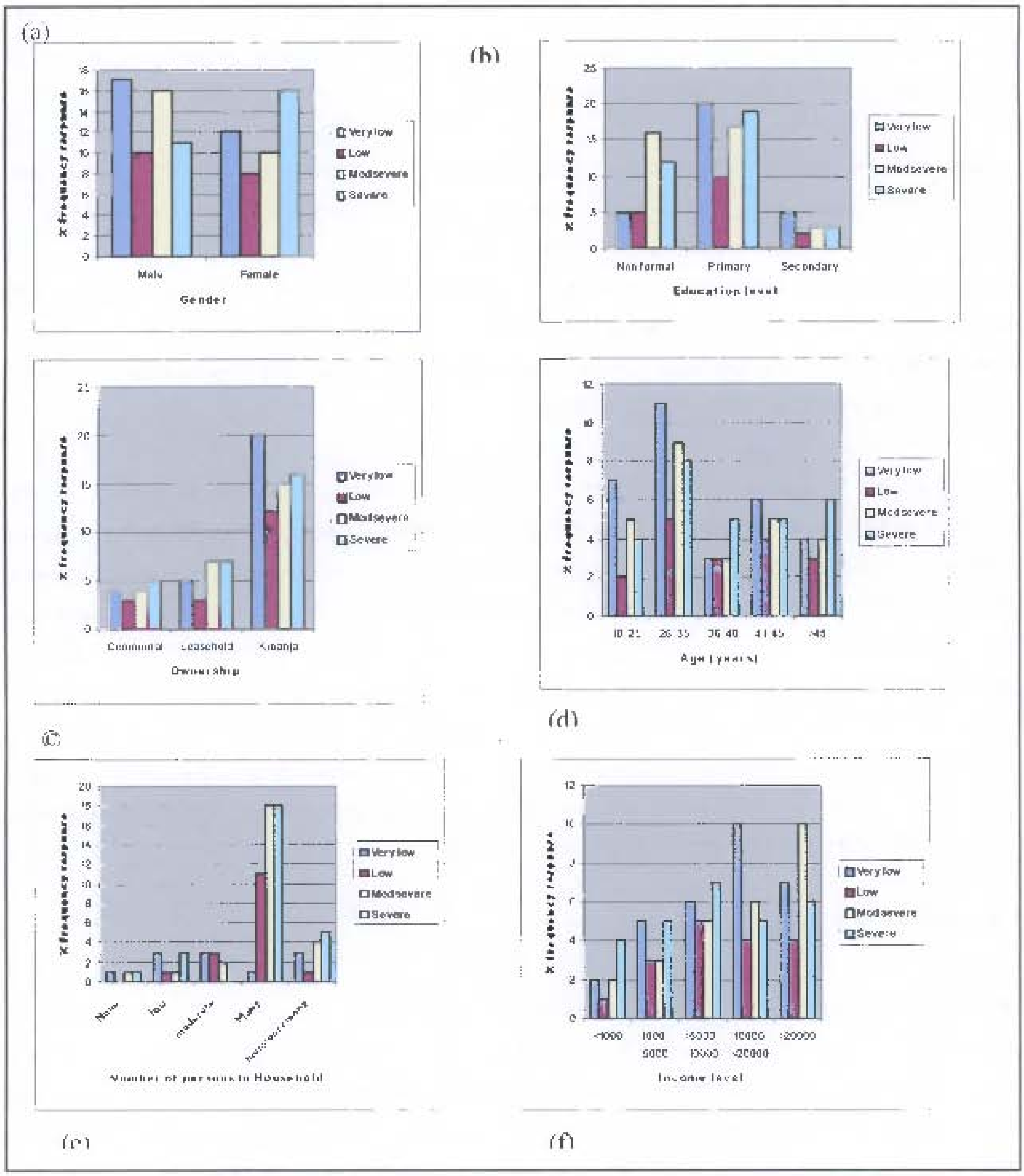



**Figure 7.6** Relationship between severity rating of soil erosion problem and respondents characteristics.

The respondents with large household size generally perceived the problem to be varying from moderately severe to severe, as opposed to those with low household size (<5). This may be explained by high pressure exerted on the land for high production by those with large families. This leads to soil exhaustion and structural deterioration in case of relatively limiting land/farm sizes and low input application. It was, however, not feasible to sample and verify the soil quality status for each respondent. Those respondents with many persons per household (5 – 10) in general perceived the soil erosion problem to be low.

A large percentage of the respondents with high relative income (above US$10 per month), compared to those with US$ <5 per month perceived the severity of the problem to be moderately severe on their farmlands. One would expect that those with higher incomes invest in land rehabilitation and have well managed farmlands hence low or no soil degradation. This appears not to be the case in view of the severity of soil degradation indicated. People who earn higher incomes are, perhaps, too busy with off-farm activities and may not have the time to adequately attend to the farmland problems.

There appears to be no definite pattern for land ownership in relation to severity rating. However, where more respondents in all the land ownership categories perceived the problem as ranging from moderately severe to severe, it shows the general consensus that the problem is perceived as tending to higher magnitude irrespective of the land ownership type. One would have expected to receive reports of more severely degraded communal lands due to associated abuses as reported in the literature. Most of the remaining communal lands are located in the low-lying and relatively flat depressions (e.g. around Lake Kyoga and River Lugogo), hence the areas with greater resilience. However, logically those communal lands located on drier land and commonly utilised throughout the year without proper conservation methods are more prone to severe degradation due to intensive grazing.

## 7.3 RESOURCE PLANNERS/MANAGERS

Semi-structured and structured interviews were administered to this category of stakeholders. A different set of questionnaires was administered to both local council chairpersons and district resource planners/managers. As noted no detailed analysis was performed on this data set due to the small numbers of respondents: four from the district and eight from the local village councils. A summary of the respondents views is analysed below to show the trend in the understandings of soil degradation and challenges faced, from the local leaders'/managers' perspective.

### 7.3.1 District Resource Managers

The resource managers interviewed at the district level included the district agricultural officer, the environmental officer, the chief administrative officer, the district veterinary officer and the national agricultural farmers' association representative. All the respondents had attained a diploma or degree at tertiary institutions. Their age ranged from 29 - 39 years and most of them have worked for a minimum of four years at the district. They provided a valuable perspective on the soil-related problems in the district.

All the managers recognised the declining soil fertility, reduced water-holding capacity, loss of nutrients and declining production levels as problems constituting the observed changes in the soils in the area. They indicated that there were scattered farm fields in areas of Nabiswera and Nakitoma sub counties with observedly persistent low crop yields and poor pasture. The soils in these areas are degraded in terms of reduced soil nutrients (e.g. nitrogen and phosphorous) as evidenced by stunted growth and yellow or purplish colour leaves in certain places. They identified the major causes of soil degradation to be poor farming practices, overstocking, bush and charcoal burning. The contribution of charcoal burning, paths/tracks and firewood collection was rated as varying from significant to very significant. Compared to the past, the current status of soil degradation in the district was rated as moderately severe to severe. They identified hotspot villages in terms of degradation including Migera, Kyamukonda, parts of Kakooge and Kasira. These observations comply with the predictions of soil erosion rate in Chapter 6 where rates ranging from moderate to severe were predicted in these areas. Migera and Kyamukonda are characterised by wide expanses of de-vegetated patches observed mostly on grazing land. Overstocking and consequently overgrazing coupled with other factors like prolonged dry conditions are likely contributors to this, as explained in Chapter 6.

The respondents pointed out that the effects of degradation have both socio-economic and environmental dimensions. The main effects include threats to food security, poverty, and accelerated water siltation and desertification. The effects of soil degradation were rated as significant, with one respondent rating them as very significant. All the respondents indicated that, over time, the conditions in Nakasongola district have become drier. Crop harvest uncertainty is increasingly felt although there are no hard data on the magnitude of the impacts at household level.

### 7.3.2 Local Village Authorities

All the LC1 chairpersons have attained formal education ranging from primary to secondary level, which is in fact part of the job requirement. All the local council chairpersons interviewed were middle aged (35 - 44 years old) and have grown up in these villages. They articulated the degradation issues and provided insights as to how the problems can be tackled.

Soil degradation was recognised as a problem by all such the respondents in the villages visited. They cited problems of infertility, low production and moisture deficiency. Soil degradation and, in particular, water erosion, was generally rated as moderately severe to severe and occurring mostly on de-vegetated and overgrazed hillslopes. The low-lying and hilltop areas in the villages were reportedly experiencing a lower degree of degradation, which could largely be attributed to lower runoff rates. Degradation by wind erosion was rated as low, particularly in the low-lying and relatively well-vegetated areas. However, during the dry season the wind erosivity becomes moderately strong on bare land where the dry loose soil particles are blown away.

The main causes of degradation identified included poor farming practices, overgrazing and lack of appropriate knowledge/sensitisation of farmers as regards soil conservation issues. Other contributing practices like charcoal burning were rated as significant by 50% of the respondents. Fuel wood was not rated as significant (80%, although paths/tracks were regarded as so by 60 % the respondents. The natural factors reported to compound soil degradation were intensified reduction and removal of vegetation by termites, persistent drought and water logging. As discussed below, despite the threat to the soil resource base, there are limited conservation practices in place and this too contributes to increased soil degradation.

According to all respondents, soil degradation is a serious constraint to agricultural production in virtually all the villages sampled (Appendix 5). The effect on agricultural production was reported to be significant by a substantial proportion (75%). It has reduced the agricultural production in certain places by as much as 60%, as lamented by one LC1 in Bujumbura village. Although there are other factors contributing to low agricultural production, such as pests, the role of soil degradation can never be overlooked. A discussion of the coping strategies to degradation problems now follows.

## 7.4 COPING STRATEGIES

### 7.4.1 Introduction

Accelerated processes of soil erosion and vegetation degradation undermine the productivity of the resource base, resulting in reduced incomes for the resource users, among other effects. These concerns affect local governments, communities and individuals in different ways and with varying magnitude, and have evoked different responses based on their perceptions of the problem.

Soil degradation, while affecting land productivity, household income and development, is not addressed in isolation from other environmental degradation matters, and there is no single strategy addressing soil degradation at national or district level (Bagoora, pers. comm. 2003). This study emphasises those mechanisms and actions (adaptive strategies) that are particularly relevant to soil degradation. At the local household level, the main responses identified include on-farm soil water conservation (SWC, migration to other areas, acquisition of additional land in other parts of the district, cultivation of new crops and other cropping strategies, a shift to off-farm alternative income generating activities and fencing the land (perimeter fencing). Orone (1996) observed that, in response to the inequalities of development and continuing poverty, local people develop approaches to cope with negative situations. He further argued that these coping mechanisms and actions, which include cutting down trees to make charcoal or firewood for sale, are not necessarily seen as degrading the environment or causing desertification. Instead, the sources of degradation are seen to be desertification and poverty. This study reveals that, some of the respondents are aware of the linkages between environmental destruction through felling of trees, but indicated that they also need to survive through harvesting of the trees.

Coping strategies at the district and central government levels include the formulation of policies and by-laws. Other actions include institutional setup and support for conservation efforts, although still modest and inadequate.

### 7.4.2 Investment In Land Improvement

#### *7.4.2.1 Adoption of SWC practices*

The resource users were asked to list the local SWC practices adopted to control or minimise soil degradation by erosion and fertility loss. The different practices mentioned include use of manure, mulch, grassbunds, runoff ditches, agroforestry (planting of trees) and use of inorganic fertilisers. Figure 7.7 shows the percentage adoption according to resource users identified.

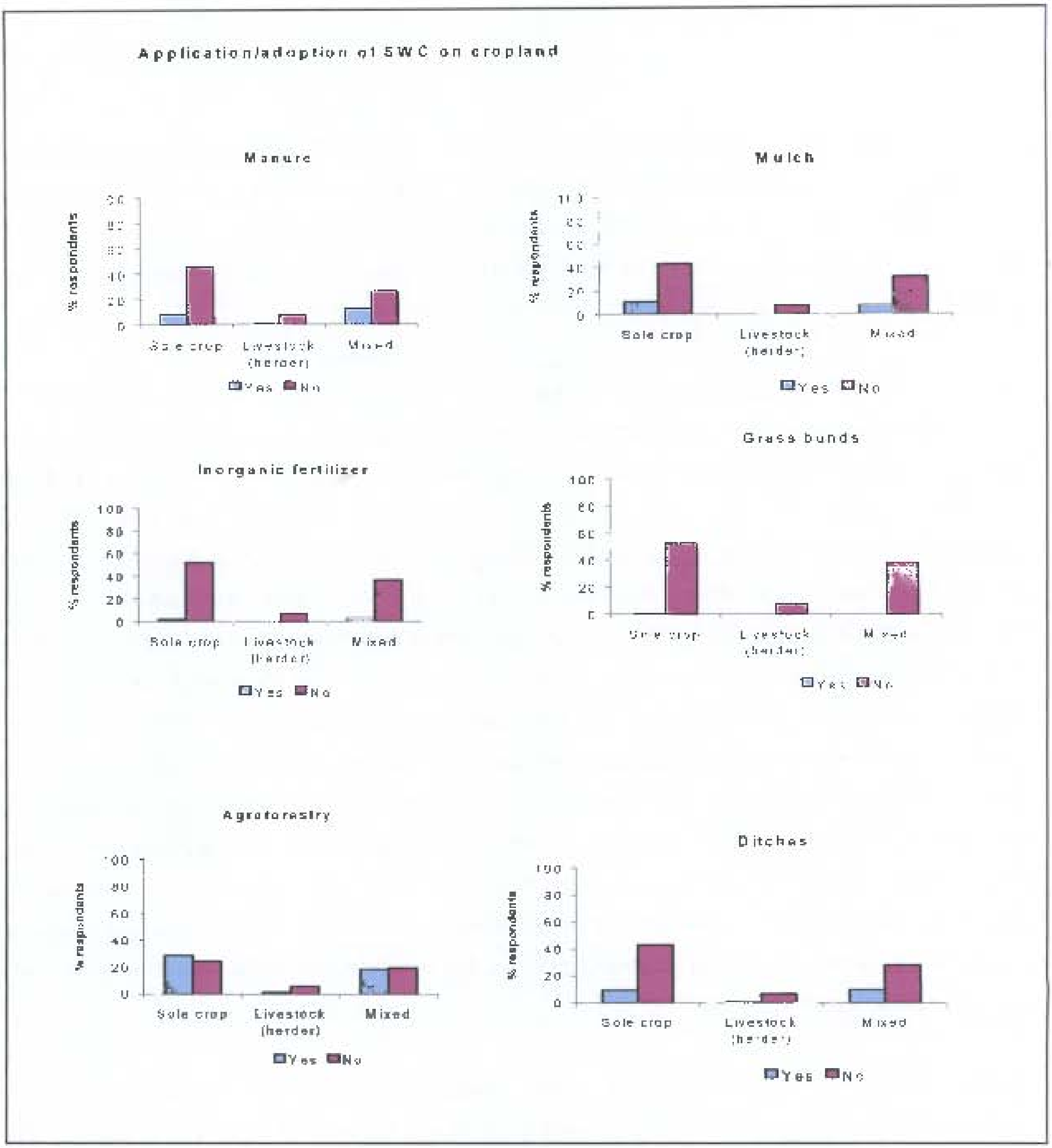



**Figure 7.7** Percentage adoption of SWC practices according to resource users in the Nakasongola district

The significant variation in the use of SWC practices (Figure 7.7), can be attributed to differences in soil conditions, land use type, labour availability, awareness and knowledge of the technologies. It is revealed that herders barely apply mulch, grass bunds or inorganic fertilisers. Very few (<20%) reported using agroforestry, ditches and manure. As noted by the former LC1 chairman of Nalukonge village, it is not a common practice for the herders to transfer animal manure (dung) from the kraals for application on the grazing fields. Interviews revealed that, in most cases, the herders shift kraals to new locations closer to the homesteads as a strategy to minimise degradation. In the past, when land was abundant, the nomadic herders could afford to migrate to another location where resources were considered plentiful. The current situation, however, does not permit this practice largely because of land shortage and changes in tenure/property rights from communal to leasehold (individualisation). Permanent buildings, constructed using iron sheets and bricks, are becoming common, yet unlike the traditional homestead type (mud and grass thatched) do not facilitate relocation. This may well have contributed to degraded patches commonly observed in the vicinity of many homesteads, moreover associated with little or no conservation structures.

Mixed farmers apply manure to a greater degree than other resource users. However, their application of grass bunds was relatively low, although the reasons for this are unclear. About 10 - 25% of the sole crop farmers had adopted conservation practices other than grass bunds. As to the reasons why the adoption of conservation practices is low in view of the recognition of the soil degradation problem, Table 7.16 shows the percentage response for the reasons advanced for non-adoption of SWC practices. A large percentage (48%) indicated lack of awareness about the importance of the practices. Another influencing factor affecting the use of SWC practices was the form of landownership and security of tenure. In this case some respondents (4%), especially those engaged in crop farming, indicated that they were squatters or renting the land and could leave at anytime. Therefore, they have no motivation to adopt certain conservation practices particularly planting trees (e.g. Mvule), which have long-term benefits or that would jeopardise their tenure ship. SWC practices such as agroforestry is a medium to long-term investment, hence some of the squatters may choose not to invest in land owned temporally. Besides, the planting of trees and grass bunds, unless authorised by the landlord, is interpreted as an intention for permanent land ownership. A few of those interviewed remarked, "*We are not protected. Why invest my effort only to be kicked out when the landlord decides to sell off his land and orders you to go off*"! What emerges from these observations is that security of land tenure influences adoption of SWC. The landlords have an upper hand in ensuring good stewardship of their land. For instance, they could provide squatters with SWC guidelines and create a positive relationship with them. Nevertheless, based on the informal interviews and field observations, a few squatters have the freedom to plant trees or establish conservation practices and this has enhanced their sense of responsibility plus security. Other reasons advanced for lack of adoption of the SWC practices were lack of labour (15%), high labour costs (19%) and old age.

**Table 7.16** Response to reasons for non-adoption of conservation practices by resource users (n = 328)

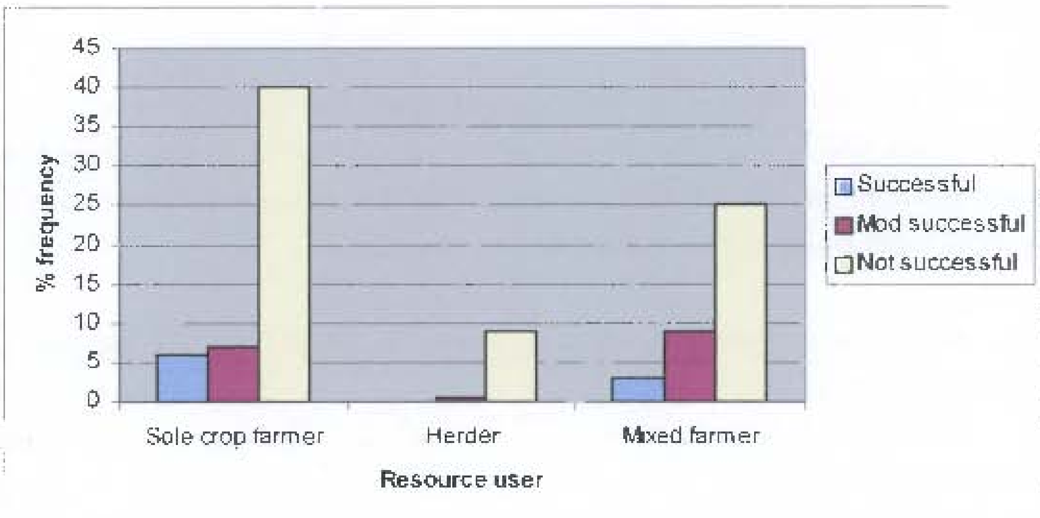
| Reason | Resource user type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Sole crop farmer | | Herder | | Mixed | | Total | |
| | N | % | N | % | N | % | N | % |
| Lack of labour | 33 | 10 | 5 | 2 | 11 | 3 | 49 | 15 |
| High labour costs | 30 | 9 | 4 | 1 | 27 | 8 | 61 | 19 |
| Unaware of their importance | 91 | 28 | 12 | 4 | 53 | 16 | 156 | 48 |
| SWC are cumbersome | 12 | 4 | 3 | 1 | 11 | 3 | 26 | 8 |
| Inadequate time | 3 | 1 | 3 | 1 | 11 | 3 | 17 | 5 |
| Persistent drought | 2 | 1 | 1 | 0 | 2 | 1 | 5 | 2 |
| Not personal land | 4 | 1 | 3 | 1 | 7 | 2 | 14 | 4 |
| Grand total | 175 | 53 | 31 | 9 | 122 | 37 | 328 | 100 |

To ascertain the mode of adoption of the conservation practices, the respondents were asked the following question: *How did you acquire these conservation practices/knowledge?* As shown in Table 7.17, the resource users acquired SWC practices in various ways. Most respondents acquired the practices through school/training (28%), parents (27%) and other farmers (25%) respectively. This, therefore, underscores the underlying significance of incorporating and emphasising education on conservation issues i.e. training conservation issues at school and to the resource users in the field. Other conservation measures were self-initiated or acquired from a combination of all or two (parents, training and other resource users).

**Table 7.17** Response to the question *How did you acquire this conservation practice/knowledge?*

| Acquisition | Resource user type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Sole crop farmer | | Herder | | Mixed | | Total | |
| | N | % | N | % | N | % | N | % |
| Parents | 25 | 17 | 0 | 0 | 14 | 10 | 39 | 27 |
| Other farmers | 19 | 13 | 2 | 1 | 15 | 10 | 36 | 25 |
| Training | 19 | 13 | 2 | 1 | 20 | 14 | 41 | 28 |
| Self initiated | 14 | 10 | | 0 | 8 | 6 | 22 | 15 |
| Parents & other farmers | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 2 |
| Parents & training | | 0 | | 0 | 2 | 1 | 2 | 1 |
| Other farmers & training | 1 | 1 | | 0 | | 0 | 1 | 1 |
| Training, parents & other farmers | 0 | 0 | | 0 | 1 | 1 | 1 | 1 |
| Grand Total | 79 | 54 | 5 | 3 | 61 | 42 | 145 | 100 |

Another question related to adoption was *whether they had been successful or not in controlling soil degradation*. The majority (74%) indicated they have not been successful (Figure 7.8) since they still continue to observe significant losses of soil/water and fertility decline on their land. There were no herders who indicated that they had been successful. This is probably not surprising in view of inadequate adoption of soil and water conservation practices as noted above. There is a concern for soil degradation by herders as earlier discussed but the practice of SWC is not incorporated in their routine work. Under such circumstances, it is likely that soil degradation problems may become more severe and further threaten livelihoods. Therefore, any external intervention on land improvement should target such resource users based on their knowledge and constraints.




($X^2$ = 13.2, df = 4, p = 0.05)

**Figure 7.8** Success in control of soil degradation by different resource users

Gully erosion is a special type of soil degradation that merits different control approaches and, therefore, it is further explored in this sub-section. Most of the gullies are localised on the degraded grazing lands (5.2.1). However, as depicted in table 7.18, limited conservation techniques are applied in the control of gullies.

**Table 7.18** Gully control methods under different land uses (n=10)

| Control method | Adoption rate Cropland | Grazing land | Total |
|---|---|---|---|
| Sandbags | - | 1 | 1 |
| Stones | | 1 | 1 |
| Tree branches/stumps (brushwood) | 1 | 2 | 3 |
| Crop residues | 1 | | 1 |

Selby (1982) urges that the most effective control of gullies is vegetation since it protects the soil against further scour and also reduces the velocity of the run-off flow. He further notes that mechanical methods, for instance timber dams, brushwood and permeable rock, are used to hold back silt and control drainage before vegetation can be established.

The usual conservation methods used, according to Heede (in Selby, 1982), are planting a catchment with densely rooting trees and developing a close ground cover of grasses, herbs and shrubs. He further notes that these methods are only effective if the climate permits close ground cover and if grazing animals can be controlled. However, some of these standard methods are not easily applicable in the Nakasongola area. For instance, the control of livestock numbers to match with the range resources available at any one time is not the usual practice in Nakasongola (district veterinary officer, Nakasongola, *pers. comm.*, 2002). Heavy grazing combined with unpredictable climatic variations, characterised by drier conditions in different parts of the district, threatens the ground cover and exposure of the soils to degradation processes. As observed in the field, most herders seem not to be seriously concerned about gullies, and yet, if left uncontrolled, they may pose a serious threat in future in view of increasing bare lands and runoff generation on sloping lands.

Correlation analyses were conducted in order to determine the extent to which socio-economic characteristics of respondents influence adoption of conservation practices (Table 7.19). As indicated by Hatibu, *et al.* (2002), the adoption of SWC is influenced by a number of socio-economic factors. Analyses indicated that gender, level of education and household sizes are negatively correlated with the adoption of conservation practices. This finding is contrary to others elsewhere (e.g. Lubwama, 1999) but has important implications in that there is a need to look beyond such factors or critically examine them when planning for conservation issues. For instance, the type and relevance of education attained at formal institutions may be more important than just the level of education. Important to note also, is the tendency for those with better education to diversify away from agriculture. Okubal and Makumbi (2002) made a similar observation in Katakwi, Uganda. Households that have dependants such as school children or those engaged in other activities other than helping in land conservation can explain the observed negative correlation for the household size. There was no correlation between the amount of land owned by resource users and the degree of adoption. However, a weak positive correlation was obtained for the variables of age, length of time stayed in the area, land ownership and household income. Further analysis, using a Chi-square test, showed that the length of time stayed in the place and the household income significantly (P< 0.05) affects the adoption of the conservation practices. The long duration of stay in farming is related to the experience gained in understanding the problems and, therefore may positively influence the decision to invest in SWC. Available literature shows that one of the major constraints to adoption of SWC is lack of funds. Thus, people with higher income levels are expected to invest in soil and land improvement, and meet the costs of the required labour for SWC practices on their land.

**Table 7.19** Pearson correlation testing relationship between socio-economic characteristics and adoption

| | Gender | Education | Age | Time stayed | Household no | Land size | Land ownership | HH income |
|---|---|---|---|---|---|---|---|---|
| r | -0.074 | -0.30 | 0.032 | 0.224 | -0.068 | 0.000 | 0.057 | 0.173 |

*7.4.2.2 Gender analysis in adoption of the land improvement practices*

Gender relations have important influences on the decisions regarding investment in land improvement. The response on the decision-making controls and the responsibilities in SWC are shown in Tables 7.20 and 7.21 respectively.

**Table 7.20** Soil water conservation decision-making controls by gender in Nakasongola district

| | Resource user type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Decision in family** | **Crop farmer** | | **Herder** | | **Both** | | **Grand Total** | |
| | **N** | **%** | **N** | **%** | **N** | **%** | **N** | **%** |
| Male | 50 | 18 | 11 | 4 | 34 | 12 | 95 | 35 |
| Female | 40 | 15 | 1 | 0 | 18 | 7 | 59 | 22 |
| Both | 55 | 20 | 9 | 3 | 52 | 19 | 116 | 42 |
| Grand Total | 146 | 53 | 22 | 8 | 105 | 38 | 273 | 100 |

**Table 7.21** Soil water conservation responsibilities by gender in Nakasongola district

| Responsibility to SWC | Resource user type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Crop farmer | | Herder | | Both | | Total | |
| | N | % | N | % | N | % | N | % |
| Male | 47 | 17 | 13 | 5 | 35 | 13 | 95 | 34 |
| Female | 45 | 16 | 1 | 0 | 18 | 7 | 66 | 24 |
| Both | 53 | 19 | 7 | 3 | 51 | 18 | 111 | 40 |
| Grand Total | 147 | 53 | 22 | 8 | 105 | 38 | 276 | 100 |

The decision to adopt and maintain SWC in the family is seen often as a joint responsibility of husband and wife (42%) (Tables 7.20 and 7.21), although individually more men are responsible. There are various possible reasons for such an observation, in particular the patriarchal nature of the society (Wahome, 2001). Men are still the prime decision- makers in the application of SWC, a responsibility that is perceived as part of their management of the household. They are in control of land transactions, before and even after marriage. The wife is frequently only regarded as an assistant (labour) but may provide general advice and implement the SWC decisions. The present developments in gender policies may lead to some changes in the balance of decision-making and ownership of property, although traditional values will prove difficult to break down. In the author's view, developing such a balance in decision-making and responsibility, including that in SWC, is important considering that women play an equal or greater role, particularly in crop farming.

### 7.4.3 Off-Farm Income

Interviews revealed that, in view of the declining returns from livestock and agricultural crops, sources of income have been diversified to include off-farm activities e.g. charcoal burning, brewing and trading. Financially viable survival options are limited in this marginal area of Nakasongola district.

**Charcoal burning**

Responses from the local chiefs indicate that charcoal burning has become a lucrative business enabling many families to survive. However, concerned respondents expressed fear that, unless charcoal burning activities are controlled, continued harvest at unsustainable rates may threaten the environmental quality of the area (Plate 7.1).

Charcoal burning is carried out both by the local inhabitants in Nakasongola district and those from other areas outside the district. The good quality trees (e.g. Combretum species) are the first to be selected for charcoal making, and yet many such trees require a long time to regenerate. During the focus group discussions, it was reported that due to increased exploitation, trees providing high quality charcoal are on the verge of disappearance in some areas (e.g. Namasa, Migera).

**Plate 7.1** Charcoal burning activity- a threat to the fragile environment in Nakasongola district; affects the soil properties and exposes the soil to erosive agents. Charcoal collection point at Migera – the charcoal for sale ready to be transported to Kampala and other urban centres (see inset photo)

There is a growing threat from the nearby urban centres, such as Migera, Nakasongola, Luwero and Kampala that provide ready markets for charcoal. This is supported by a survey report (ESD, 1995), which found that areas to the north of Kampala city, including the Nakasongola and Luwero districts, supply the bulk (36.8%) of its charcoal. Indeed charcoal is the most important urban fuel, and consumption is increasing at a rate around that of the urban population growth rate (>6% per annum) (ESD, 1995). As further highlighted by the ESD report, urban household demand in 1994 accounted for about 70% of the national demand, while commercial establishments (hotels, bars, restaurants) accounted for around 25%. The high electricity tariffs have also contributed to compelling energy users, especially in these urban centres, to divert to cheaper sources of energy such as charcoal. Despite this growing demand and consumption, the efficiency in production and utilization of charcoal is still inadequate, hence compounding problems of sustainable land utilisation. If the status quo remains, it is likely that the level of soil degradation will escalate in different areas, but most particularly where there is intensive harvest (e.g. areas close to the urban centres, and along the major roads). It is therefore, important that the concerned authorities (e.g. NFA and NEMA) in conjunction with the local communities, undertake monitoring of the harvests for possible re-planting or enrichment so as to achieve sustainable utilisation.

**Other off-farm sources of income**

A number of other alternative livelihood sources of income include casual labour (especially clearing vegetation along roads), hunting, handicrafts, processing and selling milk products (e.g. cheese, *yoghurt* or *bongo*), beekeeping and fishing. The respondents note that despite the availability of these revenue sources, very few appear to be economically sustainable. Interviews with those involved in beekeeping showed that this is a newly introduced enterprise with limited local market and stiff competition from other producers in the country. They further indicate that external sources of funding may be required to promote beekeeping, which is otherwise an activity with limited environmental consequences. The local population in the area could explore the government's 'Entandikwa scheme' initiated in 1996 but its efficacy is as yet unproven. A small number of people (ranging from 30 to 50), mainly men, are employed in road maintenance activity (i.e. vegetation clearance and desiltation of channels) along the Kampala-Gulu highway. They earn barely US $ 50 per month. This activity therefore contributes ineligible amounts to the incomes of the local community in this area. A few of the respondents indicated they were involved in hunting of wild game although it is prohibited and punishable under the current Uganda Wildlife Management laws. Hunting appears to be carried out mainly for subsistence purposes, although some respondents report that it earns them a limited income. They note that wild animals are rare and there are difficulties hunting on the privately fenced lands. Women who have developed the skills and are always confined to domestic chores mainly carry out handicraft such as basket weaving, house decoration and mat construction. The number of women involved is small and the limited income obtained from handicraft activities contribute only between 5% and 10% to household income. Men involved in local handicraft work, such as making chairs, constitute the minority; the venture requires specialised skills and is considered not very rewarding.

It can be argued that the promotion of the above income-generating activities may release pressure on the agricultural land and may facilitate increased investment in SWC to achieve better agricultural production and environmental quality. Projects involving planting of trees are good for better performance of beehive production and soil protection against raindrop and surface flow impact.

### 7.4.4 Shift Drought- Tolerant Crops

Interviews revealed that over three decades ago soil moisture was adequate and farmers successfully cultivated high moisture-dependent crops such as bananas. However, they have now had to shift to drought-tolerant crops such as cassava and annuals (e.g. millet, ground nuts and sorghum). The change to more xeric conditions experienced in the area, probably as a result of soil deterioration and changes in climatic conditions (low rainfall amount), and the consequent shift to growing more hardy crops represents a strategy aimed at minimising the risks and ensuring ample crop harvest. The current moisture deficiency may not be attributable to rainfall variation only as accelerated soil degradation is also a contributory factor. Soil degradation and, more particularly structural deterioration, undermine the infiltration and water holding capacity (Chapter 6), and therefore accentuates dry conditions experienced in the area. The shift to growing annual crops, such as groundnuts, is an appropriate strategy, though it exposes the soil to rainstorm impacts that may cause increased soil erosion and compaction during the first one to two months prior to establishment of sufficient ground cover. Inter-cropping of annuals with cassava provides an adequate multi-layered canopy for soil management and also the roots contribute to improving the soil structure thus increased water infiltration.

### 7.4.5 Migration To Other Areas

Migration to neighbouring areas can be viewed as a coping strategy to relieve pressure on some of the already degraded land, but is clearly intended to maximise survival opportunities for the migrant. Numerous factors (e.g. the magnitude of water scarcity, the nature of reception by the people in the new locality, availability of information about the place to migrate to and abudance of water) influence the decision to migrate or not. A large percentage of households (66%) expressed interest in moving to other areas should environmental conditions deteriorate. However, others indicated that they would not move to unknown areas for the simple reason that conditions may still not be favourable there. They cited the recent socio-political conflicts between the Bakiga migrants and indigenous tribe, the Banyoro, in Kabalore district, in western Uganda. The anti-migration attitude expressed by others may also be explained by cognitive dissonance. Cognitive dissonance occurs where a person perceives an environment as threatening but expects to continue living in that environment (Preston *et al.*, 1983).

According to responses obtained, this area has witnessed both out- and in- migrations over time, largely for grazing and crop farming. Scarcity of pasture and water resources is reported to be common in the Nakasongola district. Moisture deficiency, which affects plant performance (pasture), is partly exacerbated by increased soil degradation processes as indicated above, and thus, as a survival strategy, livestock is moved to areas such as the shores of Lake Kyoga and River Lugugo for both water and pasture. However, it is important to realise that this practice is being threatened by the widely observed increase in individualisation and fencing of the land (private property rights) en route to such refuges. It remains to be seen what will happen in future to the rangeland resources and pastoral life in the Nakasongola dryland. If the status quo remains, increased soil and land degradation in the area seems likely.

### 7.4.6 Other Coping Actions

The other main adaptive strategies identified include acquisition or renting/hiring of land elsewhere, access of land in low-lying wetter areas, grazing along roads and any available public or private land and termite control.

- **Acquisition/rent or hire of land**

Renting or hiring of land from other users in the neighbourhood, for grazing or farming purposes, was reported to be a common strategy aimed at supplementing household food production. There is no fixed price on this but on average the cost is US $ 5 to 10 per ha. In some cases payment is made in kind by offering produce or animals. This practice of acquiring land elsewhere relieves pressure on degrading land as well. However, as argued by Kabera (1985), it is important to note that similar misuse/malpractice on the newly acquired land may also lead to degradation unless appropriate land husbandry practices are adopted. Widespread cases of degradation or overgrazing were observed on some hired grazing land in the villages of Migera and Byamukama. The landlords do not live on the ranches but only go there to collect the rent from the tenants so there is a risk of lack of proper control in resource utilisation that can endanger the rangeland conditions.

Migrations sometimes appear to occur as a result of degradation per se. It was revealed that, some who were extremely affected by the deteriorating land conditions, including reduced crop yields, were forced to migrate. This was particularly the case where the alternative livelihood options were limiting. The entire farmland or part of it is usually sold off in order to invest in other activities such as trading. One livestock keeper noted that: *a degraded land fetches little money (40 to 60%) compared to a well-maintained and productive one.*

- **Encroachment on other ranches for resource use**

It was revealed during the informal interviews that there are herders who encroach on other ranchers' resources even if it meant cutting through fences. This is common during the drier periods when resource scarcity is severe. Asked what implication(s) this has on the resources on the ranches, the respondents pointed out that encroachment can be destructive depending on the frequency; if frequent it leads to degradation due to overgrazing and trampling. As already pointed out (Chapter 6) soil degradation accentuates resource scarcity, including pasture. One former LC1 chairman for Migera, observes "*cases for Local council court (LC1) conflict resolution on reported incidences of land/resource conflicts have become a common phenomenon in this area. Interesting to note, however, is that a number of cases are also settled outside the LC1 courts for fear of overcharging both the plaintiff and the accused*".

- **Access to low-lying wetter areas**

The sole crop farmers and livestock keepers, usually strive to buy or rent land in *mukisenyi*, which is a local term for low-lying sandy areas. These areas are strategically important during drier conditions. Although flooded during the wet season, they possess nutrients and favourable moisture conditions (section 6.4) for a significant part of the dry season, and therefore, may support crop production or be used for dry season grazing. Higher value crops like cabbages, onions and green vegetables are grown and fetch high returns during periods of scarcity in the dry season.

The low-lying areas are equally important for impoundment of water for livestock use; this is evidenced by the location of most livestock water tanks in much of Nakasongola district. Nevertheless, resource use conflicts may arise between the livestock keepers and crop farmers in such areas as indicated by the LC1 chairpersons of Kyamukama and Migera villages.

- **Grazing along roadsides and any available public or private land**

Field observations showed that most rangelands have been fenced off, leaving small buffer spaces along the roads/tracks. The width of the road reserve ranges up to 5 m on the main highways such as Nakasongola to Gulu but may be less on tracks and feeder roads. Public and/or privately owned unrestricted lands (e.g. at sub county headquarters and schools) are also available for grazing by the local communities. Such spaces constitute vital resource areas that offer options to resource-constrained livestock keepers to obtain pasture for their animals.

- **Control of termite pests**

Termites were reportedly contributing to the destruction of basal vegetation cover particularly on grazing lands hence exposing the soils to erosive agents (Chapter 6). Interviews revealed that the local community particularly in Migera has endeavoured to control these termites (macrotermes) but with limited success. Attempts have been made to destroy the termite mounds by digging out the nests and killing the queen. The termitaria are still very abundant and estimated at more than 100 per ha on some ranches. Insecticide chemicals (e.g. Diazone) were tried in the late 1990s, but later stopped after being condemned by environmentalists. There are on-going studies by a researcher from Namulonge to identify the damage and develop control methods mainly using biological means. However, considering the magnitude of the damage caused by termites, biological methods may be a long-term solution. The author argues that other solutions, including controlled use of environmental friendly (biodegradable) chemicals need to be explored, particularly in the severely affected areas such as Migera.

### 7.4.7 Household Group Initiatives

Discussions were held with the members of the Nalukonge community in Migera. It was indicated that, from 1997 the households in Nalukonge village decided to work together on an initiative aimed at tackling the most critical problems faced in their area. The problems as identified by these households included lack of pasture and reliable water sources for their animals and combating desertification. The strategies developed included constructing a water dam mainly for livestock, control of termites, planting of trees and setting up SWC particularly on seriously degraded grazing lands.

Although the approach appears participatory and 'bottom-up', the design of the project was largely top-down, money driven and less participatory. The work was carried out hurriedly on one ranch; hence much of the benefit was limited to a single individual. There was failure to sustain the project after exhaustion of the funds from the UNDP. The termites and drought destroyed most of the planted tree seedlings. The SWC trenches were ineffective against the heavy runoff from up-slope. The few trees that survive up to the present time, however, provide evidence of the ability of this environment to recover if there is proper planning, funding and execution of the project activities. The challenge of drought recurrence remains but its effects could be minimised through adoption of suitable water harvest techniques based on the local knowledge. Conservation projects are usually long term and therefore, it is hard to sustain them. However, the design of projects needs to avoid over-reliance on external assistance by developing appropriate mechanisms supported by local communities.

### 7.4.8 District Strategies For Degradation Control

Interviews with the district officials and experts from NEMA, indicate that there is no clear single strategy addressing soil degradation problems per se, but rather it is tackled as part of the broader environmental issues affecting a district and/or country.

The district of Nakasongola, until recently part of Luwero district, has not fully formed all the structures and institutions needed at the district and lower levels to cope with the environmental problems including soil degradation. However, the efforts made thus far to deal with broad environmental problems include the creation and support of the necessary institutions and departments such as the DEO, DAO, DFO, DVO and UNFA. The departments of Agriculture and Environment in particular are mandated to handle and co-ordinate any activities concerning soil degradation. In addition, these departments participate at district local council meetings in enacting policies and by-laws and also ensure the implementation of and compliance with these policies.

The district officials in Agriculture and Environment, together with the sub-county extension staff operating under them, revealed during interviews that they are engaged in sensitisation/awareness campaigns, educating resource users (farmers and pastoralists) on how to address environmental problems faced. Such campaigns include:

- Urging the local communities to avoid frequent unplanned bush/grass burning,
- Promoting the planting of trees and
- Construction of runoff diversion channels on farmlands.

However, interviews with some of the local communities contradicted the district official options in noting that there the campaigns are limited and that there is poor attendance by the local people. There was no clear reason(s) offered to explain this. Attendance at such meetings is not compulsory and perhaps a more hard-line approach would be more effective and sustainable in view of the reported soil degradation problems in the district.

Over three decades ago the Nakasongola district, which constituted of Buruli County under the Buganda Kingdom, mounted a concerted soil conservation campaign. The central government reportedly operated closely with the local authorities in ensuring that conservation measures were implemented. Today a legacy of those concerted efforts is found in different parts of the district; a case in point is the Mvule trees (*Chrolophora excelsa*) planted along the road and headquarters in Nabiswera Sub County. According to the interviews with the respondents who participated in soil and water conservation, the local authorities, at that time, were strict on this matter and sometimes coercive. They recall, however, that this helped to ensure high levels of implementation and high adoption of soil water conservation practices, such as planting grass bunds and water diversion channels on sloping lands in cultivated areas. The situation appeared to deteriorate somewhat following independence in the 1960s, probably due to disruption caused by an absence of organised political and cultural institutions, especially in the 1970s. Thus, it can be partly argued that the present low level of adoption of conservation is a result of the past political turmoil and the absence of strict stance similar to that of the colonial administration. But the colonial system is often blamed for emphasizing a top-down and unexplained harsh approach. A bottom-up approach involving all the stakeholders, including the resource users, to participate in identifying problems and solutions as provided for in the Decentralization Act, is probably more favourable. There is need for caution, however, because despite the bottom-up approach being the most recommended today, there are no clear cases of success where it has been tried. There are mixed results indicating that the degeneration of past efforts may not be entirely blamed on a top-down approach but also on the complex interacting variables that tend to negate possible successes.

## 7.5 IMPLICATION OF THE UNDERSTANDING OF DEGRADATION FOR PUBLIC POLICY

Resource user understanding and perceptions of soil degradation have an important bearing on soil resource use and management. The findings of this study have revealed some important considerations that need to be incorporated into guidelines for individuals and institutions interested in enhancing resource user awareness and control of soil degradation. These are as follows:

- To some extent farmers and pastoralists are aware of the linkages between their activities and soil degradation. However, there is a need to explore what they know and identifying gaps in their knowledge in order to create greater awareness if integrated resource management, including agro-biodiversity, is to be achieved in agro-ecosystems. The awareness programmes should pinpoint such effects and linkages related to soil degradation using, for example, simple diagrammatic tools for easy understanding by resource user beneficiaries.
- The resource users' assessment of soil degradation is varied. Specific and simple indicators should be developed based on their understanding and conveyed to them through awareness campaigns at workshops and in the farm fields. A better method of developing these indicators could be through participatory approaches involving these resource users and incorporating the knowledge they already have. Use of familiar indicators can be rewarding in terms of interacting with resource users about the condition of their land, particularly where the land is degrading or recovering after rehabilitation efforts.
- The livestock keepers understand soil degradation issues and probably link it to the stock densities on their ranches and the grazing practice. However, the adoption of conservation practices is low. In Kenya, Moore (1979b) also observed that a major problem faced in controlling semi-arid soil erosion is to reduce stock numbers or to rotate them in a more efficient manner, and that this obviously ties in with an understanding of

the socio-economic structure and perceptions and goals of the local people. As Moore has argued those policies for control of soil erosion must take into account the perceptions, the needs and aspirations of the local people whose lot is to be improved. The policies should not be applied uniformly across the country considering that the perceptions, needs and aspirations of people differ from one area to another.

- Secondary activities such as charcoal burning are perceived to be contributing to soil degradation. Such perceptive behaviour can be explored to enhance afforestation campaigns by the local authorities.
- More recent settlers are less aware of past degradation problems, and therefore, as an entry point there could be a need to focus attention on them through appropriate awareness campaigns.
- The socio-demographic characteristics should not be taken for granted when planning for the conservation or rehabilitation of the degraded lands. The findings in this study showed that the perceptions of the local people regarding soil degradation issues are not necessarily consistent with the results from elsewhere.

## 7.6 CONCLUSIONS

This chapter has explored the understanding, perceptions and response of key stakeholders in soil resource management in Nakasongola district. The summary of the findings is presented below.

Soil fertility decline, compacted soils, moisture deficiency and erosion, respectively, are the major soil degradation concerns perceived in this area on both the farm and pastoral lands. This tallies with and supplements the measurements undertaken in the field. Poor cultivation methods involving, for example, low or no inputs on small-sized plots have compounded these problems on farmlands. A number of *bibanja* holders (squatters), including recent farmer migrants, have plots barely exceeding 3 ha of land per household. Soils in the area are inherently of low to medium productivity and highly susceptible to organic matter decline due to high temperature and termite activity. This coupled with limited farm sizes and low returns, therefore, necessitate continuous use so as to meet the family needs; in the process this may accelerate soil degradation. The exposed sub-soils with iron concretions and boulders are a problem, underestimated by locals and this further threatens the quality of the rangelands if the status quo remains.

There was no significant difference among resource users in the understanding of soil processes. The understanding and perception of the problem of soil degradation was probably reflected by the majority of the respondents in each resource user type in relation to their reasonable awareness of this constraint to production.

One of the important explanations for soil degradation on the hillcrests and around homesteads, as articulated by some respondents, was that the low-lying areas are cooler at night and are associated with biting insects. Low-lying areas are thus available for grazing during daytime. During the wet seasons, these same areas are also soggy due to flooding. Livestock are very sensitive to such areas and prefer staying on hillcrests or around homesteads where conditions are warmer and relatively insect-free. Furthermore, the security of livestock is very uncertain when they are far away from homesteads; there have been increased livestock thefts in the area of recent, probably due to attractive market prices in urban areas of Kampala. These conditions force livestock concentration around hillcrests and homesteads causing trampling and deterioration of plant cover. Consequently, water runoff and soil erosion are accelerated. This was an important revelation through interviews and is based on the indigenous knowledge. Thus, when planning to solve degradation problems of this area, such local knowledge and experience should be taken into consideration, and not simply ignored.

The understanding and perceptions of soil degradation are not significantly related to resource user characteristics of age, sex, educational level and length of time spent in the area. This contrasts with findings elsewhere (e.g. Bills and Heimlich, 1984) but is in agreement with others (e.g. Okubal and Makumbi, 2002; Kranjac-Berisavljevic, *et al.*, 2002). Thus, perceptions are very complex, varied and should not be taken for granted, particularly when analysing soil degradation issues.

Secondary activities (e.g. charcoal burning) were perceived to be closely linked to soil degradation processes prevailing in the Nakasongola district. There is evidence of decline in on-farm productivity in many areas in the district. Due to this decline, the off-farm lucrative livelihood options such as charcoal burning have definitely become highly instrumental in this marginal area. The current scale of charcoal burning may not yet be critical but there is likely to be a serious problem in future due to the increasing reported harvest rate and demand from the surrounding urban centres. This is further compounded by poverty and the low growth rate of the commonly harvested woody tree species (e.g. acacia). Appropriate actions formulated by the relevant stakeholders, including the local communities and probably supported by external funding may be required to cope with this impeding problem.

Footpaths and animal tracks were also perceived to be important factors causing soil degradation through compaction of land along linear zones concentrating surface runoff and eventually leading to the formation of gullies, particularly on grazing lands located on moderate to steep slopes. The paths and tracks were reported to have been increasing with increasing in response to human-and livestock-population changes and land fragmentation. It is likely that lack of maintenance of these paths/tracks has contributed to an increased rate of degradation.

The chapter has also deliberated on the coping actions adopted by the local people and the district in view of the changing environmental and socio-economic conditions caused or contributed to by soil degradation.

The response of the individuals is diverse and reflects the multiplicity of individual decisions taken in view of the soil degradation on farmlands and the options available to them. There is, however, generally low adoption of SWC practices particularly among sole crop farmers in relation to their understanding and perception of soil degradation processes. This can be attributed to various factors including constraints of labour and funds for investments, incomplete understanding of the problem, poverty and lack of appreciation of the importance of the conservation practices. Renaud, *et al.,* (1998) have made similar observations including that of marginalisation of some farmers and poor interactions with extension services.

Some resource users appear helpless, not knowing what to do in view of the increasing land degradation. For instance, they indicate that the bare patches and gullies on grazing lands are beyond their control. A multifaceted approach therefore needs to be adopted in view of the complexity of the degradation problem. Part of the attempt could involve enhancing the efforts of innovative farmers in the hope that the ideas will diffuse to the rest of the community.

Household livelihood strategies such as charcoal burning are beneficial in terms of realising revenue but may endanger environmental quality; there is therefore a need for mechanisms that will enable the harvesting to be managed in a sustainable manner. The researcher agrees with Siri (2001 that enhancing the social and economic viability of these rural households is crucial for the welfare of a large section of the population. Besides, the participation of the affected resource users is crucial for any successful endeavour. Effective adoption by local communities of innovative and productive technologies depends on their participation in the process of developmental activity (Sivakumar and Das, no date).

Respondents indicated very limited success in addressing the causes and adverse effects of soil degradation. This emphasises the importance of integrating the role of both the local communities in this area and the government to design appropriate strategies to effectively control soil degradation. Participatory approaches should be used to ensure that the resource users' interests and constraints are clearly understood and taken into consideration to avoid mistakes of the past mistakes.

More environmentally sensitive adaptive strategies such as beekeeping are commendable but need to be promoted and enhanced by external funding for any profitable achievements by a large section of people. Thus the new government Plan for Modernisation of Agriculture (PMA) should aim to help promote such local initiatives in line with the PMA's mission to increase production and productivity that contribute to food security and poverty eradication without degrading the environment (MAAIF & MPED, 2000).

Increased numbers of migrants both for crop farming and livestock keeping were reported, particularly on the ranches. These migrants either rent or are offered land based on good will by the landlord. However, squatters who are engaged in livestock keeping indicated problems of overstocking due to intruders who claimed grazing rights granted by the landowner. There was evidence of degradation for a few of these areas visited in Kyamukama village. Such mechanisms of land distribution that compromise sustainability of rangeland conditions need to be evaluated for improvement. For instance, there is a need to evaluate the renting of land by landlords to many livestock owners with little or no consideration of its carrying capacity. Important in this direction would be the reference to the soil conservation guidelines as provided for in the soil quality standards adopted in 2000.

This chapter has examined the existing local knowledge and understanding of soil changes and degradation processes. The coping strategies at household level in relation to that at the district were evaluated. In the final chapter, the author attempts to integrate and synthesise the results and present recommendations and future directions.

# CHAPTER 8

# SYNTHESIS, CONCLUSIONS AND FUTURE DIRECTIONS

## 8.1 INTRODUCTION

This study undertook to assess the nature and magnitude of soil degradation and its associated effects using field observations and responses from the resource users and managers in the dry-land area of the Nakasongola district. The study operated at three spatial scales namely catchment level, runoff plots and household level (Chapter 4). The results have been presented and discussed in Chapters 5 to 7, and the summaries given at the end of each chapter constitute the summary of the findings of this study. This chapter brings together the major findings to concretise the understanding of the nature of soil degradation and its control in Nakasongola dryland. The major findings are presented and show how they contribute to an understanding of soil erosion and to the broader field of land degradation in the drylands of tropical Africa and beyond.

## 8.2 SYNTHESIS

Providing a comprehensive understanding of the nature and controls of soil degradation is such a challenging issue particularly in the methodological context. This case study has demonstrated the use of a multi-pronged methodological approach, involving social methods combined with field experimental setups and interpretation of images in a GIS environment, in investigating the complex problem of soil degradation. Empirical observations and field experiments have shown that soil degradation in its various forms presents a real problem in the drylands of the Nakasongola district. Such a combination of social and natural science methods can therefore foster future multidisciplinary or interdisciplinary research collaborations and initiatives.

**The forms and distribution of soil degradation in the study area** were characterised based on field observations and local community response. The case study reveals that soil degradation is a salient issue in the district of Nakasongola despite the low relief, less undulating topography and unreliable rainfall conditions. Thus, fragile low relief environments constitute 'hot spot' areas for conservation. Virtually all forms of soil degradation exist, although sheet erosion is more pronounced compared with rill and gully erosion. The concentration of surface runoff (e.g. along livestock tracks) favours the initiation and development of gullies (Nordström, 1998). The presence of gullies is a physical symptom of the deterioration of the land quality (Stocking, 1998).

Although gully erosion is presently localised, there are potential threats of expansion to other bare lands. Bare patches are associated with destruction of soil structure and compaction that leads to low infiltration rates hence accelerated surface runoff (6.2.1).

**Magnitude of soil degradation processes under different degraded surfaces in a dominant land use/ cover type:** Relatively high rates of soil and runoff were measured on the on-farm rangeland field plots (5.4). The severely degraded areas experienced a significantly ($p < 0.001$) higher average soil loss (20 t/ha) compared to the moderately- and non-degraded plots for the two years ($p=0.034$). This forms sufficient empirical evidence that soil degradation is a problem in this area. However, it is implied that in terms of conservation/rehabilitation the highly degraded areas should be the main focus by the concerned authorities. The long-term impacts are unknown but soil erosion rates in tropical ecosystems are reported to be greater than the rate of soil formation (Sparovek and Schnug, 2001). The rate of soil loss in this area is generally higher than that of soil formation estimated at less than 0.01 t/ha/year (Dunne, *et, al.*, 1978), and therefore, considering the widespread shallow and inherently poor soils, continued degradation is likely to impact negatively on the productivity of such an ecosystem.

**Impacts of soil degradation**: Field observations and local community response revealed that soil degradation (e.g. soil loss causing truncation of more fertile topsoils) has resulted in exposure of poorer sub soils, reduced infiltration rates, increased runoff and low water retention. Reduction in water retention coupled with loss of nutrients undermines plant performance. Therefore, the area seems to be tending toward drier and more fragile conditions as also noted by the local community. The growth of bare patches and incipient gullies are signals of the accentuated degradation conditions.

Despite the negative effects, soil degradation by water erosion creates benefits to the low-lying areas in terms of nutrients and moisture. Soils in lowlying areas had higher moisture retention capacity compared with those on sloping land. In general, therefore soil degradation leads to winners and losers as evidenced elsewhere (Stocking, 1994). It is, however, debatable how much of the degradation should be allowed to occur on the upslope areas, and whether those benefiting downslope should provide some incentives for the upslope resource users.

**Knowledge and perceptions of the local community on soil degradation**: A socio-ecological survey (Chapter 7) provided further insights in the understanding of soil processes. The survey revealed that, in general, the local resource users/managers are cognisant of soil processes and degradation problems in the Nakasongola district. The observed variation between the resource users' knowledge and perceptions of soil degradation is a reflection of their varied experiences and the nature of their functional environment. Socio-economic characteristics (e.g. household income, land ownership and length of stay) of respondents are known to be influential in perceptions of natural resources and management. However, in this case study they were statistically insignificant in influencing the perceptions of resource users of soil degradation. This does not imply these factors are not influential but the available data could not provide sufficient proof in support of their influence.

**Key factors influencing soil degradation**: Interplay of factors have contributed to the observed degradation in the study area including prolonged dry conditions, concentration of livestock grazing and movement and easily compacted soils. In planning for conservation of this area, these factors including the existing local knowledge need to be considered. Livestock tracks and human footpaths are significant factors influencing the formation of channel erosion. The increased livestock in the area certainly causes over-trampling along lines of frequent movement to watering points. Field observation revealed a low to moderate degree of soil degradation around watering points in relation to areas located 1 to 2 km away. This is probably explained by the location of most of the watering points in low-lying relatively moist areas hence the ability to regenerate whenever degraded. Therefore the 'plosphere' effect observed in Namibia (Imbamba, 2002) and Australia is not clearly developed here.

**Coping strategies to soil degradation**: Investigations and observations revealed that despite the existing knowledge and perception of soil degradation problems in the area, the adoption of conservation practices is still low. Adoption of conservation practices is influenced by a number of variables (Beshah, 2003). Thus, only knowledge of the problem may not be sufficient to prompt corresponding adoption of the control practices. For instance, the central and local government have set up the required institutions but these are less coordinated and often experience financial resource constraints. Therefore, monitoring and extension work have stalled. It was widely expressed that inadequate financial support has particularly hampered the operations of the agricultural extension staff and hence indirectly contributed to their ineffectiveness. This is not to overlook the inefficiency of the extension workers that may be partly explained by the poor remuneration and ill equipment in terms of appropriate knowledge to deal with farmers' challenges. These constraints need to be considered and addressed in order to realise full implementation of the conservation policy at lower levels.

At the household level, there are various constraints to soil conservation depending on the nature of the resource users. In general, however, most of the respondents agreed that they have done little to solve the problem of soil degradation, let alone recognising it as a problem. The underlying constraints are not clearly known although the herders indicated inadequate prior knowledge in conservation on smaller sized farms since most of them were converted from being nomadic pastoralists to sedentary- and agro- pastoralists in the early 1990s. They indicated that, in the past, they could graze their stock in one area and abandon it to allow for regeneration. The challenge is also compounded by inherently poor soils and uncertainties of climatic conditions. It was remarked by the DVO and the LC1 chairperson in Migera village that unreliable rains cause scarcity of water and pastures, which worries a herder, more than soil degradation issues.

Land ownership was clearly pointed out as another factor influencing investment in soil conservation. Squatters are often hesitant to invest in land that is not theirs as widely noted in other areas. As observed elsewhere, the influence of land tenure on land management practices is not conclusive. Beshah (2003) found that farmers in Ethiopia were reluctant to construct permanent conservation structures on land for which they have no sure title but that this was contrary to the situation on arable lands. These illustrations point to the need for undertaking area and culture specific studies to understand the detailed fabric in a setting before introducing interventions in a project area.

The current deteriorating conditions of the rangeland and cultivation lands partly imply that people can no longer derive enough from traditional on-farm activities hence the adoption of alternative livelihood strategies (e.g. charcoal burning). Charcoal burning is not a problem per se but the current rate of tree harvest to fulfil the increasing urban demand raises numerous questions about the future supplies and the unforeseeable threats to environmental quality in general. This requires more prudent measures to allow for sustainable utilisation for various needs of the present and future society.

The preceding discussions of the salient findings have demonstrated that to a reasonable extent, soil degradation is an issue that needs attention by the concerned institutions and the local people. The expression in Lugisu: *Umuyifi ulinda isolo yemwilowo etuleyo yosi na gifumite, aba ilibile* literally translated means 'a hunter who waits for a whole animal to come out from a hiding hole before spearing misses it'. There was conclusive field evidence that the conservation efforts so far embraced particularly on grazing land are inadequate and un-coordinated. The author reiterates that if soil the degradation problem, particularly on the severely affected grazing lands, is not attended to in the immediate future, there is a danger of it escalating to uncontrollable levels.

## 8.3 CONCLUSIONS

The drylands of the Nakasongola district have witnessed many environmental, socio-economic and political changes over the last half century and such changes are linked in one way or another to the current land degradation in general and soil degradation in particular.

In conclusion of this thesis, the author, draws the attention of the reader to main highlights pertaining to the study.

1. Different types/forms of soil degradation are spatially distributed widely though the extent and rate differed depending on the environmental conditions.

2. Water erosion was identified as the main soil degradation process. In general, though not conclusive, the magnitude of water erosion is high on the poorly managed grazing lands; intensive sheet wash and rills are very commonly observed and the emergence of gullies is a manifestation of degraded catchment and increasing magnitude of erosion (Chapter 5).

3. The study demonstrated that the causes of soil degradation (Chapter 5) clearly pinpoint the interplay of climatic changes (prolonged dry periods) aggravated by human factors such as population pressures, increases in livestock pressure and poor land use management. It was very hard and impractical to isolate the natural from the human induced factors. Nevertheless, considering that the natural factors such as climate varied in the distant past and yet no serious degradation was reported offers a strong clue that human activities in the recent past are responsible.

4. The different soil degradation types have had varied environmental and social impacts based on the scientific methods of assessment (Chapter 6) and indigenous perspective (Chapter 7). The various impacts identified include reduced infiltration capacity, changes in texture, soil profile truncation and reduced nutrient levels. Changes or reduction in soil biodiversity were perceived by the local people but not clearly linked to soil degradation.

5. The above changes in soil conditions are recognised but not all of them are fully understood by the local people as demonstrated in Chapter 7. The local people were/are, to a greater extent, able to differentiate changes due to degradation based on similar indicators as applied in western science. These changes in soil condition impact on the socio-ecological aspects in different ways and with varied degree of magnitude. Soil degradation has resulted in reduced soil fertility, leading to poor performance of pasture and crop production. Poor plant

performance is known to be associated with poor cover thus through positive feedback mechanism causes accelerated soil degradation. The degradation is, however, not uniformly experienced both spatially and temporally even on the same piece of farmland. Problems such as silting of water sources are felt not only at individual level but also by the community especially for those sources that are owned communally. Soil degradation by soil erosion can be beneficial particularly to the low-lying areas in terms of water and nutrients. The water and nutrients contribute to improved conditions, which are used to advantage by some farmers for dry grazing and cultivation.

6. There are no specific formal coping strategies at district, community or household level addressing soil degradation problem per se. Soil degradation is addressed, as part and parcel of environmental or agricultural production problems and it is probably correct to refer to coping actions other than strategies. Empirical evidence seems to suggest that these coping actions are not adequate and properly co-ordinated to tackle soil degradation. There is generally low adoption of SWC practices despite the high perception of the degradation problem. The study identified (Chapter 7) bottlenecks in conservation efforts that need to be addressed at household and district levels. The local and central government have the mandate to make policies and intervene through agencies such as extension staff. However, their contribution is lacking.

7. The author has advanced recommendations in this Chapter (section 8. 5). Important to note, however, is the need for a holistic approach when tackling soil degradation problem while also considering the various constraints experienced at household or community level as stipulated in this thesis. The challenging issue is that of coping with the natural climatic uncertainties considering the limited resources in such a rural setting.

## 8.4 FINDINGS REVEVANT TO PREVIOUS WORK ON SOIL DEGRADATION

- Resource Users (farmers and pastoralists) are generally reasonably aware of and perceptive of the soil processes and soil degradation problem in the central drylands of Uganda
- Gully erosion development is highly influenced by human activities as reflected by the linear patterns following cattle tracks and human paths.

Unresolved but interesting issues revealed by this research that needs further investigations:

- 'Transformation' of ferralsol soil type to plinthic ferralsol soils as a result of truncation of top soil horizons.

- Perceptions of soil degradation problem are significantly influenced by length of time of settlement and household income.
- Rainfall amount is strongly related to runoff and soil loss as shown by this study. However, there is need to investigate the effect of rainfall amount and intensity including the temporal and spatial rainfall pattern.
- Intensive sheet wash has led to exposure of boulders and concrete ironstones. The effects of these boulders/concretions in terms of controlling further degradation and /or accelerating it are not clearly known at least in this environment.
- Termites are part of the grazers in this ecosystem and their role in nutrient cycling is widely reported in the literature. However, there are imbalances probably enhanced by climatic changes and compounded by other grazing herbivores leading to stripping of the vegetation. The role of termites in this regard needs to be clearly understood. The author does recognize the difficulties, however, of the very thin line separating the effects of termites and other grazers in the wild setting.

## 8.5 RECOMMENDATIONS AND WAY FORWARD

This study has shed light on certain aspects of soil degradation problem and based on these some recommendations are advanced.

There is urgent need to tackle the soil degradation problem especially on grazing lands to avoid further deterioration. The observed intensive sheet erosion, developing rills and incipient gullies are a clear manifestation of a serious problem that may worsen in the near future. While recognising the biophysical and socio-economic dimensions of soil degradation as revealed in this study, the author feels that a holistic conservation approach should be more appropriate. The study pinpoints 'hotspot' areas where priority could be focused by the local authority in the immediate future.

Livestock tracks and human paths are recognised major contributors of rill and gully erosion particularly on grazing lands. The solution to this problem is not straightforward. However, one possibility is to establish more watering points to avoid long tracks/paths and in confining stock movement to existing watering points, along particular areas while avoiding as much as possible the movement up or down slope. There are, however, constraints to conservation. The herders need external assistance to be able to build more watering points; this could be in form of soft loans from the government or private scheme. The other alternative in this respect could be in terms of subsidies on the required construction materials.

Degradation is accelerated by low infiltration rates of the soils hence high runoff amounts. SWC techniques particularly water harvesting technologies are very important in controlling excessive runoff and using the harvested water to support plant growth especially considering the frequent droughts and the prolonged dry season (2-5 months) in the study area.

SWC campaigns in this drylands should emphasise management of plant cover. Plant cover is an important factor for enhancing infiltration hence reduction of surface runoff. Observations of intensive erosion on bare soils under tree cover on the grazing lands, is clear evidence of the need to maintain adequate basal cover e.g. through replanting good quality grass and other palatable shade tolerant plant species. Identification and promotion of nitrogen fixing local plant species (e.g. *Acacia Senegal*) is very important in restoring the fertility of the degraded soils and providing cover among other uses.

Knowing and perceiving soil changes and degradation problem is not sufficient to guarantee high adoption of SWC practices by the affected land users. As well there is a need to understand other controls for successful implementation of the conservation campaigns. Greater participation in soil erosion control will also be realised if land use, soils and natural resource policies are improved and made known to the local persons. Mobilisation and empowerment of the local people should be addressed to strengthen their capacity in soil degradation control.

In the final analysis, as hypothesised, soil degradation is a problem in the Nakasongola district, which has probably increased in recent decades due to land use/cover changes coupled with poor land husbandry and drought effects. There is temporal and spatial variation in terms of extent, magnitude and impacts of the problem. This study has explored the various forms and magnitude of soil degradation including limited aspects of socio-economic and ecological impacts. The magnitude of the problem particularly under cropland use/cover and the underlying factors constraining wide adoption of conservation practices in this area need further investigation. The patterns and severity of erratic rainstorms including characterisation of susceptible environments require further investigations and monitoring. Economic impacts of soil degradation need to be further explored at household and catchment levels.

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# APPENDICES

**Appendix 1** Glossary of local terminologies and acronyms

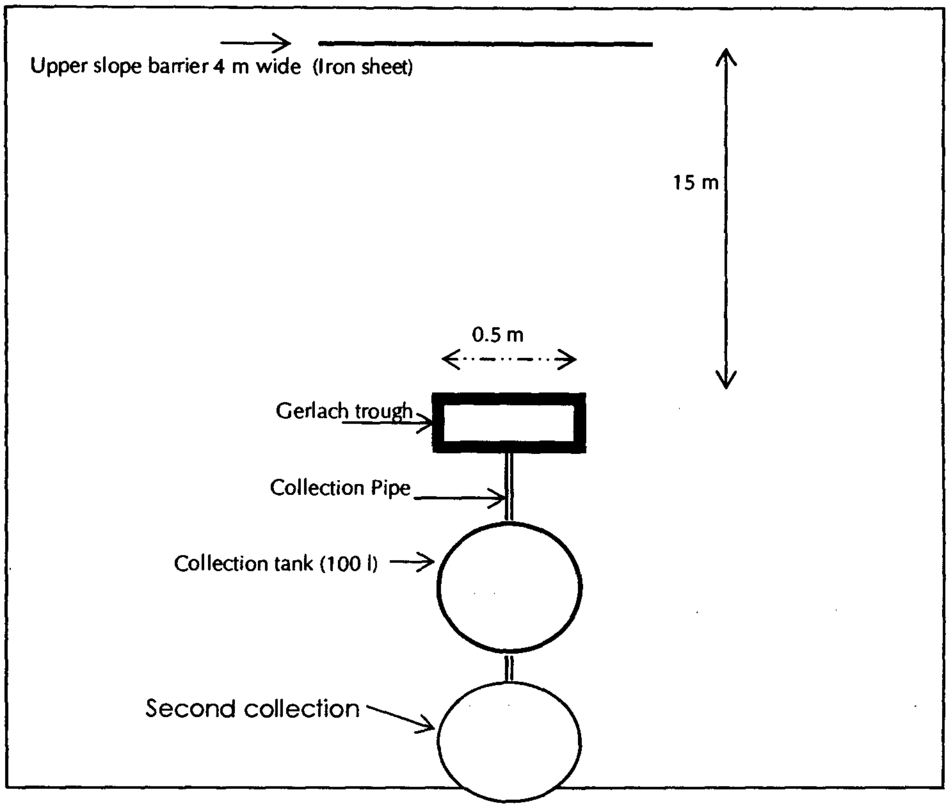
The local terminologies are in a mixture of languages commonly spoken in the Nakasongola district. These include Luruli and luganda/runyakole/runyarwanda (lularo) languages. These terminologies provide insights in understanding the local peoples knowledge of their environment in general and soil degradation in particular.

| **Local terminology** | **Direct English translation** |
|---|---|
| *Ebihazo* | Gullies |
| *Ebihandagazi* | Cattle tracks |
| *Ebihalamata* | Bare soil patches |
| *Entandikwa* | Loan for boosting or setting off a business |
| *Kibanja* | Land occupied by a squatter |
| *Mularo* | One who takes care and rears livestock |
| *Mailo* | A luganda word, which is a product of the Uganda agreement of 1900 denoting a form of absolute ownership and is applied to the land, so held, irrespective of the area and method of acquisition |
| *Kibanja* | An inheritable interest, being a small residential and cultivation tenancy, usually though not exclusively on mailo land (West, 1972). The plural is bibanja. |

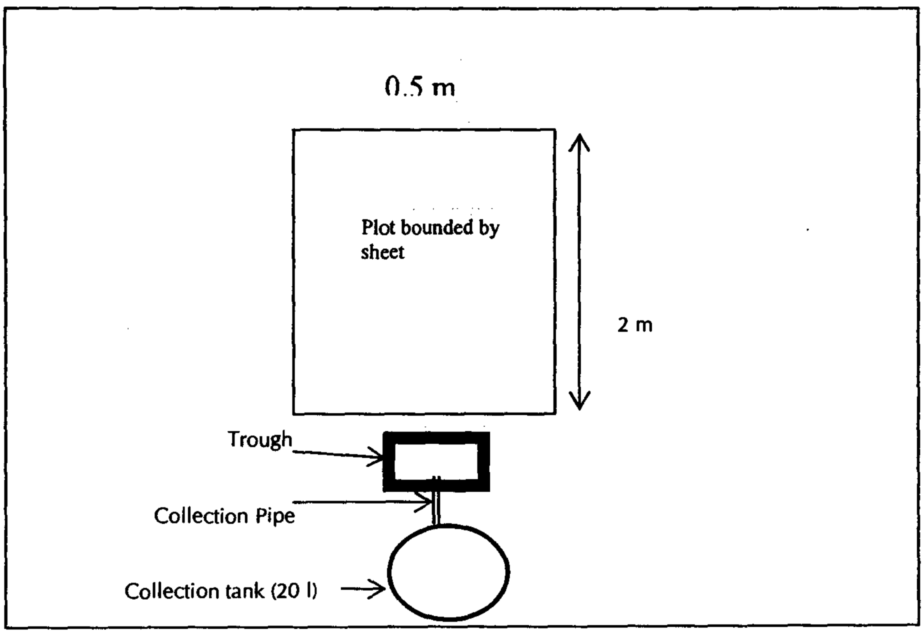
**Acronyms**

| | |
|---|---|
| **FAO** | Food and Agricultural Organisation |
| **GLASOD** | Global land and soil degradation assessment |
| **GOU** | Government of Uganda |
| **IGAD** | Intergovernmental Authority on Development |
| **IUCN** | International World Conservation Union |
| **LC** | Local council |
| **MAAIF** | Ministry of Agriculture, Animal and Fisheries |
| **MPED** | Ministry of Planning and Economic Development |
| **NAADS** | National Agricultural Advisory Staff |
| **NEAP** | National Environmental Action Plan |
| **NEMA** | National Environmental Management Authority |
| **PEAP** | Poverty Eradication and Alleviation Programme |
| **PMA** | Plan for Modernisation of Agriculture |
| **SWC** | Soil water conservation |
| **UNCCD** | United Nations Convention for Combating Desertification |
| **UNCED** | United Nations Conference on Environment and development |
| **UNEP** | United Nations Environmental Program |

**Appendix 2** Erosion plot design and collection system




**Erosion plot design and collection system**




**Simulation plot design and collection system**

The troughs were designed by the researcher and fabricated by FAB metal workshop from locally available material.

## **Appendix 3** Details of soil characterisation at the study sites

**Site 1. Migera unit 17**

0-25 cm: Red (2.5YR4/6), dry dark red (25YR3/4) moist; sand clay; coarse medium sub-angular blocky; hard, friable, stick and plastic; few fine and coarse roots; many fine and medium tubular pores; manganese coatings on peds; diffuse smooth boundary

2-90cm: Red (2.5YR4/6) dry, dark red (2.5YR 3/6) clay loam; weak medium sub-angular blocky tending to powdery; friable; sticky and plastic; few fine and many coarse roots; many fine pores; occasional krotovinas; manganese coatings on the peds; granular smooth boundary.

90cm +: Red (.5YR 4/6 moist; clay; moderate medium sub-angular blocky friable soft; sticky and plastic; few fine roots; few fine pores; thin patchy clay skin peds; more than 0% quartzite and ironstones; horizon continues.

**Site 2. Migera unit 12**

0-30 Red (2.5YR 4/6) dry; red (10 R4/6) moist; clay; strong medium sub-angular blocky; hard; sticky and plastic; few fine and medium roots; many pores; abundant animal borings; diffuse parallel boundary

30-50 cm: Dark red (2.5YR 3/6) dry; red (10 R4/6) moist; clay, moderate coarse sub-angular blocky; firm; sticky and plastic; few fine roots, many fine pores; thin patchy clay skins; diffuse parallel boundary

50-110 cm: Red (10 R 4/6) dry, red (2.5Yr 4/6) moist; clay; weak sub-angular blocky; friable; sticky and plastic; many medium and coarse roots; common fine roots; abundant animal borings diffuse parallel boundary

110 cm +: More than 90% fine ironstones and quartzite.

**Site 3. Migera unit Lp1**

0-16 cm: Red (2.5YR 3/6) dry, darkish brown (2.5 YR 3/4) moist clay loam; strong medium sub-angular blocky; hard; sticky and plastic; many fine roots; many fine and medium pores; many termite nests and channels; occasional krotovinas; diffuse parallel boundary.

16-50 cm: Red (2.5 YR 4/6) moist; clay weak fine sub-angular blocky friable; sticky and plastic; abundant fine and medium roots; many fine pores; occasional termite nests and diffuse parallel boundary.

50-130 cm: Dark red (2.5YR 3/6) mist; clay; weak medium and sub-angular blocky tending to structureless, massive, sticky and plastic; many fine and medium roots; few fine pores; many fine pores; many termite nests; horizon continues.

**Site 4. Migera unit Lp2**

This profile is located at the break of the slope; very open canopy woodland with short trees covering about 40% of surface; shrubs up to 5 m covering about 10% of surface, tufted grass underneath up to 1 m tall. Soil is a thin pebbly venier about 18 cm thick. About 50% ironstone; ironstone boulders are predominantly limonite and manganese.

0-15 cm: Dark reddish brown (2.5 YR 3/4) gravely sandy clay (more than 50% iron stone) weak fine sub-angular blocky; sticky and plastic, abundant fine medium and coarse roots; many fine and medium roots; many fine and coarse pores; many termite nest; clear parallel boundary.

15 cm: More than 80% ironstones

**Site 5: Migera unit BP5**

Profile located at the bottom of an upper subsidiary valley near a local water tank; vegetation consists of very fine open medium height trees, dominated by acacia trees with shrubs up to 5 m; grass cover sparse dominated by Brachiria spp. Area floods during the wet seasons.

0-40 cm: Very dark grey (7.5 YR 3/0) moist; clay; strong medium sub-angular blocky; very firm; sticky and plastic; many fine medium and coarse roots; many fine and medium pores; many termite tunnels; occasional krotovinas; many vertical crack upto 1 m long; clear parallel boundary.

40-80 cm: Black (5YR 2/1) moist; clay, many indistinct dark re (2.5YR 3/8), mottles along cracks, strong coarse sub-angular blocky; firm, soft; sticky and plastic; few fine roots (most roots dead); many fine and coarse pores; cracks up to 2.5 cm wide, horizon continues.

**Site 6: Migera unit BP1**

0-16 cm: red (10 R 4/6) dry, dark red (10 R 3/6) moist clay; moderate medium sub-angular blocky; soft, friable, sticky and plastic, fine and medium roots, many fine and medium roots, occasional termite nests; diffuse parallel boundary

16-55 cm: Red (10YR 4/6) dry, dark red (10 R 3/6) moist, clay, weak fine sub-angular, blocky tending to structureless; friable, soft, sticky and plastic, few fine roots, many fine and medium pores, clear parallel boundary

55 cm: More than 50% ironstone.

**Site 7. Migera unit BP2**

Almost flat surface, more than 98% bare but deep profile

0-20 cm: Weak red (10 R 4/4) dry, dusk red (10 R /4) moist, clay strong coarse sub- angular blocky; hard, firm, sticky and plastic, few fine medium roots; many fine tubular pores; diffuse parallel boundary.
20-40 cm: Dark red (10 R 3/6) dry, dark red (10 R 3 /4) moist, clay moderate medium sub angular blocky, hard, firm, sticky and plastic, very few fine medium and coarse roots; very few fine and medium pores; occasional termite nests and animal borings; parallel boundary.

40-150 cm: Dark red (10 R 3/6) moist, clay weak, sub-angular blocky, friable; sticky and plastic- horizon continues.

Physical and chemical properties of soil for different pits

Upper slope position (Degraded site at lubega):

| | Depth | pH | OM | N | P | S | C | Si |
|---|---|---|---|---|---|---|---|---|
| 3DES1 (L1PIT) | 0-25 | 4 | 1.85 | 0.03 | 6.56 | 4.8 | 4.4 | 0.8 |
| 3DES2 (L1PIT) | 25-90 | 4.3 | 1.59 | 0.03 | 8.26 | 3.6 | 5.2 | 1.2 |
| 3DES22 (L2PIT) | >90 | 4.3 | 1.33 | 0.1 | 5.95 | 4 | 5.2 | 0.8 |

Mid slope position (Less degraded site at lubega):

| | Depth | pH | OM | N | P | S | C | Si |
|---|---|---|---|---|---|---|---|---|
| 2LES4 (L2PIT) | 0-30 | 4.4 | 2.19 | 0.13 | 7.36 | 3.4 | 5.4 | 1.2 |
| 2LES5 (L2PIT) | 30-50 | 4.9 | 1.76 | 0.13 | 8.12 | 3.2 | 6 | 0.8 |
| 2LES6 (L2PIT) | 50-110 | 5.3 | 0.82 | 0.3 | 5.9 | 2.8 | 6 | 12 |

Mid slope position (highly degraded site at Bizibitukula):

| | Depth | pH | OM | N | P | S | C | Si |
|---|---|---|---|---|---|---|---|---|
| 3DES (B2PIT) | 0-20 | 3.7 | 2.6 | 0.07 | 3 | 37.5 | 56.9 | 5.6 |
| 3DES (B2PIT) | 20-40 | 3.7 | 2.2 | 0.13 | 1.5 | 19.5 | 68.9 | 11.6 |
| 3DES (B2PIT) | 40-150 | 3.8 | 1.4 | 0.05 | 2 | 23.5 | 68.9 | 7.6 |

Upper slope position 2 at lubega)

| | Depth | pH | OM | N | P | S | C | Si |
|---|---|---|---|---|---|---|---|---|
| 2LES7 (L12PIT) | 0-16 | 4.6 | 3.1 | 0.08 | 3 | 37.5 | 52.9 | 9.6 |
| 2LES (L12PIT) | 16-50 | 4.5 | 2.6 | 0.15 | 1 | 27.5 | 62.9 | 9.6 |
| 2LES (L12PIT) | 50-130 | 4.5 | 1.1 | 0.05 | 2 | 25.5 | 66.9 | 7.6 |

Upper slope position at Bizibitukula

| | Depth | pH | OM | N | P | S | C | Si |
|---|---|---|---|---|---|---|---|---|
| 2 LES (B1PIT) | 0-16 | 4.1 | 2.5 | 0.03 | 2.5 | 27.5 | 64.9 | 7.6 |
| 2 LES (B1PIT) | 16-55 | 4.1 | 1.8 | 0.33 | 2 | 29.5 | 64.9 | 5.6 |

Valley bottom position at Bizibitukula

| | Depth | pH | OM | N | P | S | C | Si |
|---|---|---|---|---|---|---|---|---|
| 1 UESPITX | 0-15 | 4.3 | 4.4 | 0.18 | 3.5 | 45.5 | 44.9 | 9.6 |
| 1 UESPITX | 15+ | 4.5 | 2.7 | 0.08 | 2 | 37.5 | 52.9 | 9.6 |

**Appendix 4.** Soil physical and chemical analysis for Nakasongola

| [illegible] | Station No | Catena | Slope position | Depth (cm) | pH | OM | N | P | K | Na | Ca | Sand | Clay | Silt | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | UES1 | | | 0-10 | 4.6 | 3.74 | 0.13 | 7.5 | 5.58 | 0.56 | 10.5 | 32 | 50 | 18 | Clay |
| 1 | UES2 | | | 0-10 | 5.3 | 3.05 | 0.1 | 7.79 | 20.72 | 0.34 | 19.8 | 64 | 30 | 6 | Sandy |
| 1 | UES3 | | | 0-10 | 5.2 | 3.4 | 0.1 | 5.71 | 14.35 | 0.34 | 18.6 | 56 | 30 | 14 | Sandy |
| 1 | UES4 | | 1 | 0-10 | 5.3 | 3.57 | 0.1 | 7.13 | 21.92 | 0.56 | 51.2 | 36 | 48 | 16 | Clay |
| 3 | DES1 (L1PIT) | 1 | 1 | 0-25 | 4 | 1.85 | 0.03 | 6.56 | 4.39 | 0.34 | 4.7 | 48 | 44 | 8 | Sandy clay |
| 3 | DES2 (L1PIT) | 1 | 1 | 25-90 | 4.3 | 1.59 | 0.03 | 8.26 | 1.6 | 0.45 | 1.2 | 36 | 52 | 12 | Clay |
| 3 | DES22 (L1PIT) | 1 | 1 | >90 | 4.3 | 1.33 | 0.1 | 5.95 | 2.39 | 0.56 | 3.5 | 40 | 52 | 8 | Clay |
| 1 | UES 5 | | | 0-15 | 4.2 | 3 | 0.07 | 1.4 | 9.01 | 0.75 | 12.2 | 56.8 | 32 | 11.3 | Sandy clay loam |
| 1 | UES 6 | | | 0-15 | 4.2 | 2.6 | 0.08 | 0.7 | 7.73 | 0.25 | 7.32 | 46.8 | 48 | 5.3 | Clay |
| 3 | DES3 | | | 0-15 | 3.7 | 1.9 | 0.02 | 1.4 | 9.87 | 0.75 | 9.76 | 60.8 | 28 | 11.3 | Sandy clay loam |
| 3 | DES4 | | | 0-15 | 4.2 | 1.7 | 0.05 | 1.4 | 6.87 | 1 | 13.41 | 66.8 | 28 | 5.3 | Sandy clay loam |
| 3 | DES5 | | | 0-15 | 3.5 | 2 | 0.05 | 0.7 | 7.44 | 0.25 | 7.32 | 48.8 | 44 | 7.3 | Sandy clay |
| 3 | DES6 | | | 0-15 | 4.4 | 2.7 | 0.05 | 0.7 | 5.58 | 0.25 | 3.66 | 56.8 | 40 | 3.3 | Sandy clay |
| 3 | DES10 | | | 0-15 | 3.8 | 2.3 | 0.03 | 1.75 | 11.6 | 0.75 | 7.32 | 52.8 | 44 | 3.3 | Sandy clay |
| 3 | DES7 | | | 0-15 | 3.6 | 2 | 0.05 | 1.4 | 9.87 | 1 | 6.1 | 46.8 | 44 | 9.3 | Sandy clay |
| 3 | DES8 | | | 0-15 | 3.2 | 1.8 | 0.03 | 0.7 | 11.16 | 0.75 | 7.32 | 40.8 | 52 | 7.3 | Clay |
| 3 | DES9 | | | 0-15 | 3.5 | 1.8 | 0.02 | 0.7 | 12.02 | 1 | 3.66 | 38.8 | 56 | 5.3 | Clay |
| 3 | DES11 (B2) | 1 | 3 | 0-15 | 4.2 | 2 | 0.05 | 4.5 | 5.58 | 0.56 | 12.8 | 63.5 | 30.9 | 5.6 | SCL |
| 2 | LES1 | | | 0-15 | 4.5 | 1.6 | 0.05 | 1.4 | 5.58 | 0.25 | 3.66 | 66.8 | 28 | 5.3 | Sandy clay loam |
| 2 | LES3 | | | 0-15 | 4.3 | 2.3 | 0.07 | 0.7 | 6.44 | 0.25 | 3.66 | 54.8 | 42 | 3.3 | Sandy clay |
| 2 | LES2 | | | 0-15 | 4.4 | 2.4 | 0.05 | 1.4 | 6.01 | 0.25 | 6.1 | 58.8 | 34 | 7.3 | Sandy clay loam |
| 2 | LES4 (L2PIT) | 1 | 2 | 0-30 | 4.4 | 2.19 | 0.13 | 7.36 | 4.39 | 0.89 | 2.3 | 34 | 54 | 12 | Clay |
| 2 | LES5 (L2PIT) | 1 | 2 | 30-50 | 4.9 | 1.76 | 0.13 | 8.12 | 6.38 | 1.34 | 7 | 32 | 60 | 8 | Clay |

**Appendix 4.** Soil physical and chemical analysis for Nakasongola

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | LES6 (L2PIT) | 1 | 2 | 50-110 | 5.3 | 0.82 | 0.3 | 5.9 | 2.39 | 0.45 | 1.2 | 28 | 60 | 12 | Clay |
| 2 | LES7 (L12PIT) | 1 | 1 | 0-16 | 4.6 | 3.1 | 0.08 | 3 | 5.58 | 0.45 | 14 | 37.5 | 52.9 | 9.6 | Clay |
| 2 | LES (L12PIT) | 1 | 1 | 16-50 | 4.5 | 2.6 | 0.15 | 1 | 3.19 | 0.45 | 4.7 | 27.5 | 62.9 | 9.6 | Clay |
| 2 | LES (L12PIT) | 1 | 1 | 50-130 | 4.5 | 1.1 | 0.05 | 2 | 1.6 | 0.78 | 3.5 | 25.5 | 66.9 | 7.6 | Clay |
| 3 | DES (B2PIT) | 1 | 2 | 0 20 | 3.7 | 2.6 | 0.07 | 3 | 4.39 | 0.56 | 12.8 | 37.5 | 56.9 | 5.6 | Clay |
| 3 | DES (B2PIT) | 1 | 2 | 20-40 | 3.7 | 2.2 | 0.13 | 1.5 | 2 | 0.56 | 5.8 | 19.5 | 68.9 | 11.6 | Clay |
| 3 | DES (B2PIT) | 1 | 2 | 40-150 | 3.8 | 1.4 | 0.05 | 2 | 1.6 | 0.67 | 18.6 | 23.5 | 68.9 | 7.6 | Clay |
| 2 | LES (B1PIT) | 1 | 1 | 0-16 | 4.1 | 2.5 | 0.03 | 2.5 | 5.58 | 0.45 | 3.5 | 27.5 | 64.9 | 7.6 | Clay |
| 2 | LES (B1PIT) | 1 | 1 | 16-55 | 4.1 | 1.8 | 0.33 | 2 | 2.79 | 0.34 | 2.3 | 29.5 | 64.9 | 5.6 | Clay |
| 1 | UESPITX | 1 | 4 | 0-15 | 4.3 | 4.4 | 0.18 | 3.5 | 16.34 | 0.67 | 12.8 | 45.5 | 44.9 | 9.6 | Sandy clay |
| 1 | UESPITX | 1 | 4 | 15+ | 4.5 | 2.7 | 0.08 | 2 | 5.18 | 0.67 | 2.3 | 37.5 | 52.9 | 9.6 | Clay |

Landuse: 1 = grazing, 2 = farming; Slope position: 1 = upper, 2 = Mid, 3 = Lower

| **Physical and chemical analysis of Buruli soils (Soils memoirs, 1960s)** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| **Buruli red deep Profile 26 (19642-47)** | | | | | | | | | | | | | | |
| **Depth ins** | **Mech analysis** | | **Exch. Bases m.e per 100g** | | | | | | **Exch H** | **Ex.C m.e** | **% sat** | **pH** | **OC %** | **Truog P ppm** |
| | **Silt** | **Clay** | **Ca** | **Mg** | **K** | **Mn** | **Na** | | | | | | | |
| 3 | 6 | 12 | 0.7 | 0.6 | <0.8 | 0.22 | 0 | | 3.2 | 4.7 | 32.2 | 4.7 | 0.96 | 10 |
| 8 | 2 | 22 | <0.4 | <0.3 | 0.19 | 0.05 | 0 | | 3.5 | 3.7 | 6.4 | 4.1 | 0.56 | 14 |
| 18 | 4 | 30 | Tr | <0.3 | 0.15 | 0.06 | 0 | | 3.7 | 3.9 | 5.4 | 4.1 | 0.29 | 11 |
| 36 | 2 | 40 | 0 | <0.3 | 0.3 | 0.06 | 0 | | 3.4 | 3.8 | 9.6 | 4.3 | 0.14 | 14 |
| 60 | 6 | 36 | <0.4 | <0.3 | 0.24 | 0.07 | 0 | | 3.5 | 3.8 | 8.1 | 4.3 | 0.2 | 23 |
| 72 | 2 | 48 | <0.4 | <0.3 | 0.16 | 0.08 | 0 | | 4.3 | 4.5 | 5.3 | 4.1 | 0.17 | 14 |
| | | | | | | | | | | | | | | |
| **Buruli Ferruginised (Profile 27 (19734-39)** | | | | | | | | | | | | | | |
| 3 | 2 | 22 | 1.8 | 0.6 | 0.2 | 0.18 | 0 | | 2.5 | 5.3 | 52.7 | 5.3 | 0.67 | 7 |
| 8 | 6 | 30 | 1 | <0.3 | 0.12 | 0.19 | 0 | | 3.5 | 4.8 | 27.2 | 4.6 | 0.7 | 2 |
| 18 | 10 | 42 | 0.5 | <0.3 | <08 | 0.07 | 0 | | 4.8 | 5.4 | 10.6 | 4.6 | 0.53 | 2 |
| 28 | 2 | 40 | N.D | ND | ND | ND | 0 | | ND | ND | ND | ND | ND | ND |
| 48 | 6 | 36 | <0.4 | <0.3 | 0.12 | 0.06 | 0 | | ND | ND | ND | ND | ND | ND |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 48+ | 0 | 46 | <0.4 | <0.3 | 0.09 | 0.03 | 0 | ND | ND | ND | ND | ND | ND |

**Average soil characteristics of topsoil (0-20cm) for fields under fallow in the Nakasongola district**

| Years of fallow | pH | om | N | P | K | Ca | Na | Sand | Clay | Silt | Text Class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-2 | 5 | 2.3 | 3 | 1.6 | 12.5 | 33.5 | 2.5 | 66 | 25.1 | 8.9 | SCL |
| 3-5 | 5.1 | 2.6 | 5 | 2.4 | 14.1 | 36 | 2.9 | 67.4 | 24.2 | 8.4 | SCL |
| 6-10 | 5.2 | 2.2 | 3 | 1.8 | 13.1 | 16.6 | 2.7 | 7.6 | 13.8 | 8.6 | SL |
| 11-20 | 5 | 2.3 | 4 | 1.5 | 11.5 | 29.6 | 2.2 | 69.5 | 20.8 | 9.7 | SCL |
| 21-30 | 5 | 2.6 | 5 | 3.5 | 11.6 | 30.5 | 2.1 | 69.8 | 20.2 | 10 | SL |

Source : Ssali H. 2001

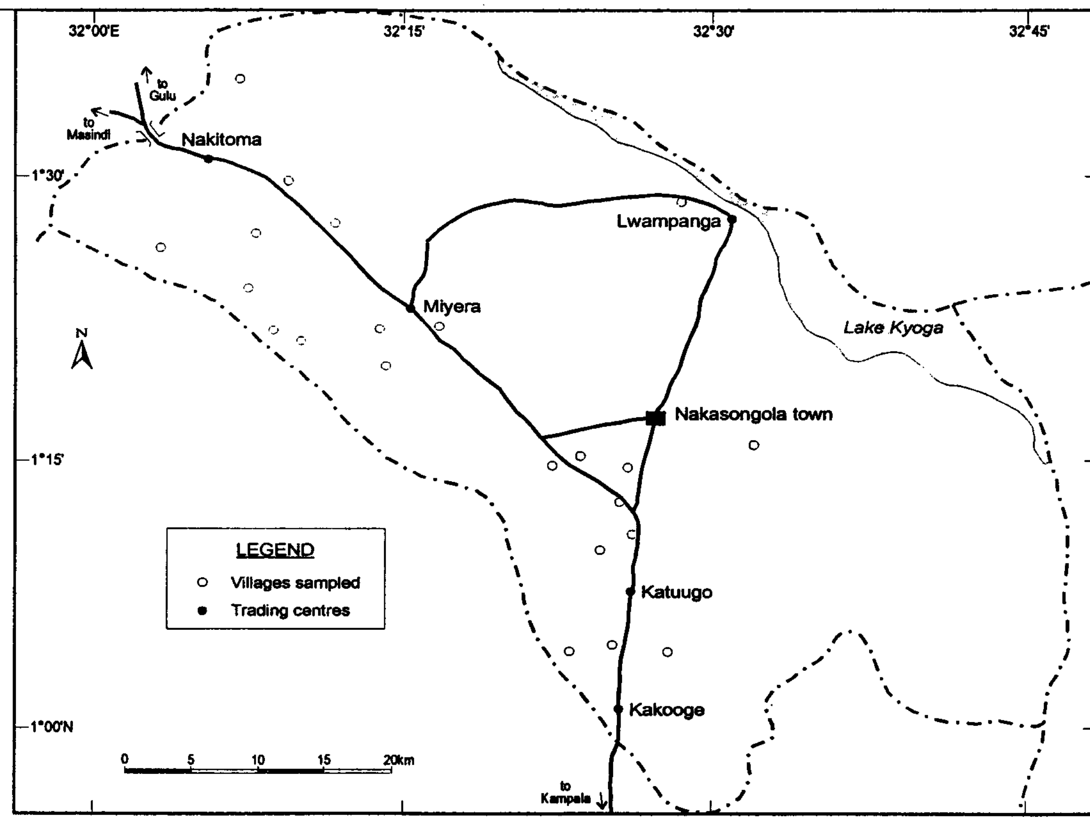
**Soil physical an chemical characteristics for the crop lands in the Nakasongola district (Machum village)**

| Sample no | Depth (cm) | pH | om | N | P | K | Ca | Na | Ma | Sand | Clay | Silt | Text Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2368 | 0-10 | 6.3 | 0.91 | 0.07 | 0.98 | 0.71 | 1.6 | 0.06 | 0.52 | 82 | 12 | 6 | S |
| 2369 | 0-10 | 5.2 | 1.48 | 0.07 | 1.67 | 0.61 | 1.6 | 0.05 | 0.65 | 68 | 28 | 4 | SC |
| 2371 | 10-20 | 5.3 | 1.48 | 0.1 | 2.56 | 0.87 | 1.5 | 0.08 | 0.65 | 68 | 26 | 2 | Sc |
| 2370 | 20-30 | 5.3 | 2.8 | 0.13 | 3.26 | 1.38 | 1.5 | 0.15 | 0.65 | 54 | 38 | 8 | SCL |
| 2365 | 10-20 | 4.6 | 1.81 | 0.1 | 2.19 | 0.92 | 0.4 | 0.09 | 0.33 | 50 | 46 | 4 | SC |
| 2366 | 0-10 | 5.1 | 1.23 | 0.03 | 1.3 | 0.51 | 1.6 | 0.04 | 0.83 | 56 | 38 | 6 | SC |
| 2367 | 0-10 | 6.2 | 1.15 | 0.07 | 1.58 | 0.77 | 1.6 | 0.06 | 0.55 | 84 | 12 | 4 | S |

**Note:**

UED = non-eroded/degraded surface/area
LES = the less or moderately degraded area
DES = the seriously degraded area
B2PIT = the soil profile pit close the plot B2

**Appendix 5** Location of villages sampled for questionnaire/interviews in Nakasongola district




Villages sampled for the questionnaire/interviews in the Nakasongola district

**Appendix 6. QUESTIONNAIRE SURVEY ON SOIL DEGRADATION**
**Target group: Householders**

***Dear Respondent,***

*This questionnaire survey is aimed at collecting information related to soil degradation in selected areas in the district of Nakasongola. The data collected is purely for academic purpose that is, fulfilment of degree requirements at the University of Cape Town, South Africa. However, the information generated will also be useful to policy makers and other stakeholders. The data collected will be treated with utmost confidence unless permission is explicitly requested and granted.*

*Please express your own opinion by writing and/or ticking a suitable choice(s) where required. Your assistance is highly appreciated and will be reflected in the final report.*

**Questionnaire no.** -------

**A. General household information**

H01. Location [village---------------------------- Sub county------------------------------------------

H02. Status of respondent; head of household **[1]** Yes **[2]** No (Specify)-----------------------------

H03. Level of formal education **[1]** Primary **[2]** Secondary **[3]** Tertiary **[4]** other--------------------

H04. Age-------**[1]** 18- 25 **[2]** 25-35 **[3]** 35-40 **[4]** 45-55 **[5]** >55 and sex **[1]** Male **[2]** Female

H05. Length of time stayed in the place **[1]** <5, **[2]** 5 to 10 **[3]** 10 to 15 **[4]** 15 to 20 **[5]** >20 years

H06. Number of members in the household------Adults ----Children-----

H06a. Do all the children contribute to farm labour------------------------------------------

H07. Amount of land owned -----------(ha) [crops---------------Livestock-----------------------

H08. Form of land ownership **[1]** hired **[2]** communal **[3]** Leasehold [4] Other (specify)--------------

H09. Main source(s) of household income **[1]** Trading **[2]** Farming **[3]** Fishing **[4]** Brewing **[5]** Civil servants **[6]** others (mention)---------------

H10. Are there some special skills you have? **[1]** Brick making **[2]** Charcoal burning **[3]** Timber harvesting

H11. Income level of household per month ***(Ug. Shs)***[1]<1000 **[2]** 1000-5,000 **[3]** 5,000-10,000 **[4]** 10,000-20,000, **[5]** >20,000

**B. Soil degradation awareness; types, causes and status**

***Awareness of soil & degradation processes***

D01. Do you have any constraints to use of your soils for agricultural purposes [1] Yes [2] No

If Yes specify--------------------------------------------------------------------------------------

--------------------------If No Why?--------------------------------------------------------------

D02. If soil degradation is cited as a problem in D01, indicate whether any of the following evidence exists on your farmland by ticking in the appropriate space *(rank in order of importance from 1= most important to 5= least important)*

| **Type** | **YES** | **NO** | **Rank** |
|---|---|---|---|
| Sheet wash | | | |
| Rills | | | |
| Gullies | | | |
| Exposed subsoil | | | |
| Compaction | | | |
| Crusting | | | |
| Fertility loss | | | |
| Others (specify) | | | |

D03. When did you recognise this problem on your land **[1]** Can not recall **[2]** 1-3 years ago **[3]** 4-5 years ago **[5]** > 10 years ago

D04. What causes these soil (degradation) problems on your farmland?

D05. Does Wind cause a problem to the soils [1] Yes [2] No

If Yes how?------------------------------------------------------------------------

If No Why?------------------------------------------------------------------------

***Severity of degradation problem***

D06. Rate the seriousness (severity) of soil erosion and give reason(s) for your rating

| **Erosion type** | **Degree** | | | | **Reason(s)** |
|---|---|---|---|---|---|
| | **Very low** | **Low** | **Moderate** | **High** | |
| Water erosion | | | | | |
| Wind erosion | | | | | |

D07. How do you rate the contribution of the following to soil degradation in the area?

| **Activity** | **Rate** | | |
|---|---|---|---|
| | **Not significant** | **Significant** | **Very significant** |
| Charcoal burning | | | |
| Fire wood collection | | | |
| Paths & tracks | | | |
| Brick making | | | |
| Fishing | | | |

D08. Have you noticed any change in the quality and productivity of the soil? **[1]** Yes **[2]** No

If Yes describe-----------------------------------------------------------------------------------------

If No why?-----------------------------------------------------------------------------------------

D09 What do you think caused change in the soil quality in D08? ---------------------------------

D09a. Where on your land is this most critical [1 ] valley land [2 ] sloping land [3 ] Hill tops-- -----------------------------------------------------

D10. How serious is this problem (in D08) **[1]** Not aware **[2]** Not serious **[3]** Serious **[4]** moderately serious **[5]** Very serious

**C. Cropping systems in relation to soil degradation**

*Answer questions C01 to C06 if you are involved in crop farming*

C01. Rank according to importance (*1 = very important-- to 6 = least important*) the types of crops grown **[ ]** maize **[ ]** millet **[ ]** banana **[ ]** cassava **[ ]** sunflower **[ ]** Others (mention)-------------

C02. Have you changed to growing any new crop(s) in the last two seasons?

If **YES** which ones and why?-------------------------------------------------------------------------

If **NO** why?-----------------------------------------------------------------------------------------

C03. Do you practice intercropping? If **yes** give reasons-------------------------------------------

If **no** go to the next question C04.

C04. What are your most important problems concerning crop farming? **Rank** in order of importance (*1= most important--- to 5 = least important*) the problems affecting crop farming **[ ]** poor market **[ ]** disease and pests **[ ]** loss of soil nutrients **[ ]** soil water deficit **[ ]** Other (mention)-----

C05 In what ways is soil degradation a threat to crop farming ---------------------------------------

C06. What have you done to address these soil problems on your cropland? -----------------------

## D. Livestock management & its effect on soil degradation

L01. Rank in order of importance to you the type of livestock kept [ ] cattle [ ] goats [ ] sheep [ ] other (specify)-----------------

L02. Number of each category of livestock; cattle (-------), goats (-------), sheep (---- & other (------)

L03. How do you graze the animals in this area [1] continuous grazing (free range) [2] rotational grazing on farm [3] mixed grazing [4] tethering [5] seasonal grazing [6] Other (specify)---------------

L04. Do you think the method you use causes soil problem [1] Yes [2] No

If Yes how? ----------------------------------------------------------------------------------------

If No Why------------------------------------------------------------------------------------------

L05. Mention the major problems faced in livestock management and rank them in order of importance

L06. How is livestock affected by soil degradation?

L07. Mention any attempts made on your grazing land to control the various forms of soil erosion and degradation (fill the answers in the Table below)

| Type | Control measure(s) |
|---|---|
| Sheet erosion | |
| Rill erosion | |
| Gully erosion | |
| Crusting | |
| Compaction | |
| Loss of nutrients | |
| Loss of organic matter | |

## E. Soil and land management practices

M01. Do you apply any of the following practices on your cropland?

| PRACTICE | YES | NO | WHERE APPLIED ON FARM |
|---|---|---|---|
| Manure | | | |
| Mulch | | | |
| Inorganic fertiliser | | | |
| Grass bunds | | | |
| Agro forestry | | | |
| Ditches/micro basins | | | |
| Others----- | | | |

M02. If nothing is applied what is/are the main reasons among the following **[1]** lack of labour **[2]** high labour costs **[3]** not aware of their importance **[4]** methods are cumbersome **[5]** other (specify)----------

M03. How did you acquire these conservation practices/knowledge--------------------------------

M04. How effective are management methods (in M01) in controlling erosion on your land

| **Conservation method** | **Not Effective** | **Effective** | **Moderately effective** | **Very effective** |
|---|---|---|---|---|
| • Grass bunds<br>• Ditches<br>• Mulch<br>• Agro-forestry<br>• Other (specify)------ | | | | |

M05. Which of the following land management practices do you use and why?

| **METHOD** | **YES** | **NO** | **BENEFITS** | **COSTS** |
|---|---|---|---|---|
| Grass bunds<br>Agro forestry<br>Slash & burn<br>Burn<br>Terraces<br>Ploughing<br>Other(s) specify— | | | | |

M06. Who in your family makes decisions on conservation practices applied?---------------------

| |
|---|
| M06a Who in the family is responsible for the field establishment and maintenance of Soil Water Conservation structures if any?----------------------------------------------- |
| M06b Why the person in M06a? ---------------------------------------------------------- |

M07 Do you have any extension staff? **[1]** Yes **[2]** No

| |
|---|
| 7a. If yes, is it government or non-government------------------------------------------ - |

M08 Rate the assistance related to soil management that is received from the extension staff [ ] Very little [ ] little [ ] Adequate [ ] More than adequate

| M8a What assistance does the extension staffs give you? ---------------------------------- |
|---|

M09. How can the government assist you better in solving soil degradation related problems-----

------------------------------------------------------------------------------------------------

**Additional questions asked if there is time**

1. Do you think you should leave this place because of your degraded land (soil problems) [1] Yes [2] No

If yes Why? ------------------------------------------------------------------------------------

------------------------------------------------------------------------------------------------

If No Why? -------------------------------------------------------------------------------------

------------------------------------------------------------------------------------------------

2. In general do you consider yourself successful in controlling soil degradation on your farm------

------------------------------------------------------------------------------------------------

------------------------------------------------------------------------------------------------

3. What do you think of the future condition of the land in this area? -----------------------------

------------------------------------------------------------------------------------------------

------------------------------------------------------------------------------------------------

4. What alternative sources of income are available-------------------------------------------

------------------------------------------------------------------------------------------------

------------------------------------------------------------------------------------------------

**Thank you**

## Appendix 7: QUESTIONNAIRE SURVEY ON SOIL DEGRADATION IN NAKASONGOLA
### Target group: Local officials and resource managers

***Dear Respondent***

*This questionnaire survey is aimed at collecting information related to soil degradation in selected areas in the district of Nakasongola. The data collected is purely for academic purpose, that is fulfillment of degree requirements at the University of Cape Town, South Africa. However, the information generated may also be useful to policy makers and other stakeholders. The data collected will be treated with utmost confidence.*

*You have been identified as a very resourceful person in contributing to this research. Please feel free to express your ideas by writing and or ticking the correct choice(s) where required. Your assistance is highly appreciated and will be reflected in the final report.*

**Questionnaire no.** -------

### A. General information

G01. Department & designation ------------------------------

G02. Level of formal education **[1]** Primary **[2]** Secondary **[3]** Tertiary **[4]** other--------

G3. Age------ and sex [1] Male [2] Female

### B. Soil degradation problem

***Types and causes***

D01. Is there a problem(s) with soils in the district [1] Yes [2] No

If No Why?------------------------------------------------------------

If Yes what?------------------------------------------------------------

*Continue with questions below (if YES)*

D02. If soil degradation is a problem in the district, Why?------------------------------

------------------------------------------------------------

D03. Type of soil degradation observed in the district (*Rank in order of importance 1= very important---4= least important)* **[ ]** water erosion, **[ ]** wind erosion, **[ ]** chemical deterioration **[ ]** compaction and crusting

D04. How do you rate the contribution of the following to soil degradation in the district

| Activity | Sub county | Rate | | | |
|---|---|---|---|---|---|
| | | Not significant | Significant | Very significant | Don't know |
| Charcoal burning | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| Fire wood collection | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| Paths & tracks | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

D05. In general how do you rank the severity of soil degradation problem in the district **[1]** Not severe **[2]** moderately severe **[3]** severe **[4]** Very severe

D06. What type of water erosion are observed [1] sheet erosion [2] rill erosion [3] gully erosion [4] other (specify)------------------------------------------

D07. How do you compare the present soil erosion rate with that in the past (e.g. 2 to 10 years) for the entire district **[1]** Very severe **[2]** Severe **[3]** moderately severe **[4]** Not severe [6] Don't know

***Affected areas in the district***

D08. List the most affected areas in the district------------------------------------------

D09. Why do you think these areas **(In D03)** are seriously affected by soil degradation? ------------------------------------------

D10. What do you think are the causes of water erosion in various sub counties of the district *(Rank causes in order of decreasing importance)*.

| | SUBCOUNTY | CAUSES |
|---|---|---|
| (a) | | |
| (b) | | |
| © | | |
| (d) | | |
| (e) | | |

D11. What do you think are the reasons for the occurrence of wind erosion (*Rank in order of importance 1= very important---5= least important*)

| | SUBCOUNTY | CAUSES |
|---|---|---|
| (a) | | |
| (b) | | |
| © | | |
| (d) | | |
| (e) | | |

D12. Rate the degree (intensity) of soil erosion and give reason(s) for your choice

| Type | Sub county | Degree | | | | Reason(s) |
|---|---|---|---|---|---|---|
| | | Very low | Low | Moderat e | High | |
| Water erosion | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Wind erosion | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

D13. What type of chemical degradation is observed in the district [1] Increased acidity [2] Decline in plant nutrients [3] Other specify---------------

D13a. In which place(s) is this most critical-----------------------------------------------
-----------------------------------------------------------------------------------------------

D14 What causes chemical soil degradation in the areas noted in the district----------
---------------------------------------------------------------------------------

D15. How serious is the problem of chemical degradation in the district---------------

**C. Soil degradation effects & Management**

M01. Is soil degradation a serious constraint to agricultural production in the district **[1]** YES **[2]** NO

*If YES, Why?* ---------------------------------------------------------------------------------

*If NO Why?*----------------------------------------------------------------------------------

M02 In general How do you rate the effect of soil degradation on agriculture in the district **[1]** Very significant **[2]** Significant **[3]** Not significant **[4]** Don't know

M03. Mention any other effects of soil degradation in the district **[1]** Siltation of water sources e.g. valley dams **[2]** Desertification **[3]** Poverty **[4]** Other (specify)------

M04. How have you tackled soil degradation problems in the district----------------
---------------------------------------------------------------------------------

(M04a) Comment of the performance of the actions taken to solve the problems above----------------------------------------------------------------------

M05 What should have been done to address soil degradation problems in the district--------------------------------------------------------------------------------

M06. What constraints do your office experience in tackling this problem ------------
---------------------------------------------------------------------------------

**Thank you**

## Appendix 8: QUESTIONNAIRE SURVEY ON SOIL DEGRADATION

***Dear Respondent***

*This questionnaire survey is aimed at collecting information related to soil degradation in selected areas in the district of Nakasongola. The data collected is purely for academic purposes. That is fulfillment of degree requirements at the University of Cape Town, South Africa. However, the information generated may also be useful to policy makers and other stakeholders. The data collected will be treated with utmost confidentiality unless otherwise as expressed by respondents.*

*You have been identified as a very resourceful person in contributing to this research. Please feel free to express your ideas by writing and or ticking the correct choice(s) where required. Your assistance is highly appreciated and will be reflected in the final report.*

**Questionnaire no.** -------

### A. General information

G01. Department & designation ------------------------------------

G02. Level of formal education of respondent **[1]** Primary **[2]** Secondary **[3]** Tertiary **[4]** other-----

G3. Age------- and sex of respondent [1] Male [2] Female

### B. Soil degradation problem

D01. Do you think soil degradation is a problem in Nakasongola district **[1]** Yes **[2]** NO
*If YES continue with questions in this section*

D02. In general how do you rank soil degradation problem in the district-------------

D03. List the most affected areas in the district-------------------------------------------

D04. Why do you think these areas **(in D03)** are seriously affected by soil degradation

D05. Type of soil degradation observed in the district (Rank in order of importance 1= very important---4= least important) **[ ]** water erosion, **[ ]** wind erosion, **[ ]** chemical deterioration **[ ]** compaction and crusting

D06. Type of water erosion observed --------------------------------------------------

D07. What do you think are the causes of soil erosion in the *area (Rank causes in order of decreasing importance)* **[1]** Don't know **[2]** Erosive rains **[3]** Sloping land **[4]** Exposed soil **[5]** Over cultivated soils **[6]** Erosive wind **[7]** Overgrazing **[08]** lack of sensitization **[09]** Other (specify)-------------------------

D08. What do you think are the reasons for the occurrence of wind erosion

D09. In your view how do you compare the present soil erosion rate with that in the past 3 to 10 years **[1]** Very severe **[2]** Severe **[3]** moderately severe **[4]** Not severe

D10. Rate the degree of soil erosion and give reason(s) for your rating

| **Erosion type** | **Degree** | | | | **Reason(s)** |
|---|---|---|---|---|---|
| | **Very low** | **Low** | **Moderate** | **High** | |
| Water erosion | | | | | |
| Wind erosion | | | | | |

D11. How do you rate the contribution of the following to soil degradation in the district

| **Activity** | **Rate** | | |
|---|---|---|---|
| | **Not significant** | **Significant** | **Very significant** |
| Charcoal burning | | | |
| Fire wood collection | | | |
| Paths & tracks | | | |

D12. What type of chemical degradation is observed in the district [1] Increased acidity [2] Decline in plant nutrients [3] Other specify-------------

D10a. In which place(s) is this most critical-------------------

D13 What causes chemical soil degradation in the areas noted in the district---------

---

D14. How do you rate the problem of chemical degradation in the district **[1]** Not aware **[2]** serious **[3]** moderately serious **[4]** Very serious

**C. Soil degradation effects & Management**

M01. Is soil degradation a serious constraint to agricultural production in the district

**[1]** YES **[2]** NO

M02. If Yes, how? ----------------------------------------------------------------------------

----------------------------------------------------------------------------------------------------

M03 How do you rate the effect of soil degradation on agriculture **[1]** Very significant **[2]** Significant **[3]** Not significant

M04. How have you tackled soil degradation problem in the district

M05. What should be done to address soil degradation problem in the area----------

----------------------------------------------------------------------------------------------------

----------------------------------------------------------------------------------------------------

M06. What constraints are experienced by your office in tackling this problem -------

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----------------------------------------------------------------------------------------------------

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**Thank you**

**Appendix 9** Official letter to the district authority

**30TH May 2002**

**The Chief Administrative Officer (CAO)**
**Nakasongola district,**
**Uganda**

Dear Sir,

**RE: SOIL DEGRADATION STUDIES IN NAKASONGOLA DISTRICT**

I am lecturer at Geography department, Makerere University and a registered student of the University of Cape Town in South Africa, undertaking research on soil degradation in Nakasongola district.

I have selected the following sub counties in Naksongola district for data collection using questionnaires/interviews to obtain the perceptions of the local communities and authorities on soil degradation problems in the area:

- **Nabiswera** . **Nakitoma**
- **Lwapanga** . **Wabinyonyi and**
- **Kakooge**

The purpose of this letter is to inform you about the above studies and request for your cooperation or any other assistance that will ensure the success of this work. A report of this study will be made available for your access at the district headquarters.

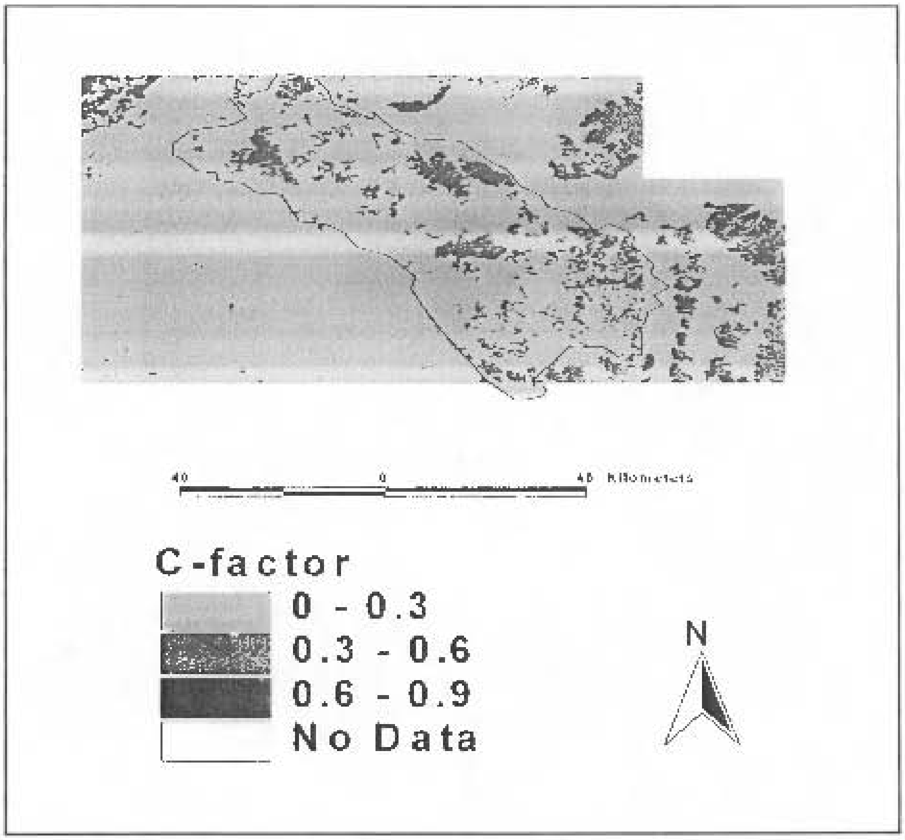
Yours faith fully

Bob Nakileza

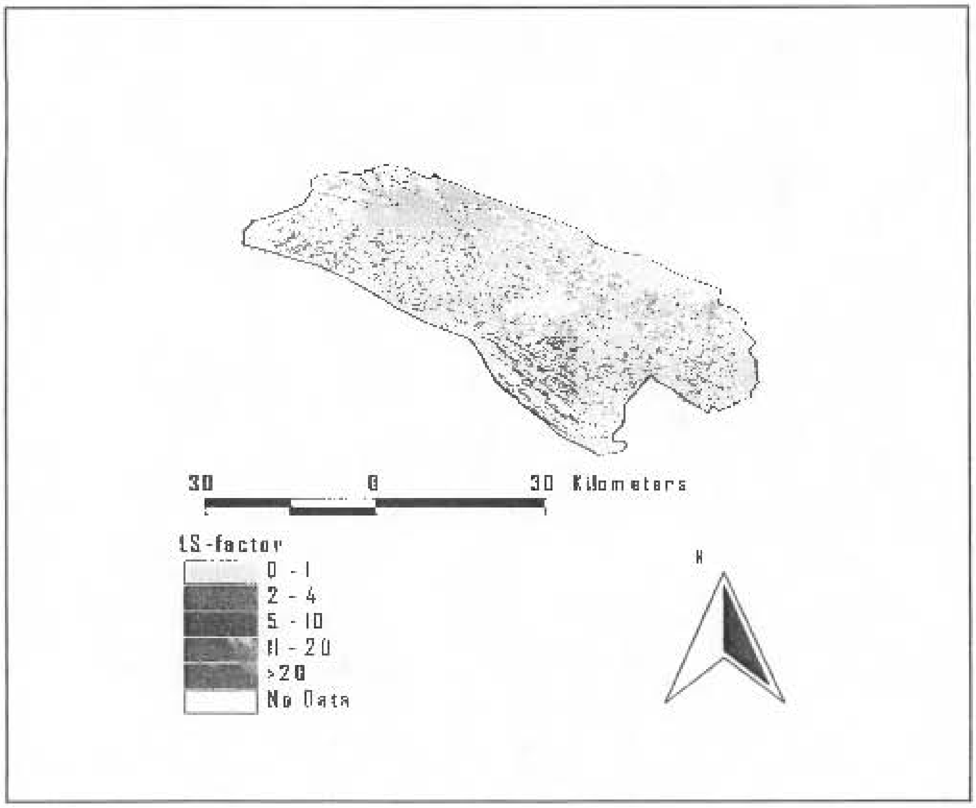
- **c.c LC3 Nabiswera**
- **c.c LC3 Nakitoma**
- **c.c LC3 Lwapanga**
- **c.c LC3 Wabinyonyi and**
- **c.c LC3 Kakoge**

**Appendix 10** Input layers for soil loss prediction in Nakasongola district

1. C-factor

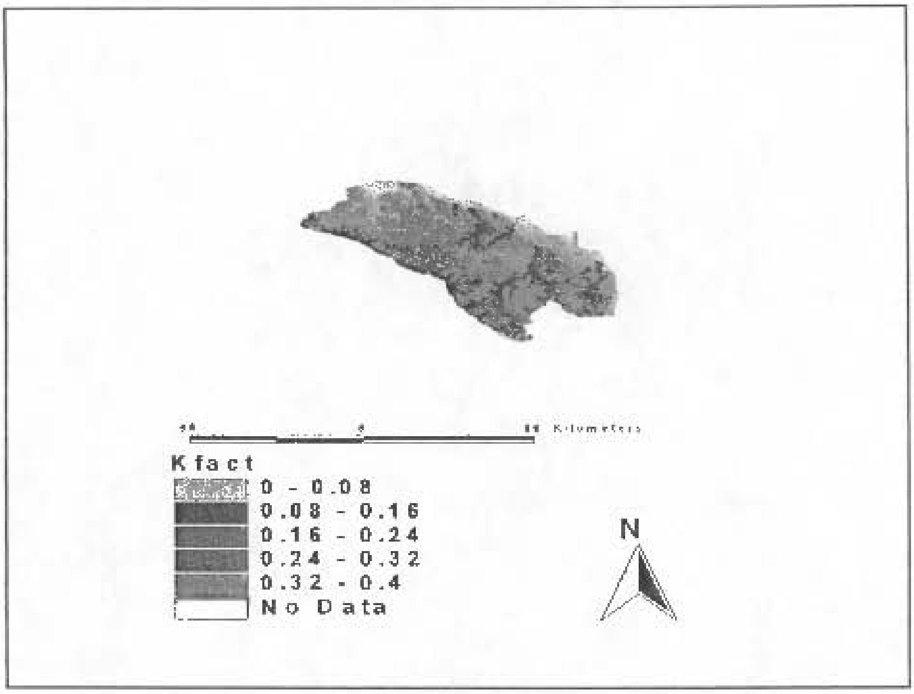



2. LS-factor

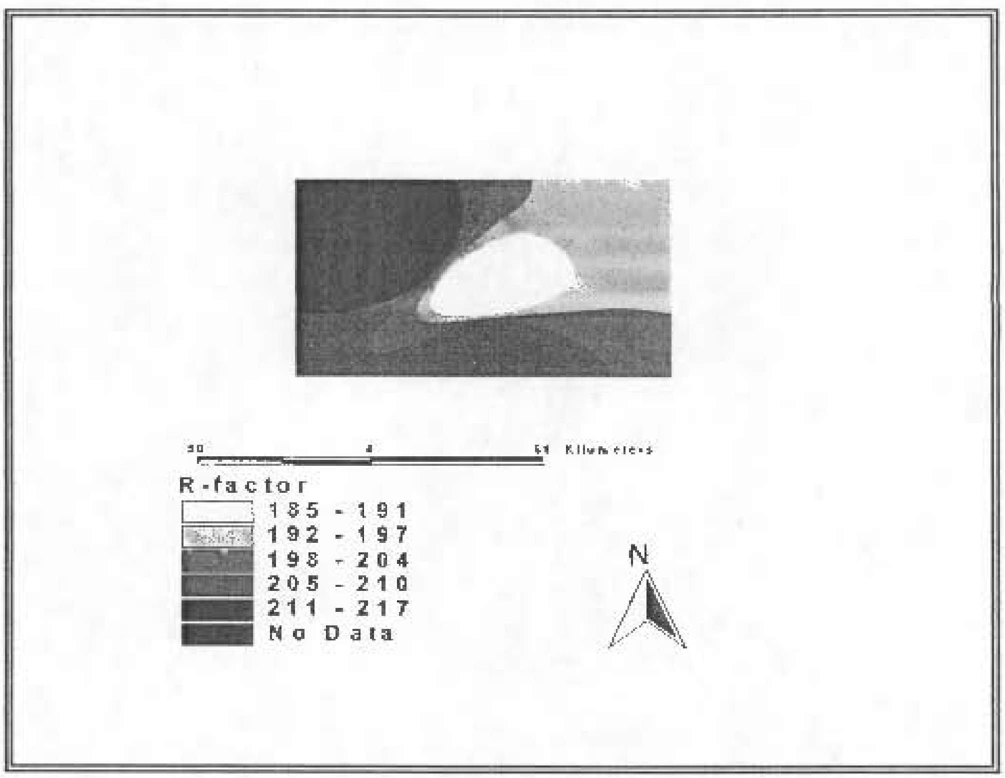


The LS-factors are generally low since much of the land is subdued and with gentle slopes.

3. K-factor




4. R-factor




5. P-factor- this was assumed to be a constant at a maximum value of one. There are few conservation structures in place. Most of those in existence were ineffective as reported by the resource users. Thus the use of a maximum p-value is justified.

**Appendix 11** Gully erosion data and computations

| 1. Sample gully 1 Sebwato micro-catchment (gully length is 65 m, CA is 1300 m²) | | | |
|---|---|---|---|
| | Width at lip (cm) | Width at valley bottom (cm) | Depth in cm |
| | 112 | 63 | 32 |
| | 170 | 123 | 26 |
| | 70 | 44 | 43.5 |
| | 52 | 32 | 48 |
| | 160 | 120 | 20 |
| | 92 | 62 | 29 |
| | 129 | 94 | 20 |
| | 184 | 126 | 37.5 |
| | 118 | 50 | 42 |
| | 89 | 54 | 32.5 |
| | 158 | 69 | 24 |
| | 140 | 74 | 27.3 |
| | 120 | 60 | 27 |
| | 88 | 45 | 41.5 |
| | 50 | 20 | 22 |
| | 100 | 67 | 11 |
| | 50 | 37 | 29.5 |
| | 120 | 74 | 7.5 |
| | 86 | 24 | 16.5 |
| | 178 | 30 | 18 |
| | 115 | 50 | 43.5 |
| **Total** | **2381** | **1318** | **598.3** |
| **Mean** | **113.38** | **62.77** | **28.49** |
| | | | |
| CA=1/2(Av W1+Av W2)/2*D | | 2509.20 | 0.76Metres |
| Gully length | 65 m | | |
| Volume of soil lost | | 163097.801 | |
| Volume of soil loss Metres cubic per metres squared | | | 0.02 |
| **Soil loss in t/ha over the entire catchment** | | | **125.46** |
| | | | |
| | | | |
| **Tributary gullies** | | | |
| | 43 | 26 | 17.5 |
| | 30 | 26 | 17.5 |
| | 36 | 26 | 17.5 |
| | 64 | 26 | 17.5 |
| Total | 173 | 104 | 70 |
| Mean | 43.25 | 26 | 17.5 |
| | | | |
| **2. Sample gully 2** | | | |
| | 90 | 50 | 110 |
| | 220 | 154 | 60 |
| | 120 | 47 | 65.5 |
| Total | 430 | 251 | 235.50 |
| Mean | 143.33 | 83.67 | 78.50 |
| | | | |

| | | | |
|---|---|---|---|
| **Gully erosion on the roadside (UWESO road)** | | | |
| | | | |
| | Width 1(cm) | Width 2 (cm) | Depth (cm) |
| | 250 | 120 | 90 |
| | 152 | 88 | 67.3 |
| | 95 | 56 | 96 |
| | 126 | 38 | 96 |
| | 86 | 30 | 45 |
| | 180 | 40 | 56.7 |
| | 163 | 128 | 37.2 |
| | 164 | 134 | 43.3 |
| | 141 | 114 | 28 |
| | 314 | 272 | 47 |
| | 200 | 146 | 44 |
| | 56 | 40 | 42 |
| | 264 | 210 | 22.6 |
| | 160 | 64 | 33.3 |
| | 224 | 98 | 40.6 |
| | 364 | 304 | 50.3 |
| | 146 | 50 | 88 |
| | 124 | 54 | 26 |
| **Total measurements** | **3209** | **1986** | **953.3** |
| **Mean** | **178.28** | **110.33** | **52.96** |
| | | | |
| CA=1/2(Av W1+Av W2)/2*D | | 7642.58 | 0.76Metres |
| Gully length | 900 m | | |
| Volume of soil lost | | 687.83M cubic | |
| Volume of soil loss metres cubic per metres squared | | 0.02 | |
| **Soil loss in t/ha over the entire catchment** | | **332.45** | |
| | | | |
| | | | |
| **Bizibitikula gully erosion** | | | |
| Lower slope | | | |
| | 165 | 72 | 19 |
| | 126 | 104 | 26 |
| | 125 | 70 | 33 |
| | 142 | 105 | 19.5 |
| | 296 | 116 | 55 |
| | 350 | 262 | 52.7 |
| | 272 | 176 | 33 |
| **Total** | **1476** | **905** | **238.2** |
| **Mean** | **210.86** | **129.29** | **34.03** |

Details of gully erosion according to slope position and slope segments

Gully dimensions in Mr Sebwatos livestock farm (GPS location 36N0417073, UTM 0150055, Alt 1077 m)

| **1. Sample gully 1** | | | |
|---|---|---|---|
| **Midslope position** | **Width at lip (cm)** | **Width at valley bottom (cm)** | **Depth in cm** |
| | 112 | 63 | 32 |
| | 170 | 123 | 26 |
| | 70 | 44 | 43.5 |
| | 52 | 32 | 48 |
| | 160 | 120 | 20 |
| | 92 | 62 | 29 |
| | 129 | 94 | 20 |
| | 184 | 126 | 37.5 |
| | 118 | 50 | 42 |
| | 89 | 54 | 32.5 |
| | 158 | 69 | 24 |
| | 140 | 74 | 27.3 |
| | 120 | 60 | 27 |
| | 88 | 45 | 41.5 |
| | 50 | 20 | 22 |
| **Total** | **1732** | **1036** | **472.3** |
| **Mean** | **115.47** | **69.07** | **31.49** |
| | | | |
| **Upperslope** | | | |
| | 100 | 67 | 11 |
| | 50 | 37 | 29.5 |
| | 120 | 74 | 7.5 |
| **Total** | **270** | **178** | **48** |
| **Mean** | **90** | **59.33** | **16** |
| | | | |
| **Lower slope position** | | | |
| | 86 | 24 | 16.5 |
| | 178 | 30 | 18 |
| | 115 | 50 | 43.5 |
| Total | **379** | **104** | **78** |
| Mean | 126.33 | 34.67 | 26 |
| | | | |
| **Tributary gullies** | | | |
| | 43 | 26 | 17.5 |
| | 30 | 26 | 17.5 |
| | 36 | 26 | 17.5 |
| | 64 | 26 | 17.5 |
| **Total** | **173** | **104** | **70** |
| **Mean** | **43.25** | **26** | **17.5** |
| | | | |
| **2. Sample gully 2** | | | |
| | 90 | 50 | 110 |
| | 220 | 154 | 60 |
| | 120 | 47 | 65.5 |
| **Total** | **430** | **251** | **235.5** |
| **Mean** | **143.33** | **83.67** | **78.50** |

**Gully erosion on the roadside (UWESO road)**

| | | | |
|---|---|---|---|
| Lower section | | | |
| | 250 | 120 | 90 |
| | 152 | 88 | 67.3 |
| | 95 | 56 | 96 |
| | 126 | 38 | 96 |
| | 86 | 30 | 45 |
| | 180 | 40 | 56.7 |
| **Total** | **889** | **372** | **451** |
| **Mean** | **148.17** | **62** | **75.17** |
| **Midslope section** | | | |
| | 163 | 128 | 37.2 |
| | 164 | 134 | 43.3 |
| | 141 | 114 | 28 |
| | 314 | 272 | 47 |
| | 200 | 146 | 44 |
| | 56 | 40 | 42 |
| | 264 | 210 | 22.6 |
| | 160 | 64 | 33.3 |
| **Total** | **1462** | **1108** | **297.4** |
| **Mean** | **182.75** | **138.5** | **37.18** |
| Upper slope section | | | |
| | 224 | 98 | 40.6 |
| | 364 | 304 | 50.3 |
| | 146 | 50 | 88 |
| | 124 | 54 | 26 |
| **Total** | **858** | **506** | **204.9** |
| **Mean** | **214.50** | **126.50** | **51.30** |
| | | | |
| | | | |

**Table 1** Bizibitikula gully erosion

| | | | |
|---|---|---|---|
| **Lower slope** | | | |
| | 165 | 72 | 19 |
| | 126 | 104 | 26 |
| | 125 | 70 | 33 |
| | 142 | 105 | 19.5 |
| **Total** | **558** | **351** | **97.5** |
| **Mean** | **139.50** | **87.75** | **24.38** |
| mid slope | | | |
| | 296 | 116 | 55 |
| | 350 | 262 | 52.7 |
| | 272 | 176 | 33 |
| **Total** | **918** | **554** | **140.7** |
| **Mean** | **306** | **184.67** | **46.90** |

Gully dimensions in other areas of Nakasongola

| **Midslope at Kabojja GPS location: 36N0435601, UTM 0138783, Alt 1096 m** | | | |
|---|---|---|---|
| | **Width at tip (cm)** | **Width at bottom (cm)** | **Depth (cm)** |
| | 104 | 30 | 35 |
| | 145 | 45 | 33 |
| | 150 | 90 | 40 |
| | 60 | 38 | 32 |
| | 130 | 80 | 22 |
| | 60 | 37 | 25 |
| | 130 | 45 | 40 |
| | 100 | 23 | 60 |
| | 90 | 48 | 45 |
| | 220 | 80 | 47 |

**Appendix 12.** Runoff and soil loss data for the two years, 2001 and 2002

| Sample No | Date | Rainfall (mm) | Runoff loss (l) | Runoff in mm | Soil loss (g/l) | Total Soil loss (Kg) | Soil loss (t/ha) |
|---|---|---|---|---|---|---|---|
| B1S10601 | 020601 | 12.3 | 82.5 | 11 | 4.8 | 0.4 | 0.53 |
| B1S10901 | 200901 | 16.6 | 100 | 13.33 | 12.1 | 1.21 | 1.61 |
| B1S11001 | 071001 | 18.4 | 102.5 | 13.67 | 4.3 | 0.44 | 0.59 |
| B1S20501 | 040501 | 12 | 76.75 | 10.23 | 2.6 | 0.20 | 0.27 |
| B1S20901 | 280901 | 15.4 | 102.5 | 13.67 | 1 | 0.10 | 0.14 |
| B1S21001 | 091001 | 6 | 10 | 1.33 | 7.1 | 0.071 | 0.09 |
| B1S30501 | 080501 | 16 | 102.5 | 13.67 | 7.6 | 0.78 | 1.04 |
| B1S30901 | 290901 | 15.2 | 102.5 | 13.67 | 9.7 | 0.99 | 1.32 |
| B1S31001 | 201001 | 15.8 | 76.25 | 10.17 | 9.3 | 0.71 | 0.95 |
| B1S41001 | 221001 | 16.4 | 100 | 13.33 | 10.9 | 1.09 | 1.45 |
| B1S41101 | 211101 | 16 | 102.5 | 13.67 | 9.3 | 0.95 | 1.27 |
| B1S51001 | 291001 | 14.8 | 50 | 6.67 | 2.4 | 0.12 | 0.16 |
| | | | | | | | |
| B1S10402 | 010402 | 14.5 | 97.5 | 13 | 7.5 | 0.73 | 0.20 |
| B1S10502 | 020502 | 30.2 | 183.75 | 24.5 | 8 | 1.47 | 1.96 |
| B1S11102 | 061102 | 8.4 | 15 | 2 | 1.9 | 0.03 | 0.04 |
| B1S20302 | 060302 | 15.9 | 92.5 | 12.33 | 4.4 | 0.41 | 0.54 |
| B1S20402 | 130402 | 9.5 | 48.75 | 6.5 | 2.1 | 0.10 | 0.14 |
| B1S20602 | 280602 | 11.6 | 80 | 10.67 | 5 | 0.4 | 0.53 |
| B1S21002 | 211002 | 31 | 192.5 | 25.67 | 2 | 0.39 | 0.51 |
| B1S30402 | 190402 | 15.5 | 112.5 | 15 | 4.9 | 0.55 | 0.74 |
| B1S30502 | 060502 | 29.5 | 191.25 | 25.5 | 19.6 | 3.75 | 4.99 |
| B1S31002 | 101002 | 15.7 | 111.25 | 14.83 | 2.7 | 0.30 | 0.40 |
| B1S31102 | 011102 | 6.8 | 2.5 | 0.33 | | 0 | 0 |
| B1S40302 | 260302 | 27.8 | 192.5 | 25.67 | 7 | 1.35 | 1.79 |
| B1S41002 | 231002 | 5.5 | 47.5 | 6.33 | 4 | 0.19 | 0.25 |
| B1S41102 | 161102 | 25.7 | 167.5 | 22.33 | 4.7 | 0.79 | 1.05 |
| B1S40402 | 200402 | 27 | 182.5 | 24.33 | 4.2 | 0.77 | 1.02 |
| B1S50402 | 230402 | 26.8 | 181.25 | 24.17 | 5.3 | 0.96 | 1.28 |
| B1S40502 | 210502 | 28 | 190 | 25.33 | 6.9 | 1.31 | 1.75 |
| B1S60502 | 300502 | 11.4 | 77.5 | 10.33 | 0.9 | 0.07 | 0.09 |
| | | | | | | | |
| B2S10701 | 280701 | 15.7 | 100 | 13.33 | 3 | 0.3 | 0.4 |
| B2S10901 | 010901 | 15.3 | 0 | 0 | | 0 | 0 |
| B2S10901 | 200901 | 16.6 | 101.25 | 13.5 | 13.4 | 1.36 | 1.81 |
| B2S11001 | 071001 | 18.4 | 100 | 13.33 | 14.8 | 1.48 | 1.97 |
| B2S11101 | 011101 | 7.3 | 32.5 | 4.33 | 2 | 0.07 | 0.09 |
| B2S20901 | 280901 | 15.4 | 97.5 | 13 | 8.3 | 0.81 | 1.08 |
| B2S21001 | 091001 | 6 | 37.5 | 5 | 6.4 | 0.24 | 0.32 |
| B2S21101 | 161101 | 19.2 | 102.5 | 13.67 | 10.7 | 1.09 | 1.46 |
| B2S30501 | 080501 | 16 | 99 | 13.2 | 3 | 0.29 | 0.40 |
| B2S30901 | 290901 | 15.2 | 100 | 13.33 | 11.4 | 1.14 | 1.52 |
| B2S31001 | 201001 | 15.8 | 101.25 | 13.5 | 10.3 | 1.04 | 1.39 |
| B2S31101 | 181101 | 9 | 32.5 | 4.33 | 2.4 | 0.08 | 0.10 |
| B2S40501 | 140501 | 14.3 | 62.5 | 8.33 | 1 | 0.06 | 0.08 |

| Sample No | Date | Rainfall (mm) | Runoff loss (l) | Runoff in mm | Soil loss (g/l) | Total Soil loss (Kg) | Soil loss (t/ha) |
|---|---|---|---|---|---|---|---|
| B2S41001 | 221001 | 16.4 | 98.75 | 13.17 | 7.9 | 0.78 | 1.04 |
| B2S41101 | 211101 | 15.1 | 110 | 14.67 | 13.5 | 1.49 | 1.98 |
| B2S51001 | 291001 | 14.8 | 100 | 13.33 | 13.2 | 1.32 | 1.76 |
| | | | | | | | |
| B2S10202 | 280202 | 5.5 | 12.5 | 1.67 | 0.1 | 0.00 | 0.00 |
| B2S10302 | 050302 | 15.6 | 95 | 12.67 | 1.5 | 0.14 | 0.19 |
| B2S10402 | 010402 | 14.5 | 92.5 | 12.33 | 1.6 | 0.15 | 0.20 |
| B2S10502 | 010502 | 16.5 | 95 | 12.67 | 2.3 | 0.22 | 0.29 |
| B2S10502 | 020502 | 30.2 | 192.5 | 25.67 | 12.6 | 2.43 | 3.23 |
| B2S10702 | 110702 | 10.4 | 67.5 | 9 | 4 | 0.27 | 0.36 |
| B2S11102 | 061102 | 8.4 | 41.25 | 5.5 | 2.3 | 0.09 | 0.13 |
| B2S20302 | 060302 | 15.9 | 100 | 13.33 | 3.7 | 0.37 | 0.49 |
| B2S20402 | 130402 | 9.5 | 40 | 5.33 | 2.3 | 0.09 | 0.12 |
| B2S20602 | 280602 | 11.6 | 75 | 10 | 3 | 0.23 | 0.30 |
| B2S20702 | 140702 | 27.5 | 191.25 | 25.5 | 9 | 1.72 | 2.30 |
| B2S21102 | 071102 | 10.3 | 71.25 | 9.5 | 7.8 | 0.56 | 0.74 |
| B2S30302 | 100302 | 3.1 | 12.5 | 1.67 | 0.8 | 0.01 | 0.01 |
| B2S30402 | 190402 | 15.5 | 100 | 13.33 | 0.9 | 0.09 | 0.12 |
| B2S30502 | 060502 | 29.5 | 192.5 | 25.67 | 6.5 | 1.25 | 1.69 |
| B2S30702 | 290702 | 14 | 95 | 12.67 | 4.8 | 0.46 | 0.61 |
| B2S31102 | 011102 | 6.8 | 5 | 0.67 | | 0 | 0 |
| B2S40302 | 260302 | 27.8 | 192.5 | 25.67 | 2.7 | 0.52 | 0.69 |
| B2S40402 | 200402 | 27 | 145 | 19.33 | 5.7 | 0.83 | 1.10 |
| B2S40502 | 140502 | 25.8 | 165 | 22 | 4 | 0.66 | 0.88 |
| B2S41102 | 161102 | 25.7 | 166.25 | 22.17 | 7.4 | 1.23 | 1.64 |
| B2S50402 | 230402 | 26.8 | 150 | 20 | 5 | 0.75 | 1 |
| B2S51102 | 201102 | 8.6 | 25 | 3.33 | 2 | 0.05 | 0.07 |
| B2S60502 | 210502 | 28 | 125 | 16.67 | 7.3 | 0.92 | 1.22 |
| B2S70502 | 300502 | 11.4 | 77.5 | 10.33 | 2.5 | 0.19 | 0.26 |
| | | | | | | | |
| B3S10501 | 010501 | 15.9 | 95 | 12.67 | 6.6 | 0.63 | 0.84 |
| B3S10701 | 290701 | 15.8 | 101.25 | 13.5 | 4.2 | 0.43 | 0.57 |
| B3S10901 | 200901 | 16.6 | 100 | 13.33 | 9.8 | 0.98 | 1.31 |
| B3S11101 | 011101 | 7.3 | 10 | 1.33 | 1.4 | 0.01 | 0.02 |
| B3S20501 | 040501 | 12 | 88.75 | 11.83 | 6 | 0.53 | 0.71 |
| B3S20901 | 280901 | 15.4 | 100 | 13.33 | 6.9 | 0.69 | 0.92 |
| B3S21101 | 161101 | 19.2 | 129.5 | 17.27 | 14.1 | 1.83 | 2.43 |
| B3S30501 | 080501 | 16 | 102.5 | 13.67 | 8 | 0.82 | 1.09 |
| B3S30901 | 290901 | 15.2 | 97.5 | 13 | 9.6 | 0.94 | 1.25 |
| B3S31101 | 181101 | 9 | 37.5 | 5 | 5 | 0.19 | 0.25 |
| B3S40501 | 140501 | 14.3 | 102.5 | 13.67 | 13.4 | 1.37 | 1.83 |
| B3S41101 | 211101 | 15.1 | 107.5 | 14.33 | 11.9 | 1.28 | 1.71 |
| | | | | | | | |
| B3S10202 | 280202 | 5.5 | 7.5 | 1 | 1 | 0.01 | 0.01 |
| B3S10302 | 050302 | 15.6 | 97.5 | 13 | 4.2 | 0.41 | 0.55 |
| B3S10402 | 010402 | 14.5 | 90 | 12 | 2.7 | 0.24 | 0.32 |
| B3S10502 | 010502 | 16.5 | 92.5 | 12.33 | 2.8 | 0.26 | 0.35 |

| Sample No | Date | Rainfall (mm) | Runoff loss (l) | Runoff in mm | Soil loss (g/l) | Total Soil loss (Kg) | Soil loss (t/ha) |
|---|---|---|---|---|---|---|---|
| B3S10502 | 020502 | 30.2 | 181.25 | 24.17 | 5.6 | 1.015 | 1.35 |
| B3S10702 | 110702 | 10.4 | 55 | 7.33 | 7.5 | 0.41 | 0.55 |
| B3S11102 | 061102 | 8.4 | 23.75 | 3.17 | 3.6 | 0.09 | 0.11 |
| B3S20302 | 060302 | 15.9 | 105 | 14 | 3.4 | 0.38 | 0.48 |
| B3S20402 | 130402 | 9.5 | 42.5 | 5.67 | 3.5 | 0.19 | 0.20 |
| B3S20602 | 280602 | 11.6 | 87.5 | 11.67 | 5 | 0.44 | 0.58 |
| B3S20702 | 140702 | 27.5 | 192.5 | 25.67 | 5.8 | 1.12 | 1.49 |
| B3S21102 | 071102 | 10.3 | 65 | 8.67 | 1.2 | 0.09 | 0.10 |
| B3S30302 | 100302 | 3.1 | 10 | 1.33 | 0 | 0 | 0 |
| B3S30402 | 190402 | 15.5 | 107.5 | 14.33 | 5.1 | 0.55 | 0.73 |
| B3S30502 | 060502 | 29.5 | 170 | 22.67 | 3.6 | 0.61 | 0.82 |
| B3S30702 | 290702 | 14 | 92.5 | 12.33 | 5 | 0.46 | 0.62 |
| B3S31102 | 131102 | 9 | 2.5 | 0.33 | 0 | 0 | 0 |
| B3S40302 | 260302 | 27.8 | 192.5 | 25.67 | 3.1 | 0.60 | 0.80 |
| B3S40402 | 200402 | 27 | 165 | 22 | 2.5 | 0.41 | 0.55 |
| B3S40502 | 140502 | 25.8 | 185 | 24.67 | 2.8 | 0.52 | 0.69 |
| B3S41102 | 161102 | 25.7 | 170 | 22.67 | 6.9 | 1.17 | 1.56 |
| B3S50402 | 230402 | 26.8 | 170 | 22.67 | 5.6 | 0.95 | 1.27 |
| B3S51102 | 201102 | 8.6 | 40 | 5.33 | 0.2 | 0.01 | 0.01 |
| B3S60402 | 280402 | 6.4 | 42.5 | 5.67 | 1.1 | 0.05 | 0.06 |
| B3S60502 | 210502 | 28 | 192.5 | 25.67 | 6.5 | 1.25 | 1.69 |
| B3S70502 | 300502 | 11.4 | 73.75 | 9.83 | 1.7 | 0.13 | 0.17 |
| | | | | | | | |
| B4S10901 | 200901 | 16.6 | 102.5 | 13.67 | 0.5 | 0.05 | 0.07 |
| B4S11101 | 011101 | 7.3 | 6.25 | 0.83 | 0.1 | 0.00 | 0.00 |
| B4S20901 | 280901 | 15.4 | 98.75 | 13.17 | 3 | 0.30 | 0.40 |
| B4S21101 | 161101 | 19.2 | 82.5 | 11 | 6.1 | 0.50 | 0.67 |
| B4S30901 | 290901 | 15.2 | 2.5 | 0.33 | 0.7 | 0.00 | 0.00 |
| B4S31101 | 181101 | 9 | 6.25 | 0.83 | 0.2 | 0.00 | 0.00 |
| B4S41101 | 211101 | 15.1 | 82.5 | 11 | 3.9 | 0.32 | 0.43 |
| | | | | | | | |
| B4S10402 | 010402 | 14.5 | 93.75 | 12.5 | 2 | 0.19 | 0.25 |
| B4S10502 | 010502 | 16.5 | 77.5 | 10.33 | 0.8 | 0.06 | 0.08 |
| B4S10502 | 020502 | 30.2 | 90 | 12 | 1.9 | 0.17 | 0.23 |
| B4S20302 | 060302 | 15.9 | 102.5 | 13.67 | 2.4 | 0.25 | 0.33 |
| B4S21102 | 071102 | 10.3 | 47.5 | 6.33 | 1.4 | 0.07 | 0.09 |
| B4S30402 | 190402 | 15.5 | 30 | 4 | 1.5 | 0.05 | 0.06 |
| B4S30502 | 060502 | 29.5 | 52.5 | 7 | 1.8 | 0.10 | 0.13 |
| B4S31102 | 131102 | 9 | 7.5 | 1 | 0 | 0 | 0 |
| B4S40302 | 260302 | 27.8 | 130 | 17.33 | 1.9 | 0.25 | 0.33 |
| B4S40402 | 200402 | 27 | 102.5 | 13.67 | 1.7 | 0.17 | 0.23 |
| B4S40502 | 140502 | 25.8 | 110 | 14.67 | 2 | 0.22 | 0.29 |
| B4S41102 | 161102 | 25.7 | 127.5 | 17 | 4.9 | 0.62 | 0.83 |
| B4S50402 | 230402 | 26.8 | 157.5 | 21 | 2 | 0.32 | 0.42 |
| B4S51102 | 201102 | 8.6 | 5 | 0.67 | 0.1 | 0.00 | 0.00 |
| B4S60502 | 210502 | 28 | 123.75 | 16.5 | 1.4 | 0.17 | 0.23 |
| | | | | | | | |

| Sample No | Date | Rainfall (mm) | Runoff loss (l) | Runoff in mm | Soil loss (g/l) | Total Soil loss (Kg) | Soil loss (t/ha) |
|---|---|---|---|---|---|---|---|
| L1S10501 | 010501 | 15.9 | 91.25 | 12.17 | 9.4 | 0.86 | 1.14 |
| L1S10601 | 020601 | 14.7 | 100 | 13.33 | 5.6 | 0.56 | 0.75 |
| L1S10801 | 90801 | 6.5 | 22.5 | 3 | 1.4 | 0.03 | 0.04 |
| L1S11001 | 071001 | 16.9 | 97.5 | 13 | 10.5 | 1.02 | 1.37 |
| L1S20501 | 040501 | 11 | 70 | 9.33 | | 0 | 0 |
| L1S20601 | 080601 | 15 | 96.25 | 12.83 | 1.2 | 0.12 | 0.15 |
| L1S20801 | 110801 | 14.4 | 75 | 10 | 4.8 | 0.36 | 0.48 |
| L1S20901 | 040901 | 16 | 100 | 13.33 | 13.3 | 1.33 | 1.77 |
| L1S21001 | 091001 | 5.4 | 0 | 0 | | 0 | 0 |
| L1S21101 | 161101 | 19.2 | 102.5 | 13.67 | 17.8 | 1.82 | 2.43 |
| L1S30501 | 080501 | 14.3 | 90 | 12 | 7.6 | 0.68 | 0.91 |
| L1S30801 | 170801 | 13.6 | 71.25 | 9.5 | 5.2 | 0.37 | 0.49 |
| L1S30801 | 270801 | 15 | 82.5 | 11 | 7.8 | 0.64 | 0.86 |
| L1S30901 | 200901 | 14.8 | 75 | 10 | 11.4 | 0.86 | 1.14 |
| L1S31001 | 201001 | 15.8 | 102.5 | 13.67 | | 0 | 0 |
| L1S31101 | 181101 | 13.3 | 75 | 10 | 1 | 0.08 | 0.1 |
| L1S40501 | 100501 | 14.8 | 95 | 12.67 | 9.6 | 0.91 | 1.22 |
| L1S40801 | 300801 | 15.8 | 95 | 12.67 | 3.7 | 0.35 | 0.49 |
| L1S40901 | 280901 | 15.2 | 100 | 13.33 | | 0 | 0 |
| L1S41001 | 221001 | 14.4 | 72.5 | 9.67 | | 0 | 0 |
| L1S41101 | 211101 | 15.1 | 102.5 | 13.67 | 7.6 | 0.78 | 1.04 |
| L1S50501 | 140501 | 14.3 | 87.5 | 11.67 | 9.8 | 0.86 | 1.14 |
| L1S51001 | 291001 | 14.8 | 101.25 | 13.5 | 8.6 | 0.87 | 1.16 |
| L1S70501 | 310501 | 13.6 | 92.5 | 12.33 | 2.6 | 0.24 | 0.32 |
| | | | | | | | |
| L1S10202 | 280202 | 6.5 | 20 | 2.67 | 1.1 | 0.02 | 0.03 |
| L1S10302 | 050302 | 15.9 | 110 | 14.67 | 1.5 | 0.17 | 0.22 |
| L1S10402 | 010402 | 15 | 80 | 10.67 | 4.2 | 0.34 | 0.45 |
| L1S10502 | 020502 | 29.8 | 195 | 26 | 10 | 1.95 | 2.6 |
| L1S10702 | 110702 | 10.3 | 70 | 9.33 | 4.8 | 0.34 | 0.45 |
| L1S10802 | 130802 | 22.6 | 157.5 | 21 | 5 | 0.79 | 1.05 |
| L1S20302 | 060302 | 28.6 | 190 | 25.33 | 5.9 | 1.121 | 1.50 |
| L1S20402 | 130402 | 8.2 | 50 | 6.67 | 2.2 | 0.11 | 0.15 |
| L1S20602 | 280602 | 9.6 | 50 | 6.67 | | 0 | 0 |
| L1S20702 | 140702 | 26.8 | 165 | 22 | 6 | 0.99 | 1.32 |
| L1S30402 | 190402 | 14.8 | 100 | 13.33 | 2.5 | 0.25 | 0.33 |
| L1S30302 | 100302 | 3.5 | 7.5 | 1 | 0.4 | 0.00 | 0.00 |
| L1S30502 | 060502 | 28 | 195 | 26 | 8.4 | 1.64 | 2.18 |
| L1S31002 | 221002 | 14.1 | 86.25 | 11.5 | 2.3 | 0.20 | 0.27 |
| L1S31102 | 011102 | 15 | 95 | 12.67 | 1.5 | 0.14 | 0.19 |
| L1S40302 | 190302 | 1.4 | 100 | 13.33 | 1.3 | 0.13 | 0.17 |
| L1S40302 | 260302 | 25.5 | 125 | 16.67 | 2.7 | 0.34 | 0.45 |
| L1S40402 | 200402 | 15 | 100 | 13.33 | 2.1 | 0.21 | 0.28 |
| L1S40502 | 140502 | 21.6 | 127.5 | 17 | 3.3 | 0.42 | 0.56 |
| L1S50402 | 230402 | 28.4 | 177.5 | 23.67 | 6 | 1.07 | 1.42 |
| L1S51102 | 201102 | 8.6 | 45 | 6 | 5.7 | 0.26 | 0.34 |
| L1S60402 | 280402 | 22 | 152.5 | 20.33 | 5.2 | 0.79 | 1.056 |

| Sample No | Date | Rainfall (mm) | Runoff loss (l) | Runoff in mm | Soil loss (g/l) | Total Soil loss (Kg) | Soil loss (t/ha) |
|---|---|---|---|---|---|---|---|
| L1S60502 | 210502 | 28 | 180 | 24 | 14.7 | 2.65 | 3.53 |
| | | | | | | | |
| L2S10901 | 200901 | 14.8 | 102.5 | 13.67 | 4 | 0.41 | 0.55 |
| L2S11001 | 071001 | 16.9 | 0 | 0 | | 0 | 0 |
| L2S20601 | 080601 | 15 | 102.5 | 13.67 | | 0 | 0 |
| L2S20901 | 280901 | 15.2 | 102.5 | 13.67 | 13.8 | 1.41 | 1.89 |
| L2S21001 | 091001 | 5.4 | 15 | 2 | 0.7 | 0.01 | 0.01 |
| L2S21101 | 161101 | 19.2 | 127.5 | 17 | 19.7 | 2.51 | 3.35 |
| L2S30501 | 080501 | 14.3 | 75 | 10 | 11.2 | 0.84 | 1.12 |
| L2S31001 | 201001 | 15.8 | 102.5 | 13.67 | 12.5 | 1.28 | 1.71 |
| L2S31101 | 181101 | 13.3 | 70 | 9.33 | | 0 | 0 |
| L2S40501 | 100501 | 14.8 | 82.5 | 11 | 8.6 | 0.71 | 0.95 |
| L2S40801 | 270801 | 15 | 58.75 | 7.83 | | 0 | 0 |
| L2S41001 | 221001 | 14.4 | 102.5 | 13.67 | 6.8 | 0.70 | 0.93 |
| L2S41101 | 211101 | 15.1 | 97.5 | 13 | 8.4 | 0.82 | 1.09 |
| L2S50501 | 141401 | 17 | 100 | 13.33 | 5.2 | 0.52 | 0.69 |
| L2S51001 | 291001 | 14.8 | 68.75 | 9.17 | | 0 | 0 |
| L2S70501 | 310501 | 13.6 | 72.5 | 9.67 | 4.5 | 0.33 | 0.44 |
| | | | | | | | |
| L2S10402 | 010402 | 15 | 87.5 | 11.67 | 2.8 | 0.25 | 0.33 |
| L2S10502 | 020502 | 29.8 | 191.25 | 25.5 | | 0 | 0 |
| L2S20102 | 050102 | 8 | 25 | 3.33 | 0.4 | 0.01 | 0.01 |
| L2S20302 | 060302 | 28.6 | 185 | 24.67 | 4.1 | 0.76 | 1.01 |
| L2S20402 | 130402 | 8.2 | 50 | 6.67 | 1.1 | 0.06 | 0.07 |
| L2S20502 | 040502 | 14.7 | 92.5 | 12.33 | 4.4 | 0.41 | 0.54 |
| L2S20602 | 280602 | 9.6 | 52.5 | 7 | 1.6 | 0.08 | 0.11 |
| L2S20702 | 120702 | 29.6 | 195 | 26 | 12 | 2.34 | 3.12 |
| L2S20902 | 230902 | 27.8 | 192.5 | 25.67 | 3.8 | 0.73 | 0.98 |
| L2S30402 | 190402 | 14.8 | 95 | 12.67 | 1.5 | 0.14 | 0.19 |
| L2S30502 | 060502 | 28 | 195 | 26 | 1.6 | 0.31 | 0.42 |
| L2S31102 | 121102 | 12 | 47.5 | 6.33 | 4.1 | 0.19 | 0.26 |
| L2S40402 | 020402 | 16.4 | 100 | 13.33 | 1.5 | 0.15 | 0.2 |
| L2S40502 | 140502 | 21.6 | 127.5 | 17 | 1.4 | 0.19 | 0.24 |
| L2S41002 | 231002 | 23 | 147.5 | 19.67 | 2.5 | 0.37 | 0.49 |
| L2S10802 | 130802 | 22.6 | 133.75 | 17.83 | 1.3 | 0.17 | 0.23 |
| L2S41102 | 161102 | 29.4 | 192.5 | 25.67 | 3.5 | 0.67 | 0.90 |
| L2S50402 | 230402 | 28.4 | 169.75 | 22.63 | 5.6 | 0.95 | 1.27 |
| L2S60402 | 280402 | 22 | 137.5 | 18.33 | 1.1 | 0.15 | 0.20 |
| L2S60502 | 210502 | 28.8 | 192.5 | 25.67 | 2 | 0.39 | 0.51 |
| L2S61102 | 111102 | 7 | 10 | 1.33 | 0.1 | 0.00 | 0.00 |
| | | | | | | | |
| L3S10701 | 280701 | 15.7 | 97.5 | 13 | 6.5 | 0.63 | 0.85 |
| L3S40801 | 221002 | 14.1 | 98.75 | 13.17 | 3 | 0.30 | 0.40 |
| L3S10801 | 090801 | 6.7 | 40 | 5.33 | 2 | 0.08 | 0.11 |
| L3S10901 | 010901 | 15.3 | 95 | 12.67 | 2 | 0.19 | 0.25 |
| L3S11001 | 071001 | 16.9 | 95 | 12.67 | 22.1 | 2.10 | 2.80 |
| L3S20501 | 040501 | 11 | 52.5 | 7 | 0.9 | 0.05 | 0.06 |

| Sample No | Date | Rainfall (mm) | Runoff loss (l) | Runoff in mm | Soil loss (g/l) | Total Soil loss (Kg) | Soil loss (t/ha) |
|---|---|---|---|---|---|---|---|
| L3S20801 | 110801 | 14.4 | 85 | 11.33 | | 0 | 0 |
| L3S20901 | 040901 | 16 | 102.5 | 13.66 | 4.5 | 0.46 | 0.62 |
| L3S21001 | 091001 | 5.4 | 27.5 | 3.67 | 10 | 0.28 | 0.37 |
| L3S31001 | 201001 | 15.8 | 97.5 | 13 | 16.7 | 1.63 | 2.17 |
| L3S21101 | 161101 | 19.2 | 132.5 | 17.67 | 24.5 | 3.25 | 4.33 |
| L3S30501 | 080501 | 14.3 | 105 | 14 | 8.6 | 0.90 | 1.20 |
| L3S30801 | 170801 | 13.6 | 87.5 | 11.67 | 1.8 | 0.16 | 0.21 |
| L3S30901 | 200901 | 14.8 | 95 | 12.67 | 11 | 1.05 | 1.39 |
| L3S31101 | 181101 | 13.3 | 97.5 | 13 | | 0 | 0 |
| L3S40801 | 270801 | 15 | 97.5 | 13 | 5.2 | 0.51 | 0.68 |
| L3S40901 | 280901 | 15.2 | 95 | 12.67 | | 0 | 0 |
| L3S41001 | 221001 | 14.4 | 95 | 12.67 | 17 | 1.62 | 2.15 |
| L3S41101 | 211101 | 15.1 | 105 | 14 | 14.7 | 1.54 | 2.06 |
| L3S50801 | 300801 | 15.8 | 97.5 | 13 | | 0 | 0 |
| L3S51001 | 291001 | 14.8 | 107.5 | 14.33 | | 0 | 0 |
| | | | | | | | |
| L3S10202 | 280202 | 6.5 | 38.75 | 5.17 | 1.9 | 0.07 | 0.10 |
| L3S10302 | 050302 | 15.9 | 95 | 12.67 | 2.5 | 0.24 | 0.32 |
| L3S10402 | 010402 | 15 | 88.75 | 11.83 | 4.5 | 0.40 | 0.53 |
| L3S10502 | 020502 | 29.8 | 192.5 | 25.67 | 7.3 | 1.41 | 1.87 |
| L3S10602 | 170602 | 9 | 90 | 12 | 2 | 0.18 | 0.24 |
| L3S10702 | 110702 | 10.3 | 72.5 | 9.67 | 3.5 | 0.25 | 0.34 |
| L3S20102 | 050102 | 8 | 43.75 | 5.83 | 1.1 | 0.05 | 0.06 |
| L3S20302 | 060302 | 28.6 | 172.5 | 23 | 9.3 | 1.60 | 2.14 |
| L3S20402 | 130402 | 8.2 | 52.5 | 7 | 1.4 | 0.07 | 0.10 |
| L3S20502 | 040502 | 14.7 | 95 | 12.67 | 5.3 | 0.50 | 0.67 |
| L3S20602 | 280602 | 10.2 | 68.75 | 9.17 | 4 | 0.28 | 0.37 |
| L3S20702 | 140702 | 26.8 | 187.5 | 25 | 11 | 2.06 | 2.75 |
| L3S30302 | 100302 | 3.5 | 15 | 2 | 0.2 | 0.00 | 0.00 |
| L3S30402 | 190402 | 11.2 | 77.5 | 10.33 | 3 | 0.23 | 0.31 |
| L3S30502 | 060502 | 28 | 191.25 | 25.5 | 5.7 | 1.09 | 1.45 |
| L3S30702 | 290702 | 20.4 | 142.5 | 19 | 4.3 | 0.61 | 0.82 |
| L3S31102 | 121102 | 12 | 97.5 | 13 | 8.9 | 0.87 | 1.16 |
| L3S40302 | 260302 | 25.5 | 197.5 | 26.33 | 12 | 2.37 | 3.16 |
| L3S40402 | 200402 | 15 | 97.5 | 13 | 4.2 | 0.41 | 0.55 |
| L3S40502 | 140502 | 21.6 | 155 | 20.67 | 3.6 | 0.56 | 0.74 |
| L3S41002 | 231002 | 23 | 160 | 21.33 | | 0 | 0 |
| L3S41102 | 161102 | 29.4 | 202.5 | 27 | 14.5 | 2.94 | 3.92 |
| L3S50402 | 230402 | 28.4 | 197.5 | 26.33 | 6.7 | 1.32 | 1.76 |
| L3S51102 | 201102 | 8.6 | 37.5 | 5 | 6.7 | 0.25 | 0.34 |
| L3S60402 | 280402 | 22 | 162.5 | 21.67 | 3.9 | 0.63 | 0.85 |
| L3S60502 | 210502 | 28 | 190 | 25.33 | 15.4 | 2.93 | 3.90 |
| L3S61102 | 111102 | 7 | 27.5 | 3.67 | 0.9 | 0.03 | 0.03 |
| L3S70502 | 300502 | 12.9 | 82.5 | 11 | 1.5 | 0.12 | 0.16 |
| | | | | | | | |
| L4S10901 | 200901 | 14.8 | 24 | 3.2 | | 0 | 0 |
| L4S11001 | 071001 | 16.9 | 20 | 2.67 | 1.8 | 0.04 | 0.05 |

| Sample No | Date | Rainfall (mm) | Runoff loss (l) | Runoff in mm | Soil loss (g/l) | Total Soil loss (Kg) | Soil loss (t/ha) |
|---|---|---|---|---|---|---|---|
| L4S20901 | 280901 | 15.2 | 17.5 | 2.33 | 1.8 | 0.03 | 0.04 |
| L4S21001 | 091001 | 5.4 | 7.5 | 1 | 0.2 | 0.00 | 0.00 |
| L4S31001 | 201001 | 15.8 | 65 | 8.67 | 4.2 | 0.27 | 0.36 |
| L4S51001 | 291001 | 14.8 | 25 | 3.33 | 4.4 | 0.11 | 0.15 |
| L4S41101 | 211101 | 15.1 | 78.75 | 10.5 | 0.9 | 0.07 | 0.10 |
| Total 2001 | | 98 | 237.75 | 31.7 | | | 0.70 |
| L4S10402 | 010402 | 15 | 50 | 6.67 | 0.9 | 0.05 | 0.06 |
| L4S10502 | 020502 | 29.8 | 137.5 | 18.33 | 1.2 | 0.17 | 0.22 |
| L4S20102 | 050102 | 8 | 23.75 | 3.17 | 0.25 | 0.01 | 0.01 |
| L4S30502 | 060502 | 28 | 162.5 | 21.67 | 1.5 | 0.24 | 0.33 |
| L4S40402 | 200402 | 15 | 77.5 | 10.33 | 2.1 | 0.16 | 0.22 |
| L4S40502 | 140502 | 21.6 | 100 | 13.33 | 1.6 | 0.16 | 0.21 |
| L4S41102 | 161102 | 29.4 | 160 | 21.33 | 2.3 | 0.37 | 0.49 |
| L4S51102 | 201102 | 8.6 | 10 | 1.33 | 0.1 | 0.00 | 0.00 |
| L4S60402 | 280402 | 22 | 135 | 18 | 2.6 | 0.35 | 0.47 |
| | | | | | | | |

**Appendix 13** Rate of Runoff discharge and sediment loss for rainfall simulation experiments in Nakasongola

Note: Rep = replication; UWRC = upper slope wet run; AvWRC = average wet run; DRC = Dr run

| 1 (a) Rates of runoff discharge (l) for the wet and dry run simulation experiments at upper slope position in Bizibitukula catchment | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| **Time in min** | **UWRC rep1** | **UWRC rep2** | **AvUWRC** | **DRC Rep1** | **DRC Rep2** | **AvDRC** |
| 5 | 1.88 | 1.88 | 1.88 | 1.5 | 0.15 | 0.83 |
| 10 | 4.13 | 1.88 | 3 | 2.63 | 0.75 | 1.69 |
| 15 | 4.5 | 1.5 | 3 | 3.38 | 1.13 | 2.25 |
| 20 | 4.13 | 0.75 | 2.44 | 4.88 | 1.88 | 3.38 |
| 25 | 5.63 | 1.13 | 3.38 | 4.88 | 3 | 3.94 |
| 30 | 6 | 1.13 | 3.56 | 4.5 | 1.5 | 3 |
| 35 | 6.38 | 1.13 | 3.75 | 4.5 | 2.25 | 3.38 |
| 40 | 5.63 | 1.13 | 3.38 | 4.88 | 2.63 | 3.75 |
| 45 | 7.13 | 1.88 | 4.5 | 4.13 | 1.5 | 2.81 |
| Total rainfall = 30.16mm | | | | | | |
| Total discharge | 45.38 | 12.38 | 28.88 | 35.25 | 14.78 | 25.01 |
| | | | | | | |
| **1(b). Rate of sediment loss (g/M2) for the wet and dry run simulation experiments at upper slope position in Bizibitukula catchment** | | | | | | |
| **Time in min** | **UTSD WRrep1** | **UTSD WRrep2** | **AvTSD** | | | |
| 5 | 8.44 | 7.5 | 7.97 | | | |
| 10 | 10.73 | 4.88 | 7.8 | | | |
| 15 | 18 | 3 | 10.5 | | | |
| 20 | 12.38 | 1.5 | 6.94 | | | |
| 25 | 22.5 | 3.94 | 13.22 | | | |
| 30 | 18 | 3.38 | 10.69 | | | |
| 35 | 27.41 | 4.5 | 15.97 | | | |
| 40 | 14.63 | 2.25 | 8.44 | | | |
| 45 | 28.5 | 12.19 | 20.34 | | | |
| | | | | | | |
| **2 (a) Rate of runoff discharge (l) for the wet and dry run simulation experiments at midslope position in Bizibitukula catchment** | | | | | | |
| **Time in min** | **MWRC rep1** | **MWRC rep2** | **AvMWRC** | **DRC Rep1** | **DRC Rep2** | **AvDRC** |
| 5 | 5.25 | 3 | 4.13 | 1.5 | 0.15 | 0.83 |
| 10 | 7.5 | 5.25 | 6.38 | 2.63 | 0.75 | 1.69 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 15 | 7.13 | 4.88 | 6 | 3.38 | 1.13 | 2.25 |
| 20 | 7.88 | 5.63 | 6.75 | 4.88 | 1.88 | 3.38 |
| 25 | | | | 4.88 | 2.63 | 3.75 |
| 30 | | | | 4.5 | 1.5 | 3 |
| 35 | | | | 4.5 | 2.25 | 3.38 |
| 40 | | | | 4.88 | 2.63 | 3.75 |
| 45 | | | | 4.13 | 1.5 | 2.81 |
| | | | | | | |
| Total discharge= | 37 | 27.75 | 25 | 35.25 | 14.4 | 24.83 |
| | | | | | | |
| **2(b). Rate of sediment loss (g/m$^2$) for the wet and dry run simulation experiments at mid slope position in Bizibitukula catchment** | | | | | | |
| **Time in min** | **MTSD rep1** | **MTSDrep2** | **AvMTSD** | **TSDep1** | **TSDep2** | **AvTSD** |
| 5 | 21 | 12 | 16.5 | 6 | 0.53 | 3.26 |
| 10 | 15 | 11.55 | 13.28 | 10.5 | 1.95 | 6.23 |
| 15 | 21.38 | 14.63 | 18 | 7.43 | 4.5 | 5.96 |
| 20 | | 28.13 | | 12.19 | 4.69 | 8.44 |
| 25 | | | | 9.75 | 11.81 | 10.78 |
| 30 | | | | 18 | 0 | 9 |
| 35 | | | | 11.7 | 5.63 | 8.66 |
| 40 | | | | 26.81 | 14.44 | 20.63 |
| 45 | | | | 12.38 | 8.25 | 10.31 |
| Total rainfall= Midslope Dry = 32.8 mm; wet=24.6 mm | | | | | | |
| | | | | | | |
| 3 (a) Rate of runoff discharge (l) for the wet and dry run simulation experiments on lower slope position in Bizibitukula catchment | | | | | | |
| Time in min | LWRC Rep1 | LWRC Rep2 | AvLWRC | DRC Rep1 | DRC Rep2 | AvWRC |
| 5 | 0.98 | 3.3 | 2.14 | 3.38 | 0.75 | 2.06 |
| 10 | 1.88 | 4.88 | 3.38 | 0.38 | 4.5 | 2.44 |
| 15 | 2.63 | 6.75 | 4.69 | 0.75 | 5.25 | 3 |
| 20 | 2.63 | 6 | 4.31 | 2.25 | 5.63 | 3.94 |
| 25 | 2.25 | 5.63 | 3.94 | 2.25 | 4.88 | 3.56 |
| 30 | 1.88 | 5.25 | 3.56 | 1.5 | 3.75 | 2.63 |
| 35 | 2.63 | 6.38 | 4.5 | 2.63 | 7.13 | 4.88 |
| 40 | 1.88 | 4.13 | 3 | 1.88 | 5.63 | 3.75 |
| 45 | 2.63 | 6.38 | 4.5 | 2.25 | 4.88 | 3.56 |
| Total discharge | 19.35 | 48.68 | 34.01 | 17.25 | 42.38 | 29.81 |
| Total rainfall=Wet run 32.8 mm; Dry run=31.7mm | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3(b). Rate of sediment loss (g/m²) for the wet and dry run simulation experiments on lower slope position at Bizibitukula catchment | | | | | | |
| **Time in min** | **LWRC rep1** | **LWRC rep2** | **AvLTSD** | **DRC rep1** | **DRC rep2** | **AvTSD** |
| 5 | 0 | 13.2 | 6.6 | 13.5 | 2.63 | 8.06 |
| 10 | 12.38 | 21.94 | 17.16 | 1.5 | 11.7 | 6.6 |
| 15 | 5.25 | 15.53 | 10.39 | 1.65 | 21 | 11.33 |
| 20 | 2.1 | 11.4 | 6.75 | 5.63 | 14.06 | 9.84 |
| 25 | 4.95 | 11.25 | 8.1 | 4.5 | 21.94 | 13.22 |
| 30 | 4.31 | 11.03 | 7.67 | 6 | 0 | 3 |
| 35 | 7.88 | 0 | 3.94 | 6.83 | 17.81 | 12.32 |
| 40 | 2.81 | 14.44 | 8.63 | 10.31 | 30.94 | 20.63 |
| 45 | 7.88 | 12.75 | 10.31 | 6.75 | 26.81 | 16.78 |
| Total soil loss | 47.55 | 111.53 | 79.54 | 56.66 | 146.89 | 101.78 |
| Total rainfall = lower slope wet=32.8 mm; Dry=31.7mm | | | | | | |
| Rainfall intensity (m/s) | | 32.8 | | | | |
| | | | | | | |
| 4 (a) Rate of runoff discharge (l) for the dry run simulation experiments on lower slope position in Bizibitukula catchment (CONTROL) | | | | | | |
| Time in min | LDRC Rep1 | LDRC Rep2 | AvLDRC | | | |
| 5 | 0 | 0 | 0 | | | |
| 10 | 1.88 | 1.88 | 1.88 | | | |
| 15 | 5.63 | 4.13 | 4.88 | | | |
| 20 | 4.88 | 4.13 | 4.5 | | | |
| 25 | 4.88 | 4.13 | 4.5 | | | |
| 30 | 5.25 | 4.13 | 4.69 | | | |
| 35 | 5.25 | 4.13 | 4.69 | | | |
| 40 | 4.13 | 4.13 | 4.13 | | | |
| 45 | 5.25 | 5.25 | 5.25 | | | |
| | | | | | | |
| Total discharge | 37.13 | 31.88 | 34.5 | | | |
| Total rainfall=Dry run=9.92mm =20.8mm; Ponding time = 2min; Runoff time = 6 min | | | | | | |
| | | | | | | |
| | | | | | | |
| 4(b). Rate of sediment loss (g/m²) for the wet and dry run simulation experiments on lower slope position at Bizibitukula catchment (CONTROL) | | | | | | |
| **Time in min** | **LTSD Rep1** | **LTSD Rep2** | **AvLTSD** | | | |
| 5 | | | | | | |
| 10 | 2.44 | 3.38 | 2.91 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 15 | 5.63 | 4.95 | 5.29 | | | |
| 20 | 3.9 | 2.89 | 3.40 | | | |
| 25 | 6.83 | 5.78 | 6.3 | | | |
| 30 | 4.2 | 5.36 | 4.78 | | | |
| 35 | 7.35 | 4.54 | 5.94 | | | |
| 40 | 8.25 | 4.95 | 6.6 | | | |
| 45 | 6.83 | 9.45 | 8.14 | | | |
| | 45.41 | 41.29 | 43.35 | | | |

**1B (a) Rates of runoff discharge (l) for the wet and dry run simulation experiments at Upper slope position in Bizibitukula catchment (Verification)**

| Time in min | UWRC Rep 1 | UWRC Rep 2 | AvUWRC | DRC Rep1 | DRC Rep2 | AvDRC |
|---|---|---|---|---|---|---|
| 5 | 0.38 | 1.88 | 1.13 | 0 | 0 | 0 |
| 10 | 1.5 | 4.13 | 2.81 | 0.38 | 2.63 | 1.5 |
| 15 | 1.28 | 3.75 | 2.51 | 2.63 | 6.38 | 4.5 |
| 20 | 1.13 | 3.75 | 2.44 | 2.63 | 4.13 | 3.38 |
| 25 | 1.13 | 3.38 | 2.25 | 2.63 | 4.88 | 3.75 |
| 30 | 1.35 | 3.75 | 2.55 | 3 | 5.25 | 4.13 |
| 35 | 1.28 | 4.5 | 2.89 | 1.88 | 2.63 | 2.25 |
| 40 | 2.25 | 6 | 4.13 | 2.63 | 4.88 | 3.75 |
| 45 | 1.95 | 4.58 | 3.26 | 2.78 | 4.88 | 3.83 |
| Total discharge | 16.3 | 35.7 | 23.96 | 18.53 | 35.63 | 27.08 |

Total rainfall = 25.6mm; Ponding time = 3min; Runoff time = 4min

**1B (b). Rate of sediment loss ($g/m^2$) for the wet and dry run simulation experiments at Upper slope position in Bizibitukula catchment (Verification)**

| Time in min | UTSD Rep1 | UTSD Rep2 | AvUTSD | TSD Rep1 | TSD Rep2 | AvTSD |
|---|---|---|---|---|---|---|
| 5 | 1.24 | 9.19 | 5.21 | 0 | 0 | 0 |
| 10 | 11.25 | 9.49 | 10.37 | 1.99 | 18.11 | 10.05 |
| 15 | 9.56 | 15 | 12.28 | 9.45 | 21.04 | 15.24 |
| 20 | 0.23 | 13.5 | 6.86 | 7.88 | 11.55 | 9.71 |
| 25 | 4.05 | 15.53 | 9.79 | 7.09 | 16.58 | 11.83 |
| 30 | 5.27 | 0 | 2.63 | 10.8 | 22.58 | 16.69 |
| 35 | 11.35 | 33.3 | 22.32 | 6 | 14.96 | 10.48 |
| 40 | 4.05 | 12.6 | 8.33 | 9.45 | 5.36 | 7.41 |
| 45 | 5.85 | 13.73 | 9.79 | 10.27 | 27.3 | 18.78 |
| Total soil loss | 52.84 | 122.33 | 87.58 | 62.92 | 137.48 | 100.20 |

**Appendix 14** Infiltration measurements in Nakasongola district

| Infiltration rate measurements in Nakasongola drylands | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Site number | | | | | | | | | | | | | |
| Time (min) | I for B1R1 | I for B1R2 | I for B2R1 | I for B2R2 | I for B3R1 | I for B3R2 | I for B4R1 | I for B4R2 | I for L3R1 | I for L3R2 | I for L2R1 | I for L2R2 | I for L1R1 | I for L1R2 |
| 1 | 0.8 | 0.7 | 0.3 | 0.8 | 0.9 | 0.3 | 0.6 | 0.6 | 0.2 | 0.5 | 0.5 | 0.7 | 0.2 | 0.2 |
| 2 | 0.8 | 0.6 | 0.1 | 0.7 | 0.6 | 0.5 | 0.6 | 0.6 | 0.3 | 0.4 | 0.3 | 0.5 | | 0.3 |
| 3 | 0.5 | 0.7 | 0.1 | 0.7 | 0.5 | 0.5 | 0.2 | 0.3 | 0.5 | 0.3 | 0.3 | 0.5 | | 0.4 |
| 4 | 0.4 | 0.4 | 0.1 | 0.7 | 0.5 | 0.4 | 0.3 | 0.4 | 0.3 | 0.3 | 0.3 | 0.5 | 0.03 | 0.2 |
| 5 | 0.3 | 0.5 | 0.1 | 0.6 | 0.4 | 0.4 | 0.5 | 0.5 | 0.3 | 0.3 | 0.4 | 0.5 | 0.1 | 0.3 |
| 10 | 0.32 | 0.44 | 0.06 | 0.56 | 0.38 | 0.32 | 0.2 | 0.36 | 0.2 | 0.26 | 0.28 | 0.38 | 0.04 | 0.12 |
| 15 | 0.3 | 0.28 | 0.08 | 0.5 | 0.28 | 0.26 | 0.1 | 0.3 | 0.16 | 0.2 | 0.26 | 0.36 | 0.04 | 0.3 |
| 20 | 0.24 | 0.16 | 0.06 | 0.42 | 0.22 | 0.2 | 0.06 | 0.28 | 0.16 | 0.16 | 0.2 | 0.38 | 0.04 | 0.24 |
| 25 | 0.18 | 0.24 | 0.06 | 0.38 | 0.18 | 0.2 | 0 | 0.26 | 0.14 | 0.1 | 0.2 | 0.44 | 0.04 | 0.22 |
| 30 | 0.16 | 0.26 | 0.06 | 0.36 | 0.2 | 0.2 | 0.02 | 0.24 | 0.08 | 0.14 | 0.2 | 0.3 | 0.02 | 0.28 |
| 35 | 0.14 | 0.24 | 0.12 | 0.32 | 0.2 | 0.18 | 0.02 | 0.22 | 0.06 | 0.14 | 0.28 | 0.28 | 0.04 | 0.22 |
| 40 | 0.14 | 0.14 | 0.08 | 0.22 | 0.2 | 0.14 | 0.04 | 0.2 | 0.1 | 0.12 | 0.2 | 0.34 | 0.02 | 0.18 |
| 45 | 0.12 | 0.28 | 0.08 | 0.36 | 0.18 | 0.14 | 0.02 | 0.22 | 0.12 | 0.1 | 0.2 | 0.28 | 0.02 | 0.16 |
| 50 | 0.12 | 0.24 | 0.12 | 0.26 | 0.2 | 0.1 | 0.04 | 0.2 | 0.12 | 0.1 | 0.2 | 0.4 | 0.04 | 0.16 |
| 55 | 0.1 | 0.14 | 0.08 | 0.26 | 0.16 | 0.14 | 0.04 | 0.18 | 0.1 | 0.1 | 0.18 | 0.36 | 0.04 | 0.14 |
| 60 | 0.1 | 0.22 | 0.08 | 0.26 | 0.14 | 0.12 | 0.04 | 0.2 | 0.1 | 0.1 | 0.2 | 0.36 | 0.04 | 0.14 |
| 70 | 0.11 | 0.16 | 0.08 | 0.21 | 0.12 | 0.13 | 0.04 | 0.15 | 0.08 | 0.07 | 0.2 | 0.36 | 0.04 | 0.13 |
| 80 | 0.1 | 0.22 | 0.08 | 0.2 | 0.13 | 0.11 | 0.04 | 0.15 | 0.08 | 0.07 | | 0.32 | | 0.12 |
| 90 | | 0.16 | | 0.2 | 0.13 | 0.1 | | 0.15 | 0.08 | 0.08 | | 0.34 | | 0.12 |
| 100 | | 0.16 | | 0.16 | 0.13 | 0.09 | | 0.15 | | 0.08 | | | | 0.12 |
| 110 | | 0.16 | | 0.16 | | 0.1 | | 0.15 | | | | | | |
| 120 | | 0.15 | | 0.16 | | 0.1 | | | | | | | | |

**Appendix 15** Distribution of soil macro-fauna

Population of soil macro-fauna under different degradation conditions on grazing lands

| | Status of land | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Order | Non-degraded | | | Mod. degraded | | | Degraded | | |
| | 0-10 cm | 10-20 cm | 20-30 cm | 0-10 cm | 10-20 cm | 20-30 cm | 0-10 cm | 10-20 cm | 20-30 cm |
| Arachnida | 1.2 | 0.6 | 0.6 | 1.6 | 0.8 | 0.4 | 2.8 | 1.6 | 0.4 |
| Isoptera | 204 | 29 | 10.4 | 50 | 18 | 10.2 | 266 | 24 | 11.6 |
| Hymenoptera | 30 | 16.2 | 4.0 | 120 | 18.6 | 4.8 | 6.0 | 5.2 | 3.6 |
| Oligocheta | 5.2 | 3.0 | 0.8 | 1.4 | 0.4 | 0.8 | 0.6 | 1.4 | 0.4 |
| Coleoptera | 1.6 | 1.4 | 0.6 | 2.6 | 1.2 | 0.6 | 0.0 | 0.8 | 0.4 |
| Diplopoda | 10.4 | 5.8 | 1.2 | 2.8 | 1.4 | 0.2 | 0.2 | 0.4 | 0.0 |
| Chilopoda | 0.6 | 1.2 | 0.8 | 1.0 | 0.8 | 0.4 | 0.0 | 0.4 | 0.2 |

Population and distribution of soil macro-fauna under different management practices and degradation conditions on croplands

| | Status of land | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Order | Non-degraded | | | Mod. Degraded | | | Degraded | | |
| | 0-10 cm | 10-20 cm | 20-30 cm | 0-10 cm | 10-20 cm | 20-30 cm | 0-10 cm | 10-20 cm | 20-30 cm |
| Arachnida | 2.2 | 1.4 | 0.4 | 1.8 | 1.0 | 0.2 | 0.8 | 0.2 | 0.0 |
| Isoptera | 31.6 | 34.8 | 15.6 | 59.2 | 26.8 | 7.0 | 9.4 | 2.6 | 1.4 |
| Hymenoptera | 9.6 | 3.0 | 1.0 | 7.2 | 6.2 | 2.0 | 5.6 | 2.6 | 1.0 |
| Oligocheta | 3.4 | 1.6 | 1.6 | 6.2 | 2.0 | 0.6 | 1.0 | 0.2 | 0.0 |
| Coleaptera | 1.8 | 0.6 | 0.2 | 1.8 | 0.8 | 0.8 | 1.6 | 0.6 | 0.4 |
| Diplopoda | 2.4 | 1.0 | 0.4 | 1.6 | 0.8 | 0.6 | 0.8 | 0.6 | 0.2 |
| Chilopoda | 1.0 | 0.8 | 0.0 | 1.4 | 0.4 | 0.4 | 0.6 | 0.2 | 0.0 |

| Location | Quadrant no. | Soil state | Counts | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Termites | Earthworms | Beetles | Masibili (young beetles) | Centipede | Millipede | Black ants |
| Bups | 1 | Mod. Degraded | >1000 | 0 | 0 | 7 | 0 | 0 | 300 |
| Bups | 2 | Degraded | 500 | 3 | 0 | 0 | 0 | 1 | 20 |
| Bups | 3 | Degraded | 800 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bmsp | 1 | Non-deg. | 10 | | 0 | 1 | 20 | 3 | 10 |
| Bmsp | 2 | Degraded | 20 | 0 | 0 | 0 | 0 | 0 | 0 |
| BLsp | 1 | Non-deg. | 700 | 20 | 0 | 2 | 21 | 0 | 50 |
| BLsp | 2 | Degraded | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lmslp | 1 | Non-deg. | 200 | 3 | 1 | 4 | 0 | 0 | 20 |
| Lmslp | 2 | Degraded | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| IMslp | 3 | Non-deg. | 80 | 1 | 0 | 1 | 0 | 0 | 10 |

Detailed count of macro-fauna by quadrant, state of the land and depth

| Location | Quadrant no. | Soil depth (cm) | | | State | Count | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0-10 | 10-20 | 20-30 | | A | Co | Ch | D | OL | H | I |
| Mid slope | 1 | * | | | Mod deg | - | 1 | - | - | - | 1 | 1 |
| | | | * | | | - | - | - | | | 1 | 16 |
| | | | | * | | - | - | - | - | - | - | - |
| Mid slope | 2 | * | | | Mod deg | - | 5 | - | - | - | 16 | 220 |
| | | | * | | | - | - | - | 1 | - | 10 | 73 |
| | | | | * | | - | 3 | - | 3 | - | 4 | 7 |
| Mid slope | 3 | * | | | Non-deg | - | - | 1 | - | 3 | 3 | 20 |
| | | | * | | | - | - | - | - | - | 2 | 52 |
| | | | | * | | - | - | - | - | - | - | 23 |
| Mid slope | 4 | * | | | Non-deg | - | - | - | - | 5 | 30 | 118 |
| | | | * | | | - | - | 1 | - | 1 | - | 62 |
| | | | | * | | - | - | - | - | 7 | - | - |

| Location | Quadrant no | Soil depth (cm) | | | State | Count | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0-10 | 10-20 | 20-30 | | A | Co | Ch | D | Ol | H | I |
| Upper | 5 | * | | | Fallow | - | 4 | 1 | - | - | - | - |
| | | | * | | | - | 2 | 1 | - | - | - | 1 |
| | | | | * | | - | - | - | - | - | - | - |
| Upper | 6 | * | | | Fallow | - | 1 | - | - | 2 | - | 38 |
| | | | * | | | - | - | - | - | - | - | - |
| | | | | * | | 1 | - | - | - | - | - | - |
| Upper | 7 | * | | | Cassava garden | - | 2 | - | 2 | 8 | - | 15 |

## **Appendix 16** Perceptions on soil degradation in Nakasongola district

This is a partial summary of the response from the questionnaires administered.

### A. SOCIO-DEMOGRAPHIC DATA:

Summary tables on respondents' sex, age distribution, education levels, income levels and period of stay in the area

1. Education level

| | Education level | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sub-county | Primary N | % | Secondary N | % | Tertiary N | % | Non Formal N | % |
| Kakooge | 61 | 19 | 11 | 3 | 0 | 0 | 10 | 3 |
| Lwampanga | 12 | 4 | | 0 | 1 | 0 | 5 | 2 |
| Nabiswera | 72 | 22 | 10 | 3 | 2 | 1 | 27 | 8 |
| Nakitoma | 54 | 17 | 12 | 4 | 1 | 0 | 18 | 6 |
| Wabinyonyi | 20 | 6 | 4 | 1 | | 0 | 5 | 2 |
| Grand Total | 219 | 67 | 37 | 11 | 4 | 1 | 65 | 21 |

2. Education level by age

| | Age | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Education level | 18-25 N | % | 25-35 N | % | 35-40 N | % | 41-45 N | % | 45-55 N | % | >55 N | % |
| Primary | 38 | 12 | 87 | 27 | 29 | 9 | 35 | 11 | 28 | 9 | 1 | 1 |
| Secondary | 7 | 2 | 10 | 3 | 12 | 4 | 3 | 1 | 4 | 1 | | |
| Tertiary | 1 | 0 | 2 | 1 | | 0 | | 0 | 1 | 0 | | |
| No formal | 8 | 2 | 14 | 4 | 5 | 2 | 15 | 5 | 22 | 7 | | |
| Grand Total | 54 | 17 | 113 | 35 | 46 | 14 | 53 | 16 | 55 | 17 | 1 | 1 |

3. Sex

| Count of Sex | Sub county | | | | | |
|---|---|---|---|---|---|---|
| Sex | 1 | 2 | 3 | 4 | 5 | Grand Total |
| Male | 38 | 12 | 35 | 62 | 12 | 159 |
| Female | 45 | 7 | 60 | 23 | 18 | 154 |
| Grand Total | 83 | 19 | 95 | 85 | 29 | 311 |

4. Age

| Count of Age | Sub-county | | | | | |
|---|---|---|---|---|---|---|
| Age | 1 | 2 | 3 | 4 | 5 | Grand Total |
| 1 | 17 | 1 | 18 | 15 | 3 | 54 |
| 2 | 32 | 10 | 27 | 31 | 10 | 110 |
| 3 | 11 | | 14 | 9 | 8 | 42 |
| 4 | 11 | 3 | 15 | 21 | 3 | 53 |
| 5 | 11 | 5 | 20 | 8 | 5 | 49 |
| Grand Total | 82 | 19 | 94 | 84 | 29 | 308 |

5. Amount of land

| Amount of land (ha) | Sub-county | | | | |
|---|---|---|---|---|---|
| | Kakooge | Lwamapnga | Nabiswera | Nakitoma | Wabinyonyi |
| Average | 1.86 | 2.38 | 2.41 | 3.78 | 3.5 |
| Maximum | 6 | 5 | 6 | 6 | 10 |
| Minimum | 1 | 1 | 1 | 1 | 1 |

6. Land ownership

| | Sub county | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land ownership | Kakooge N | % | Lwampanga N | % | Nabiswera N | % | Nakito-ma N | % | Wabinyon-yi N | % | Total | % |
| Hired | 7 | 2 | | 0 | 10 | 3 | 3 | 1 | | 0 | 20 | 6 |
| Communal | 1 | 0 | | 0 | 13 | 4 | 2 | 1 | 2 | 1 | 18 | 6 |
| Leasehold | 13 | 4 | | 0 | 22 | 7 | 27 | 8 | 2 | 1 | 64 | 20 |
| Kibanja | 60 | 18 | 17 | 5 | 62 | 19 | 50 | 15 | 23 | 7 | 212 | 65 |
| Hired & communal | 1 | 0 | | 0 | 4 | 1 | 1 | 0 | | 0 | 6 | 2 |
| Hired & Kibanja | 1 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 5 | 2 |
| Leasehold & Kibanja | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 1 |
| Grand Total | 83 | 25 | 19 | 6 | 112 | 34 | 84 | 26 | 29 | 9 | 327 | 100 |

7. Income

| Count of HH income level | HH income level | | | | | |
|---|---|---|---|---|---|---|
| Sub-county | 1 | 2 | 3 | 4 | 5 | Grand Total |
| 1 | 8 | 13 | 19 | 17 | 23 | 80 |
| 2 | 3 | 5 | 4 | 4 | 2 | 18 |
| 3 | 15 | 20 | 23 | 18 | 14 | 90 |
| 4 | 2 | 11 | 13 | 24 | 31 | 81 |
| 5 | 2 | 4 | 8 | 5 | 10 | 29 |
| Grand Total | 30 | 53 | 67 | 68 | 80 | 298 |

8. Period of stay

| | Sub county | | | | |
|---|---|---|---|---|---|
| Period of stay (Years) | Kakooge | Lwampanga | Nabiswera | Nakitoma | Wabinyonyi |
| Average | 3 | 4 | 4 | 3 | 3 |
| Maximum | 5 | 5 | 8 | 5 | 5 |
| Minimum | 1 | 1 | 1 | 1 | 1 |

9. Special skills

| Count of Special skills | Special skills | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sub-county | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Grand Total |
| 1 | 8 | 32 | 1 | 19 | 17 | 1 | 1 | | 1 | 1 | 2 | 83 |
| 2 | 1 | | | 13 | 3 | | | 1 | | 1 | | 19 |
| 3 | | 32 | 1 | 24 | 30 | 1 | 2 | | 1 | | | 91 |
| 4 | 6 | 11 | 2 | 12 | 46 | | 3 | 2 | | | | 82 |
| 5 | 1 | 9 | | 4 | 11 | | 2 | | | | 1 | 28 |
| Grand Total | 16 | 84 | 4 | 72 | 107 | 2 | 8 | 3 | 2 | 2 | 3 | 303 |

**Note:**

Sub-counties
1 = Kakooge; 2 = Lwampanga; 3 = Nabiswera; 4 = Nakitoma; 5 = Wabinyonyi

## B. CAUSES AND CONCERN OF SOIL DEGRADATION

**Percentage responses on the causes of soil degradation in the different sub- counties**

| Causes | % Frequencies | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kakooge | | Lwampanga | | Nabiswera | | Nakitoma | | Wabinyonyi | |
| | N | % | N | % | N | % | N | % | N | % |
| Erosive rains | 20 | 3 | 0 | 0 | 19 | 3 | 19 | 3 | 9 | 1 |
| Sloping land | 37 | 5 | 5 | 1 | 13 | 2 | 23 | 3 | 15 | 2 |
| Erodible soils | 23 | 3 | 0 | 0 | 11 | 2 | 17 | 3 | 7 | 1 |
| Overcultivation | 46 | 7 | 6 | 1 | 38 | 6 | 29 | 4 | 8 | 1 |
| Overgrazing | 8 | 1 | 1 | 0 | 4 | 1 | 5 | 1 | 1 | 0 |
| Deforestation | 31 | 5 | 0 | 0 | 41 | 6 | 46 | 7 | 9 | 1 |
| Charcoal burning | 11 | 2 | 0 | 0 | 10 | 1 | 5 | 1 | 2 | 0 |
| waterlogging | 2 | 0 | 0 | 0 | 1 | 1 | 5 | 1 | 0 | 0 |
| Drought | 4 | 1 | 0 | 0 | 9 | 1 | 5 | 1 | 2 | 0 |

**Factors explaining why wind is a problem in the area**

| | Factors of wind erosion | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sub-county | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Grand Total |
| Kakooge | 2 | 28 | 3 | | 5 | 2 | | 40 |
| Lwampanga | | 4 | | | | | | 4 |
| Nabiswera | | 45 | 4 | 7 | | 6 | 1 | 63 |
| Nakitoma | 1 | 29 | | 2 | | 7 | | 39 |
| Wabinyonyi | | 9 | | 1 | | 1 | | 11 |
| Grand Total | 3 | 115 | 7 | 10 | 5 | 16 | 1 | 157 |

**Change in soil quality and productivity**

| | Change in soil quality | | | |
|---|---|---|---|---|
| Sub-county | Yes | | No | |
| | N | % | N | % |
| Kakooge | 68 | 26 | 13 | 5 |
| Lwampanga | 7 | 3 | 3 | 1 |
| Nabiswera | 57 | 22 | 12 | 5 |

| | | | | |
|---|---|---|---|---|
| Nakitoma | 63 | 24 | 16 | 6 |
| Wabinyonyi | 20 | 8 | 6 | 2 |
| Grand Total | 215 | 81 | 50 | 19 |

**Evidence and rank of sheet erosion**

| Count of evidence & rank of sheet erosion | Sub-county | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kakooge | | Lwampanga | | Nabiswera | | Nakitoma | | Wabinyonyi | |
| | N | % | N | % | N | % | N | % | N | % |
| Most important | 28 | 15 | 2 | 1 | 34 | 18 | 33 | 17 | 13 | 7 |
| Important | 15 | 8 | 0 | 0 | 13 | 7 | 14 | 7 | 3 | 2 |
| Mod important | 10 | 5 | 4 | 2 | 9 | 5 | 4 | 2 | 1 | 1 |
| Less important | 4 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 0 | 0 |
| Least important | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| Total | 57 | 30 | 7 | 4 | 58 | 30 | 54 | 28 | 17 | 10 |

**Evidence and rank of rill erosion in the sub-counties**

| Count & Rank of rills | Kakooge | | Lwampanga | | Nabiswera | | Nakitoma | | Wabinyonyi | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % | N | % |
| Most important | 2 | 2 | 1 | 1 | 0 | 0 | 2 | 2 | 0 | 0 |
| Important | 12 | 11 | | 0 | 12 | 11 | 11 | 10 | 2 | 2 |
| Mod important | 5 | 5 | | 0 | 10 | 9 | 9 | 8 | 5 | 4 |
| Less important | 4 | 4 | 3 | 3 | 6 | 5 | 5 | 5 | 3 | 3 |
| Least important | 6 | 5 | 1 | 1 | 1 | 1 | 7 | 6 | 2 | 2 |
| Not important | 1 | 1 | | 0 | | 0 | | 0 | | 0 |
| Grand Total | 30 | 27 | 5 | 5 | 29 | 26 | 34 | 31 | 12 | 11 |

**Evidence and rank of gully erosion in the sub-counties**

| Count of Evidence & rank of gullies | Sub-county | | | | | |
|---|---|---|---|---|---|---|
| | Kakooge | Lwampanga | Nabiswera | Nakitoma | Wabinyonyi | Grand Total |
| Most important | 2 | 1 | 0 | 0 | 1 | 4 |
| Important | 1 | 1 | 0 | 1 | 1 | 4 |
| Mod important | 7 | 0 | 2 | 5 | 2 | 16 |
| Less important | 3 | 0 | 1 | 6 | 1 | 11 |
| Least important | 2 | 1 | 5 | 2 | 6 | 16 |
| Not important | 0 | 0 | 2 | 1 | 0 | 3 |
| Grand Total | 15 | 3 | 10 | 15 | 11 | 54 |

**Evidence and rank of exposed soil in the sub-counties**

| Count of Evidence & rank of exposed soil | Sub-county | | | | | |
|---|---|---|---|---|---|---|
| | Kakooge | Lwampanga | Nabiswera | Nakitoma | Wabinyonyi | Grand Total |
| Most important | 2 | | 4 | 3 | | 9 |
| Important | 9 | | 6 | 7 | 2 | 24 |
| Mod important | 14 | 1 | 11 | 11 | 5 | 42 |
| Less important | 9 | | 7 | 10 | 2 | 28 |
| Least important | 2 | 1 | 2 | 1 | | 6 |
| Not important | 36 | 2 | 30 | 32 | 9 | 109 |
| Grand Total | 72 | 3 | 60 | 64 | 9 | 218 |

**Evidence and rank of compaction in the sub-counties**

| Count of Evidence & rank of compaction | Sub-county | | | | | |
|---|---|---|---|---|---|---|
| | Kakooge | Lwampanga | Nabiswera | Nakitoma | Wabinyonyi | Grand Total |
| Most important | 17 | 4 | 23 | 10 | 6 | 60 |
| Important | 18 | 1 | 28 | 19 | 7 | 73 |
| Mod important | 9 | | 9 | 9 | 2 | 29 |
| Less important | 8 | 1 | 8 | 6 | 1 | 24 |
| Least important | 3 | 1 | 2 | 2 | 1 | 9 |
| Not important | 1 | | | 1 | | 2 |
| Grand Total | 56 | 7 | 70 | 47 | 17 | 197 |

**Evidence & rank of fertility loss in the sub-counties**

| Count of Evidence & Rank of fertility loss | Sub-county | | | | | |
|---|---|---|---|---|---|---|
| | Kakooge | Lwampanga | Nabiswera | Nakitoma | Wabinyonyi | Grand Total |
| Most important | 33 | 2 | 22 | 16 | 4 | 77 |
| Important | 20 | 3 | 16 | 13 | 7 | 59 |
| Mod important | 13 | | 8 | 5 | 3 | 29 |
| Less important | 5 | | 7 | 3 | 2 | 17 |
| Least important | 1 | 2 | 2 | 4 | 1 | 10 |
| Not important | | 1 | 2 | | | 1 |
| Grand Total | 72 | 8 | 57 | 41 | 17 | 195 |

**Description of observed changes in soil quality by resource user type**

| | Resource user type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| If yes describe | Sole crop farmer N | % | Herder N | % | Mixed N | % | Total N | % |
| 1 | 6 | 3 | 1 | 0 | 2 | 1 | 9 | 4 |
| 2 | 77 | 34 | 14 | 6 | 60 | 26 | 151 | 67 |
| 3 | 5 | 2 | 1 | 0 | 1 | 0 | 7 | 3 |
| 4 | 1 | 0 | 1 | 0 | 2 | 1 | 4 | 2 |
| 5 | 10 | 4 | 2 | 1 | 6 | 3 | 18 | 8 |
| 6 | 2 | 1 | | 0 | 3 | 1 | 5 | 2 |
| 7 | 12 | 5 | 2 | 1 | 11 | 5 | 25 | 11 |
| 8 | 2 | 1 | 1 | 0 | 4 | 2 | 7 | 3 |
| 9 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| Grand Total | 115 | 51 | 23 | 10 | 89 | 39 | 227 | 100 |

**Land ownership according to different resource users**

| | **Resource user** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Land ownership | Crop farmer N | % | Herder N | % | Both N | % | Grand Total N | % |
| Hired | 15 | 5 | 1 | 0 | 4 | 1 | 20 | 7 |
| Communal | 9 | 3 | 2 | 1 | 5 | 2 | 16 | 5 |
| Leasehold | 17 | 6 | 15 | 5 | 26 | 9 | 58 | 20 |
| Kibanja | 112 | 38 | 9 | 3 | 68 | 23 | 189 | 64 |
| Both hired & communal land | 2 | 1 | 0 | 0 | 4 | 1 | 6 | 2 |
| Hired and Kibanja | 1 | 0 | 0 | 0 | 3 | 1 | 4 | 1 |

## Adoption of SWC by different resource users

Note for practice 1 = Yes; 2 = No; Resource user 1 = Sole crop farmer; 2 = Herder 3 = Mixed farmer

| Practice | Resource user type | | | | | | |
|---|---|---|---|---|---|---|---|
| Land mgmt GB | 1 | | 2 | | 3 | | Grand Total |
| 1 | 6 | 2.390438 | 0 | 0 | 8 | 3.187251 | 14 |
| 2 | 134 | 53.38645 | 17 | 6.772908 | 86 | 34.26295 | 237 |
| Grand Total | 140 | 55.77689 | 17 | 6.772908 | 94 | 37.4502 | 251 |
| | | | | | | | |
| | Resource user type | | | | | | |
| Land mgmt Agroforestry | 1 | | 2 | | 3 | | Grand Total |
| 1 | 74 | 28.90625 | 3 | 1.171875 | 50 | 19.53125 | 127 |
| 2 | 68 | 26.5625 | 14 | 5.46875 | 47 | 18.35938 | 129 |
| Grand Total | 142 | 55.46875 | 17 | 6.640625 | 97 | 37.89063 | 256 |
| | | | | | | | |
| | Resource user type | | | | | | |
| Land mgmt slash/burn | 1 | | 2 | | 3 | | Grand Total |
| 1 | 24 | 9.561753 | | 0 | 15 | 5.976096 | 39 |
| 2 | 114 | 45.41833 | 17 | 6.772908 | 81 | 32.27092 | 212 |
| Grand Total | 138 | 54.98008 | 17 | 6.772908 | 96 | 38.24701 | 251 |
| | | | | | | | |
| | Resource user type | | | | | | |
| Slash/mix | 1 | | 2 | | 3 | | Grand Total |
| 1 | 84 | | 1 | | 44 | | 129 |
| 2 | 53 | | 15 | | 50 | | 118 |
| Grand Total | 137 | | 16 | | 94 | | 247 |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | Resource user type | | | | | | |
| Terrace | 1 | | 2 | | 3 | | Grand Total |
| 1 | 3 | 1.209677 | 0 | 0 | 1 | 0.403226 | 4 |
| 2 | 136 | 54.83871 | 17 | 6.854839 | 91 | 36.69355 | 244 |
| Grand Total | 139 | 56.04839 | 17 | 6.854839 | 93 | 37.5 | 248 |
| | | | | | | | |
| | | | | | | | |
| Count of Lnad mgmt mulch | Resource user type | | | | | | |
| Lnad mgmt mulch | 1 | | 2 | | 3 | | Grand Total |
| 1 | 6 | 2.531646 | | 0 | 7 | 2.953586 | 13 |
| 2 | 126 | 53.16456 | 17 | 7.172996 | 81 | 34.17722 | 224 |
| Grand Total | 132 | 55.6962 | 17 | 7.172996 | 88 | 37.1308 | 237 |
| | | | | | | | |
| | | | | | | | |
| | Resource user type | | | | | | |
| Land mgmt ploughing | 1 | | 2 | | 3 | | Grand Total |
| 1 | 20 | 8.064516 | 1 | 0.403226 | 9 | 3.629032 | 30 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | 117 | 47.17742 | 17 | 6.854839 | 84 | 33.87097 | 218 |
| Grand Total | 137 | 55.24194 | 18 | 7.258065 | 93 | 37.5 | 248 |
| | | | | | | | |
| | Resource user type | | | | | | |
| Land mgmt ploughing | 1 | | 2 | | 3 | | Grand Total |
| 1 | 20 | 8.064516 | 1 | 0.403226 | 9 | 3.629032 | 30 |
| 2 | 117 | 47.17742 | 17 | 6.854839 | 84 | 33.87097 | 218 |
| Grand Total | 137 | 55.24194 | 18 | 7.258065 | 93 | 37.5 | 248 |

**In general do consider yourself successful in controlling soil degradation on your farm?**

| Resource user type | Total number of respondents |
|---|---|
| Sole crop farmer | 147 |
| Herder | 26 |
| Mixed farmer | 103 |
| Blank(missing) | 2 |
| Total | 278 |

**Appendix 17.** Characteristics of plots at the time of instalment in Nakasongola district

| Position | Plot | GPS location | Slope angle | Condition | Land cover/activity |
|---|---|---|---|---|---|
| **Upper slope** | B1 | 36N 0417305 UTM 0154043 Alt 1095 m | 2-3° | Moderately degraded, moderately deep soil with a some concretions | Mod. grazed, low grass cover approx. 60% with some tussocks separated by bare soil |
| | L1 | 36N 041567 UTM 0154763 Alt 1096 m | 2-3° | Degraded, exposed/ compacted soils, Evidence of sheet wash patterns | Very low veg. cover (1-5%) Limited grazing, fenced off |
| **Mid slope** | B3 | 36 N0417253 UTM 0153839 Alt 1091 m | 3-5° | Degraded; almost bare ground, Very few plant shrubs/grass tussocks | Almost bare ground, Very few plant shrubs/grass tussocks |
| | L2 | 36N 0415683 UTM 0154514 Alt 1094 m | 4-6° | Mod. Degraded, Soils may not be so compacted | Mod. Grazed, low grass 60%, with relatively dense tree canopy <40% |
| **Lower slope** | B2 | 36N 041748 UTM 0153639 Alt 1076 m | 8-10° | Degraded- bare land, compacted, Some exposed stones | Bare land with very few scattered shrubs 10% |
| | L3 | 36N 0415985 UTM 0154549 Alt 1092 m | 7-9° | Degraded, under rehabilitation, evidence of rills & sheet wash | Very scanty veg. cover < 5%, Some SWC trenches installed |
| | L4 | | 4-6% | Non degraded | Relatively dense grass cover (>70%) and canopy cover (20%) |

**Appendix 18:** Seasonal runoff for 2001 and 2002

A). Seasonal and monthly runoff (mm) for different degraded areas in the year 2001

| | Non-degraded | | Moderately degraded | | Severely degraded | | | |
|---|---|---|---|---|---|---|---|---|
| **Season 1** | B4 | L4 | B1 | L2 | B2 | B3 | L3 | L1 |
| Jan | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Feb | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mar | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Apr | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| May | 0.00 | 0.00 | 28.00 | 44.00 | 21.53 | 51.83 | 21.00 | 70.17 |
| Jun | 0.00 | 0.00 | 11.00 | 13.67 | 0.00 | 0.00 | 0.00 | 26.17 |
| Seasonal total | 0.00 | 0.00 | 39.00 | 57.67 | 21.53 | 51.83 | 21.00 | 96.34 |
| Season 2 | | | | | | | | |
| July | 0.00 | 0.00 | 0.00 | 0.00 | 13.33 | 13.5 | 13.00 | 0.00 |
| August | 0.00 | 0.00 | 0.00 | 7.83 | 0.00 | 0.00 | 67.00 | 46.17 |
| September | 27.17 | 3.20 | 40.67 | 27.33 | 39.83 | 39.67 | 39 | 36.67 |
| October | 0.00 | 15.6 | 45.17 | 38.5 | 53.33 | 0 | 69.5 | 49.83 |
| November | 23.67 | 10.5 | 13.67 | 39.33 | 37 | 36.6 | 44.67 | 37.33 |
| Dec | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 |
| Seasonal total | 50.84 | 29.30 | 99.51 | 112.99 | 143.49 | 436.13 | 233.17 | 170.00 |

Seasonal and monthly runoff (mm) for different degraded areas in the year 2002

| | Non-degraded | | Moderately degraded | | Severely degraded | | | |
|---|---|---|---|---|---|---|---|---|
| Season 1 | B4 | L4 | B1 | L2 | B2 | B3 | L3 | L1 |
| Jan | 0.00 | 3.17 | 0.00 | 3.33 | 0.00 | 0.00 | 0.00 | 0.00 |
| Feb | 0.00 | 0.00 | 0.00 | 0.00 | 1.67 | 1.00 | 5.17 | 2.67 |
| Mar | 31.00 | 0.00 | 38.00 | 24.67 | 53.33 | 54 | 64 | 71.00 |
| Apr | 51.17 | 35.00 | 93.30 | 85.30 | 70.33 | 82.33 | 90.17 | 88.00 |
| May | 60.50 | 0.00 | 85.67 | 106.50 | 113.00 | 119.33 | 120.83 | 93.00 |
| Jun | 0.00 | 0.00 | 10.67 | 7.00 | 10.00 | 11.60 | 27.00 | 6.67 |
| Seasonal total | 142.67 | 38.17 | 227.64 | 226.80 | 248.33 | 268.26 | 307.17 | 261.34 |
| Season 2 | | | | | | | | |
| July | 0.00 | 0.00 | 0.00 | 26 | 47.17 | 25.67 | 53.67 | 31.33 |
| August | 0.00 | 0.00 | 0.00 | 17.83 | 0.00 | 0.00 | 0.00 | 21.00 |
| September | 0.00 | 0.00 | 0.00 | 25.67 | 0.00 | 0.00 | 0.00 | 0.00 |
| October | 0.00 | 0.00 | 46.33 | 19.67 | 0.00 | 0.00 | 21.30 | 11.50 |
| November | 25.00 | 22.67 | 37.00 | 33.33 | 41.17 | 40.17 | 48.67 | 18.67 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Dec | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Seasonal total | 25.00 | 22.67 | 83.33 | 122.5 | 88.34 | 65.84 | 123.64 | 82.50 |

Seasonal and monthly soil loss (t/ha) for different degraded areas in the year 2001

| | Non-degraded | | Moderately degraded | | Severely degraded | | | |
|---|---|---|---|---|---|---|---|---|
| Season 1 | B4 | L4 | B1 | L2 | B2 | B3 | L3 | L1 |
| Jan | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Feb | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mar | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Apr | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| May | 0.00 | 0.00 | 1.31 | 3.19 | 0.48 | 4.47 | 1.26 | 4.74 |
| Jun | 0 | 0 | 0.53 | 0 | | 0 | 0 | 0.9 |
| **Seasonal total** | **0** | **0** | **1.84** | **3.19** | **5.03** | **4.47** | **1.26** | **5.64** |
| Season 2 | | | | | | | | |
| July | 0 | 0 | 0 | 0 | 0.4 | 0.57 | 0.85 | 0 |
| August | 0 | 0 | 0 | 0 | 0 | 0 | 1.04 | 2.34 |
| September | 0.47 | 0.04 | 3.08 | 2.43 | 4.41 | 3.47 | 7.89 | 2.91 |
| October | 0 | 0.41 | 3.24 | 2.65 | 6.48 | 0 | 2.01 | 2.53 |
| November | 1.1 | 0.09 | 1.27 | 4.44 | 3.63 | 4.41 | 6.39 | 3.57 |
| December | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Seasonal total** | **1.57** | **0.54** | **7.59** | **9.52** | **14.92** | **8.45** | **18.18** | **11.35** |

Seasonal and monthly soil loss (t/ha) for different degraded areas in the year 2002

| | Non-degraded | | Moderately degraded | | Severely degraded | | | |
|---|---|---|---|---|---|---|---|---|
| Season 1 | B4 | L4 | B1 | L2 | B2 | B3 | L3 | L1 |
| Jan | 0 | 0.01 | 0 | 0.01 | 0 | 0 | 0 | 0 |
| Feb | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.1 | 0.03 |
| Mar | 0 | 0 | 2.34 | 1.01 | 1.39 | 1.82 | 5.62 | 2.34 |
| Apr | 0.96 | 0.75 | 4.15 | 2.26 | 2.54 | 3.14 | 4.1 | 3.69 |
| May | 0.96 | 0.55 | 8.8 | 1.71 | 7.55 | 5.04 | 8.81 | 8.87 |
| Jun | | 0 | 0.53 | 0.11 | 0.3 | 0.58 | 0.67 | 0 |
| **Seasonal total** | **1.92** | **1.31** | **15.82** | **5.1** | **11.78** | **10.59** | **19.3** | **14.93** |
| Season 2 | | | | | | | | |
| July | 0 | 0 | 0 | 3.12 | 3.26 | 2.66 | 3.91 | 1.77 |
| August | 0 | 0 | 0 | 0.23 | 0 | 0 | 0 | 1.05 |
| September | 0 | 0 | 0 | 0.98 | 0 | 0 | 0 | 0 |
| October | 0 | 0 | 1.16 | 0.49 | 0 | 0 | 0 | 0.26 |
| November | 0.92 | 0.49 | 1.09 | 1.16 | 2.57 | 1.79 | 5.44 | 0.53 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Dec | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Seasonal total** | **0.92** | **0.49** | **2.25** | **5.98** | **5.83** | **4.45** | **9.35** | **3.61** |

**B).** Comparison of soil loss on different degraded surfaces; mod = moderately degraded, Sev = severely degraded, Undeg = non-degraded

**Table 5.3** A comparison of average soil loss on different range condition for 2001/2002 for Each individual plot replica

| | | Soil loss (t/ha) | | |
|---|---|---|---|---|
| **Range condition** | **Plot No** | **Year 2001** | **Year 2002** | **Average (t/ha)** |
| Severely degraded | L1 | 17.4 | 20.6 | 20.4 |
| | B3 | 16.5 | 18.0 | |
| | B2 | 16.5 | 21.7 | |
| | L3 | 21.8 | 28.6 | |
| | B1* | | 22.8 | |
| Moderately degraded | B1 | 10.8 | | 12.8 |
| | L2 | 12.7 | 14.2 | |
| Non-degraded | B4 | 1.0 | 3.2 | 1.8 |
| | L4 | 0.4 | 2.7 | |

**Note:** According to the evidence in the field (see Chapters 3 and 4), the plot B1, which initially was categorised under a moderately degraded area at the time of installation, experienced deterioration of basal cover hence was placed under a severely degraded category in the second year, 2002.