LAND DEGRADATION IN MHONDORO (ZIMBABWE): AN ENVIRONMENTAL ASSESSMENT OF COMMUNAL LAND USES AND RESOURCE MANAGEMENT PRACTICE

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously, in its entirety or in part, submitted it at any University for a degree.

Signed Date.

ABSTRACT

When land loses its intrinsic qualities or suffers a decline in its capabilities it is said to be degraded. Land degradation manifests itself in various forms such as deforestation, soil erosion, land, air and water pollution. In the context of sustainable development land degradation has become one of the world's major concerns. Now, more than ever before, it has become urgent to carry out empirical studies on the nature and extent of land degradation and to come up with appropriate responses to the problem.

In much of the developing world communal natural resource management practices are common. It is often assumed that communal exploitation of common property resources such as woodlands, pastures, water sources and wildlife inevitably leads to land degradation. This is due to the belief that humankind would seek to derive maximum benefit from common pool resources without incurring any costs towards the conservation of those resources.

This study was an environmental assessment of the impacts of communal land-use systems and common property resources management practices in the Mhondoro communal lands of Zimbabwe. The area has been subject to human settlement for over a century and is regarded as a typical representation of a well-established communal land management system. Several methods were used to make the assessment. These included the following: a questionnaire survey; interviews with key informants; soil and vegetation traverses and field measurements; tree density counts in demarcated plots; calculation of the population density and livestock density for the study area; completion of an environmental evaluation matrix and a communal projects sustainability index checklist; and analysis of geo-referenced time-lapse aerial photography covering a fifteen year period (1982-1997).

It was established that serious land degradation had occurred in Chief Mashayamombe's ward in Mhondoro. Degradation manifested itself in the form of soil erosion and stream sedimentation, woodland depletion, pasture degradation and wildlife habitat destruction.

Communal land-use and natural resource management practices are only partially to blame for this state of affairs. The fragile nature of the sandy soils of the uplands, the sodic soils of the vlei areas, combined with the fairly high rainfall amounts (annual average 750mm) make the area prone to soil erosion. Rainfall intensity tends to be high in the area and when the rain falls on the poorly vegetated, and highly erodible soils erosion occurs. The land has become severely stressed due to over-utilisation; a population density of 93 people per km^2 and livestock density of 110 cattle per km^2 were recorded. The land available for communal settlement in the area has been limited in extent. Due to the general poverty of the communal farmers the replacement of nutrients into the cultivated soil has not kept pace with the deteriorating condition of the land.

Contrary to popular misconceptions, communal area residents have shown concern for environmental conservation through fallowing their fields, gully reclamation efforts, grazing schemes, woodland preservation and tree growing practices. Remedial and/or mitigatory measures for the environmental recovery of the area could adopt some of these well-established practices and incorporate them in a whole-catchment management strategy.

Key words

Land degradation, environmental degradation, pollution, environmental assessment, common property resources, communal land uses, sustainable resources management, sustainability indicators, soil erodibility, soil erosivity

OPSOMMING

Wanneer grond sy intrinsieke waarde verloor of 'n afname in sy vermoë toon, kan gesê word dat die grond gedegradeer is. Gronddegradasie manifesteer in verskeie vorme, soos ontbossing, gronderosie, grond, lug en water besoedeling. Gronddegradasie het binne die konteks van volhoubare ontwikkeling wêreldwyd van besondere belang geword. Nou, meer as ooit vantevore, is dit noodsaaklik om empiriese studies uit te voer aangaande die aard en omvang van gronddegradasie, en om vorendag te kom met toepaslike reaksies tot die probleem.

Gemeenskaps natuurlike hulpbron bestuur praktyke is algemeen in die ontwikkelende wêreld. Daar word dikwels veronderstel dat uitbuiting van gemeenskaplike eiendoms hulpbronne deur die gemeenskap, soos woude, weivelde, waterbronne en wild, onvermeidelik lei na gronddegradasie. Hierdie aanname het ontwikkel as gevolg van die oortuiging dat die mensdom daarna sal streef om maksimum voordeel te trek uit gemeenskaplike hulpbronne, sonder om enige koste aan te gaan ten opsigte van die bewaring daarvan.

Hierdie studie behels 'n omgewings evaluering van die impakte van gemeenskaps grondgebruik sisteme en gemeenskaplike eiendoms hulpbron bestuur praktyke in die Mhondoro gemeenskaplike grond van Zimbabwe. Die area word al vir meer as 'n eeu deur mense bewoon, en word beskou as 'n tipiese voorbeeld van 'n gevestigde gemeenskaps grondbestuur sisteem. Verskeie metodes is toegepas met die evaluering, en sluit in: 'n vraelys opname; onderhoude met sleutel segspersone; grond en plantegroei opnames en veldopnames; boom digtheidstelling in afgebakende persele; berekening van bevolkings- en veedigtheid vir die studiegebied; opstelling van 'n omgewing evaluerings matriks en 'n gemeenskap projek volhoubaarheids indeks kontroleerlys; en 'n analise van *geo-referenced time-lapse* lugfoto's wat strek oor 'n tydperk van 15 jaar (1982-1997).

Daar is vasgestel dat ernstige gronddegradasie voorkom in Hoofman Mashayamombe se wyk in Mhondoro. Degradasie word gemanifesteer in die vorm van gronderosie en stroom sedimentasie, uitputting van woude, weiveld degradasie en die verwoesting van wild habitatte. Gemeenskaps grondgebruik en natuurlike hulpbron bestuurspraktyke is net gedeeltelik verantwoordelik vir die stand van sake. Gronderosie vind plaas ook as gevolg van die sensitiewe aard van die sanderige grond van die hoogland, die **sodic** grond van die vlei areas, in kombinasie met redelike hoë reënval (gemiddeld 750mm per jaar). Reënval intensiteit in die area is geneig om hoog te wees, en erosie vind plaas wanneer reën val op die hoogs erodeerbare grond wat met yl plantegroei bedek is. Die grond verkeer onder geweldige druk as gevolg van oorbenutting; 'n bevolkingsdigtheid van 93 mense per km2 en veedigtheid van 110 beeste per km2 is aangeteken. Die grond beskikbaar vir vestiging van gemeenskappe word in omvang beperk. Die vervanging van grondvoedingstowwe in bewerkte grond hou nie tred met die agteruitgang in die kondisie van die grond nie, as gevolg van die algemene armoede van die gemeenskapsboere.

Inwoners van die gemeenskapsarea , teenstrydig met algemene wanopvattings, toon besorgdheid ten opsigte van omgewingsbewaring deur die grond braak te lê, donga herwinnings pogings, weivelds planne, bewaring van woude en praktyke ten opsigte van die groei van bome. Remediërende en/of versagtende maatstawwe vir die herstel van die omgewing kan van hierdie gevestigde praktyke inkorporeer in 'n bestuursstrategie wat die hele opvangsgebied insluit.

Sleutelwoorde

Gronddegradasie, omgewingsdegradasie, besoedeling, omgewingsassessering, gemeenskaplike eiendoms hulpbronne, gemeenskaplike grondgebruik, volhoubare hulpbron bestuur, volhoubaarheids aanwysers, grond erodeerbaarheid, grond verwering.

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1.1 RATIONALE FOR STUDY

The issue of environmental degradation is central to sustainable development and the Rio Declaration on Environment and Development referred to this theme several times. "The growth of world population and production combined with unsustainable consumption patterns places increasingly severe stress on the life-supporting capacities of our planet" (Grubb, *et al*, 1993; Robinson, 1993: 43;). Land degradation is a more specific form of this environmental stress. Perceptions of *land* should be interpreted in the broadest terms to include the many elements of the biophysical environment such as the soil, the indigenous and exotic plants and animals, the soil biota, the insects and the birds, the streams and groundwater (Conacher, 1995).

When land suffers a loss of its intrinsic qualities or a decline in its capabilities it is said to be degraded (Barrow, 1991). Degradation is often viewed in the context of the environmental elements' usefulness to humankind. Land degradation manifests itself in various forms. These include deforestation and soil erosion by wind and water, desertification, soil compaction and crusting, waterlogging, nutrient depletion, acidification and salinization (Conte, 1999; Darkoh, 1998; Hudson, 1986; Kotb, *et al,* 2000; United Nations Environment Programme (UNEP), 1992).

Research into the many aspects of land degradation is necessary in order to inform human endeavours in persuance of the goals of food security, shelter provision and an improved quality of life. In our efforts to cater for our ever-growing requirements we should not lose sight of the need to keep within the carrying capacity of our immediate environment as well as the environments of other life-forms affected by our activities. The search for the most appropriate people-environment interactions should be persistent if the goal of sustainable development is ever to be achieved.

1.2 LAND DEGRADATION AS A RESEARCH FIELD

The problem of land degradation is not new. It can be traced back to ancient historical times through humankind's evolution of more efficient methods of exploitation of the biophysical environment for survival (Butzer, 1974). What is new, perhaps, is that our understanding of the impacts of man-environment interactions has improved over the centuries and the realization that our responses to these impacts has to be continuously reviewed, for the survival of the human race. Several studies have, therefore, been carried out in various contexts in order to advance human knowledge of aspects of the causes, processes and effects of land degradation.

1.2.1 **Land degradation**

It is a composite term describing the aggregate diminution of the productive potential of the land, including its major uses (rainfed arable, irrigated, rangeland, forestry), it's farming systems and it's value as an economic resource (Stocking, 1993). It is the loss of utility or potential utility or the reduction, loss or change of features or organisms which cannot be replaced (Barrow, 1991). Land degradation results in the loss of soil quality, with adverse impacts on agricultural productivity and food security; it lowers the environmental and habitat functions of the ecosystems, leading to hydrological disturbance, loss of genetic resources and biological diversity and increased carbon dioxide emisions (Koohafkan, 2000). Some writers refer specifically to *soil degradation* as a decline or decrease in soil quality and productivity now and in the future (Lal, 1988; Stocking, 1993). Landa, *et al,* (1997) use the term *environmental deterioration* to refer to deforestation and soil erosion.

Some land degradation is due to natural or biophysical causes (Barrow, 1991; Crozier, 1999; Garland, 1987; Landa, *et al*, 1997); other degradation is due to anthropogenic causes. Often, it is a combination of both natural and human causes. This study concentrates on human-induced land degradation and attempts to deal with the effects of degradation.

Soil erosion is one of the main processes of land degradation and entails the physical detachment of soil particles by wind and water and their translocation elsewhere in the landscape (Barrow, 1991; Stocking, 1993). Other land degradation processes include deforestation, land and water pollution, soil acidification, soil salinization, alkalinization, waterlogging, subsidence, species invasion, global warming (leading to aridification and desertification), mining and quarrying.

1.2.2 **Assessment of land degradation**

The extent and spatial distribution of land degradation on a national, regional and global scale is not easy to measure. However, assessments of degradation have been undertaken in a number of countries in the context of land resource surveys and land evaluations. A number of techniques are used for natural resources monitoring; they include aerial photography, remote sensing and the analysis of the data so gathered (Botha & Fouche, 2000; Clarke, 1986; Gray, 1999; Haines-Young, 1999; Lutchmiah, 1999). Graef, *et al*, (1998) report on a methodology involving remote sensing and detailed ground transect investigations for mapping spatial soil and terrain data with the aid of a geographical information system (GIS). Techniques and models for estimating soil loss due to erosion are explained by a number of writers (Abel and Stocking, 1987; Smith, 1999; Yu, *et al*, 2000). Davidson (1992) surveys techniques used in several countries (e.g. Canada, USA, UK, the Netherlands) in land classification. These include the use of the FAO's Framework for Land Evaluation and the use of GIS for input, processing and output of spatially referenced data.

Pickup (1996) describes and explains a method that uses remote sensing and models of grazing and herbage dynamics to estimate the effects of land degradation and rainfall variation on productivity in rangelands. Haines-Young (1999) explains in some detail how the remote sensing procedure works. Land cover maps are used as baseline data against which environmental change can be detected and measured. A global scale study of desertification was done by the United Nations Environmental Programme (UNED, 1992). The measurements and inventories used in most studies comprise estimates of degraded areas as percentages of total areas (Landa, *et al*,1997; Roberts, 1990); spatial distribution of degraded areas (Koohafkan, 2000; UNEP, 1992); estimated quantities of annual soil losses (Roberts, 1990; Stocking, 1993); and costs of soil loss (Stocking, 1993).

1.2.3 **Causes, processes and results of degradation**

The causes of land degradation are diverse and degradation manifests itself through a wide range of processes such as deforestation, desertification, soil erosion and pollution.

1.2.3.1 **Degradation of forests and woodlands**

In a fairly detailed survey of degradation of tropical rainforests, subtropical forests, woodlands and scrublands Barrow (1991) provides a useful summary of the salient aspects of deforestation. He examines the extent of the rainforest, the extent of the damage, problem regions and reasons for deforestation. Among the causes of deforestation are population increase, improved communications (construction of roads, railways, power transmission lines, and canals), large dams, clearing for agriculture, demand for timber, woodchips, pulp and forest products, administrative causes, land settlement schemes, fuelwood collection, and fire. Causes of degradation of seasonally-dry and Meditteranean-type forests, woodlands and scrub include fire, overgrazing, fuelwood collection, logging, and clearing for agriculture. High latitude forest and woodland degradation is caused by timber and pulp demand, acid deposition, fire and other pollution (e.g. industrial and motor vehicle emissions).

Lean and Hinrichsen (1992) put shifting cultivation at the top of all the causes of deforestation, followed by indiscriminate logging and conversion to pasture. Other writers examine deforestation in specific contexts. In the Brazilian Amazon government land reform policies were found to be unwittingly encouraging violent conflicts between large landowners and squatters over land, resulting in rapid deforestation (Alfston, *et al*, 2000). A study in La Monta in rural Mexico, found rapid deforestation to be due to accelerated demographic growth, agricultural development and over-exploitation of natural resources (Landa, *et al*, 1997). In the Peruvian Amazon *slash and burn* agriculture based on rice cropping led to invasion of fields by problematic weeds which drove farmers to clear more forest rather than try to combat the weeds (Fujisaka, *et al*, 2000). Some South African studies attributed serious deforestation in Kangwane and the former homelands of Transkei, Ciskei, KwaZulu and Gazankulu, to the fuelwood crisis (Munnik, 1991; Viljoen, 1991). A study on collapsing baobabs in the Limpopo Province of South

Africa and a similar study in Zimbabwe suggested that the trees were dying due to the drying up of ground water supplies. This seemed to be accelerated by land use practices such as irrigation, heavy grazing of plants, fires and deforestation (Caplan, 1995).

Consequences of deforestation include species loss, climatic change, loss of access to forest products, outbreaks of certain diseases, economic impacts and aesthetic losses (Barrow, 1991; Viljoen, 1991). Soil erosion is one of the main results of deforestation (Landa, *et al*, 1997; Marathianon, *et al, 2000;* Viljoen, 1991).

Conservation measures efforts include preservation of existing forests and woodlands, substitution of forest products, alternate energy sources, agroforestry – the planting of trees on croplands and pastures (Barrow, 1991; Campbell, *et al*, 1991; Kang, 1997; Munnik, 1991).

1.2.3.2 **Non-erosive soil degradation**

The degradation of soil *in situ* involves internal deterioration, i.e. decrease in soil quality by physical and chemical processes, thereby predisposing the soil to erosion.

Biological degradation is the loss or reduction of soil organic matter, which may be from the removal of crops, fodder, woodfuel and dung, and bushfires, or stubble burning, or overgrazing, without the return of any material to compensate (Barrow, 1991; Igwe, 1999; Lal, 1988; Stocking, 1993). Degradation may also result from alteration of soil drainage or tillage that accelerates oxidation of organic matter (Barrow, 1991).

In *physical degradation* soil structure degrades easily if biological activity falls below a certain minimum threshold (Lal, 1988). Physical degradation is an adverse change in properties such as porosity, permeability, bulk density and structural stability (Stocking, 1993). It manifests itself through the following observable end results:

Compaction is due to use of heavy machinery and trampling by livestock on soils with a low structural stability; livestock trampling can also lead to crusting. The result of trampling is to reduce the number and size of voids and pores, making it difficult for plant roots to grow (Bezkorowajnyj, *et al*, 1993; Chleq & Dupriez, 1988; Lal, 2000; UNEP, 1992).

Sealing and crusting are mostly due to clogging of soil pores by fine grained silt and clay particles dispersed by raindrop impact - commonly in areas where vegetation is inadequate to protect the soil surface from the impact of raindrops (Chleq & Dupriez, 1993; Lal, 2000; Molope, 1992; UNEP, 1992).

Waterlogging includes flooding by river water and submergence by rain water caused by human intervention in natural drainage systems. It usually results from over-irrigation and poorly managed irrigation systems; it leads to severe loss of soil air content and accumulation of toxic substances, with adverse effects on plant growth. It also causes salinization and sodication (Barrow, 1991; Kotb, *et al*, 2000; Rauta, 1992; UNEP, 1992).

Sodication is a physical consequence of salinization. It occurs when saline water in a soil is concentrated by evapotranspiration, leaving sodium ions dominant in the soil solution (calcium and magnesium tend to precipitate as carbonates). The result is a structureless saline soil almost impermeable to water and unfavourable to root development (UNEP, 1992).

Subsidence of organic soils occurs when peaty materials become susceptible to oxidation after drainage and deflation, resulting in lowering of the land (UNEP, 1992).

Chemical degradation occurs as a consequence of natural biophysical or human-triggered processes that affect soil chemistry. It manifests itself in the following ways:

Nutrient depletion is due to over-cultivation and the inadequate application of replacement nutrients; natural vegetation clearance, burning in savanna areas of poor soils; increased runoff also removes nutrients in solution (Blair, 2000; Lal, 1988; Rauta, 1992; UNEP, 1992).

Acidification or acid precipitation is due to increasing SO_2 and NO_X emissions from fossil fuel combustion in power stations, industrial boilers, factories, houses and vehicles, particularly in industrialised nations (Barrow, 1991; Lean & Hinrichsen, 1992; Webb, 1999; UNEP, 1994). Acidification causes forest die-backs, interferes with soil biology and soil chemistry, inhibits bacterial activity and disturbs nutrient cycles; it also destroys the biological communities in aquatic ecosystems (Compton, 1993). Damage from acid rain has been recorded in north-east USA, Canada, Sweden, Norway, Germany, former European Russia, Poland, Romania, and former Czechoslovakia; China, India, Nigeria, Colombia, Venezuela and Brazil (Lean & Hinrichsen, 1992).

Salinization is the surface or near-surface accumulation of salts - mainly chlorides, sulphates and carbonates of sodium and magnesium (UNEP, 1992). High salinity may arise naturally through evaporation, mineral dissolution and airborne sea salt. Human activities axacerbate the problem through: irrigation agriculture (raises the water table) in arid and semi-arid climatic zones (Barrow, 1991; Kotb, *et al*, 2000; Webb, 1999); over-exploitation of groundwater reserves, promoting intrusion of saline groundwaters; mining activities, landfill leachates, leaking sewers, disposal of oilfield brines and highway de-icing (Webb, 1999). Salt accumulation reduces soil pore space and the ability to hold soil air and nutrients. High salt concentrations are toxic to many plants, especially during the seedling stage (UNEP, 1992).

Alkalinization is the excess accumulation of sodium, which arises in association with the dissolved salt load of irrigation water (UNEP, 1992). High levels of salt or alkali will hinder the extraction of nutrients from the soil and suppress plant growth (Barrow, 1991).

1.2.3.3 **Degradation by displacement of soil material**

Erosion, mass movement and solution, which act to remove material from a site, are natural processes (Barrow, 1991). Human actions have often accelerated soil loss well beyond natural rates. This survey focuses on forms of erosion referred to as *accelerated soil erosion* (Lal, 1988) or *anthropogenic erosion* (Barrow, 1991). It dwells on water and wind as the main agents of erosion and on humankind's role in the whole soil degradation process.

Erosion by water: causes, processes and effects

The causes of soil erosion are fairly well documented: overgrazing, over-cropping, deforestation, population pressure (Chleq & Dupriez, 1993; Eger, *et al*, 1996; Koohafkan, 2000; Lal, 1988). Among the more specific causes of erosion are listed shifting agriculture, livestock concentration around boreholes, timing and technique of ploughing, fire, tourist off-road trails, commercial agriculture demands and artificial land drainage (Barry, 1991). Repeated cultivation of soils with limited soil organic material inputs - *soil mining* - eventually leads to major aggregate disintegration leaving the soil vulnerable to compaction, crusting and sealing (Blair, 2000; De Graaff, 1993: Syers, *et al*, 1996). This results in enhanced surface runoff, which promotes erosion by water. In a study based in rural Mexico, the causes of soil erosion were found to include accelerated demographic growth and social conflicts related to land (Landa, *et al*, 1997). A study on the Greek island of Lesvos found that terraced hilly areas under cereals or grazing were more severely eroded by water than similar areas under pine and oak forest or olive groves (Marathianon, *et al*, 2000). Some studies report on tillage-induced soil translocation in steepland oxisols (Quine, *et al*, 1999; Thapa, *et al*, 1999). Studies on soil erosion in Australia trace the history of land clearing, overgrazing, injudicious burning and irrigation; they estimate that about 71% of degraded land is due to water erosion (Malafant, *et al*, 1999; Roberts, 1990). An analysis of population pressure in the highlands of Tanzania showed that areas suffering from water erosion had been subjected to increased cropping frequency at the expense of the fallow period (Jones, 2000). An economic perspective is also examined (Bojo, 1991; De Graaff, 1993; Sinden, *et al*, 1990; Stocking, 1988).

Several studies have been done on soil erosion in South Africa. Soil erosion in the former *homeland* of Bophuthatswana was reported to be due to overpopulation and overgrazing (due to overstocking), deforestation, intensive row cropping and monoculture, excessive and untimely ploughing (Molope, 1992). A study on the former homelands cites deep *dongas*, heavy siltation and seasonal drying up of rivers in the Ciskei, Lebowa and Bophuthatswana (Cooper, 1991). The causes of soil erosion in these areas are as documented in other studies on the former homelands: fragile soils, politically enforced overpopulation, overstocking, overcropping, the fuelwood crisis and lack of access to resources and infrastructure (Durning, 1990; Dzivhani, 2000; Kruger, 1991; Stocking, 1995; Viljoen, 1991). In addition to these, inappropriate farming techniques, inequitable land ownership and tenure and lack of access to credit are also stated as contributing to soil erosion (Penny, 1991). One study examines erosion risk from footpaths and vegetation burning in the Central Drakensberg (Garland, 1987).

While most of the studies reviewed so far look at the causes and results of erosion by water a few examine the erosion processes themselves such as rill, gully and sheet erosion (Garland, 1987; Grindley, 1984; Molope, 1992; Morel, 1998; Viljoen, 1991). To these may be added piping, tunnel erosion, pinnacle erosion, and mass movement or solifluction (Barrow, 1991; Hudson, 1986; Stocking, 1978).

Erosion by wind: causes, processes and results

One study was of the occurrence of drift sands in the Sandveld area in the coastal region of the Western Cape province of South Africa. It attributed wind erosion to the combined effects of overgrazing, severe fires and a high wind regime (Morel, 1998). A study on a section of coastal New Zealand established that sand mobility had been caused by deforestation, fire, grazing animals and the introduction of pests (rabbits and hares) in an area exposed to strong winds (Gadgil & Ede, 1998). A study of wind erosion sensitive areas of South Africa identified the main factors promoting wind erosion as sandy top soils, particle size distribution of the soil, wind speed, topography type, soil cover, soil water content and aggregation of soil particles (Schoeman, *et al*, 1992). It concluded that about 25% of South Africa was occupied by soils that were highly sensitive to wind erosion. An experimental study concluded that wind erosion on tilled lands would depend on factors such as amount of erodible material available, surface roughness, crop residue and wind velocity (Potter, 1990). Some surveys examine wind erosion processes such as deflation and abrasion and their effects (Barrow, 1991; Chleq & Dupriez, 1988). A study on wind erosion in southern Niger reports farmers' observations on the effects of wind erosion on their fields: eroded fields lose fertility and produce less whereas deposition of material results in higher fertility and production (Sterk & Haigis, 1998).

Soil and water conservation

A whole range of conservation measures is covered in the literature and includes water conservation as it is conceptually inappropriate to separate it from soil conservation. In wind eroded areas measures include planting trees as windbreaks and for holding the soil together, natural regeneration of woody vegetation; application of manure and mulching with crop residues and use of pits filled with compost for sowing crops (Critchley, *et al*, 1994; Lean & Hinrichsen, 1992; Morel, 1998; Sterk & Haigis, 1998). In water eroded areas conservation measures include construction of contour walls, water ducts and small-scale check dams (Chleq & Dupriez, 1988; Hudson, 1986; Morel, 1998), reduced cultivation or no-till (Blair, 2000; Chleq & Dupriez, 1988; Nel, 1998), covering fields with crop residues and using organic manures, proper use of artificial fertilisers (Blair, 2000; Sterk & Haigis, 1998), alley cropping (Kang, 1997), terracing of hilly areas (Marathianon, *et al*, 2000), afforestation (Munnik, 1991; Chleq & Dupriez, 1988), contour cultivation and use of vegetative strips (Barrow, 1991).

Several writers review indigenous conservation methods and how they can be incorporated into development projects. These methods include traditional agroforestry in Zimbabwe (Campbell, *et al*, 1991), stone terracing in South Africa's Limpopo Province (Critchley & Netshikovela, 1998), earth and/or stone bunds, trash lines, wooden barriers, pits and basins, and vegetative strips - in various developing countries (Critchley, *et al,* 1994; Scoones*, et al*, 1996b).

Conservation methods have changed internationally from site-based remedies to solutions based on the whole farming system, including indigenous technical knowledge, land tenure, market prices and cultural taboos (Stocking, 1995). Holistic land management strategies recognize the unity of the hydrological cycle and link land use in the catchment area with water conservation (Collings, 1997; Cooper, 1991; Rabie, 1997; Rao, *et al*, 1999; Savory, 1988; Van Niekerk, 1994). The goal of the landcare or stewardship philosophy and campaign is to reverse land degradation and optimize productivity through sustainable use of natural resources (Barrow, 1991; Nabben & Nduli, 2000; Roberts, 1990).

1.2.3.4 **Other forms of land degradation**

Various other forms of land degradation are covered in the literature using varied terminology. Degradation of soil resources (ground water and surface) through *contamination* occurs in various forms. These include mining, on-site dumping of mining waste-rocks, tailings and slag; radio-active dumps, excavation of open pits, contaminated effluent from mineral processing and acid mine drainage (Coetzee & Cooper, 1991; Hestor & Harrison, 1994; Korentajer, 1992; Mtetwa, 1994; Whitlow, 1990; Young, 1992); *pollution* by pulverised fly ash dumps from power-generating plants, nuclear wastes (Forster, 1991; Korentajer, 1992); *industrial pollution*, organic materials and toxic chemicals in sewage, and acid rain (Korentajer, 1992; Lean & Hinrichsen, 1992; Mtetwa, 1994; Rosenthal & Carter, 1991; Webb, 2000), and *agricultural pollution* such as excessive application of manures and fertilisers, use of pesticides and herbicides, acidification from irrigation and effluents from dairies and abbatoirs (Forster, 1991; Hiscock, 1993; Joshua, *et al*, 1998; Mtetwa, 1994; Webb, 1999).

Pasture degradation manifests itself in several ways. These include extensive soil compaction, decreased soil cover, diminished water infiltration and bush encroachment (Ho, 2000; Lange, *et al*, 1998; Sharpe, 1991; Tanner, *et al*, 1986; Vera, *et al*, 1998). The causes of degradation include overstocking (Lange, *et al*, 1998), use of marginal pastures (Van Rooyen, 1998), extensive digging for medicinal herbs (Ho, 2000), and inappropriate management strategies (Sharpe, 1991). Both natural and improved pastures are ecologically sustainable if appropriately managed (Weinhold, *et al*, 2001). A sustainable, village level approach for the rehabilitation of sylvo-pastoral lands is outlined in one study (Kessler, *et al*, 1998). A survey based on livestock production in communal pastures in some of South Africa's former homelands, questions the basis for claims of overstocking in these areas (Cousins, 1996). One study makes some rather unconventional recommendations on pasture management and rehabilitation of degraded pastures (Savory, 1988).

Desertification is defined as land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities (Millington, 1999). Similar definitions and case studies of desertification will be found in several sources (Bonfiglioli, 1988; Chleq & Dupriez, 1988; Clarke, 1991; Falloux & Rochegude, 1988; Gambiza, 1996; Grainger, 1990; Lean & Hinrichsen, 1992; Wangari, 1996; Ward & Ngairorue, 2000; UNEP, 1992). References to the following forms of degradation will also be found in various sources: *wetland degradation* (Gadgil & Ede, 1998; Glavovic, 1997; Wade & Lopez-Gunn, 1999); *coastal degradation* (Crawford, 1994; Gadgil & Ede, 1998; Glavovic, 1997; Grant & Jickels, 2000); degradation by *invasive plants and animals* (Barrow, 1991; Matthews, 2000); degradation due to *global warming* (Bezuidenhout, 1999; Compton, 1993; Lal, 2000b; Rosenzweig & Hillel, 2000), and degradation due to *armed conflict* (Anstey, *et al*, 1994; Barrow, 1991).

1.3 LAND DEGRADATION IN ZIMBABWE'S COMMUNAL AREAS

Several studies of land degradation and related subjects have been carried out in Zimbabwe in various contexts. There have been studies on a national level dealing with various forms of land degradation. These include studies on soil erosion (Beinart, 1984; Firth, 1991; Grant, 1981; Stocking & Elwell, 1976a; Stocking & Elwell, 1976b; Tevera, 1994; Whitlow, 1979; Whitlow, 1986; Whitlow, 1987; Whitlow, 1988; Whitlow & Campbell, 1989), detailed studies of gully formation and morphology (MacFarlane & Whitlow, 1992; Stocking, 1978; Whitlow, 1994; Whitlow, 1996), studies relating to wetlands use and degradation (Hough, 1986), and studies with a bearing on policy issues (Kay, 1976; Lado, 1999; Matiza, 1992; Palmer, 1990; Ranger, 1993; Scoones, 1991; Stocking, 1988; Zinyama, 1986a ; Zinyama, *et al*, 1990). Local area studies have been done for certain parts of Zimbabwe (Du Toit & Campbell, 1989; Dye & Spear, 1982; Scoones, 1992b; Scoones, 1996a; Wekwete, 1995; Whitlow & Firth, 1989).

Several studies of peasant farmers' responses to land degradation, including soil and water conservation efforts and experimentation, have been conducted (Bradley & Dewees, 1993; Elliott, 1987; Hagmann & Murwira, 1996; Lawton, 1982; Nel, 1995; Nyamapfene, 1983; Nyamapfene, 1988; Nyamapfene, 1989). Some research on woodlands and agroforestry examples has been carried out in several localities (Bradley & Dewees, 1993; Campbell, *et al*, 1991; Campbell, *et al*, 1993; Clarke & Gumbo, 1993; Fortman, 1993; Fortman, *et al*, 1997; Matose & Mukamuri, 1994; Nhira & Wilson, 1989;

Price & Campbell, 1998). Resource inventory studies have been done in a number of areas on woodland resources (Campbell, *et al*, 1997) and on wild fruit and other foods (Gomez, 1988; Malaisse & Parent, 1985; Zinyama, *et al*, 1990).

1.4 LAND DEGRADATION IN MHONDORO COMMUNAL LANDS

Two studies were undertaken on gully formation and morphology in the Muzvezve catchment area on the border between Mhondoro and Ngezi communal areas (Stocking, 1978; Whitlow & Firth, 1989). Some detailed soil profile studies in the study area were carried out and these offer valuable insights into local soil characteristics and soil dynamics (Purves & Blythe, 1969; Thompson, 1965a ;Thompson & Purves, 1978). A study on land tenure, population change and environmental stress in the Mupfure catchment, though focusing on a much larger area, includes the study area (Tevera, *et al*, 1999). While some studies based in Mhondoro are not focusing on degradation, *per se*, they provide useful background information (Mehretu, 1995; Mubvami & Olthof, 1991; Nhira & Fortman, 1993; Zinyama, 1986b). A study conducted in districts to the west of Mhondoro in the same province of Mashonaland West provides some insights into communal areas' farming practices (Gobbins & Prankerd, 1983).

1.5 RESEARCH OBJECTIVES

The study is an environmental assessment of the impacts of communal land-use systems and common property resources management practices in Chief Mashayamombe's ward in the Mhondoro communal lands of Zimbabwe. The objectives are:

- To determine the nature of and to map the spatial extent of land use types in Mashayamombe ward, Mhondoro
- To determine the nature of and to map the spatial extent of the main forms of land degradation in Mashayamombe ward, Mhondoro
- To provide an analysis of the linkages between communal land use practices and land degradation in Mhondoro
- To assess temporal changes in the status of land degradation (deforestation and gully erosion) in Mashayamombe ward between 1982 and 1997

- To assess the sustainability of present communal natural resources management practices in the area

1.6 RESEARCH METHODOLOGY AND DATA ACQUISITION

Several research techniques were employed in this study. They included a survey of the relevant literature, analysis of maps and statistical data relating to the study area, use of aerial photographs and GIS technology to assess temporal changes to land degradation. They also involved observations in the field, interviews with key informants with intimate knowledge of the study area, a questionnaire survey of households, and soil and vegetation traverses in selected areas.

1.6.1 Literature survey

An extensive literature survey was done to obtain relevant information on various forms of land degradation on scales ranging from the local to the global. Land evaluation and land reform, which are closely related to land degradation, were also examined. This was done in the context of land reform programmes in South Africa and other countries which have had reasons to review their land policies. Sources on land degradation and communal natural resources management in rural Zimbabwe were reviewed. The few available sources on Mhondoro's biophysical environment and local soil erosion studies were also reviewed. The sources consulted included articles published in reputable journals and books, conference papers, as well as post-graduate students' theses. These sources are acknowledged in the "references" section of this report.

1.6.2 Documentary analysis

Valuable information on various aspects of the study was obtained from analysis of a number of official documents and records. A useful line of inquiry was to follow up on something observed in the documents, i.e to compare the reality on the ground to what was in the documentation..

1.6.2.1 **Demarcation of the study area**

Cadastral data on communally administered areas was not easily available. The boundaries of the wards under individual chiefs' control are based on natural features such as rivers and lines of hills. Some discussions over Mashayamombe ward' s boundary were held with the chief in charge of the study area (Mashayamombe, 2001) and the Administrative Offcer of the Mhondoro sub-office of Chegutu District Council (Bangira, 2001). It was decided to use the Mhondoro district schools map (Surveyor General's Department, 1997) to demarcate the study area as it was felt that the map was fairly accurate.

1.6.2.2 **Statistics on the study area**

Documentary sources with information relevant to the study area included national population census data tables, climatic data tables and local cattle records. Cattle dipping records were provided by the Verterinary Department's sub-office at Mubayira and the verterinary technician gave some useful insights into livestock-rearing practices in the study area (Mhlanga, 2001). It was not possible to obtain accurate figures on livestock such as goats and sheep as their records were not kept as meticulously as those for cattle. Efforts to obtain human health related statistics for the study area were fruitless.

1.6.2.3 **Map-based data**

The map Mubayira 1: 50 000 was used in the calculation of the average slope gradient as an erodibility factor for the study area (see Table 2 and Appendix C for results of calculations). The digital map of the study area was used in calculations for population carrying capacity and cattle carrying capacity for the study area; it was also used for coding the main land uses (Figure 3.4).

1.6.2.4 **Aerial photographs**

Two sets of aerial photographs taken over the study area in 1982 and 1997 were used. The photographs were georeferenced in ArcInfo UNIX and registered to a coordinate system of a digital coverage of the study area's rivers. Two combined images of the geo-referenced photographs (1982 and 1997) were used for on-screen digitizing in ArcView. Two land use coverages resulted from this and these, in turn, were overlayed to produce a Detailed analysis of documentary sources of information on Mhondoro involved extracting relevant data tables from Zimbabwe's national census reports for 1982 and 1992, studying soil and vegetation maps and 1: 50 000 topographic maps of the study area, examining aerial photographs of the area taken in 1982 and 1997, and checking for certain terrain details on a black and white Panchromatic SPOT satellite image of the study area taken in 1993. A meteorological sub-station is maintained at Mubayira and climatic data recorded there date as far back as the 1930s; however, the complete data set could only be obtained from the Meteorological Services Department headquarters in Belvedere, Harare.

1.6.3 **Field survey techniques**

Using information gleaned from documentary sources and informal interactions with people familiar with the study area an initial visit to Mashayamombe ward, Mhondoro, was undertaken. The services of two field assisstants were engaged and this proved very useful in facilitating contact with role players relevant to the study, identifying the locations of locally well-known manifestations of soil erosion and administering the questionnaire survey (Takawira, 2001; Shayawaedza, 2001). It was then decided to use such survey methods as personal interviews, a questionnaire survey and field observations and measurements..

1.6.3.1 **Interviews**

Several formal and informal interviews were conducted with a number of people in the study area. The questions paused in informal interviews were deliberately left open-ended as it was found that informants tended to talk more freely and volunteer more information in these interviews than in the more formal ones. Information was elicited on communal land uses, power relations in the management of communal resources such as pastures and woodlands, residents' perceptions of land degradation and attitudes to communally managed projects (Bangira, 2001; Muhlaba, 2001; Mhlanga, 2001; Shayawaedza, 2001; Takawira, 2001).

Structured questions were put to certain individuals so as to corroborate information from census data tables and from other key informants. Responses were sought on local land allocation practices, the sizes of households' land holdings, people's responses to control led use of communal natural resources, the status of wildlife habitats, and settlement patterns in the study area (Bangira, 2001; Mashayamombe, 2001; Muhlaba, 2001). Information was provided on gravel and river sand mining and water resources management, especially in drought years (Bangira, 2001; District Development Fund (DDF) staff, 2001; Mashayamombe, 2001). Informative responses were obtained on the workings of the fenced-in grazing schemes and people's attitudes towards them (Mashayamombe, 2001; Mhlanga, 2001; Shayawaedza, 2001; Takawira, 2001)

1.6.3.2 **The questionnaire survey**

Given budgetary constraints and the logistical problems of visiting the entire study area it was decided to construct, test and administer a questionnaire survey of the study area. The closed-response questions were designed to ellicit responses on the environmental effects of Mashayamombe ward residents' interactions with their biophysical environment. In particular, the survey was designed to examine communal land use practices, their impacts on the environment, and residents' attitudes to environmental degradation.

A total of 110 out of an estimated 3149 households were sampled, using systematic random sampling. The required sample size, based on a 90% confidence level and a 10% confidence level, was 68 households. It was anticipated that there would be a high non-return rate of completed questionnaires and it was, therefore, decided to take a much larger sample. Further details of the sampling procedure are given in Section 3.1.2.1.

1.6.3.3 **Field observations and measurements**

Field visits were made to parts of Mashayamombe ward to do some ground truthing and up-dating on aspects of land degradation observed on the satellite image and the aerial photograps of the study area. The visits were also intended as a follow-up on information provided by the key informants on gullies, tracks and the condition of local dams. Detailed observations on gully erosion were done on Bhinda gully just to the north of Bhinda Business Centre (BC). This involved measuring the width and depth of the gully at its widest and deepest parts using a tape measure and estimating its length. Efforts at gully reclamation and stabilization were observed and photographs of illustrative material were taken. Two other gullies were observed as explained in Chapter 3. Since Mashayamombe dam is located just below the gully it was visited at the same time as the gully and its water examined. The condition of the water that was observable with the naked eye was noted. Later on, sections of the Nyangweni river above and below the bridge near Mubayira were examined for the quality of their water: this was later compared with the quality of water in the dams.

One major cattle and human track was measured for its width and depth and its general condition was observed. This track starts at Bhinda BC and heads in a northerly direction towards Mashayamombe village. Two other tracks were observed: one just east of Bhinda BC and the other just south-east of Zibwowa school. A smaller track was measured just west of Mubayira dip. Hundreds of tracks were evident throughout the area and could be observed from a vehicle along any of the local roads.

Two active gravel mining sites were visited: one east of Mubayira and the other on the road between Mubayira and Chipashu school. The degraded status of these sites was observed. One abandoned gravel mining site was observed just south of Mubayira BC. This site was observed to be rehabilitating by itself; a photograph of the site was taken. A river sand mining site was observed downstream of the bridge on the Nyangweni river south of Mubayira BC. A photograph of the site was taken to illustrate the erosion potential of such sites.

A major sediment deposition site was observed on a tributary of the Nyangweni river just east of the bridge to the south of Mubayira BC. This site is a major crossing point for several livestock and human tracks. An illustrative photograph of the site was taken.

Other visits involved observations at a garbage dumping site south-east of Mubayira BC, examining garbage disposal practices at three shopping centres, three schools, two clinics, Mhondoro District Hospital at Mubayira BC and at sixteen homesteads.

1.6.3.4 **Soil and vegetation traverses (transect walks)**

The methods involved in the soil traverses entailed walks from the valley bottoms towards the crests of the uplands along two selected transects (see Figure 3.1, page 34). They included observation of soil characteristics, mainly soil colour and soil texture; this included wetting small sods of soil and running the wet soil through the fingers to feel it.

Vegetation traverses entailed walking along the same two transects used for soil traverses and identification of the most common tree and grass species. In a third transect, the traverse included observation of the quality of pastures in fenced paddocks. On other sites activities included tree density counts in demarcated plots, and observation of the numbers of homesite woodlots and the numbers and types of trees grown on them.

1.6.4 **Data processing and analysis**

Once collected, both secondary and primary data were processed and prepared for analysis in various ways, as outlined in the sections that follow.

1.6.4.1 **Map preparation**

Using the map Mubayira: 1: 50 000 a location map and a land use map for the study area were digitized in PC ArcInfo and edited in Arcedit module (Figures 2.1 and Figure 3.4). A map of the study area indicating some of the the sites visited on the field trip was also digitized (Figure 3.1). The fourth map, showing temporal changes to woodlands, cultivated areas, and gullies was built up in stages from the geo-referenced aerial photographs of the study area (on-screen digitizing and overlaying of coverages); the map shows the extent of certain aspects of land degradation between 1982 and 1997 (Figure 4.1).

1.6.4.2 **Generating graphs and tables**

Information gathered from documentary sources was used to construct several graphs. These included a composite climatic graph (Figure 2.2), a graph showing livestock ownership patterns in the study area(Figure 3.16), a comparative graph of the proportion of cultivated to fallow land (Figure 3.18), and a graph on the distribution of household toilet facilities in Mhondoro (Figure 4.17). Questionnaire survey data yielded several graphs on communal environmental resources mnagement (Figures 4.2.4-.16). Tables for livestock figures were also compiled from dip records and a national livestock survey, as well as from questionnaire survey data (Tables 3.3, 3.4, and 3.6).

1.6.4.3 **Evaluation matrices**

An environmental evaluation matrix for the study area, adapted from several sources, was compiled and environmental impacts indicated on it. This was filled in partially during the field survey and completed later after some of the information from the field study had been processed. A sustainability indicators checklist was constructed and completed using criteria adopted from two sources on the evaluation of the sustainability of communally managed development projects (Buzzard, 1995; Timberlake, 1985).

1.6.4.4 **Illustrative photographs**

Out of the 13 illustrative photographs used in the study 12 were taken during the field trips and one was taken from the aerial photographs acquired for the purposes of the study. The photographs highlight certain aspects of land degradation observed in Mashayamombe ward, Mhondoro.

1.6.4.5 **Integrating results and writing research report**

Primary and secondary data were organized into maps, graphs and tables; these were analyzed in conjunction with information gained through interviews and direct observations. Insights from the literature survey also played a crucial part in the analysis and interpretation of the data assembled for the study. These included an understanding of environmental impact assessment procedures, considerations of ecosystem carrying capacity and a broad view of manifestations of land degradation. The study then proceeded to make a number of conclusions and recommendations. The whole study report was then written out as outlined.

1.6.5 **Research design (schematic representation)**

The schematic representation of the research design (Figure 1) outlines the research programme and the procedures followed in pursuit of the stated research aim and objectives. While the general research plan was followed there was some overlap of certain procedures; the literature survey, for instance was updated continuously for the duration of the study period.

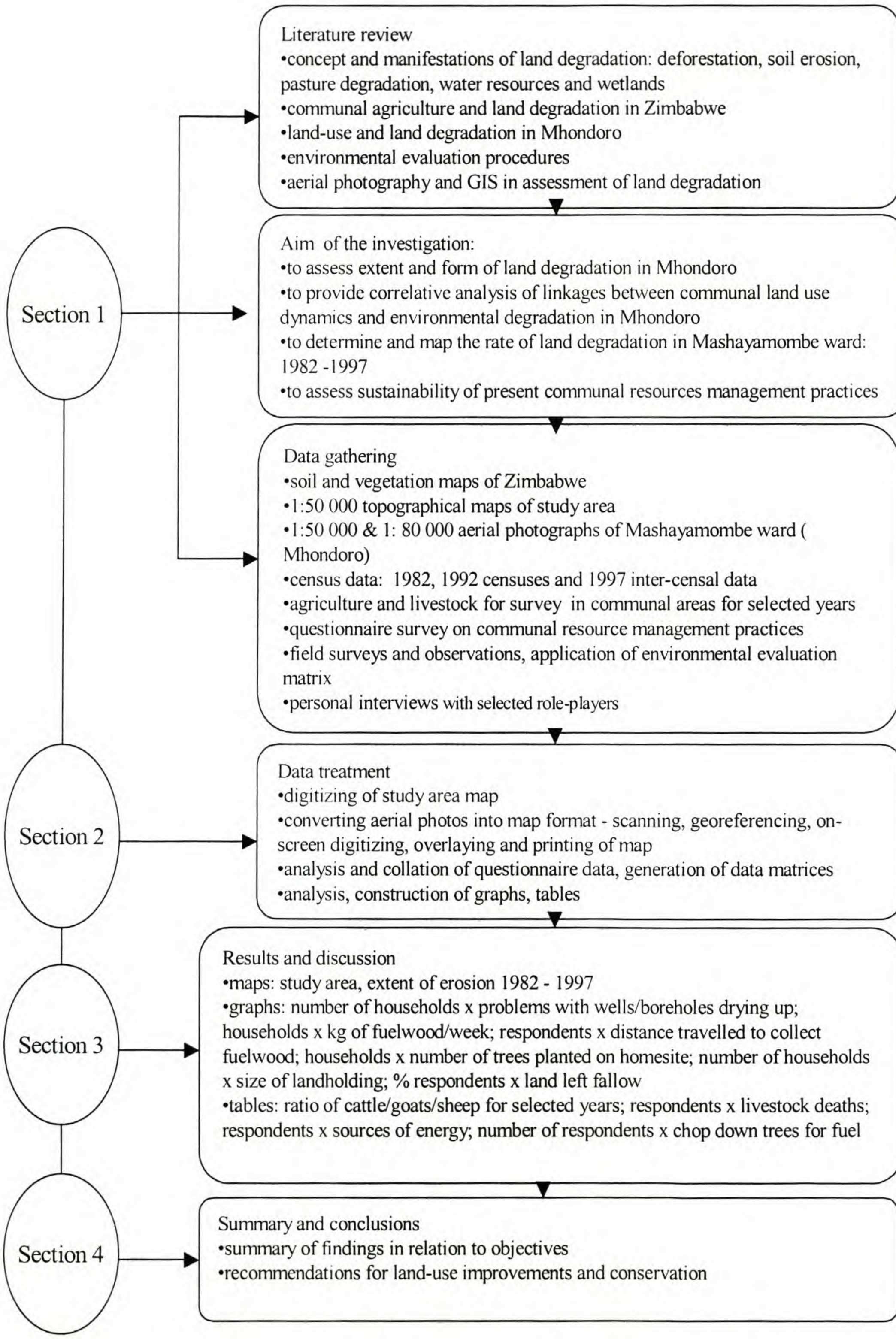


Figure 1: Research framework for a study of land degradation in Mhondoro communal lands

CHAPTER 2 MASHAYAMOMBE WARD, MHONDORO: BIOPHYSICAL ENVIRONMENT AND VULNERABILITY TO SOIL EROSION.

The Mhondoro communal lands are located south-south-west of Harare, with the district council offices at Mubayira service centre, about 83 km from Harare (see Figure 2.1). Administratively, Mhondoro falls under Chegutu District, Mashonaland West Province. The Mhondoro communal lands, which are 1291 km^2 in extent, are surrounded by large-scale commercial farms to their west, north and east; the area is separated from Ngezi communal lands to its south by the Muzvezve river.

2.1 EXTENT OF THE STUDY AREA

Mashayamombe ward, approximately 170 km^2 in extent, is bounded to the north by the Mupfure river. To the east it is bounded by the Nyakondowe river, the Nyundo river and the Nyangweni river. To the west it is bounded by the Tumbgwi and Nyamawanga rivers. Its southern boundary is just south of the road linking Rukuma Business Centre and Neuso Business Centre (see Figure2. 1). These boundaries are loosely defined and are based on the Mhondoro district schools map (Surveyor General's Department, 1998). In terms of geographical coordinates the area falls between 18° 15' S, 18° 28' S and 30° 30' E, 30° 41' E.

2.2 THE BIOPHYSICAL ENVIRONMENT

While Mhondoro's climate may be similar to that of the surrounding commercial farming areas its soils are very different due to its rather localised geological attributes.

2.2.1 Geology of study area

Mhondoro lies on the Zimbabwean highveld, which is part of the great African craton which stretches unbroken from South Africa to the southern borders of the Sahara. The

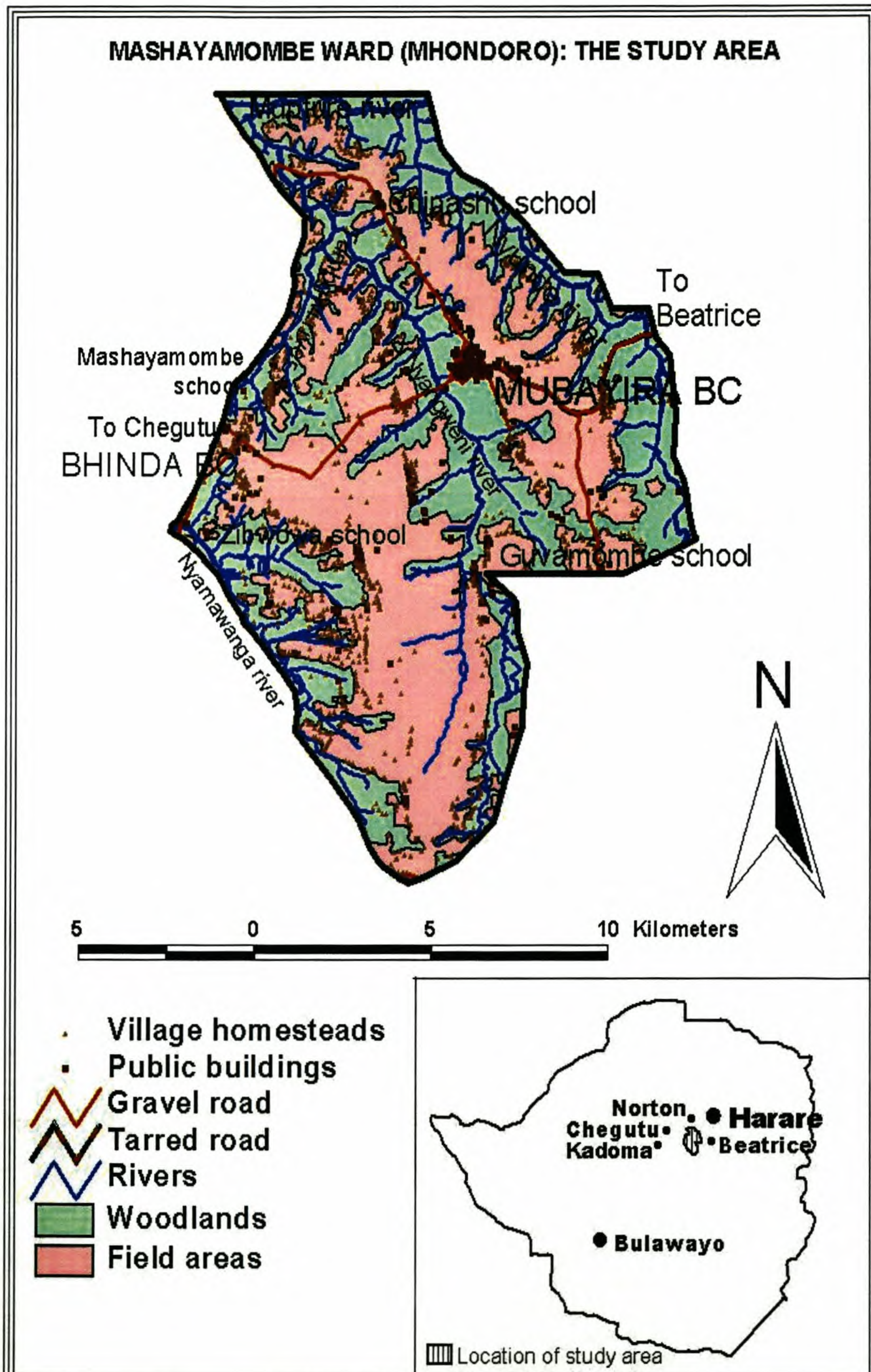


Figure 2.1 The study area

plateau has an ancient surface of old granites, with only small areas of more resistant rocks such as schists, sandstones, quartzites and dolomite. On this surface was overlaid later sedimentary beds of fresh water deposition and aeolian origin, such as the Karoo beds (Tankard, *et al*, 1982; Wellington, 1955). The Karoo sandstone breaks down easily to form pale sandy soils (Du Toit, 1955). An island of Karoo sandstone overlies the southern half of Mhondoro and Ngezi communal lands. Interspaced with slivers of the sandstones are granitic and dolerite rocks in the northern half of Mhondoro (Bond, 1965).

2.2.2 **Geomorphology**

The study area lies in the highveld which constitutes the Zambezi-Limpopo/Save watershed at an altitude of 1220-1526m above sea level (Lister, 1965). This central belt of territory straddles the Plumtree-Bulawayo-Gweru-Chivhu-Harare road and continues east to Marondera and the eastern highlands. North and south of this watershed the land surfaces fall gently towards the Zambezi and Limpopo/Save rivers. The highest mountains run from north to south along the eastern border of Zimbabwe.

2.2.3 **Soils**

The dominant soils in the study area fall into the fersiallitic group (Thompson, 1965a). Karoo sandstone is the parent material with a significant influence of granite, which underlies the sandstone formation at relatively shallow depths.The unjointed underlying granite hinders internal drainage and this results in a relatively high but seasonally fluctuating water table; a perched water table in some soil profiles occurs only during the rainy season (Purves & Blyth, 1969). The soils are deep and consist of dark greyish brown fine sands without weatherable minerals, overlying sandy loams and sandy clay loams; there is an abrupt transition from the A to the B horizon. The soils on the upland areas possess some hydromorphic features while areas of sodic soil occur in the depressions (Thompson, 1965a; Thompson, 1965b; Thompson & Purves, 1978).

A detailed study of the catenary sequence of soils at a site five kilometres south of Mubayira established that the B horizons of the middle and lower slopes were sodic

(Purves & Blyth, 1969). The drying of the soil subsequent to the seasonal rise and fall of the permanent water table results in increased concentration of salts in the soil solution. During the summer months the perched water table removes dispersed clay from the B horizon. The study concluded that there had been large-scale translocation of clay from the middle levels of the catena towards the lower end, and the presence of sodium, both on the clay complex and in the laterally moving water, had been responsible.

While fersiallitic soils on the central plateau (red clays on mafic rock) tend to be highly productive because of their good physical properties and the relatively high rainfall (700-950mm) those on granite, like the Mhondoro soils, tend to have less favourable physical properties and a lower agricultural potential (Watson, 1978). They have a relatively low inherent fertility and low available water capacity due to their low clay content. They require maintenance of adequate levels of plant nutrients and a soil pH of about 5.4 if they are to be used continuously or intensively for cropping productivity (Thompson & Purves, 1978). A combination of a lack of such maintenance and poor vegetative cover leads to an accentuated erosion hazard.

2.2.4 **Climate**

Four climatic seasons may be distinguished: a rainy season from November to mid/late March; the post-rainy season from mid/late March to mid-May (when occurrence of moist air and frequency of showers decrease and temperatures fall steadily); the cool dry season from mid-May to mid-August; the warm dry season from mid-August to the onset of the rains, in November (Kay, 1970). Despite the low latitude in which the study area is located, the altitude of the highveld moderates the temperatures.

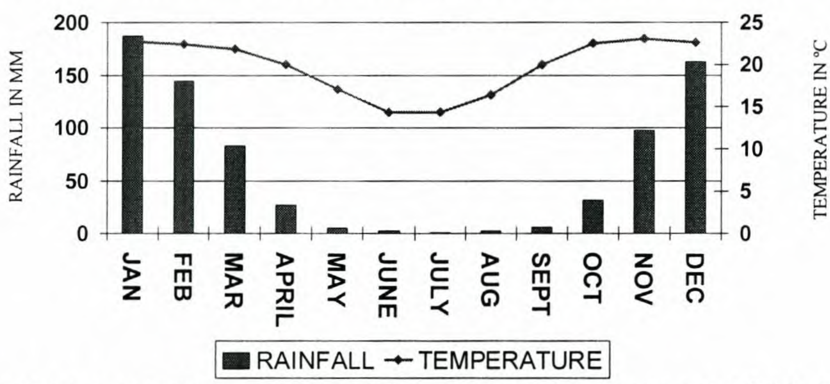
2.2.4.1 **Temperatures**

The average temperature conditions outlined in this study are based on records taken at Mubayira by officers of the Meteorological Services Department over an extended period (1962-2000). The graph in Figure 2 summarises both the mean monthly rainfall and mean monthly temperature figures for the Mhondoro area. The mean annual temperature for

Mhondoro is 19.7°C. The mean maximum temperature for the hottest month, October, is 30.7°C; for January it is 28.5°C; and for July it is 23.3°C. These high temperatures contribute to relatively high evaporation rates which, together with intense summer rains, lead to rapid degradation of soil quality in areas that have been converted from natural to agricultural ecosystems (Lal, 2000)..

2.2.4.2 **Rainfall**

As shown on the graph in Figure 2.2 (and in Appendix A) the mean monthly rainfall ranges from 0.6 mm for June to 187.3 mm for January. The mean annual rainfall is 750 mm, with the main rain season lasting from November to March. The seasonal nature of



Record period: rainfall: 1930-2000 temperature: 1962-2000
Source: (Figures): Department of Meteorological Services, Harare

Figure 2.2 Mean monthly rainfall and temperature figures recorded at Mubayira

the rainfall and, therefore, of the vegetative cover on the soil, is an important factor of soil erosion and pasture degradation.

2.2.5 **Vegetation**

The area has a long history of human settlement and it would be difficult to find large areas whose 'natural vegetation' has not been affected by anthropogenic influences of one kind or another. Remnants of vegetation typical of the area were observed along roadsides, at long established business centres and in fields or on contour ridges.

2.2.5.1 **Uplands**

The vegetation consists mainly of open grassland (*Eragrostis, Tristachiya and Hyperrhenia spp*), with a few scattered *Protea spp, Julbernadia globiflora, Brachystegia boehmii and Parinari curatellaefolia.* These dominant species are accompanied by others such as the muzhanje (*uapaca kirkiana*), mutamba (*strychnos), combretum spp* and *Terminalia sericea* (Dye & Blyth, 1969; Nyamapfene,1988; Rattray & Wild, 1961; Thompson, 1965a; Wild, 1965). In addition, there is a characteristic ground flora of dwarf plants with very well developed root stocks which penetrate to available water supplies; they include the dwarf red *Hibiscus (H. rhodanthus), Dolichos molasanus*, the yellow *Melhania randii* and the dwarf red *Combretum (C. oatesii*) (Wild, 1965). Since most of the cultivated fields are in upland areas and natural vegetation cover in these areas is minimal land management efforts by residents seem to focus on preserving what little vegetation remains.

2.2.5.2 **Lowland areas and along water courses**

Along the valley of the Mupfure river and the valleys of its tributaries such as the Nyundo, Nyangweni and Tumbgwi rivers are *Acacia nilotica, Acacia karoo, Acacia rehmanniana, Albizia, Balusanthus*, with a dominance of *Brachystegia spiciformis, Julbernadia globifora* and *parinari* in localities. Some *colespermum mopane* and *colespermum mopane* shrub savanna are found in sections of the valleys (Wild, 1965). The presence of the mopane in relatively high rainfall areas such as Mhondoro is indicative of sodicity in the soil (Nyamapfene, 1988).

2.3 **SOIL EROSION CONTROL VARIABLES AND SOIL EROSION PROCESSES RELEVANT TO THE STUDY AREA**

Soil erosion is always taking place in the process of sculpturing of the earth's surface. Normally people are not concerned about geological erosion or normal erosion; however, concerns have often been raised about accelerated erosion or human-induced erosion.

2.3.1 **Soil erosion control variables**

Among the many factors contributing to soil erosion are soil erodibility, rainfall erosivity, extent of vegetation cover, slope gradient and length, and human activities.

2.3.1.1 **Soil erodibility**

Erodibility is the vulnerability or susceptibility of the soil to erosion (Hudson, 1986). Soils vary considerably in their erodibility due to their differences in physical and chemical characteristics and the management of the soil (Hudson, 1986; Stocking, 1976a). Percentages of sand, silt and clay, soil bulk density and soil aggregation are some of the important physical soil properties that affect soil erodibility (Hofmann & Ries, 1991). In the case of Zimbabwe, the high intensity and kinetic energy of the rainfall causes the finer particles of the soil to be dispersed and to fill the pore spaces between the larger particles, giving rise to soil capping. This reduces the soil's infiltration rate (Stocking, 1976a). The result is that overland flow and immediate runoff build up quickly.

The soils of Mhondoro, classified as fersiallitic, are derived from Karoo sandstone with significant influence of granite, which underlies the sandstone formation at relatively shallow depth. The influence of granite manifests itself on the soil in relative proportions of coarse, medium and fine sub-fractions of the total sand fractions. It also has an influence on the hydromorphic as well as the sodic character of the soil (Thompson, 1965; Thompson & Purves, 1978; Watson, 1978). Thus, the sandveld soils of Mhondoro are subject to capping, making them susceptible to erosion. The sodium-rich soils found in certain localities, especially in depressions, are very unstable and inappropriate land uses may trigger serious piping and gully erosion (Stocking, 1976b).

Laboratory analysis of soil samples is normally done to test for, among other things, soil texture or the mechanical composition of the soil. Indices of erodibility are usually expressed as a ratio such as (% sand + % silt) / % clay or (% silt + % very fine sand) x (100 - % clay) or variations of this relationship. The basic relationship is that sand and silt increase erodibility while clay decreases it (Hudson, 1986). Studies of soil samples taken from soil profiles in the Mhondoro area showed that sand and silt fractions in the top 25cm of the soil profile in upland areas were as high as 80-95%, with clay making up only a small percentage (Purves & Blyth, 1969; Thompson & Purves, 1978). This indicates that the soils of the area are highly susceptible to erosion. The measurement of chemical properties of soils such as soil pH, salinity and sodicity, while relevant for testing a soil's suitability for agricultural activities, can also help to indicate the soil's susceptibility to certain forms of erosion. In certain localities of the study area the combination of sodic soils and the relatively high rainfall means that the area is susceptible to tunnel erosion in view of the nature of this form of erosion (Hudson, 1986; Stocking, 1978; Whitlow & Firth, 1989).

2.3.1.2 **Rainfall erosivity**

Rainfall erosivity is the potential ability of rain to cause soil detachment and transport (Lal & Elliot, 1994). Rainfall amount and intensity are contributory factors to erosivity as they have a bearing on the kinetic energy expended in soil erosion processes. Energy is used in breaking down soil aggregates, in splashing them in the air, in causing turbulence in surface run-off, and in scouring and carrying away soil particles (Hudson, 1986). Several empirical methods have been developed to measure rainfall momentum, its kinetic energy, and its erosivity. These models have been applied to soil loss prediction (Lal & Elliot, 1994). They include the erosivity index (R) of the USLE (Wischmeier & Smith, 1976) and the kinetic energy (KE) index (Hudson, 1986). The problem with these models has been whether their application in different climatic conditions is appropriate, given the fact that they were developed empirically for specific geographical locations.

Elwell and Stocking (1975) used threshold values from both intensity and amount in calculating erosivity indexes for various sites in Zimbabwe. They produced a rainfall erosivity map which showed erosion being at maximum in the zone of 600-800 mm mean annual rainfall. This was because a higher percentage of erosive rainfall than that of areas receiving over 800 mm fell on bare ground as the rainfall was insufficient to give a reliably good vegetation cover (Elwell & Stocking, 1976; Stocking, 1976a; Stocking, 1984; Stocking, 1994). Mhondoro communal lands, with a mean annual rainfall of 750 mm, falls within this zone of maximum erosion.

2.3.1.3 **Erosion and vegetative cover**

Vegetative cover affects soil erosion processes in several ways. The interception of raindrops by vegetation protects the soil in two ways. It reduces the amount of water that reaches the ground, through evaporation; the kinetic energy of the raindrops is reduced because it is absorbed by the vegetation rather than by the soil structure (Stocking & Elwell, 1976).

Many interactive processes between a plant and its soil affect erosion. They include: the physical binding of the soil by plant stems and roots; detention of runoff by stalks and organic litter, improved infiltration along root channels, and increased faunal and biological activity, leading to better soil structure (Stocking, 1994). The soil's infiltration capacity tends to be low where vegetation is sparse; this increases the amount of runoff and, ultimately, aids erosion (Hudson, 1986; Morris & Biggs, 1995; Rowntree, 1984; Savory, 1988).

Some of the soil factors generally associated with soil erodibility include soil bulk density, soil water, root weight, soil aggregation, and soil particle size. While these may be important for explaining soil loss and runoff rates in cropland studies, a study by Hofmann & Ries (1991) concluded that on pastures and rangelands vegetation and groundcover were more important factors than soil erodibility factors.

2.3.1.4 **Slope gradient and length**

Slope gradient is the inclination of the surface of the soil from the horizontal (Soil Survey Divion Staff, United States Department of Agriculture (SSDS-USDA), 1993)). Steep land is more susceptible to water erosion than flat land as the erosive forces of splash, scour and transport have a greater effect on steep slopes (Hudson, 1986). Assessments of sediment yields from river basins have employed various parameters such as average stream gradient, change in elevation across and along the basin (Hudson, 1986). The shape of the slope is also significant. A uniform straight slope loses more soil than a concave slope, but less than a convex slope (SSDS-USDA, 1993; Young & Mutchler, 1969).

The effect of the length of the slope, when combined with slope steepness, is to allow a progressive build-up of both volume and velocity of runoff (Lal & Elliot, 1994; Hudson, 1986). For field measurements at a particular point it may be useful to record the length of slope that contributes water to the specific point – the point runoff slope length (SSDS-USDA, 1993).

2.3.1.5 **Human factors**

The many socio-economic activities of humankind in the biosphere impact soil degradation in one way or another. Those impacts with a bearing on soil erosion in particualar include deforestation, pasture degradation, soil compaction and soil nutrient depletion.

Soil compaction results from the use of heavy machinery and trampling by humans and by livestock. Compaction impedes infiltration and contributes to the rapid build–up of run-off. In fragile environments human and livestock tracks, if left unchecked, may provide pathways for the development of gullies (Garlands, 1987; Trimble & Mendel, 1995; UNEP, 1992; Wells & Andriamihaja, 1993).

Among the many causes of deforestation are clearing for agriculture, fuelwood collection, logging and injudicious use of fire. Deforestation may lead to serious soil erosion as it leaves the soil unprotected from the direct action of falling rains and overland flows (Marathianon, *et al*, 2000; Viljoen, 1991). Overgrazing can similarly lead to soil erosion. "Overgrazing reduces water and mineral cycling by exposing soil and limiting litter production while decreasing soil structure, porosity, and organic content" (Savory, 1988: 154).

Soil nutrient depletion may result from mismanagement of land through continued cultivation with inadequate application of replacement nutrients. This affects soil structure and predisposes the soil to erosion (Blair, 2000; Egboka & Okpoko, 1984; Lal, 1988).

2.3.2 Soil erosion processes relevant to the study area

Soil erosion involves the pysical removal of soil particles from one location and their translocation to another position in the landscape.

2.3.2.1 Water erosion

The initial step is the detachment of soil material by raindrop impact and the splashing of the sediment into the water of overland flow (Rose, 1994; SSDS-USDA, 1993). The most commonly recognised forms of accelerated water erosion are sheet, rill, gully and tunnel erosion (piping).

Sheet erosion is the more or less uniform removal of soil from an area without the development of conspicuous water channels. Numerous tiny or tortuous unstable channels develop; these enlarge and straighten as the volume of runoff increases. Sheet erosion is more serious as slope gradient increases (SSDS-USDA, 1993). *Rill erosion* is the removal of soil through the cutting of many small, but conspicuous, channels where runoff concentrates (SSDS-USDA,1993). *Gully erosion* results from water cutting down into the soil along the line of flow. Gullies form in exposed natural drainageways, in plow furrows, in animal trails, in vehicle ruts, between rows of crop plants, and below broken man-made terraces (Stocking, 1976; SSDS-USDA, 1993).

Tunnel erosion is a form of erosion where soil is carried away by water through holes in the ground as surface water infiltrates downwards through the soil surface (Hudson, 1986; Stocking, 1976). Where there is an outlet the water may flow laterally through the soil over a less permeable layer and the fine particles of the more porous soil may be washed out. As the lateral flow increases the pipe is enlarged, sometimes leading to roof collapse, turning the pipe or tunnel into a gully (Hudson, 1986). The surface-connected macropores or holes that trigger the process may include dessication cracks or rodent burrows (SSDS-USDA, 1993). A study on tunnel erosion in the Muzvezve valley on the Mhondoro-Ngezi border concluded that the sodic nature of the soil facilitated the dispersion of the soil rather than the prior existence of any shrinkage cracks (Stocking, 1976b).

Pinnacle erosion leaves upright needle-like features or pinnacles in gully sides and bottoms. It results from deep vertical rills cutting back rapidly, joining until pinnacles are left like islands in the bed of the gully. A more resistant soil layer of gravel or stones often caps the pinnacle, protecting the soil beneath. This form of erosion is often found along with pipe erosion and is usually found where the soils are unstable due, for instance, to excessive sodium and complete deflocculation (Hudson, 1986).

2.3.2.2 **Wind erosion**

In regions of low rainfall wind erosion can be widespread, especially during periods of drought (SSDS-USDA,1993). Factors promoting wind erosion include loose , dry , finely divided top soils, a smooth soil surface devoid of vegetative cover, high wind speed, steep topography, low soil water content and low aggregation of soil particles (Schoeman, *et al*, 1992; Skidmore, 1994). On pastoral rangelands subject to excessive grazing during dry periods, the composition of pastures deteriorates, with the proportion of edible perennial plants decreasing and the proportion of annuals increasing. This makes the pastures vulnerable to vegetation thinning and death during dry seasons and droughts, causing soil conditions to deteriorate, and increasing the fraction of erodible aggregates on the soil surface (Skidmore, 1994). In rainfed agriculture the clearing of the original vegetation and fallow expose the soil to accelerated wind and water erosion.

2.3.2.3 **Sediment deposition**

This occurs as a result of sediment settling out under the action of gravity (Rose, 1994). Deposition is likely wherever the velocity of running water is reduced, such as at the mouths of gullies, at the bases of slopes, along stream banks, on alluvial plains, in reservoirs and at the mouths of streams (SSDS-USDA, 1993). Aeolian material transported from elsewhere may also contribute significantly to sediment deposition.

CHAPTER 3 METHODS OF DATA GATHERING AND DATA TREATMENT

After the literature survey, several sources of information about aspects of the study area were investigated. Data were collected and later organized into various formats in readiness for interpretation.

3.1 DATA COLLECTION

Available secondary sources were accessed through library searches, contact with or visits to several government agencies and departments.

Secondary data consisted of: a 1: 50 000 topographic map of the study area, sheet 1830 B3, Mubayira (Surveyor General's Department (SGD), 1997); two sets of aerial photographs of the study area: a 1982 set, taken in July by a contractor for the Canadian International Development Association, at a scale of 1: 80 000 (SGD, 1982) and a 1997 set, taken in July-August by British Military Survey, at a scale of 1: 50 000 (SGD, 1997); satellite imagery: black and white Panchromatic SPOT scenes from July 31, 1993 to October 25, 1993 - sheet 1830B3, Beatrice (SGD,1993); national census data: 1982 census (Central Statistical Office (CSO), 1989); 1992 census (CSO, 1994); data from national socio-economic surveys (CSO, 1999a; CSO, 1999b; CSO, 1999c); livestock records (cattle dip records); and climatic data: 1930-2000 rainfall records and 1962-2000 temperature records for Mubayira meteorological sub-station (Meteorogical Services Department, 2001).

Primary data were gathered through field research. After a preliminary study of aerial photographs and satellite imagery for the study area field visits to the area were undertaken. Research was carried out over a two and a half week period from June 10 to June 28, 2001. It generated several facts and figures and provided some insights into Mhondoro residents' relationship with their biophysical environment. The methods of inquiry used included field observations, measurements and recording, a questionnaire survey, soil and vegetation traverses, interviews with key informants and partial completion of an environmental evaluation matrix and a sustainability checklist especially adapted for the study.

3.1.1 **The questionnaire survey**

As the questionnaire survey was expected to take quite some time to administer it was decided to get on with it quite early in the field study. After a preliminary visit to the area and some interviews with local people the questionnaire was designed and tested on a few individuals. After the necessary adjustments 114 copies of the questionnaire were then printed (see Appendix B for the English version). Two locally based field assistants were engaged for the duration of the survey.

Sampling procedure

The sample frame, i.e. the statistical population from which the sample was taken, consisted of an estimated 3149 households averaging 5 people and residing in Chief Mashayamombe's ward in the Mhondoro communal area, covering some 170 km^2. The

Estimation of number of households in study area

$$n = \left(\frac{P_2}{h}\right)$$

Where n = Estimated number of households in 2001

h = Ave. size of household in ward in 1992 (4.7+5.1+5.2)/3 = 5 (CSO, 1994: 61)

P_2 = Estimated ward population for 2001: $P_2 = P_1 * \left(\frac{r}{100}+1\right)^t = 14019 * \left(\frac{1.3}{100}+1\right)^9$

P_1 = Population of ward in 1992 census : 14 019 (CSO, 1994: 61)

r = Inter-censal annual population growth rate 1982 - 1992: 1.3% (Tevera, *et al*, 1999: 40)

t = Period of population change (1992–2001): 9 years

Estimated number of households $n = \left(\frac{15747.153}{5}\right) = 3149$

number of households was estimated as shown in the box.

The sample size was determined on a confidence level of 90% and a confidence interval of 10%. This means that on the basis of the Standard Normal Probability Distribution of the sample population there is a 90% certainty that no estimated percentage will be off the mark by more than +/- 10% (Kumar, 1996; Mason, *et al*, 1988; Sedlack & Stanley, 1992; Sheskin, 1985; Walford, 1995). The formula for calculating the required sample size (*n*) for a '90 and 10' accuracy level is shown in the box below.

Calculation of required sample size

$$n = \left(Z\sqrt{\frac{PQ}{C}}\right)^2$$

Where Z = 1.645 for 90% confidence that a result lies within the given confidence interval

P = the percentage about which a confidence interval is computed, expressed as a proportion

Q = 1 – P

C = the desired size of the confidence interval, expressed as a decimal number.

In practice, a worst-case scenario is assumed where *n* is largest when P = 0.5 and Q = 0.5 and 0.5 is substituted for $\sqrt{PQ}$. The sample size is then calculated thus (Sheskin, 1985: 36):

$$= \left(\frac{1.645x0.5}{0.1}\right)^2$$

= 68 cases (67.7 rounded off to nearest whole number)

On the basis of a sample size of 68 households it was decided to target 110 households, allowing for the non-return of as many as 42 questionnaires. In the end 99 completed questionnaires were retrieved.

Systematic sampling was used to select the 110 households from the universe of 3149 households. A starting point was selected at random and a sampling interval of 10 was used (Mason, *et al*, 1988). After visiting the first household the researcher and two field assistants thereafter selected every tenth household for questionnaire completion (see

Figure 3.1 for location of sampled area). One problem experienced was that more than one household lived at the same homestead in quite a few cases. This was overcome, to a large extent, through informal discrete inquiries and making use of the local knowledge of the field assistants. As far as possible every tenth household was interviewed up to the 110th.

3.1.2 **Field observations and measurements**

Field observations entailed extensive travel within the study area, interviews with local residents, observations of grazing lands, soils and vegetation, gullies, evidence of gravel and sand mining; photographing of examples of vegetation, a gully, sand deposition site, land pollution, human and cattle tracks; and measurement of some human tracks, cattle tracks, and a gully.

3.1.2.1 **Grazing lands**

Communal grazing is the standard practice in the area. Pastures consisted of fallow lands within the field area, abandoned fields, grasslands between and within woodlands, and fenced-in paddocks.

Several fields on either side of the Beatrice-Mhondoro-Chegutu road in Mashayamombe ward, were observed to be lying fallow, especially to the east of Mubayira and around Bhinda (see Figure 3.1). The quality of grazing observed in the fallow fields consisted of remnants of weed grasses, re-growths of a few bushes and thinly spread grasses.

Abandoned fields that had reverted to grazing land were observed at a number of sites. These included extensive areas east and north of Zibwowa school; south and east of Bhinda business centre; and just north of the tarred road in a stretch approaching the Nyundo river in an easterly direction, towards Beatrice (see Figure 3.1). These areas were almost bare of trees, except for a few clusters of bushes and small trees on termite

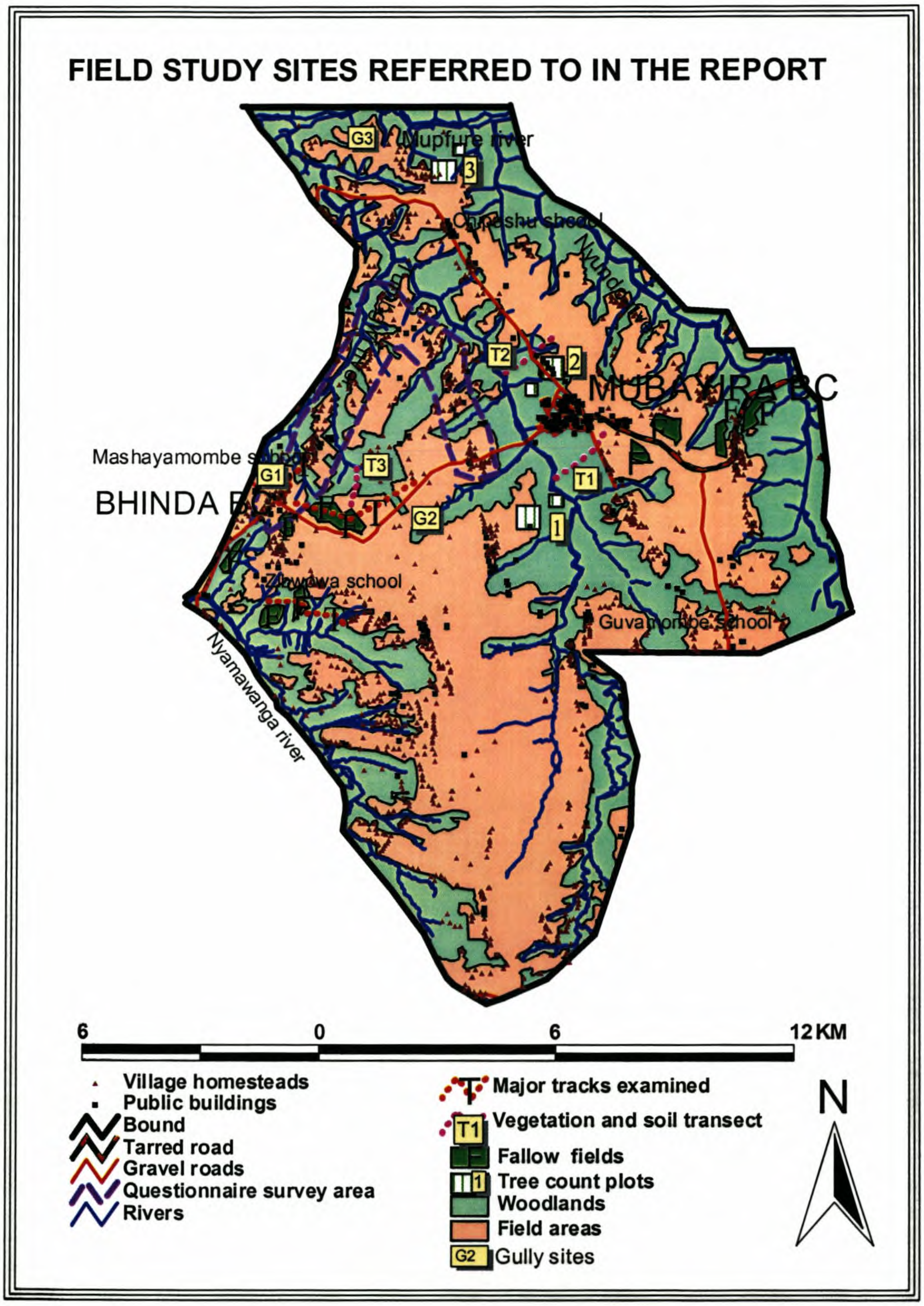


Figure 3.1 Field sites referred to in the study report

mounds or on contour drains. The grass was very short, with some bare patches of ground; this was partly the result of livestock grazing during the summer months.

Grasslands between and within woodlands were mostly confined to the lowland and valley areas. Grazed grasses up to about 30cm high were observed, especially in areas not directly under tree canopy. In some localities, such as around the dams and dip tanks, the grass had been so severely grazed as to make the ground almost bare (see Figure 3.2). Several open areas between clumps of trees were occupied by thickets of bushes and shrubs of the *Acacia tortillis* species. Conversations with some of the older villagers (Mashayamombe, 2001; Muhlaba, 2001) confirmed that there had been bush encroachment on pastures (see Figure 3.3).

Fenced-in paddocks, referred to as "active grazing schemes" in Figure 3.4, made a sharp contrast from the other grazing lands. Grasses up to 120cm high were observed in sections of the paddocks. The four-paddock scheme had been managed under a twenty-one day rotation cycle, with break periods. Members of the grazing schemes had been using the open access grazing lands while restricting access to paddocks to their members' livestock only. The shrubs and bushes were relatively intact as livestock had barely used them for forage. At the time of the survey livestock were grazing in post-harvest, crop-free fields. During the cropping season the fields are used exclusively by the families who till them; in the dry season they revert to communal use. Members of grazing schemes would return their livestock to the paddocks later in the dry season, taking care not to exhaust the grass in the paddocks, in case the next rain season turned out to be a drought (Shayawaedza, 2001).

3.1.2.2 **Gullies**

Gullies were observed at three sites (Figure 3.1). The gully studied in detail is on the upper Tumbgwi river, about 1km north of Bhinda business centre. The gully was about 110m in length from the gully head to the small dam below the gully. It measured 14.2m in width at its widest point and 2.47m deep, 2m from the gully head (Figure 3.5).

Figure 3.2 Severely overgrazed open-access pasture just south-west of Mashayamombe village

Figure 3.3 An example of bush encroachment just south of Mubayira, with original vegetation in background

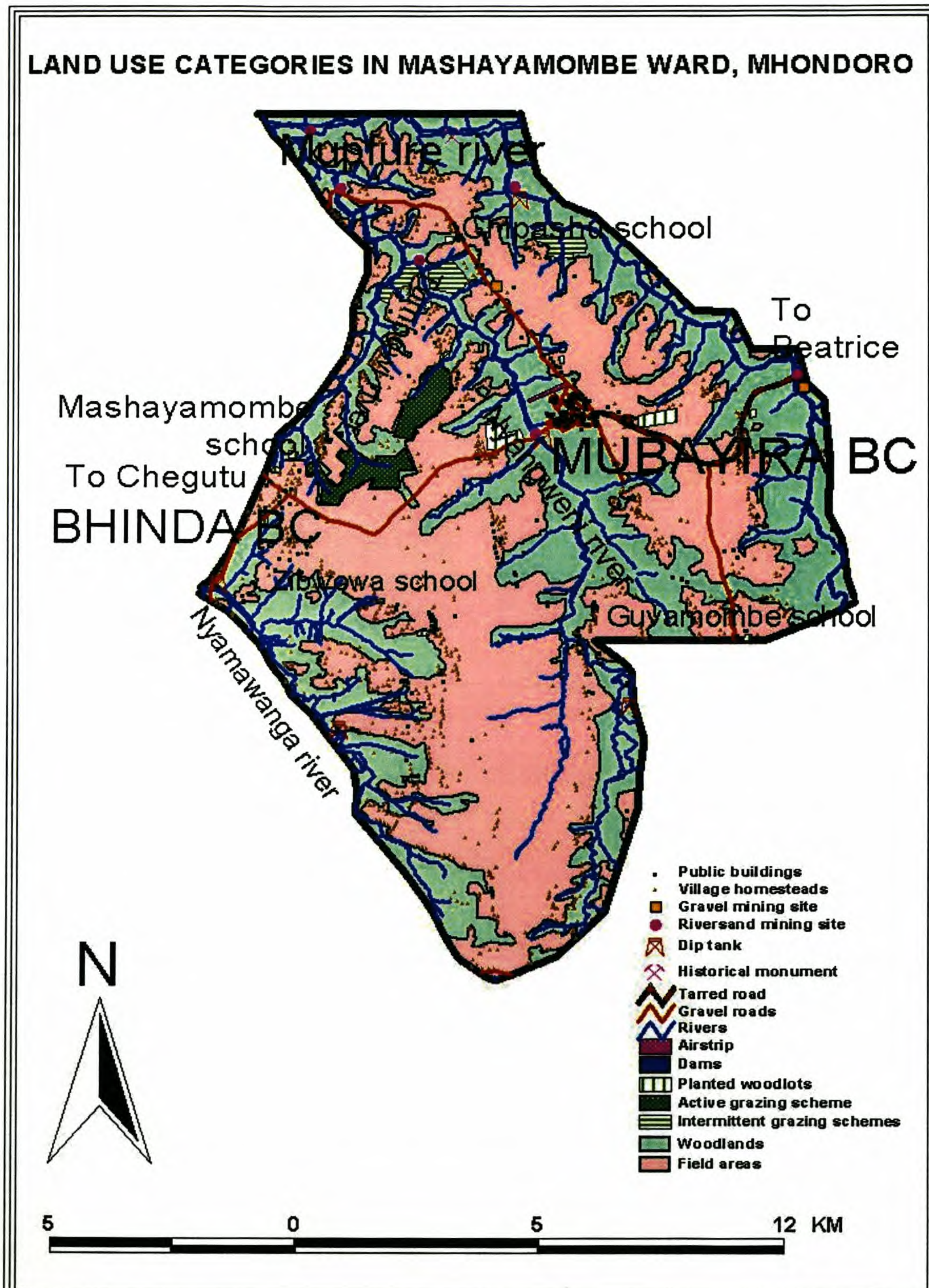


Figure 3.4 Land uses in Mashayamombe ward, Mhondoro

Figure 3.5 View of Bhinda gully from gully head in direction of Mashayamombe dam

Figure 3.6 Fenced-in part of Bhinda gully head, under rehabilitation

This gully had been stabilized and was being rehabilitated through fencing off, the growth of trees and other plants at its head, and filling in with stones and rubble (Figure 3.6 on page 44 and Figure 3.7 on the next page). The upper section of the gully had been incorporated into the fenced-in grazing scheme and had been thus protected. The lower section was outside the fence and renewed erosion in it had been triggered off by a new footpath cutting across the gully and excavations for clay on its southern wall (Figure 3.8 on next page).

Two other gullies were visited. One is on a minor tributary of the Mupfure, the main river in the area, near the north-western boundary of the study area. It is located in grid square 4179 on the Mubayira 1:50 000 map (see Figure 3.1). Villagers were trying to stabilize this gully as it was encroaching on their fields. The third gully, located south of the Mubayira-Bhinda road, is on a tributary of the Nyangweni river. It is located in grid square 4170 on the Mubayira 1: 50 000 map (see Figure 3.1). Though the gully was not as deep as the one near Bhinda it had several gully heads arranged in a dendritic fashion, following the pattern of the streams comprising the headwaters of this river.

While the average slope gradient of the study area was found to be less than one degree the slope gradient of the valley sides was slightly steeper, going up to 1.10 degrees in places (see section 3.3.2). This gradient does not seem to be particularly significant for promoting rapid run-off. However, when one examines the depths of the gullies and the riverbeds it appears that the rivers in the area have experienced some rejuvenation and have been engaged in substantial down-cutting (see Figure 3.5). The fairly unimpeded long slopes, i.e. in view of the sparse vegetation and evenness of the terrain, seem to play an important role in the build up of overland flow. The sheer volume and kinetic force of the runoff contributes to the erosion processes as the water makes the drop from the fairly flat land above the river banks to the riverbed some metres below. A study of gully erosion in the Muzvezve valley to the south of the study area suggested that rejuvenation could have been the reason for the observed down-cutting (Whitlow & Firth, 1989).

Figure 3.7 Protected upper end of gully on the upper Tumbgwi river, about 1km north of Bhinda BC

Figure 3.8 Unprotected lower end of gully at Bhinda, showing renewed erosion

3.1.2.3 **Human and livestock tracks**

Literally, hundreds of human and livestock tracks traverse the Mashayamombe ward area. These tracks are used to travel from villages to business centres, schools, clinics, water points, bus stations, dip tanks and other villages. The tracks are used by pedestrians, cyclists, scotch carts, wheel barrows and, sometimes, by motor vehicles. The action of trampling of the soil along these paths results in loosening of the top layer of the soil, rendering it liable to removal by running water in the rainy season. The surface immediately below the loosened soil is compacted by the weight of all the traffic passing through. The compaction and the soil capping (resulting from the flowing action of the wetted loose soil) reduces the infiltration of water into the soil, thereby promoting increased runoff, leading to erosion. The tracks themselves act as rivulets, concentrating run-off in specific areas and aiding the erosion processes.

Examples examined in some detail include a track from Bhinda business centre to Mashayamombe village (Figure 3.1). This track averaged a width of 2.6m across for the first 420m, and because of continued erosion over the years, had deepened to an average of 18cm. In each year of normal average rainfall, most of the loose soil is removed by overland flow, exposing a new surface to be loosened further and removed by the following season's rains. This particular track is fenced off on either side, to keep livestock from straying into the fields on the one side and into the homesteads on the other. This also means that users of the track cannot start a new track on the side so as to rest the old track, as often happens with the other tracks. Thus, this track continues to lose more soil with each rain season and also to transport soil deposited into it from its sides.

Another busy track examined was one designed to cut short the distance along the road from Bhinda Business Centre to Mubayira Business Centre; it rejoins the road just 3km from the bridge on the Nyangweni river (Figure 3.1). This had developed virtually into a road; it was even used by some motorists. However, unlike the official roads, it was not maintained or resurfaced by the local authorities.

While some trampling of the soil by animals is regarded as good for the health of the soil

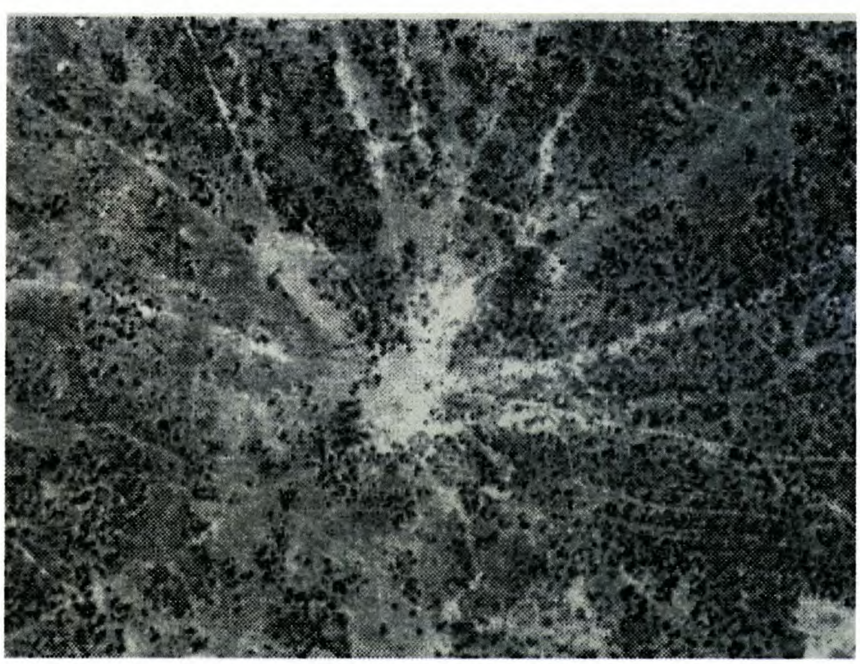
(Savory, 1988: 43), excessive soil trampling can lead to serious problems of erosion. Cattle tracks were examined at Mubayira dip, near where the Bhinda-Mubayira road crosses the Nyangweni river, and around Mashayamombe dam, just north of Bhinda. Because of the legal requirement for cattle to be dipped regularly the cattle are driven to dip tank sites, making tracks averaging about 45cm in width and several centimetres deep (see Figure 3.9 on next page). Livestock also drink from dams, rivers and boreholes; they often move in single file to these watering sites, making tracks. A common site is of numerous tracks converging on a watering hole with the area in its immediate vicinity being severely overgrazed and trampled (see Figure 3.10 on next page).

Human and livestock tracks could trigger severe gully erosion as has been observed in other studies (Trimble, 1995; Wells & Andriamihaja, 1993). Mashayamombe ward has been spared this catastrophe because of the relative flatness of the area; this tends to reduce the speed of rainfall run-off. Another factor is that most of the dip tank sites are located close to rivers where the soils have a high clay content and are fairly resistant to detachment and removal by overland flow. As a result, the dip tank sites show much degradation of the vegetation around them but little evidence of severe soil erosion (see Figure 3.11 on page 51).

3.1.2.4 **Sedimentation of rivers**

Several sites showing evidence of massive sediment deposition were examined (marked D on Figure 3.1). Soil deposited on the sites came from the fields, the grazing lands, the gullies, the numerous tracks, and the untarred roads. The practice of cultivating gardens in wetland areas along the rivers, common in areas along the Mupfure and the lower valleys of some of its tributaries, added to this problem. Major deposition sites included river confluences (see Figure 3.12 on page 51), entrances to dams, bridge crossings, the inside curves of river meanders and flat areas crossed by rivers. The area had experienced an unusually wet 2000/2001 season and there was evidence of fresh depositions due to flooding.

Figure 3.9 Cattle and human track just west of Mubayira dip



Source: Sheet 17 (Surveyor General's Department, 1982)

Figure 3.10 Aerial photo showing cattle and human tracks converging at a borehole in Mashayamombe area, south of the Nyangweni river

Figure 3.11 Dip tank site just south-east of Mubayira showing the effect of cattle trampling

Figure 3.12 Major sediment deposition site on a tributary of the Nyangweni river, south-east of Mubayira

3.1.2.5 **Soil and vegetation traverses**

The traverses ran from the valley bottoms towards the crests of the uplands along selected transects (see Figure 3.1). The soils displayed a catenary sequence in their surface characteristics and vegetation changes generally followed this pattern.

Soils

The soils displayed a catenary sequence in their surface characteristics and vegetation changes generally followed this pattern. Exposed dry river channels showed dark grey soil at the bottom of the river bed, overlain with freshly deposited greyish brown sand. The soil was sticky to the touch when wetted. This type of soil was observed to occupy a belt 120m to 300m wide on either side of the Nyangweni river. From there the soil exhibited various shades of brown, gradually becoming a sandy grayish brown towards the crest of the upland areas. Upland soils looked and felt virtually like just loose sand, with very little amounts of clay, except in the flatter watershed areas, where more clay seemed to be present. In several secluded patches evidence of the removal of top soil by sheet wash erosion was observed. This was in the form of small soil pedestals surrounded by slightly lower ground with lighter-coloured "scars" where soil had been detached from and carried away.

Vegetation

Uncultivated upland areas consisted of open grassland with clusters of trees in places. Individual trees were observed to be growing in fields and around several homesteads. The valleys were well wooded in some parts; the open areas were occupied by taller grass than that on the uplands.

Adopting a methodology employed in resource survey studies elsewhere three tree density plots of 30m x 30m in woodlands along watercourses were marked out and trees of a height above 2,5m were counted (Campbell, *et al*, 1995; Campbell, *et al*, 1997; Peters, *et al*, 1989; Peters, *et al*, 1994). In the upland areas, including field and settlement areas where trees were fewer than in lowland woodlands, three plots of 50m x 500m (estimated) were demarcated and tree counts done. The approximate locations of the sites are marked as 1, 2, and 3 on Figure 3.1 (smaller rectangles for the 30m x 30m plots and larger rectangles for the 50m x 500m plots). The results of the tree density counts were as were as shown in Table 3.1.

Table 3.1 Tree counts in study plots in Mashayamombe ward

	Site 1	Site 2	Site 3
Lowland woodland area (30m x 30m): number of trees	68	52	58
Upland woodland area (50m x 500m): number of trees	61	43	81

In the valley bottoms tree species included *Acacia gerrardi, Acacia mellifera,* and *Acacia tortillas* growing in separate stands, *Cythula lanceolata*, some *Brachystegia boehmi; Bauhinia toningii,* and isolated *Colophospermum mopane* and scrub-type mopane. In the better drained and sandier areas of the middle lands and the crests of the uplands several mature individual trees included *Brachystegia boehmi*, *Brachystegia spiciformis, Julbernadia globiflora, Terminalia sericea*, and *Parinari curatellifolia.* Several smaller species were also identifiable. Locally, indigenous names are used (see Appendix D). Many of the trees are quite large and it is remarkable that such a fairly large number of trees have been preserved despite the local people's woodfuel needs.

Homesite woodlots

In a traverse of homesteads along the main Beatrice-Mubayira-Chegutu road woodlot plantations of mainly *Eucalyptus spp* (gum trees) were observed to be present at an estimated 40-60% of homesteads, particularly those to the east of Mubayira. Fruit trees were observed to be present at an even higher percentage of homesteads, although tree holdings varied in number from a single tree to several dozens per homestead. These figures were later found to be comparable to those quoted by respondents in the questionnaire survey (see Figure 5.14). The most commonly grown fruit trees included mangoes, guavas, lemons and peaches. A remarkable example of agroforestry was observed at the home of a retired meteorological office technician living at Mubayira;

exotic and indigenous fruit trees are grown together with crops at the homefield (see Appendix E).

Grasses

There is hardly any extensive areas of open grassland in the study area. What must have been grasslands were virtually all used for agricultural fields and the remainder have been modified by almost constant intensive grazing. In the woodland areas the main grasses were of the *Hyparrhenia* species in the valley bottoms and the *Loudetia* species on the drier fringes of these areas (Rattray, 1961; Rattray & Wild, 1961; Wild, 1965). These grasses have shown some resilience in the face of almost constant grazing pressure; they also help to hold the soil together, reducing soil erosion.

3.1.2.6 **Gravel mining and river sand mining**

Two gravel mining sites were examined; one to the east of Mubayira and the other to its north. The District Development Fund (the local government agency that maintains local infrastructure) mines the gravel and uses it for surfacing or resurfacing roads. When the gravel mine runs out of the desired size of gravel, it is abandoned. Apparently, no attempt is made to refill the hole or to rehabilitate the site. The effect is to generally degrade the land as the sites are an eyesore and there is no further use for the abandoned mine. Some of these big holes collect water during the rain season and are used by villagers as temporary watering holes for livestock. As many of them are on firm stony ground there appears to be no serious erosion resulting from the abandoned mines. Some of the sites slowly rehabilitate themselves as soil is deposited in them by runoff and some vegetation begins to grow in them (see Figure 3.13 next page).

River sand is used by local builders in the construction of brick houses. Contractors with lorries drive to sites on river banks, usually near a bridge or other easily accessible spot. Digging for the sand and the weight of the heavily laden lorries leave behind a damaged streambank which then acts as an erosion channel when the next rains come (see Figure 3.14 next page). Depending on the location of the site with respect to river morphology and the frequency of visits these sites can develop into a serious erosion problem.

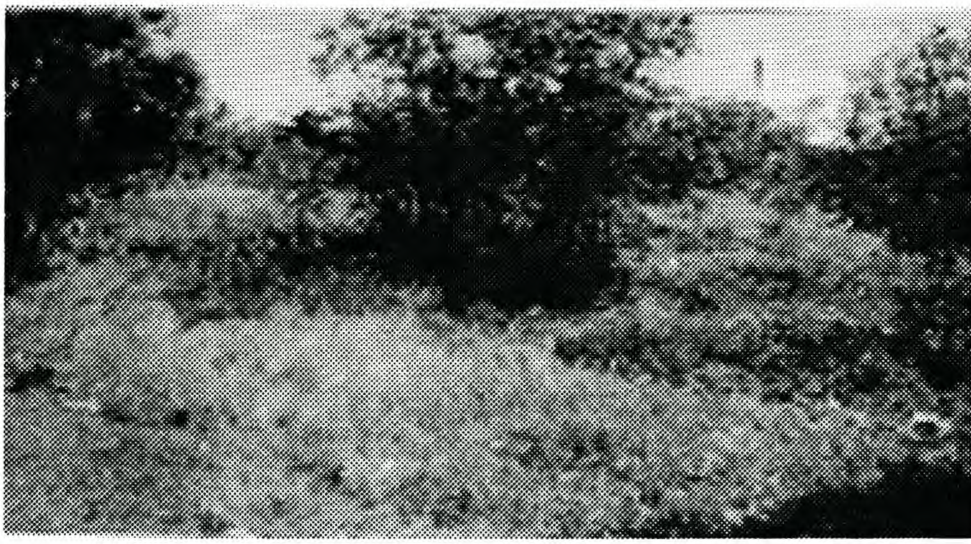


Figure 3.13 Rehabilitated gravel mining site at southern edge of Mubayira Business Centre

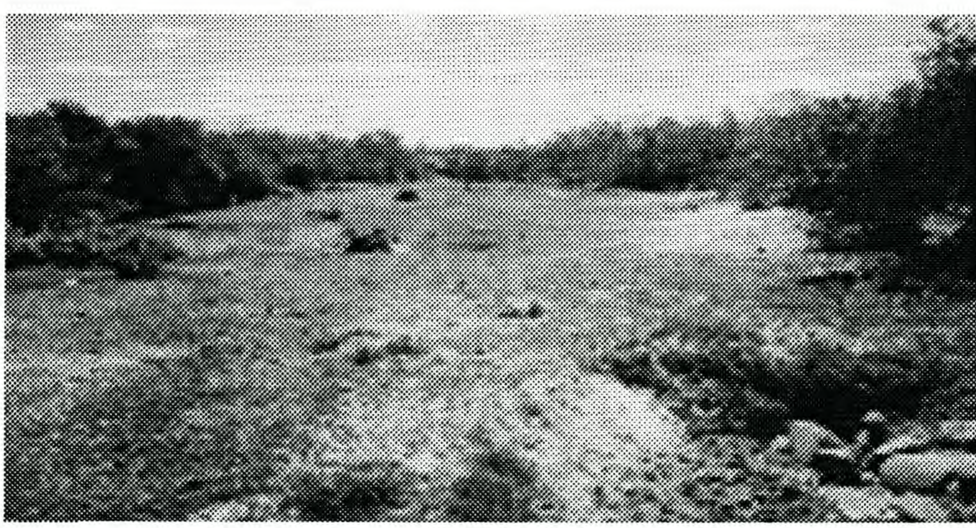


Figure 3.14 River sand mining site just below bridge immediately south of Mubayira Business Centre

3.1.2.7 **Quality of water in rivers and dams**

Sections of the Nyangweni river above and below the bridge near Mubayira were examined for the quality of their water. During the dry season the riverbed is dry except for certain sections. While it was not possible to carry out or arrange for water chemistry tests at the time of the study, physical examination of the water revealed certain trends.

The water in calm and settled sections of the river appeared clear; however, the water in the more recently disturbed sections appeared murky. Livestock drinking from the river were observed to indulge in instream trampling, direct faecal and urine deposition into the water and damaging the streambanks at entry points and thus contributing to sediment deposition into the river.

The water quality situation in the local dams is similar to that of the rivers as livestock also drink form the dams. At Mashayamombe dam the water was covered by algal bloom and layers of sediment were evident at the point where the river entered the dam. It was observed also that many households in the area did not have proper toilets and residents relieved themselves in the bush (see Figure 3.17). During the rainy season faecal material in runoff finds its way into the streams and dams, along with dissolved nutrients from fertilizers and manure from the fields. The combined effects of these and other related practices is that the water in the dams and rivers is not fit for direct human use.
Studies done elsewhere have shown that there can be several varied effects of livestock grazing and trampling on aquatic and riparian species and habitats (Belsky, *et al*, 1999; Kauffman & Krueger, 1984; Kondolf, 1993; Loft, *et al*, 1991). Nutrient concentrations in streams lead to reduced dissolved oxygen, possible water salinizatioin in isolated pools, and alteration of instream species composition. Bacteria and protozoa may increase in the water through faecal deposition resulting in higher human and wildlife disease-producing potential from pathogens. Sediments may bury spawning gravel, suffocating fish embryos and juveniles. Dissolved oxygen levels may decline due to higher water temperatures (increased solar exposure due to reduced shade from streamside vegetation), high biological oxygen demand of faecal material and algal blooms. This results in insufficient oxygen in spawning gravels, reducing the growth and survival of several aquatic species, it reduces decomposition rates and increases the toxicity of toxicants in the water.

While it was difficult to establish how many of these environmental problems applied to the surface water in Mashayamombe ward, indications were that the water was in a poor state. Several older residents of the area (Mashayamombe, 2001; Muhlaba, 2001) stated categorically that there had been a time when local rivers had flowed perennially. These rivers are now ephemeral in nature, indicating a deterioration in environmental conditions. Other indicators were the presence of algal bloom in some of the dams, such as Mashayamombe, and the abscence of fish in the rivers and dams (except those that migrate upstream temporarily in the rain season). However, the Mupfure river seems to have a lot of fish. When asked about using surface water several residents stated that no-one in the area used the water for drinking or cooking. There was general consensus that only water from boreholes and wells was suitable for human consumption without treatment.

3.1.2.8 **Land pollution**

Residents of the area handle household waste by putting it either on a heap or in a pit in a designated place on the edge of the homestead yard. Some just dump it in the field adjacent to the homestead. The waste includes sweepings, ashes, papers and left-over food. Eventually, the waste serves as a compost for manuring the field or the garden. Undegradable materials such as glass, plastics and tins are buried in pits.

While waste handling at institutions such as schools, clinics and the main hospital at Mubayira seemed fairly efficient, the same could not be said for business centres. The problem was encountered at a number of the centres but observations were focused on Mubayira business centre. Approximately 2500 people live at or close to the business centre. Substantial amounts of garbage are generated at the bus stop-cum-market, at the numerous shops and restaurants, at administrative offices and garages, and at a number of informal repair shops. Mubayira seems caught up in a dilemma between developing into a town and remaining a rural service centre; this policy puzzle is reflected in its garbage collection practices. Accumulated garbage was observed at a dumping site just south-east of the business centre, towards Mubayira dip tank. The waste included paper, discarded plastic paper and containers, waste metal pieces, glass, used oil, and rubble (see Figure 3.15 next page). The site is an eyesore and a potential environmental disaster. The settlement is in need of a formal landfill site, carefully chosen with all environmental considerations taken into account.

Figure 3.15 Garbage dumping site south-east of Mubayira Business Centre

3.2 ENVIRONMENTAL ASSESSMENT

Environmental impact assessment (EIA) is the process of identifying and predicting the likely effects or impacts of human-initiated actions on the environment, both bio-physical and social dimensions of the environment (Fuggle, 1992; Morgan, 1998). It usually precedes the sanctioning of a proposed development project; one of its main purposes, therefore, is to provide decision-makers with objective information about the likely consequences for the biophysical environment and for humankind's health and welfare of implementing such a project (Weston, 1997). "The essential purpose of EIA is to identify proposals that will have unacceptable impacts on the environment so that the impacts can be avoided or ameliorated by changes to the proposal, or compensation can be arranged for people affected by subsequent unavoidable impacts, or the proposal can be rejected" (Morgan, 1998: 13).

Communal land use practices in Mashayamombe ward, Mhondoro, have quite a long history. Assessing their impact on the environment was, therefore, done in the context of post-project evaluation. This involves assessing the impacts of a project that has been in operation for some time (Mitchell, 1989). Thus the the study being reported here was a state of the environment report on the study area. The study set out to examine the cumulative impacts of several communal land use practices. Cumulative impacts are those that result from interactions of many incremental activities, each of which may have an insignificant effect when viewed alone, but which become cumulatively sigfnificant when seen in the aggregate (Dickert & Tuttle, 1985).

Methods of environmental assessment or evaluation include environmental checklists, matrix approaches, overlays and mapping, spatial analysis, network analysis, biogeographical analysis, and ecological modelling (Fuggle, 1992; Morris, 1995; Morris & Biggs, 1995; Smit & Spalling, 1995). Each of these methods has its own advantages and disadvantages. The choice of method may be influenced by cost considerations, the amount of detail required in the assessment and the information gathering and processing capabilities available to the assessors. For the Mhondoro study three methods were used: a method combining time-lapse aerial photography and a geographical information system (GIS) with some ground proofing (Section 3.3.3), an adaptation of the Leopold matrix (Leopold, *et al*, 1971), incorporating an association between cause and effect (see Tables 4.1a and 4.1b); and completion of a sustainability index checklist with accompanying text (see Table 5.1a and 5.1b).

3.3 **DATA TREATMENT**

To prepare data for analysis both secondary and primary data were processed and put into appropriate formats as outlined in the sections that follow.

3.3.1 **Map preparation**

Various maps were digitized in PC ArcInfo and edited in Arcedit module (Environmental Systems Research Institute (ESRI), 1981a; Zietsman, n.d.); further digitizing and editing were done in ArcView (ESRI,1981b). A map of the study area, Mashayamombe ward, Mhondoro (Figure 2.1), was digitized from the map Zimbabwe: Mubayira: 1: 50 000. Coverages included those of contours, rivers, roads, woodlands, cultivated areas and settlements. A map of the study area showing some of the sites visited during the field trip and referred to in the report was prepared (Figure 3.1). Maps were also digitized from geo-referenced aerial photographs of the study area. Overlays of the maps were then used in the analysis of the extent of land degradation in the area.

3.3.2 **Map-based data**

Calculation of average slope gradient as a soil erodibility factor for the study area was done from the topographic map, Mubayira 1: 50 000. Two approaches were used and they yielded similar results, i.e. a slope gradient of slightly above one percent (calculations shown in Table 2 and table in Appendix C). The digitized map of the study area was used in the calculation of population carrying capacity and livestock carrying capacity for the study area (see section 5.1). It was also used for coding and separating the main land uses in the study area for mapping purposes (see Figure 4.4).

3..3.3 **Aerial photographs**

Processing of aerial photographs involved a number of steps. The aerial photographs were individually scanned onto a compact disc, the 1982 photos at a resolution of 16 microns (6250 dots per centimeter), the 1997 year photos at 24 microns (4170 dots per centimeter); they were then imported into the computer. The next stage was geo-referencing of the aerial photographs. This step is very important in correcting the inevitable geometric distortion in aerial photographs arising from camera tilt, relief displacement, lens distortion and atmospheric refraction at the time the photographs are taken. The aerial photographs are geo-referenced and registered to a coordinate system and map projection (Barrette, *et al,* 2000; Tesfamariam, 2000). Digital coverages of roads and rivers can be used for locating ground control points (GCPs); at least four GCPs per photograph are required for the rectification of the aerial photographs (i.e matching four points on the map image to four points on the photograph (Rulli & Shah, 1998).

Each aerial photograph was individually geo-refenced in ArcInfo UNIX in stages SRI, 1982). The scanned images were converted into grids using the IMAGEGRID command.

Table 3.2 Calculation of average slope gradient (for the study area) as a factor of soil erodibility

Profile number	Profile height (number of contours x 20m vertical interval)		Profile length in km	Formula: (Vertical distance/horizontal distance) x 100	Slope gradient: profile height as % of profile length*
1	3 x 20	60m	5	(60m/5000m) x 100	1.2
2	13 x 20	260m	13	(260m/13000m) x 100	2
3	5 x 20	100m	15	(100m/15000m) x 100	0.66
4	7 x 20	140m	9	(140m/9000) x 100	1.5
5	5 x 20	100m	12	(100m/12000m) x 100	0.83
6	6 x 20	120m	20	(120m/20000m)x 100	0.60
7	8 x 20	160m	11	(160m/11000) x 100	1.45
8	5 x 20	100m	7	(100m/7000m) x 100	1.43
9	5 x 20	100m	29	(100m/29000m) x 100	0.34
10	7 x 20	140m	14	(140m/14000) x 100	1
11	7 x 20	140m	23.68	(140m/23680m) x 100	0.59
12	5 x 20	100m	11	(100m/11000m) x 100	0.90
13	7 x 20	140m	15	(140m/15000m) x 100	0.93
14	10 x 20	200m	15	(200m/15000m) x 100	1.33
Total					14.76
Average slope for all 14 profiles**				14.76/14	1.05
Average slope for the whole study area					= 1.05%

* SSDS-USDA (1993: 64-65).
**Adapted from the formula: *number of contours crossing the distance between two points along a slope profile on the map divided by distance between the two points, expressed as slope angle in degrees*. This is done for at least 14 profiles on the map and the average slope is calculated (Stocking, 1972).

The GCPs were chosen and registered on the images by running the CONTROLPOINTS command. The images were then finally warped using the GRIDWARP command, mosaiced into a single image and imported in ArcView (Tesfamariam, 2000; ESRI,1982). Three main land use categories were used in on-screen digitizing of polygons in ArcView from the two sets of geo-referenced aerial photographs. The two land use coverages

(1982 and 1997) were overlayed and edited to produce a final map which was then analysed for temporal changes to woodlands, cultivated areas, and gullies.

3.3.4 Generating graphs and tables

Mean monthly rainfall and mean monthly temperature figures were used to construct a composite climatic graph for the study area (see Figure 2.2). Population figures for the study area were calculated from national census data and used to calculate population carrying capacity for Mashayamombe ward (see section 3.1.2.1). Livestock figures from dip records, the questionnaire survey, and a national survey (CSO, 1999a) were used to compile tables (see Tables 3.3, 3.4, 3.5 and 3.6). The figures were also used to construct a graph showing livestock ownership patterns in the study area (Figure 3.15) and a graph comparing cattle ownership trends in Mashayamombe ward to trends in other areas in Mashonaland West Province (Figure 3.16). A comparative graph of the proportion of cultivated to fallow land in Mashayamombe ward and Mashonaland West province was constructed from national survey figures and questionnaire survey figures (Figure 3.17). Data from the 1982 national census was used to construct a graph showing the pattern of distribution of toilet facilities according to households for the whole of Mhondoro (Figure 3.18).

Questionnaire survey data was selected, collated, analysed and used in the construction of several graphs depicting relationships between livestock management, woodland resources and environmental conditions in Mashayamombe ward (Figures 4.4-4.17). A table listing the indigenous and botanic names of some of the tree species found in the study area was compiled (Appendix D).

3.3.5 Environmental evaluation matrices

An environmental evaluation matrix and a sustainability indicators checklist were prepared for the study area. The environmental evaluation matrix was adopted from several sources (Devuyst, 1993; Du Toit, 1982; Leopold, et al, 1971: Mitchell, 1989; Morris & Therivel, 1994). The list of items in the matrix was drawn up during the initial

Table 3.3 Cattle numbers in Mashayamombe ward (Mhondoro), April 2001

NAME OF DIP	NUMBER OF CATTLE
NYAKANDOVE	2093
CHIRIMUUTA	1771
ZIBWOWA	2699
MUSINAMI	6342
CHIMBITI	2069
MUBAYIRA	2866
TOTAL	18650

Source: Dipping records supplied by Verterinary Departmnet, Mubayira

Table 3.4 Cattle ownership trends in Mashayamombe ward (Mhondoro): 1999 and 2001

			TOTAL NUMBER OF CATTLE			
SIZE OF HERD	HOUSEHOLDS	% HOUSEHOLDS	1999	% total	2001	% total
None	19	19.2	0		0	
1 - 4	7	7.1	19	1.8	46	3.2
5 - 9	21	21.2	146	13.5	178	12.3
10 - 14	24	24.2	284	26.3	291	20.1
15 - 19	6	6.1	95	8.8	237	164
20 - 29	10	10.1	142	13.2	207	14.3
30 +	12	12.1	394	36.5	487	33.7
TOTAL	99	100	1080	100	1446	100

Source: Compiled by author from questionnaire data

Table 3.5 Cattle ownership trends in Mashonaland West Province, 1998

			TOTAL NUMBER OF CATTLE	
SIZE OF HERD	HOUSEHOLDS	% HOUSEHOLDS	CATTLE	% total
None	48 343	50.6	0	
1 - 4	21 237	22.2	54 230	18.2
5 - 9	15 442	16.2	99 603	33.4
10 -14	7 488	7.8	85 526	28.7
15 - 19	1 262	1.3	19 384	6.5
20 - 29	1 729	1.8	39 120	13.1
30 +	0	0	0	
TOTAL	95 500	100	297 864	100

Source: Adapted from CSO survey (CSO:1999)

Table 3.6 Changes in livestock numbers in Mashayamombe ward (Mhondoro): 1999 - 2000

	Change	Cattle	Goats	sheep
1999 total		1080	337	63
Loss through death	-	83	31	3
Sold or slaughtered	-	91	41	8
Purchased	+	85	26	7
Increase by calving	+	159	67	22
2001 total		1150	358	81
Net change in livestock numbers		+ 6.5%	+ 6.2%	+28.6%

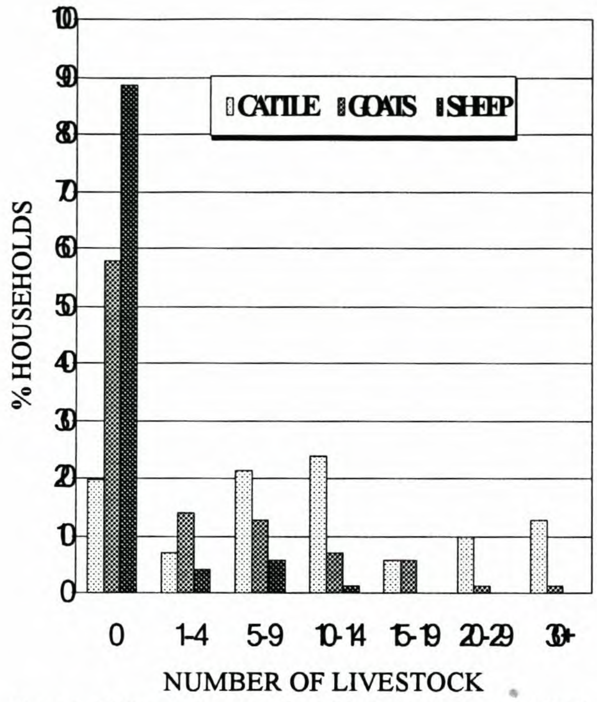


Figure 3.16 Livestock ownership in Mashayamombe ward, 2001

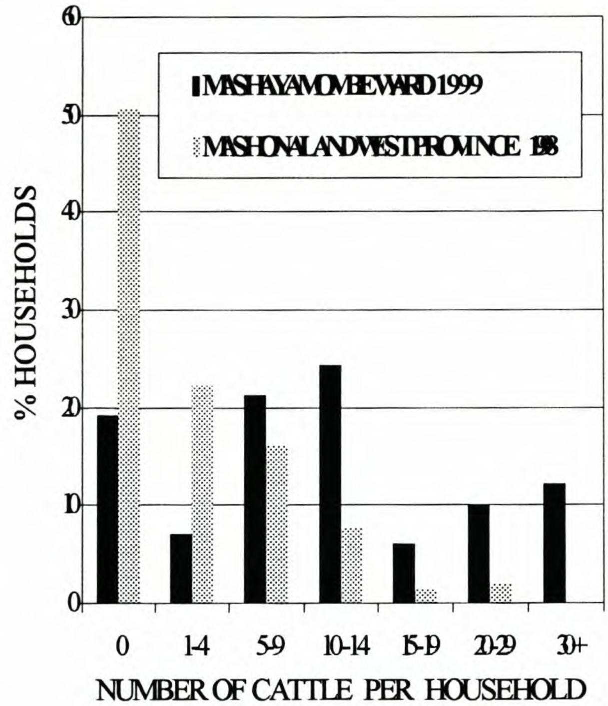
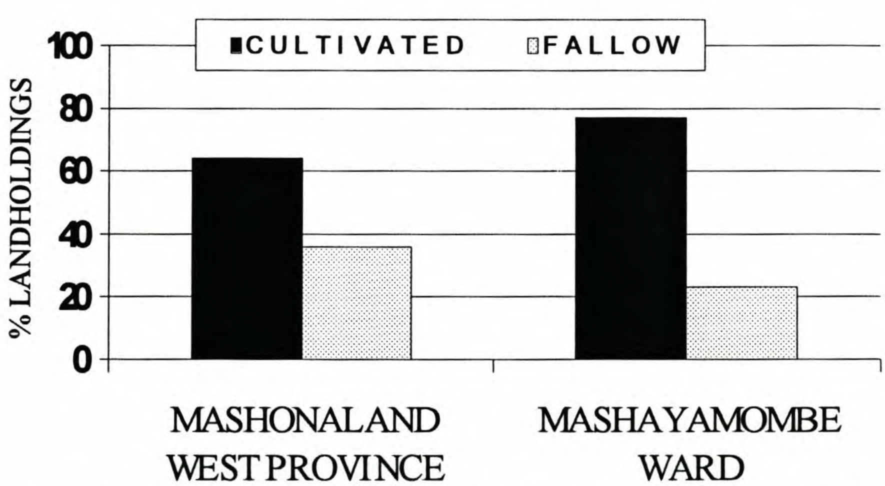


Figure 3.17 Comparison of cattle ownership trends in Mashayamombe ward and in other communal areas in Mashonaland West Province



Source: Provincial % computed from national survey (CSO), 1998: 1); Mashayamombe ward % computed by author from questionnaire data

Figure 3.18 Proportion of landholdings under cultivation and under fallow as a percentage of total in Mashayamombe ward and in Mashonaland West Province visit to the study area following detailed discussions of communal land uses with some of the key informants (Bangira, 2001; Mashayamombe, 2001; Takawira, 2001). Some of the boxes in the matrix were filled in during the field survey and the rest were completed after analysis and interpretation of field survey data.

The sustainability indicators checklist was an attempt to assess the long-term viability of communal natural resources management in the study area. The assessment was based on field survey observations and some responses to the questionnaire survey. The criteria used in the assessment were based on methods used to evaluate the sustainability of communally managed development projects (Buzzard, 1995; Timberlake, 1985).

3.3.6 **Illustrative photographs**

Figures 3.2-3.8 and 3.10-3.14, from photographs taken during the field study, were scanned and captioned to make them ready for insertion into the study report. Figure 3.9 is a portion of one of the aerial photographs (Photo 17) taken over the study area in 1982 (SGD, 1982).

CHAPTER 4 DATA ANALYSIS AND INTERPRETATION

Mashayamombe ward is occupied by over 15 000 people whose main occupation is a mixed economy of small-scale crop cultivation and livestock rearing. While families do not legally own the land they work they have exclusive use of the field areas during the cropping season, usually from November to about April-May (Zimbabwe, 1982). Grazing lands, alongside woodlands and river courses, are a communal resource or open access resource.

One definition of an open access resource is that it is "a depletable, fugitive resource characterized by rivalry in exploitation; it is subject to use by any person who has the capability and desire to enter into harvest or extraction of it" (Stevenson, 1991: 8). This definition from an economics perspective tallies with the general perception that common property resources, also known as *commons*, tend to be over-exploited as users aim to maximise the benefits of use while they incur no costs. This view was encapsulated by Hardin in his *tragedy of the commons* article (Hardin, 1968). In practice, a common property resource may be turned into a limited access resource by the adoption of certain resource management strategies (Feeney,*et al*, 1990).

This study set out to examine communal resources management practices in a well-established communal area of Zimbabwe. The intention was to find out what the impacts of these practices on the biophysical environment have been and the extent to which any land degradation in the area is due to the inherent nature of communal land use practices.

4.1 **POPULATION DENSITY AND CARRYING CAPACITY**

Using the population figure calculated for sample purposes in section 4.1.2.1 and cattle figures from Table 3, the population and cattle densities were calculated as shown in the box on page 63. Other livestock were not included in the calculations for livestock density as only cattle numbers were available. By the standards of a semi-subsistence economy of a developing country the population density of Mashayamombe ward is quite heavy. The figure for cattle density applies to the dry months, when even the fields are

Calculation of population density and cattle density for Mashayamombe ward

a. Population density: Estimated total population divided by total land area

15 952 / 170 = 93 people per km^2

b. Livestock density: Total cattle numbers divided by total land area

18 650/170 = 110 cattle per km^2 or 1.1 animals per hectare. Conversion rate: $1km^2$ = 100ha

open to communal grazing. In the cropping season only about 47% of the land is available for grazing, including the woodlands (see Map 3). This increases the cattle density to 2.33 animals per hectare, or 0.43 hectare per animal. When other livestock such as goats and sheep are included the pressure on the land becomes even greater.

The concept of carrying capacity is defined in various ways, depending on whether the author is an ecologist, economist, agriculturalist or other specialist. There is also no universal way of measuring carrying capacity (Behnke, 1985; Caughley, 1979; Ricci, 1978; Street, 1969). However, carrying capacity is generally defined in terms of a given number of people or livestock per square kilometre and is dependent, in part, on land quality (Whitlow, 1979). Studies of livestock carrying capacity estimate that in sub-humid to semi-arid tropical savanna regions with a mean annual rainfall of 750mm (and range production total of dry matter of 3000kg per hectare per year) 9.53 ha of pasture per tropical livestock unit (TLU) are needed (TLU = 1.5 cattle = 10 sheep = 12 goats = 2 donkeys) (Coe, *et al*, 1976). Maximum sustainable densities under subsistence pastoralism are estimated to be 42 TLU per km^2 per year for livestock and 7 adult equivalents per km^2 per year (Lamprey, *et al*, 1983; Le Houerou & Hoste, 1977). When these figures are compared with those calculated for Mashayamombe ward (see box above) it will be appreciated that this area has exceeded its carrying capacity by far.

In subsistence cultivation systems, such as those seen in parts of Mashayamombe area, a strong correlation has been established between increasing population and increasing agricultural intensity (Boserup, 1993; Turner, *et al*, 1977). One consequence of this for the study area has been a reduction in the crop-fallow ratio as pressure on land increases (see Figure 4.17). In addition, the many communal uses to which the land has been put have resulted in various levels of environmental degradation as summarised in Tables 5.1a and 5.1b. As can be seen from these tables land degradation has been mainly due to woodland clearance, excessive livestock grazing and poor management of croplands. Whichever definition of carrying capacity is used, the situation in this part of Mhondoro calls for close scrutiny on the part of the planning authorities.

4.2 OPEN ACCESS PASTURE

This is the most commonly practised method of livestock grazing in the area. During the cropping season, as already stated, livestock is restricted to the woodland areas. Most of the former savanna grassland areas have been turned into fields. Fallow or abandoned fields also make up part of these pastures. As can be seen from 4.2, these pastures can be severely overgrazed in particular areas. In the event of a drought the pastures cannot carry the livestock through to the next season. Farmers have to resort to selling the stock and replacing them with new stock after each major drought, as happened after the 1999 drought (see Table 3.6). Farmers in Mhondoro are landlocked and stock movement restrictions limit their ability to adopt opportunistic livestock management strategies observed to be in use elsewhere (Cousins, 1989; Cousins, 1996; Leach & Mearns, 1996; Scoones, 1991; Scoones, 1992b; Scoones, 1995; Scoones,1996; Scoones, *et al*, 1996).

4.3 ROTATIONAL GRAZING (PADDOCKS)

The paddocks or grazing schemes are seen as part of a strategy for preventing environmental degradation and for improving the management of communal area livestock production (Zimbabwe, 1987). While the intentions of the strategy are laudable an extensive review of experiments on rotational grazing cast doubts on their effectiveness. "No rotational system consistently resulted in improved pasture or increased animal production" (Gammon, 1978: 75). The Mashayamombe scheme worked on a four-paddock rotation system but also involved using open access grazing for part of the year (Shayawaedza, 2001). The long-term viability of the scheme was questionable. If all cattle owners joined the scheme, for instance, and the whole open access grazing area was fenced off into paddocks there would be no facility for the fenced rotated grazing

Table 4.1a Environmental evaluation matrix

Procedure for completion of matrix

1. Identify all actions (located across the top of the matrix) that are part of the project/s whose impacts are being assessed.

2. Under each of the stated actions, shade the box at the intersection with each item on the side of the matrix if an impact is identified.

3. Key to the shading

- □ Negligible impact/No impact
- ▒ Minor and/or local and/or temporary impact
- ■ Major and/or extensive and/or permanent impact
- \+ Positive impact
- \- Negative impact

4. The accompanying text (Table 4.1 b) discusses the significant impacts, those columns and rows with large numbers of shaded boxes and the +/- sign in each box.

			A. Modification of regime					B. L… a	
ENVIRONMENTAL COMPONENTS		PROJECT ACTIVITIES	a. Modification of habitats	b. Exotic flora modification	c. Alteration of ground cover	d. Alteration of groundwater hydrology	e. Road surfacing or paving	a. Brick moulding	[illegible]
PHYSICAL, CHEMICAL AND CULTURAL CHARACTERISITICS	1. Earth	a. Construction materials		■ -				■ -		
		b. Soils			▒	■ -	■ -		▒	
		c. Landform								
	2. Water	a. Surface water					▒			
		b. Groundwater					▒			
		c. Quality					▒			
	3. Atmos	a. Quality (gases, particulates)								
		b. Climate (micro, macro)								
		c. Temperature								
	4. Biological factors	Flora								
		a^1.Woodlands		■ -	▒					■
		b^1.Grassland areas		■ -		■ -				
		Fauna								
		a^2. Large mammals		■ -						
		b^2. Small game, etc		■ -						
	5. Processes	a. Floods								
		b. Erosion						▒		
		c. Deposition (sedimentation, precipitation)								
		d. Compaction and sealing								
	6.Cultural factors	Land use								
		a. Agriculture				■ -	■ -			
		b. Pasture				■ -				
		c. Built-up area								
		d. Social forestry			▒					▒
		e.Historical monument:Kaguvi's stronghold								

Source: Adapted from several sources (Leopold, et al, 1971; Devuyst, 1993; Morris & Therivel, 1994; Mitchell, 1989; Du Toit, 1982

...ation ...on	e. Small dam construction
	f. Powerlines and telephone lines
C. Resource extraction	a. Building poles (cutting)
	b. Thatching grass (cutting)
	c. Felling trees for fuelwood
	d. Livestock grazing: open access pasture
	e. Livestock grazing: fenced-in pasture
	f. Livestock watering: dams
	g. Livestock watering: rivers
	h. Livestock watering: boreholes, wells
	i. Gravel mining
	j. Riversand mining
	k. Digging up termitaria
	l.Collecting leaf litter form woodlands
	m.Ground water abstraction: bore-holes & wells
	n. Cultivation of gardens in wetlands
D.Resource renewal	a. Afforestation
	b. Gully reclamation
	c. Agroforestry practices
	d.Fallowing
E Changes in traffic	a. Human tracks
	b. Livestock tracks
	c.Road traffic
F Waste emplacement and treatment	a.Waste disposal: household waste
	b. Waste disposal: human excreta
	c.Waste disposal: business centres and institutions
	d.Dust generation and deposition

Table 4.1b Environmental evaluation matrix interpretation

ENVIRONMENTAL EVALUATION MATRIX: MAIN ENVIRONMENTAL IM					
V	H	Nature of impacts	V	H	Nature of impacts
Aa	1a	Degradation and/or depletion of woodlands, grasslands and soils	Bc	4b1	Abandoned/fallowed agricultural land unable to rec
Aa	4a1	Woodland depletion	Bc	4a2	Large mammals moved out of area to less affected a
Aa	4b1	Degradation of grasslands	Bc	4b2	Small game no longer as abundant as before
Aa	4a1	Large mammals moved out of area to less affected areas	Bc	6a	Field areas now need heavy fertilization with manur
Aa	4b1	Small game no longer as abundant as before	Be	1a	Stones and soil used in construction
Ab	1b	Minor effect on soils at local level	Bd	1b	Soil fertility very low as poor farmers are unable to
Ab	4a1	Has added to amount of woodland in the area	Bd	5b	Soil loss through rill and sheet erosion is common d
Ab	6d	Adversely affected due to depletion of natural forest	Bb	5c	Deposition of eroded soil much in evidence at sever
Ac	1b	Soils: reduced infiltration rate and reduced organic content	Bf	4a1	Trees cleared along line routes; regular trimming of
Ac	4b1	Grasslands degradation and depletion	Ca	1b	Soil nutrients depleted and soil exposed to erosion
Ac	6a	Agriculture replaced natural vegetation in large areas	Ca	4a1	Woodland depletion and degradation
Ac	6b	Pasture depletion and degradation	Cb	1a	Thatching grass now hard to find
Ad	1b	Vertical flow of water through soil profile adversely affected	Cb	4b1	Woodlands scoured for any type of grass usable as t
Ad	2a	Surface water adversely affected	Cc	1b	Soil exposed to erosion
Ad	2b	Amount and quality of groundwater adversely affected	Cc	5b	Soil erosion aided by removal of trees
Ad	2c	Quality of surface water adversely affected	Cc	6d	Social forestry adversely affected
Ad	6a	Agriculture adversely affected by water management practices	Cd	4a1	Some woodland species used as browse - degrading
Ae	1a	Gravel and stones required on a continuing basis	Cd	4b1	Grasslands severely overgrazed in areas
Ae	5b	Surfacing and maintenance affect run-off and infiltration - affects erosion	Cd	4a2	Wild large mammals now a rarity in the area
Ba	1b	Negatively affects soil locally - soil dug up and used in process	Cd	4b2	Small game no longer as abundant as before
Bb	4a1	Woodlands depleted and degraded	Cd	6b	Pasture degradation
Bb	6d	Social forestry adversely affected	Cd	5b	Pastures prone to erosion after extended drought
Bc	1b	Soil nourishing /protection role of trees removed, soils poorer	Cd	5d	Compaction and capping regularly occur due to tram
Bc	2b	Groundwater supplies affected as trees assist in groundwater recharge	Ce	4a1	Woodlands tend to be protected by restricting access
Bc	4a1	Woodland dwindled over the years			

V = vertical axis H = horizontal axis

AL RESOURCES MANAGEMENT PRACTICES IN MASHAYAMOMBE WARD (MHONDORO)

	V	H	Nature of impacts	V	H	Nature of impacts
a	Ce	4b1	Grassland not overgrazed in one season	Db	1b	Stabilizes the gullies and rehabilitates the soil in the damaged areas
	Ce	4a2	Large mammals absent, virtually	Dc	1b	Common practice in the area, helps to preserve soil fertility and structure
	Ce	4b2	Small game more in evidence than in open-access	Dc	6a	Aids sustainable agriculture with minimum application of artificial fertilizers
	Cf	2a	Surface water murky due to livestock wading in and muddy dam bottom	Dd	1b	Fallowing has assisted soils to recover from continuous cultivation
	Cf	2c	Water quality poor, unfit for human use	Dd	6a	Has benefited agriculture when used properly as part of a rotation system
	Cg	2a	Surface water of variable quality - tends to be muddy	Dd	6b	Has helped to increase the size of the pastures, temporarily
	Cg	2c	Water quality poor, unfit for human use without further treatment	Ea	1b	Soils adversely affected by trampling
	Ch	2b	Groundwater problems in extended drought; water table goes deeper	Ea	5b	Aids the erosion process: detaches the soil and/or compacts the soil
	Ch	2c	Water quality good; however some wells are too close to pit latrines	Ea	5c	Creates material for eventual deposition
	Ci	1a	Gravel mining has degraded land at several sites along the main road	Ea	5d	Compaction and sealing follow from this process
	Ci	5b	Effect on erosion localized; some gravel pits actually rehabilitated	Eb	5b	Erosion has resulted from livestock tracks
	Cj	1a	River sand extraction modifies sand habitats	Eb	5d	Compaction and sealing have resulted from this
	Cj	5b	Riversand extraction damages banks causing erosion	Ec	5b	Road traffic in untarred road loosens material eventually removed by run-off
	Ck	1b	Improves mineral content of soil locally in area where termitaria is applied	Ec	5d	Road traffic in untarred road has trampling effect on the soil
	Cl	1b	Locally improves organic content of soil where litter has been applied	Fa	2a	Locally, household waste disposal practices affect surface water adversely
	Cl	6a	Benefits agriculture on a localized scale	Fa	2c	Water quality affected adversely by dumping of waste in the open
	Cl	5b	Exposes soil to overland flow; may aid erosion	Fb	2a	Many households lack pit latrines; human excreta contaminates surface water
	Cm	2c	Groundwater depletion in extended drought; water table goes deeper	Fb	2b	Contamination may occur locally if pit latrines are located too close to wells
	Cm	2b	Water quality good; wells too close to pit latrines may lead to contamination	Fb	2c	Surface water not good, groundwater generally safe for direct human use
	Cn	2a	Gardens in wetlands deplete supplies of surface water	Fc	2a	Surface water adversely affected by dumping practices
	Cn	4a1	Has increased agricultural productivity	Fc	2b	Groundwater generally of good quality - inspected by licensing authorities
	Cn	4b1	Depletes and degrades pastures as less land is available for pasture	Fc	2c	Water quality quite good
k	Cn	5a	Flood risk may increase due to removal of sponge effect of wetlands	Fd	4c	Dust a major problem as greater part of the road is untarred
	Da	1b	Provides the soil with organic matter and facilitates mineral exchange	Fd	5c	Settled dust contibutes to cappig during the rainy season
	Da	6d	Social forestry benefits as community meets its wood needs			

schemes to be "rested". The paddocks would have to be in use continuously during the cropping season. It was apparent that the paddocks could not sustain such pressure. As things stood, non-members continually challenged the expropriation of open access pasture by a select group, resulting in the intermittent nature of some of the fenced paddocks.

4.4 EXTENT OF WOODLAND DEGRADATION AND GULLYING, 1982-1997

The map resulting from the coverages digitized from the geo-referenced aerial photographs for 1982 and 1997 indicates that significant deforestation occured in the fifteen-year period (Figure 4.1). Table 4.2 illustrates some of the main changes.

Table 4.2 Temporal changes to extent of woodland area and cultivated area: 1982 - 1997

Land use type	1982		1997		% loss/gain
	Area (km^2)	% cover	Area (km^2)	% cover	
Natural woodland	96.3	56.7	78.7	46.3	- 18.3
Planted woodland	-	-	1.2	0.7	+ 0.7
Cultivated area	73.7	43.3	90.0	53	+ 22.3

The net loss of woodland (18.3%) was due to the expansion of field areas at the expense of the woodland areas and the encroachment of cultivated areas right onto the banks of the rivers in several places.

After the Communal Land Act of 1982 had transferred the power to allocate land from central government to district councils the 1980s saw some contradictions in the land allocation procedures and apparently some people took advantage of that to settle in areas previously forbidden. "Chiefs and headmen and entrepreneurs and village committees and peasant households were all involved in the processes of land allocation, appropriation, and use in the communal areas during these years" (Ranger, 1993: 363). It is important to state, however, that many individual trees were visible in fields, despite

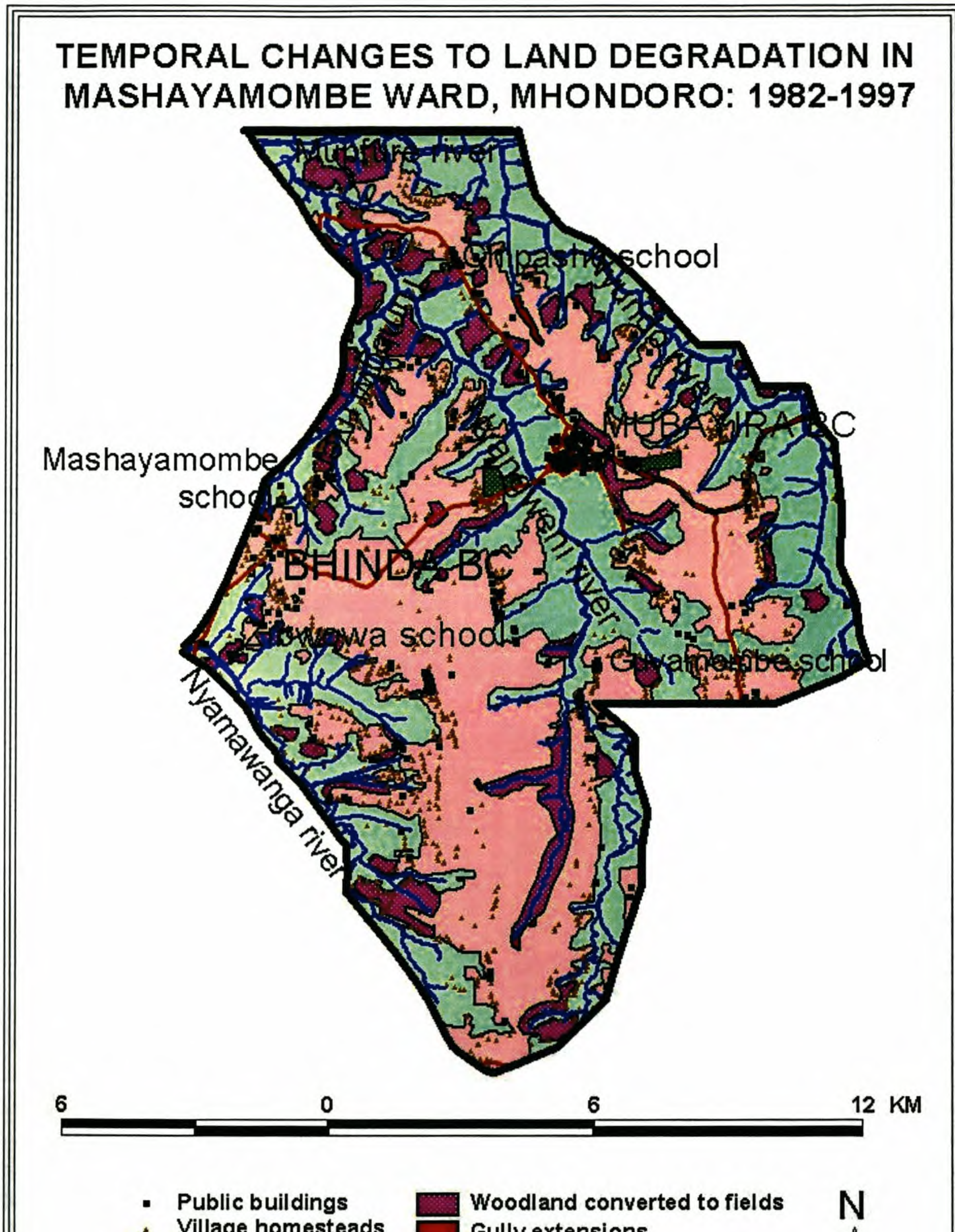
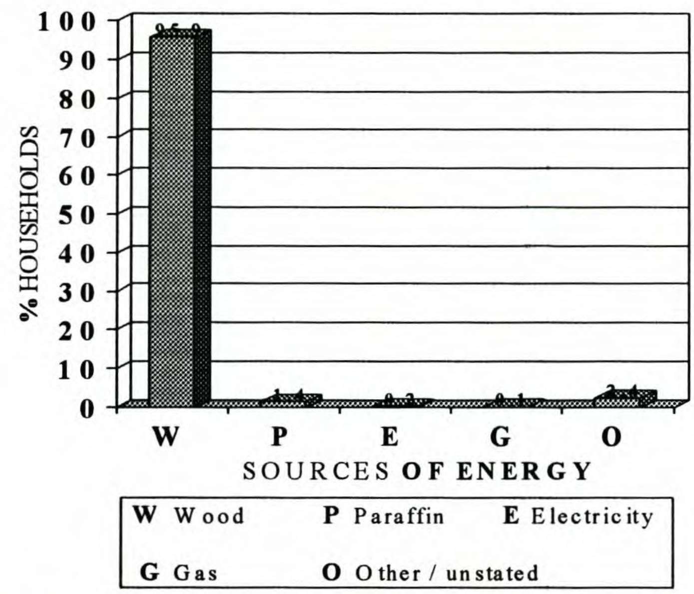


Figure 4.1 Woodland depletion, field expansion and gully encroachment, 1982-1997

the apparent deforestation.

4.5 WOODFUEL AND WOODLAND MANAGEMENT

Most people in the area use woodfuel as the main source of energy, with a few using paraffin, electricity and gas, as illustrated in Figure 4.2. A study on demand for wood in



Source: Adapted from 1982 national census data (CSO, 1990: 15)

Figure 4.2 Type of energy used for cooking: Mashonaland West Province, 1982

Zimbabwean communal lands, including those in Chegutu district where the study area is situated, came up with some staggering amounts of wood requirements as shown in Figure 4.3 on the following page (Whitsun Foundation, 1981). Most houses in the area are built of bricks, and poles are required only for roofing. Not all households require livestock kraals and, once built, the kraals can last for several years before they need to be repaired. The demand is, therefore, greater for fuelwood than for other purposes. The graph in Figure 4.4 (next page), based on responses to the questionnaire survey, reflects a comparable pattern to that of the earlier study. It shows a large demand for fuelwood in Mashayamombe area, with 55% of households requiring 500kg of wood per week each. Such fuelwood consumption patterns place woodland resources under severe strain.

Figure 4.5 illustrates the distances travelled by villagers in search of firewood. Normally, longer distances would indicate scarcity of woodfuel near the homesteads. However, in this case there is not much woodland left to go to; people have to find fuelwood within 5km of their homes. The time spent by household members gathering woodfuel for the week is a measure of the magnitude of the problem. About 66% of households spend 2 –5 hours (or more) gathering one week's supply of woodfuel (Figure 4.6).

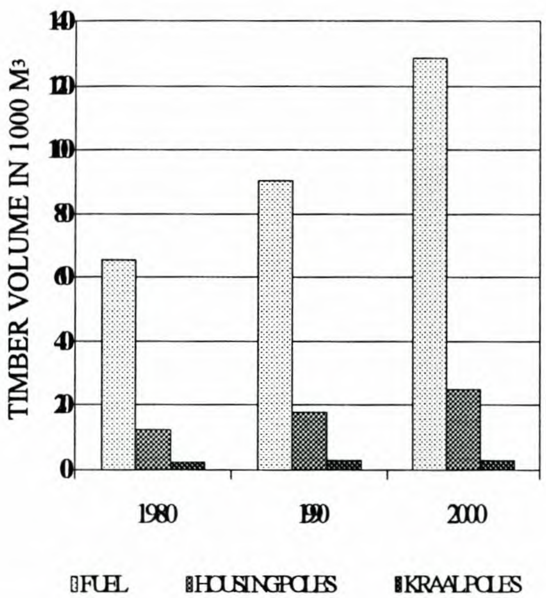


Figure 4.3 Estimated quantities of timber used in communal lands of Chegutu district per decade, 1980-2000

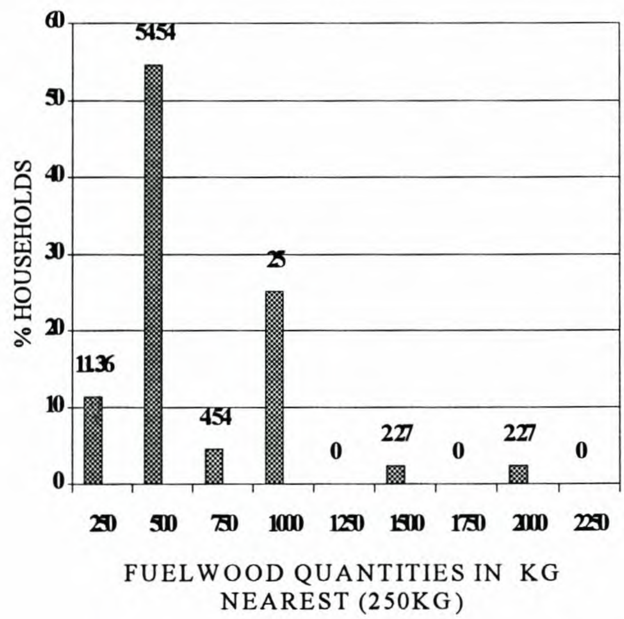


Figure 4.4 Weekly supply of fuelwood collected by households in Mashayamombe ward

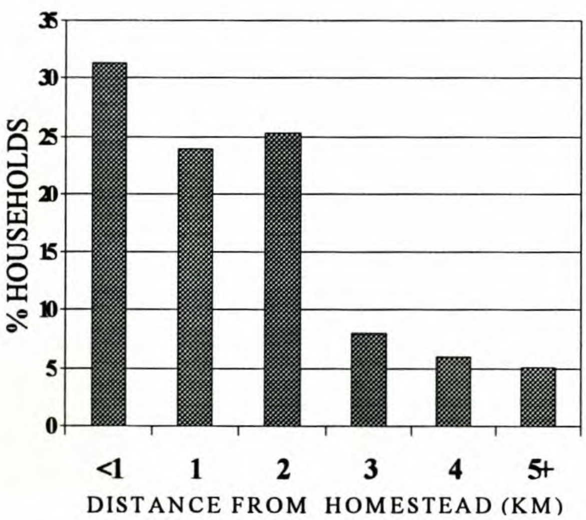


Figure 4.5 Distance travelled by villagers to gather fuelwood

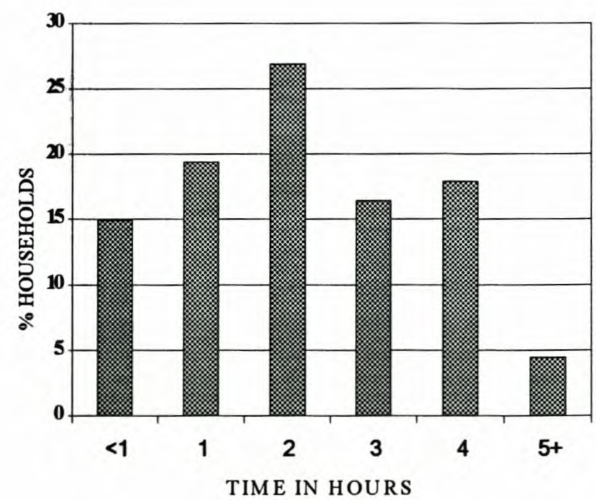
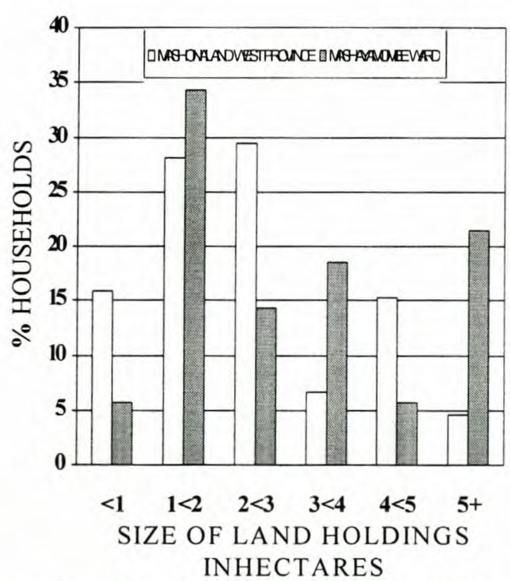


Figure 4.6 Time spent gathering one week's supply of fuelwood

species in the area, is in an ambivalent position. It is conserved in fields but because its canopy covers so much farmland beneath it (and, one suspects, because it burns beautifully!) the farmers regularly lop off its branches and use them as firewood.

Villagers showed that they valued woodlands as natural resources in various contexts and appreciated the need for conservation. Figure 4.9 on the preceding page summarises the various uses of woodland products as stated by the householders. Thatching grass was another valued product which, unfortunately, had become scarce as indicated by the varied nature of sources of thatch grass (Figure 4.10, on preceding page). Some 44% of households got their thatch grass requirements from contour ridges in fields and 18% of households from commercial farms (mostly without the consent of the farmers!). Land hunger was apparent in both Mashonaland West Province, with 80% of households cultivating under 4 hectares each, and Mashayamombe ward, with 71% of households cultivating under 4 hectares each (Figure 4.11). Despite the limited size of many of the landholdings in the area about 72% of households were prepared to devote some of their land to private woodlots adjacent to the homestead (Figure 4.12). Both exotic fruit trees and non-fruit trees were grown at homesites and in the



Source: Provincial % computed from national survey(CSO, 1998: 2) Mashayamombe ward % compiled from questionnaire data.

Figure 4.11 Size of communal landholdings in Mashonaland West Province and Mashayamombe ward, 1998/2001

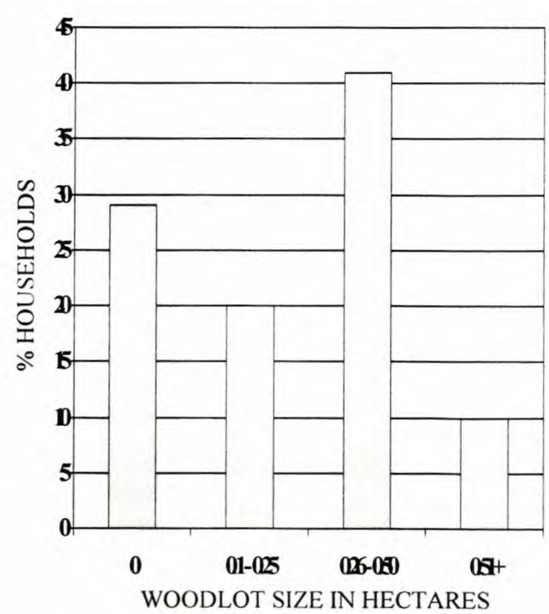


Figure 4.12 Size of homesite woodlots owned by Mashayamombe households

fields. Over 51% of households owned at least 1 – 5 exotic fruit trees and 1 – 5 exotic non-fruit trees at homesites (Figure 4.13, next page). In the fields 40% of households owned 1-5 fruit trees and 21%

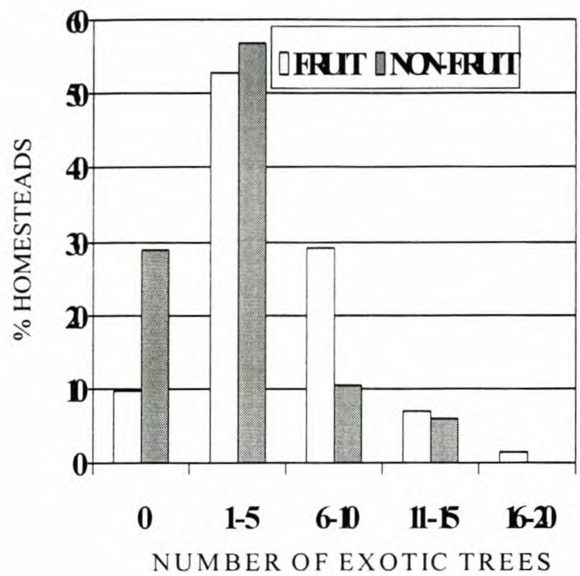


Figure 4.13 Number of exotic trees owned at homesites

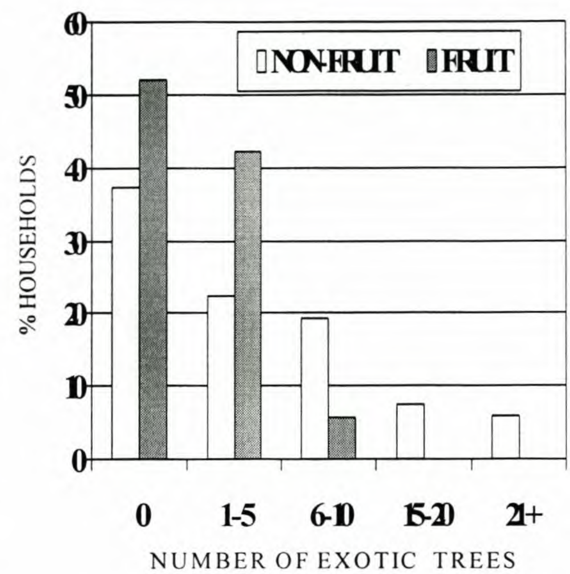


Figure 4.14 Exotic trees owned by households in Mashayamombe ward

of households owned 1–5 non-fruit trees (Figure 4.14). This tree-growing tradition could be put to good use in environmental conservation programmes.

4.6 TEMPORAL CHANGES IN SPATIAL EXTENT OF GULLIES

While in some localities there have been efforts to stop and then to stabilize gullies, the area affected by gully erosion and the number of gullies increased significantly between 1982 and 1997. Extensions to gullies covered an area of at least 0.42 km^2, with the largest gully located east of the Chipashu-Mubayira road, on a tributary of the Nyundo river (Figure 3.1). The clearing of woodlands and ploughing of fields almost right up to the banks has put the land on either side of the river banks at risk.

5.7 WATER RESOURCES AND POLLUTION

There appears to be adequate supplies of surface water for livestock and wildlife in the area for most of the year. However, the quality of the surface water is such that it is not advisable for humans to use the water directly, without first treating the water or boiling it. The majority of the people use water from wells and boreholes; 69% of households used water from their own wells and 16% of households depended on communal boreholes (Figure 4.15). While groundwater supplies seem adequate during years of normal rainfall the potential for the drying-up of these sources in drought years is ever- present as indicated by some of the residents' responses (Figure 4.16). Some 15% of households reported that underground water sources had dried up in the ten-year period preceding the study. In periods of extended drought the DDF had to deepen some of the wells to ensure continued supplies (DDF staff, 2001).

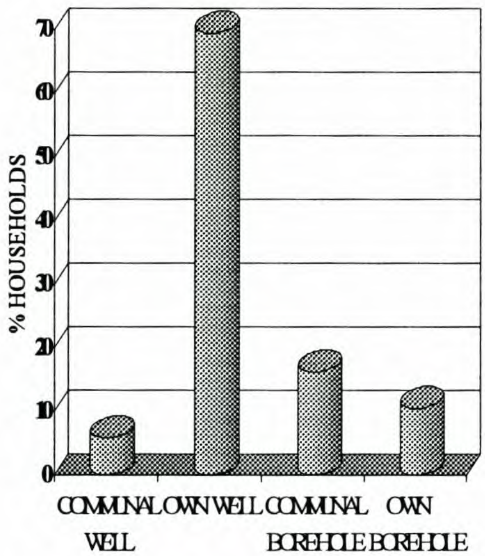


Figure 4.15 Source of water for domestic use by Mashayamombe residents

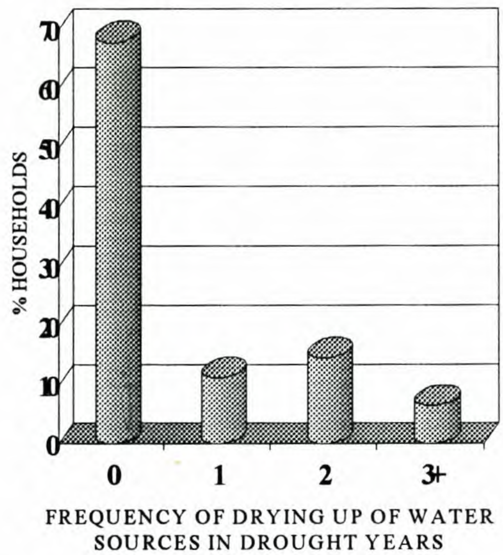
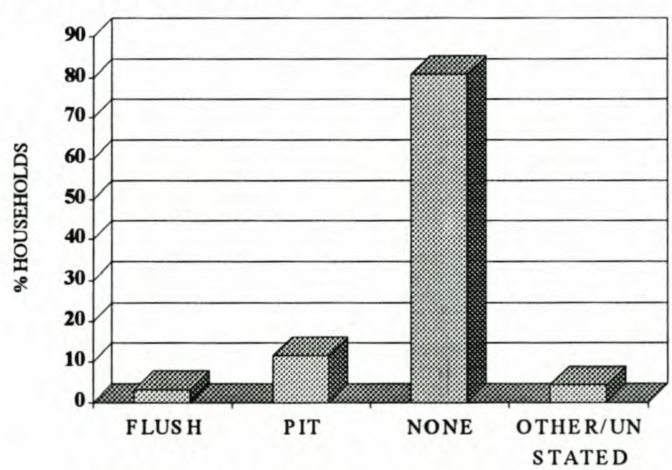


Figure 4.16 Reported experiences of groundwater shortages in drought years in the period 1990-2000

The siting of some of the wells with respect to pit latrines raises the spectre of groundwater contamination. Surface water quality is poor because of the sanitary habits of many of the inhabitants; 81% of households had no toilets and residents relieved themselves in the bush (Figure 4.17). The rivers and dams are also polluted by the actions of livestock as already explained



Source: Adapted from 1982 national census data (CSO, 1990: 15)

Figure 4.17 Type of toilet facility for Mhondoro residents, 1982

(see Section 4). Though the problem of land pollution has not yet reached the magnitude of urban waste management problems, it is a growing concern, especially at the numerous business centres spread throughout the study area.

4.8 EXTENT AND SEVERITY OF LAND DEGRADATION IN ASHAYAMOMBE WARD AREA

An examination of time-lapse aerial photography of the area and related maps followed by field studies of parts of the area will confirm that the area has succumbed to land degradation in its various forms. There has been a progressive depletion of woodlands (see table 3.7); grasslands have gradually given way to fields, and in the uncultivated areas, to bush encroachment. Degradation has also manifested itself in the form of gully erosion, stream sedimentation, pasture degradation and wildlife habitat degradation.

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

It is apparent that land degradation has occured in Mashayamombe ward, Mhondoro, and it manifests itself in different forms. These include soil erosion and stream sedimentation on a substantial scale, woodland depletion, pasture degradation and wildlife habitat degradation. Degradation has been partly due to the fragile nature of the soils, their continued intensive use over long periods of time without adequate replacement of soil nutrients, and high population and livestock densities. Overutilisation of the land rather than the communal nature of land use and natural resources management is the problem. Mhondoro is hemmed in by commercial farms and expansion of settlements into neighbouring areas has proved difficult.

The fragile nature of the sandy soils of the uplands, the sodic soils of the vlei areas, combined with the fairly high rainfall amounts (annual average 750mm) make the area prone to soil erosion. Rainfall intensity tends to be high in the area and when the rain falls on the poorly vegetated, extensively compacted and highly erodible soils erosion occurs.

The area has been home to human settlement for over a century (Ranger, 1967). As the human population has increased over the years, reaching a density of around 93/km^2 by the year 2001, together with increased livestock numbers (cattle density of 110/km^2), the biophysical environment has come under severe strain. The savanna grasslands and most of the woodlands have given way to agriculture. The soils of the area have a relatively low inherent fertility and require regular soil organic and inorganic material inputs. Due to the general poverty of the communal farmers (Mehretu, 1995) the replacement of nutrients into the soil has not kept pace with the deteriorating condition of the land. The low–input low–output communal style of agriculture, has had to grapple with striking a balance between traditional farming practices and adopting a market-oriented agricultural system reliant on artificial fertilizers and chemicals. Some authors see a contradiction between certain official policies which advocate agricultural practices that result in deforestation (e.g. emphasis on cash crops has led to clearance of more land)) and attempts at sustainable vegetation conservation (Chipika & Kowero, 2000).

The environmental evaluation matrix and its accompanying text summarize the aspects of the environment that have been degraded and the extent to which they have been degraded (Tables 4.1a & 4.1b). These include degradation and erosion of soils, woodland depletion and degradation, and pasture degradation.The results of the tree density counts (Table 4.1) indicate a worsening woodfuel problem in view of the levels of consumption indicated (Figure 4.4). While many households owned woodlots, it was interesting that hardly anybody mentioned a preference for using the gum trees in the woodlots for woodfuel. The sustainability indices checklist suggests that local natural resources management practices have to change if the communal lifestyle is to be sustainable ecologically and socio-economically (Tables 5a & 5b).

5.1 CONCLUSIONS

The nature and extent of land degradation in Mashayamombe ward in Mhondoro can be summed up thus:

- Serious sheet erosion occurs in the area whenever the rains are fairly heavy; evidence of substantial stream sedimentation supports this
- Gully erosion is quite serious in certain localities though some efforts are being made to stabilize and to stop the gullies
- Pasture degradation has reached disturbing levels and manifests itself through bush encroachment, changes in grass species and soil erosion
- Soil nutrient depletion is evident even in the communally managed areas where abandoned fields do not seem to re-grow any meaningful levels of vegetation
- The degradation of wildlife habitats is illustrated by the scarcity of bigger game in the area and fish in the rivers and dams
- The area appears to have exceeded optimum levels for population carrying capacity and livestock numbers.

Remedial and/or mitigatory measures for the environmental recovery of the area should take a regional approach such as whole-catchment management. They should involve the

Table 5a. Sustainability indicators checklist

SUSTAINABILITY INDICATORS FOR COMMON PROPERTY RESOURCES PROJECTS IN MASHAYAMOMBE WARD, MHONDORO

Questions	A Grazing schemes: fenced paddocks	B Open-access pasture	C Communal woodlot (planted)	D Natural woodlot management	E Gully control and reclamation	F Dam project (several dams)	G Communal use of rivers
1.Is project oriented to needs of users?	●	●	●	●	●	●	●
2.Is focus on women or rural disadvataged?	○	○	○	○	○	○	○
4.Are local human resources (skills, knowledge, values, organizations) used?	●	●	●	●	●	●	●
5. Are local materials (land, energy) used?	●	●	●	○	●	●	○
6.Is project sustainable in the long term? (ecologically & socio-economically)	○	○	●	●	○	○	●
7.Is aid limited in amount to prevent aid dependency?	●	○	●	○	●	●	○
8.Are new group alliances formed (or is poor-rich gap widened)?	○	○	○	○	●	●	○
9.Is regional coordination sufficient (or is there conflict with regional plans)?	○	○	○	○	○	○	○
10.Is there shift in power toward disadvantaged groups?	○	○	○	○	○	○	○
11.Is leadership style open & participatory?	●	○	○	○	●	○	○
12.Do the chiefs, councillors participate?	●	●	●	●	●	●	●
13.Is management elected/replaced democratically?	○	○	○	○	○	○	○
14.Is there a project budget & regular financial reporting?	○	○	○	○	○	○	○
15.Project management plan?	●	○	●	●	○	○	○
16.Compliance & monitoring (i.e. monitoring)?	●	○	●	●	○	○	○
17.Enforcement arrangements?	●	○	●	●	○	○	○
18.Any training for members?	○	○	○	○	○	○	○
19.Subscriptions, whole group determined?	●	○	○	○	○	●	○
20.Any income generation? (Does it cover cost?)	○	○	●	○	○	○	○

Source: Questions 1-10, Timberlake (1985: 218-219) ● YES ○ NO/NOT APPLICABLE

Questions 11-20, adapted from Buzzard (1995: 18) Shading and interpretation of checklist are author's own

Table 5b. Interpretation of sustainability checklist

Ideally, any activity or project for which the answer to all the 20 questions is YES should be sustainable. In practice, any one or several of the questions resulting in a NO answer may be an indication that the project will not be sustainable. It is the writer's assessment that out of the seven communally managed projects only three wil be sustainable under current practices, namely, communal woodlot management, natural woodlot management, and communal river usage. Common causes for the actual and/or potential unsustainability of all the projects are as follows: failure of projects to focus on women or the rural disadvantaged, insufficient regional coordination of policies and practices, project failure to empower disadvantaged groups, imposition of unelected management, lack of regular and accountable financial reporting, and inadequate or lack of training for project activities. The failure to focus on women is of particular significance for sustainability given that in communal farming households in Mhondoro and elsewhere much of the agricultural work and routine decision-making are in the hands of women (Zinyama, 1986).

Specific threats to sustainability of each project

A 6	Schemes currently subsidised by open access pasture	D 13	Project management not democratically elected - may lead to disputes over entitlements
A 9	Insufficient coordination of project activities regionally	E 6	Whole catchment management strategy needed
A 10	Project does not empower disadvantaged groups	E 9	Insufficient coordination of project activities regionally
B 6	Livestock carrying capacity now stretched to the limit	E 14	No project budget
B 8	The rich tend to take advantage of open access pasture at the expense of the poor	E 18	No training for specific project activities
B 9	Insufficient coordination of project activities regionally	F 9	No operational whole catchment management strategy for water resources
B 10	Project does not empower disadvantaged groups	F 14	No project budget
C 8	Project run by council officials - people's support for project dependent on perceived benefits	F 15	No coherent official management plan
C 9	Woodlots located in a few localities - benefits may not be apparent to those not near them	F 18	No training for specific project activities
C 10	The influential derive more benefits from project than the rest	G 8	Residents need to cooperate in controlling streambank cultivation
C 13	Management not elected - in event of disputes representativity of managers may be contested	G 9	Insufficient coordination of project activities regionally
D 8	The richer may exploit greater share of a communal resource (woodland)	G 14	No project budget
D 10	Project does not empower disadvantaged groups	G 15	No evident management plan for project

participation of local residents throughout the whole cycle of project planning, implementation and monitoring (Scoones & Cousins, 1989). Studies have shown that small-scale farmers can successfully adapt their tree conservation traditions to their current wood needs by planting of purpose-specific species in designated areas (Bradley, 1991; Bradley & Dewees, 1993; Campbell, *et al*, 1991; Clarke, 1994).

5.2 RECOMMENDATIONS REGARDING SOLUTIONS

More specifically the following measures are recommended:

- A comprehensive gully reclamation and rehabilitation strategy, involving both mechanical and biological controls, should be launched and sustained on a catchment-wide scale rather than the current piece-meal approach
- The well-established agroforestry practices of the area should be encouraged and supported officially as they will assist in the recovery of the pastures and the soil and slow down soil erosion
- The practice of rotational grazing in a communal management setting is problematic; it should either be discontinued or radically revised
- The development of woodlots should focus on indigenous species as these are preferred for woodfuel; smaller areas could be set aside for exotic species grown as commercial timber
- There should be a moratorium on new settlements in the area and an upper limit should be set on the number of livestock a household can keep.

5.3 EVALUATION OF THE RESEARCH

The research project was a case study of the environmental impacts of communal land uses and natural resource management practice in Zimbabwe's communal areas. The research was conducted on a limited budget and the approach chosen tried to strike a balance between an academically sound and thorough inquiry and a relatively inexpensive yet comprehensive study.

5.3.1 **Strengths of the research**

- The combined use of time-lapse aerial photography, GIS, ground truthing, a questionnaire survey and interviews with key informants enabled the carrying out of an environmental assessment of a fairly large area by one researcher with the help of two assistants. Normally, this task requires input from an expensive multi-disciplinary team of assessors.
- Analysis and interpretation of data gathered on the few strategic sites visited on the field trips, together with that of data from documentary sources and interviews, yielded a fairly accurate picture of the state of land degradation in Mashayamombe ward, Mhondoro.
- The study will provide some useful baseline data for any future studies on land degradation in the area or for planning and management of communal land use in Mhondoro and similarly designated rural areas.

5.3.2 **Limitations of the research**

- The major drawback with aerial photographs is that they depict historic or static environmental conditions; they do not show the current status of the environment of concern. Ground truthing partially remedies the problem. Ideally, on-going regular monitoring of the situation can be done through analysis of the latest satellite imagery of the area, where this is available.
- The combined use of aerial photographs and GIS requires access to the technology and personnel competent in its use. These are not available in many parts of the developing world; aerial photographs for certain areas are not available. In these circumstances a different approach to environmental assessment needs to be adopted.
- Due to financial constraints it was not possible to carry out or arrange for detailed physical and chemical tests to determine water quality as an indicator of pollution levels in the dams and the rivers. It would have entailed bacterial tests, testing pH, alkalinity, nitrate, phosphate, and chloride levels and testing for dissolved oxygen

levels and suspended solids. These tests have to be done several times and in different seasons of the year (Hill, *et al,* 2000).

- Due to several logistical problems beyond the control of the researcher it proved impossible to get useful statistical information on the environmental health status of the community in the study area. It would have been instructive to look at hospital records to see the most common ailments suffered by residents and to check for any link between the causes of the ailments and the condition of the local environment.

5.3.3 Further research: recommendations

Future research could focus on modeling ideal communal settlement patterns in the light of the above findings. Attention could be given to finding the optimum population densities and animal densities for given agro-ecological regions of Zimbabwe (or other countries experiencing similar land degradation problems).

One of the major causes of deforestation in the communal areas is the ever-present need for woodfuel as a source of energy for most households. Research is needed, therefore, to examine effective ways of cutting down on wodfuel demand or increasing the quantities of wood produced through tree-growing programmes. Alternative sources of energy which are fairly inexpensive and sustainable should be explored.

The question of land degradation should be approached in terms of integrated, community-based catchment management solutions. To this end, research could examine ways of promoting public participation in environmental management planning and monitoring, as well as in environmental impact assessments.

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PERSONAL COMMUNICATIONS

Bangira, R 2001. Administrative Officer, Mhondoro sub-office of Chegutu District Council. Mubayira. Interviews on June 11 and June 14 about land allocation, planted communal woodlots, communal management of woodlands, communal land uses and the overall condition of the biophysical environment in Mashayamombe ward and in the rest of Mhondoro.

District Development Fund staff (DDF staff) 2001. Field depot staff. Mubayira. Interview on June 21 about maintenance of rural infrastructure in Mhondoro, i.e roads, bridges, boreholes and communal wells.

Mashayamombe, M 2001. Chief in charge of Mashayamombe administrative ward, Mhondoro. Mubayira. Interview on June 14 about the boundaries of the ward, grazing schemes, communal land uses, enforcement of communal woodland management rules, land allocation to new arrivals and land degradation in the ward and in Mhondoro generally.

Mhlanga, M 2001. Verterinary technician for Mhondoro. Mubayira. Interview on June 21 about the numbers and condition of livestock in Mashayamombe ward, as well as about grazing schemes in the area.

Muhlaba, R 2001. Retired Meteorological Services technician resident on the outskirts of Mubayira Business Centre. Interview on June 21 about communal land uses, observed manifestations of environmental degradation in Mhondoro, and his evident expertise in the practice of agroforestry.

Shayawaedza, T 2001. Semi-retired small business operator and community leader (committee member of grazing scheme group). Mashayamombe village. Interview on June 22 about grazing schemes, gully reclamation efforts and communal woodland resources management.

Shayawaedza, M 2001. Resident of Mashayamombe village and one of the field assistants. Interview on June 22 about communal land uses, grazing schemes and efforts at rehabilitation of eroded areas.

Takawira, T 2001. Teacher at Rio Tinto High School, Mhondoro, and one of the field assisstants. Mubayira. Iterviews on June 11 and June 24 about grazing schemes, planted communal woodlands, land degradation and efforts at rehabilitation of eroded areas.

APPENDIX A

MONTHLY AVERAGE RAINFALL AND TEMPERATURE FIGURES FOR MUBAYIRA, MHONDORO

Average temperatures (^{0}C): 1962-2000				Average rainfall (mm): 1930-2000
Minimum	Maximum	Average		
16.9	28.5	22.7	JANUARY	187.3
16.5	28.3	22.4	FEBRUARY	144.4
15.2	28.6	21.9	MARCH	82.4
12.5	27.5	20	APRIL	26.7
8.6	25.5	17.05	MAY	5.6
5.4	23.4	14.4	JUNE	2.7
5.4	23.3	14.35	JULY	0.6
7.0	25.9	16.45	AUGUST	2.9
10.7	29.3	20	SEPTEMBER	6.3
14.2	30.7	22.45	OCTOBER	31.3
16.1	30.0	23.05	NOVEMBER	97.5
16.8	28.4	22.6	DECEMBER	162.3
			Mean yearly total rainfall	750

Source: Figures recorded at Mubayira meteorological sub-station and supplied by the Meteorological Services Department, Harare.

APPENDIX B

QUESTIONNAIRE ON MANAGEMENT OF WOODLANDS, PASTURES AND WATER RESOURCES IN MASHAYAMOMBE WARD, MHONDORO COMMUNAL LANDS

Householders are kindly requested to answer the questions that follow as truthfully as they can. Responses will be treated in the strictest confidence. The purpose of the exercise is to build up knowledge on management of pastures and woodlands in communal areas. As a guarantee of your anonymity you are not required to give your name and address; no one will ever know which answers came from which respondents.

SECTION A: Personal details

1. Sex

M	F

2.Age

3. How long have you lived in Mashayamombe ward area (years)?

4.How many people make up your household?

SECTION B: Tree holdings, woodlots and natural woodlands

5.State the number of trees owned by your household as follows:

	Homestead	Field
Exotic trees		
Fruit trees		
Non-fruit trees		

	Homestead	Field
Indigenous trees		
Fruit trees		
Non-fruit trees		

6. Size of your household's landholding (all fields) - in hectares.

7.Area occupied by homestead woodlot (exotic/indigenous trees) – (hectares):

8. List seven products members of your household obtain from natural woodlands.

9. How far from your homestead do members of your household have to travel for fuelwood? (use **one** of miles or yards/ km or metres).

miles	yards	kms	metres

10.How much time do members of your household spend on gathering the family's one week supply of fuelwood?

Hours	Minutes

11.How much fuelwood does your household use per week? Estimate using ***one*** of the following units. *

Kilograms (1kg = 2.2 pounds)	
Headloads (1 headload = 29 kg)	
Cords (1 cord = 1m x 1m x 3m stacked wood = 1000kg)	
Scotchcarts (1 scotchcart = 1000kg)	

* units for headloads, cords and scotch carts taken from Campbell, *et al* (1995: 86)

12.State the names of four types of trees your household uses most / prefers for woodfuel.

13.Name any five trees or tree types members of your family avoid harvesting (cutting/collecting) for woodfuel.

14.Indicate which ***one*** statement best describes your household's fuelwood gathering habits. Put an X in the box next to the most appropriate statement.

a.Sometimes chop down live trees to supplement woodfuel stocks	
b.Always collect dry wood and/or chop down dead trees only	
c.Regularly chop down live and dead trees as well as collect dead wood	

d. None of the above	

15. Do you think natural woodlands should be preserved – even when there is a woodfuel shortage?

YES	NO

16. Do members of your household collect the following from the woodlands for use as a form of manure in the fields?

	YES	NO
a.leaf litter		
b.*termitarria* (termite mounds)		

17.Is your household a member of the following communal projects?

	YES	NO
a.Grazing scheme (paddocks)		
b.Communal woodlot		
c.Dam project		
d. Gully reclamation		

18.Have you as a household in the last five years permanently abandoned your old fields for new fields?

YES	NO

19.Are pastures in Mashayamombe area adequate for the numbers of livestock in the area?

YES	No

20. Where does your family get thatching grass from?

a.From fallow/abandoned fields	
b.From contour ridges in fields	
c.From the commercial farms	
d.From grazing lands	
e. From other source	

SECTION C: Livestock

21. Indicate changes in your livestock's numbers over time as follows:

	Change	Cattle	Goats	sheep
1999 total				
Loss through death	-			
Sold or slaughtered	-			
Purchased	+			
Increase by calving	+			
2001 total				

SECTION D: Water resources

22.Do you as a household use:

	YES	NO
a) a communal borehole?		
b) your own private borehole?		
c) a communal well?		
d) your own private well?		

23. Over the last ten years how many times has this borehole/well run out of water?

a. never	
b. once	
c.two times	
d.three times or more	

24.What is the source of drinking water for your livestock ?

a.River	
b.Dam	
c.Borehole	
d.Well	

APPENDIX C

CALCULATION OF AVERAGE SLOPE OF STUDY AREA AS ERODIBILITY FACTOR USING THE RATIO METHOD

This method expresses the difference in height between two points on a slope (one upslope, E^1, the other downslope, E^2) as a ratio of the distance, D, between the two points (SSDS-USDA, 1993:64-5). The map referred to here is Mubayira 1:50 000. The distance used was that from a point just west of Makaure school, at grid reference 500564, travelling in a north-westerly direction between the Nyangweni and Nyundo rivers, to a point on the banks of the Mupfure river, at grid reference 430796.

Slope gradient =

$$\left(\frac{E1-E2}{D}\right)x100$$

$$\left(\frac{1320-1240m}{48.6cm}\right)x100$$

$$\left(\frac{80m}{24.3km}\right)x100$$

$$\left(\frac{80m}{24300m}\right)x100$$

$$= 0.329\ \%$$

The average slope gradient of the study area is therefore of an angle of less than 1 %.

APPENDIX D

TREE SPECIES IN MASHAYAMOMBE WARD (MHONDORO)

SPECIES BOTANICAL NAME	SPECIES LOCAL NAME
Maytenus spp.	Chizhuzhu
Acacia karoo	Mubayamhondoro
Pterocarpus angolensis	Mubvamaropa
Zizyphus mucronata	Muchecheni
Mimusops zeyheri	Muchechete
Lannea discolor	Mugan'acha
Combretum molle / C. apiculatum	Mugodo
Combretum molle	Mugoro
Parinari curatellifolia	Muhacha
	Mujoki
Burkea africana	Mukarati
Acacia nigrescens	Mukochokocho
Terminalis sericea	Mukonono
Syzygium guineense	Mukute
Julbernadia globiflora	Munhondo
Flacourtia indice	Munhunguru
Ficus sycomorus / F. capensis / ficus sur	Muonde
Colophospermum mopane	Mupani
Dichrostachys cinerea	Mupangare
Brachystegia boehmii	Mupfuti
Annona senegalensis	Muroro
Colophospermum mopane	Musaru
Bauhinia thoningii /Piliostigma thoningii	Musekesa
Lannea discolor	Mushamba
Brachystegia spiciformis	Musasa
	Musosamakuva
Terminallia sericea	Mususu
Strychnos spinosa/Strychnos cocculoides	Mutamba
Gardenia asperula	Mutarara
Azanza garckeana	Mutohwe
Pseudo-lachnostylis maprineaefolia	Mutsonzowa
Vitex payos	Mutsubvu
Ximenia americana	Mutsvanzva
Albizia tanganyicensis	Mutsvedzagudo
Vangueriopsis lanciflora	Mutufu
Acacia tortillis	Muunga
Brachystegia glaucescens	Muunze
Peltophorum africanum	Muzeze
Uapaca kirkiana	Muzhanje

Sources (botanical names): Campbell, *et al*, 1995; Campbell, *et al*, 1989; Clarke, 1994; Mushongahande & Mazodze, 1996.

APPENDIX E

EXAMPLE OF AGROFORESTRY AND EXAMPLES OF WOOD USAGE

A good example of agroforestry in practice at Mr R Muhlaba's plot just in front of Rio Tinto High School's main entrance

Firewood for cooking pupils' lunch at Rio Tinto High School

Maize stored in a structure built of poles and wire mesh; firewood

Tree branches and saplings cut and used as fencing material

Examples of wood usage in Mashayamombe ward, Mhondoro