THE USE OF DAMBOS IN RURAL DEVELOPMENT with reference to Zimbabwe

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THE USE OF DAMBOS IN RURAL DEVELOPMENT, WITH REFERENCE TO ZIMBABWE

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SUMMARY

This report presents the results of a research project funded by the Overseas Development Administration (ODA) of the U.K. and carried out jointly by the University of Loughborough, U.K., and the University of Zimbabwe, between 1984 and 1987. Its subject is the role played in rural development by DAMBOS. These are small valley wetlands found commonly on the plateau savanna regions of eastern and southern Africa. Dambos are a multi-purpose land and water resource, being used for water supply, grazing and cultivation. The present study focusses on their use for small-scale garden cultivation in the communal areas of Zimbabwe. We estimate that Zimbabwe's dambo gardens cover 15-20 thousand hectares. Significantly, these have developed through local initiative and without the assistance of government or other outside agencies. In fact dambo cultivation in Zimbabwe has been discouraged by colonial legislation, still in force, which seriously constrains wetland cultivation for fear that it will cause erosion and drying-up of streams. In this study we assess whether existing and possible future cultivation could significantly deplete the natural resource base, and consider the constraints on and benefits of dambo use in three different communal areas of Zimbabwe.

Socioeconomic surveys were carried out on 200 households in four study sites covering access to, use of and income from dambo gardens. These socioeconomic studies, combined with an air photograph survey, reveal important differences between and within communal areas in terms of the density and size of gardens, the seasonality of cultivation and the type of crops grown. In the communal area with fewest and smallest gardens (Gutu), major constraints include an adverse natural environment and the strict implementation of legislation preventing garden cultivation.

In contrast, in the area with most gardens (Chiota) dambo cultivation forms an integral part of the agricultural system throughout the year, and offers an insurance against years when rainfed crops fail. This occured, for example, in 1986-87 when the only maize produced in many areas came from dambo gardens. Forty households were monitored in detail through the 1985-86 farming year, and three of these are used in this report to illustrate contrasting patterns of agricultural activity, labour expenditure and food consumption with regard to dambo utilisation.

Soil analyses were undertaken on catenas in five dambos and show that the upper dambo zone, which normally remains wet throughout the year, has many advantages over dryland ('sandveld') soils in terms of the potential for crop cultivation.

Investigation of organic matter content at 108 paired sample sites - one cultivated, the other not - showed no significant differences in soils with organic matter below 5%. Similarly, erosion plot and gully monitoring studies suggest that garden cultivation does not appreciably increase soil losses from dambos. It is concluded that the upper part of sandy dambos can be cultivated without destroying the soil resource base.

Hydro-meteorological studies included the establishment of a meteorological station, a gauging weir, a system for measurement of evapotranspiration (DREAM), and a network of piezometer holes within a single dambo catchment (Chizengeni). It is established that evapotranspiration losses from gardens cultivated without irrigation will not differ substantially from those under grazed dambo grassland, and that cultivation has a minimal effect on dry season streamflow. This is because groundwater storage - the source of water for dambo cultivation - lies mostly beneath the dryland part of the catchment. This is largely isolated from stream baseflow by a relatively impermeable horizon which causes water to seep out in the upper dambo zone, which is explained here in terms of a storage-seepage model. Finally calculations of the effect of expanding dry season irrigation to cover the whole of the cultivable upper zone of Chizengeni dambo predict that in an average rainfall year the water table would fall only by an additional 10-20%.

It is concluded that existing dambo cultivation brings important benefits to farmers in Zimbabwe's communal areas, whilst having few - if any - adverse environmental consequences. Gardens provide food security through the production of staple crops, a varied diet from vegetables and also cash incomes. Cultivation of a garden, over which the farmer has control, provides an additional means of improving household welfare. Garden cultivation appears best suited to the upper, wet zone of dambos, and should not normally exceed 10% of the total catchment area. Within these and other environmental limits outlined in this report, there exists the potential for a five-fold increase in dambo garden cultivation in Zimbabwe. To facilitate such an expansion, there is a need to clarify national policy, in particular regarding restrictive legislation, and assist with the provision of agricultural advice and credit. It should be borne in mind that past successes in dambo cultivation have been achieved without outside (ie. government) assistance. Dambo cultivation is far from unique in this respect and forms part of what is termed here MICRO-SCALE IRRIGATION. While taking a variety of different forms, this is already an important and integral part of indigenous African agriculture which should not be ignored in rural development plans.

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1. INTRODUCTION

1.1 Background to study

1.1.1 Definition and distribution of dambos

Dambos are a small-scale environmental resource which are widespread in Africa's tropical plateau savannas. They are shallow, seasonally waterlogged depressions at or near the head of a drainage network (Mackel, 1985). Dambos are generally treeless and the vegetation is dominated by grasses and sedges. Under natural vegetation cover a dambo land unit is most easily identified by the often abrupt contact between dry, typically miombo woodland on the dryland and open herbaceous vegetation on the dambo itself (Malaisse et al 1972). This contrast is particularly clear on air photographs and LANDSAT imagery. Further information on dambos as landform units and ecosystems can be found in the collection of papers edited by Thomas and Goudie (1985). Dambo catchments are thought to act as hydrological reservoirs, storing water in the rainy season and releasing it for evapotranspiration on the dambo surface and for dry season streamflow (Hough,1986).

Dambo is a bantu word of Malawian-Zambian origin meaning valley meadow land. In eastern Africa similar features are known by the term *mbuga* (Swahili), while related west African wetlands include the *fadamas* of Nigeria and the *bolis* of Sierra Leone. No systematic attempt has yet been made to map the extent and distribution of dambos or other valley-bottom wetlands at a continental or sub-continental scale. However it is known that dambos have a core area in central southern Africa (Figure 1) within which they occupy around 10% of the total land surface.

In Zimbabwe - the focus of the present report - dambos are known by the names *bane* (Shona) and *vlei* (Afrikaans). It should be noted that in Zimbabwe the term *vlei* is applied to any seasonally wet area of ground, including pans and downstream alluvial valleys, as well as headwater depressions (Thompson, 1972). While forming part of a larger set of wetland habitats, dambos have certain characteristics which place them apart from environments such as alluvial valleys, and which justify their study as a separate resource (Adams and Carter, 1987). In comparison with floodplains, dambos `receive water and nutrients from upslope not from upstream. Therefore the control of land use which affects the soil and water budgets lies locally with the community that uses the dambo rather than with communities that are far upstream.

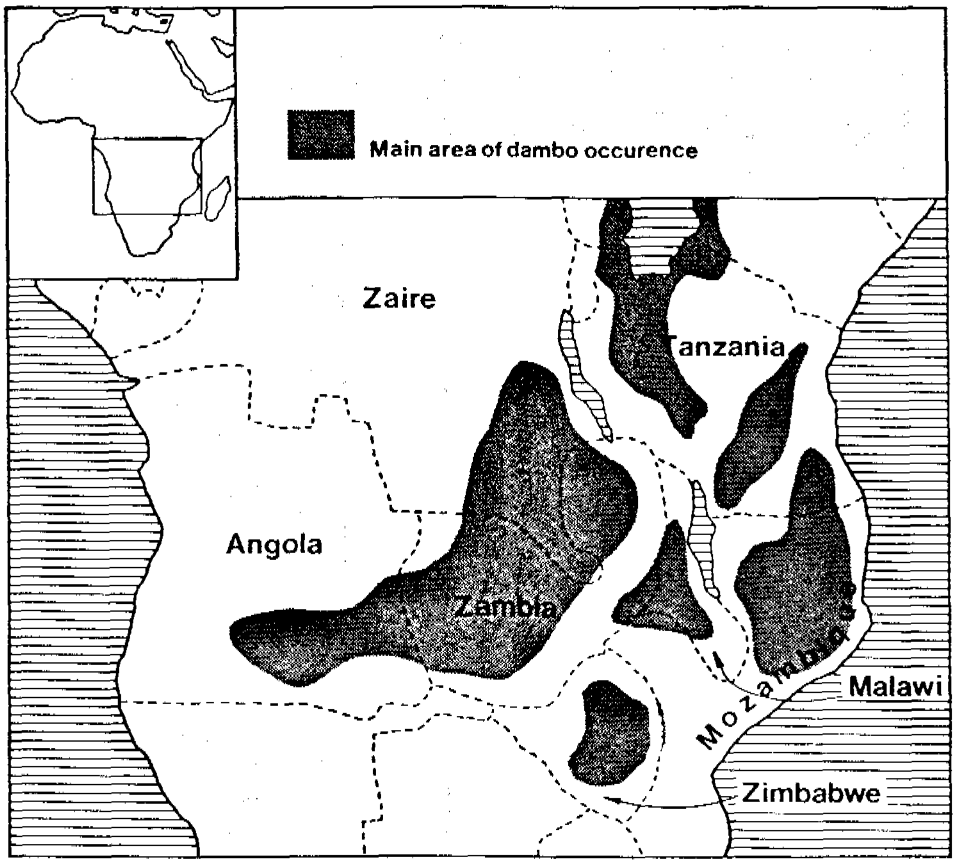

Figure 1 Dambo distribution in southern Africa

Individual dambos are much smaller than many other forms of wetland, being typically 0.1 to 1.0 km wide and 0.5 to 5.0 km long. This implies that a small scale approach is most appropriate for their use in rural development. However it also means that they have tended to be overlooked in development plans and soil surveys as being individually too small to be significant despite the fact that in total area they are more important than many other land classes. An important feature of dambos is their dispersed distribution pattern at a regional scale which makes dambo land physically accessible to a high proportion of the rural population in regions where dambos are found. Only those areas conforming to the definition of dambos used above were included in the present investigation, although many of the conclusions will apply to other types of vlei wetland.

Whitlow (1984) has mapped Zimbabwe's dambos using 1:80,000 scale air photograph cover and shown that they are located mainly on the gently undulating highveld plateau above 1200 m (Figure 2). Within this central watershed region, dambo density is greater towards the north where mean annual rainfall is above 800 mm. In Chiota Communal Area, where much of the present research was carried out, dambos occupy about one-third of the total land surface. Whitlow calculated that in Zimbabwe as a whole dambos cover 1.28 million ha or 3.6% of that country's land area. Because of inequitable colonial land allocation, the majority of the highveld, which is the area with most dambos, is now used for large-scale commercial farming (Figure 3). Nonetheless the estimated 0.26 million ha of dambo land in communal areas represents an important resource for Zimbabwe's small-scale, peasant farmers.

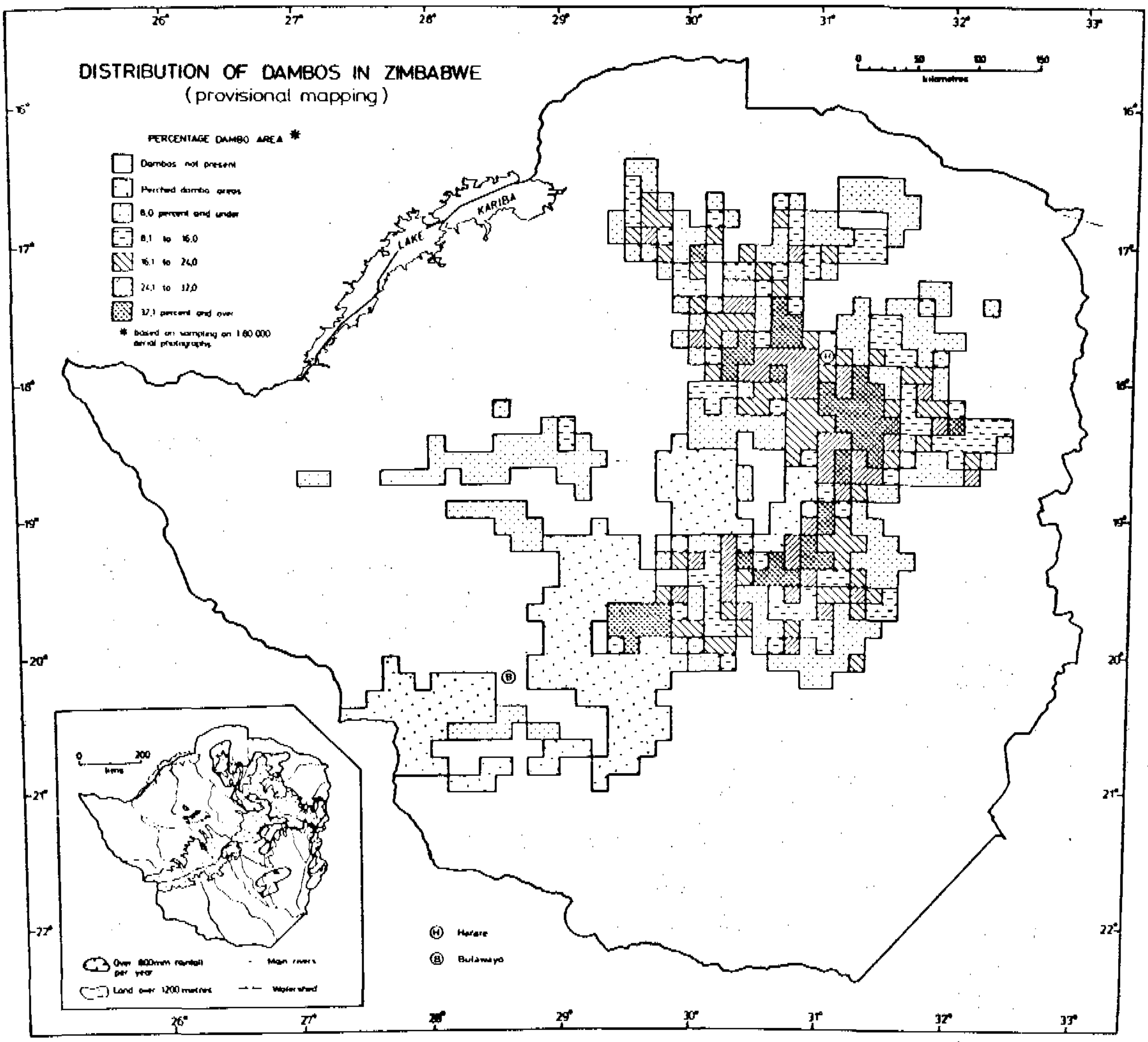

Figure 2 Dambo distribution and density, Zimbabwe (after Whitlow 1984)

1.1.2 Dambo resource use

Most environmental resources in rural Africa have multiple uses and need to be seen in this context when planning any development programmes. Dambos are an example of such a multiple resource, fulfilling three main purposes in Zimbabwe's communal lands - water supply, livestock grazing, and garden cultivation.

Because they remain moist during the dry season, dambos represent a reliable, near-surface water supply for human and animal consumption. They are especially important in areas where alternative water sources are remote or prone to drying up. Shallow, open wells can be easily dug and require minimal pumping technology to raise the water. The role of dambos in providing domestic water supply is considered further in section 2.2.2.

Dambos support a vigorous growth of grasses when other forms of grazing are in short supply. Consequently grazing of cattle and other livestock is one of the most common forms of dambo land use. The quality of this grazing is largely dependent on the pH of the soil-vegetation system and the intensity and character of the grazing pressure. Acres et al (1985) have suggested that carrying capacities for one livestock unit of 250 kg (ie a small cow) range between 0.5 and 5.0 ha, with capacities being lower on sour (= acid) dambos, such as exist in northern Zambia (Perera, 1982).

The other main form of dambo land use in peasant agriculture is cultivation based on indigenous water management techniques. In many cases this takes the form of dry season cultivation of vegetables in fenced gardens, known in Malawi as dimba gardens (Russell, 1971). There is a long tradition to this form of simple irrigation in southern Africa, stretching back into the pre-colonial era. This is evidenced not only from early travellers' reports but also from abandoned field systems of ridges and hollows (Whitlow, 1983). It is clear that the extent of informal garden irrigation has increased significantly in many parts of Africa during recent decades. In northern Nigeria, for instance, it is reported that fadama wetland cultivation increased almost seven-fold between 1958 and 1978 (Turner, 1984 and 1986; Kay et al, 1985). In Zambia, interest in the contribution of dambos to agriculture prompted a recent national workshop on their use (Republic of Zambia, 1986).

In climatically drier dambo areas such as Zimbabwe's highveld, cultivation of maize, rice and vegetables is carried out in the wet season without irrigation. In wetter areas such as the Tabora region of Tanzania, the rainy season crop is often wetland rice (Acres et al, 1985). In many areas wetland (eg dambo) cultivation traditionally complements dryland farming.

Garden cultivation of dambos includes what we term here MICRO-SCALE IRRIGATION (Lambert et al 1987). Irrigation is often assumed to take the form of specific technologies such as sprinkler or flood-basin irrigation, and is seen as something to be promoted and planned on a large scale. This narrow definition of irrigation means that formal-sector schemes using advanced technology are normally the only ones to be considered under the heading of irrigation. All too often small gardens in the informal sector, irrigated by simple traditional methods, are ignored although they may contribute far more to the rural population and the nation than the much more costly formal schemes. In this discussion we use the term irrigation in its broadest sense to mean the application of water to land for the purpose of growing a crop. The scale of operation and technology used may vary widely, and at the small and simple end of the spectrum lies micro-scale irrigation.

1.1.3 Dambo degradation - an ecological scapegoat ?

The dambo ecosystem is not only fertile but can also be fragile. This is especially true where their utilisation is most intense and in drier dambo areas where mean annual rainfall is below 1000 mm, as is the case in the communal lands of Zimbabwe. Here dambos indeed show clear evidence of environmental degradation in the form of gully erosion and dambo desiccation (Whitlow, 1985). Prevention of land degradation in stream source areas such as dambos has been attempted in Zimbabwe by legislation which closely regulates any cultivation of wetland (Section 1.2.1). This legislation was prompted by three main fears discussed in various previous papers (Rattray et al,1953; Elwell and Davey, 1972; Elwell, 1983).

1. that cropping of wetland would lower the water table and reduce dry season streamflow.
2. that cultivation would increase the hazard of soil erosion by both gullying and sheetflow, in turn adding to the problem of siltation (eg in reservoirs) downstream.
3. that cropping would 'burn up' organic matter in sand *vleis* , rendering the soil infertile and giving it the appearance of building sand.

However erosion and desiccation are the products of a complex chain of events ultimately linked to non-environmental factors including the enforced relocation and concentration of the indigenous population and the historical lack of investment in the non-commercial rural sector.

More immediately, dambo degradation can be caused by overgrazing by animal stock as well as other forms of land use such as garden cultivation. Limited grazing can improve the quality of the grassland (by preventing tall grasses such as *Hyparrhenia* from producing seed heads, and thus ensuring a continuous growth of grasses through most of the dry season). On the other hand excessive grazing can degrade the vegetation by encouraging less palatable plant species such as *Sporobolus* and by reducing the height and percentage ground cover of grasses. There is more surface runoff and less infiltration during heavy rainfall events and a more peaked stream flow regime. Similarly burning can lower water tables, have a deleterious effect on soil nutrient budgets and, if over-frequent, kill off valuable plant species. Cattle trampling along pathways and on saturated ground can be important in gully initiation. For these and other reasons, Zimbabwe's existing legislation, which acts solely to prevent dambo cultivation while leaving other forms of land use uncontrolled, has been criticised in some quarters as inappropriate (Theisen, 1976; Whitlow, 1983; Wilson, 1986).

1.1.4 Project Context in Zimbabwe

Over the last 40 years an extensive literature has been produced on agriculture in Zimbabwe. In this, many papers and reports have appeared on the possible uses of dambos (vleis) (eg Rattray et al , 1953; Cormack, 1972; Elwell and Davey, 1972; Theisen, 1975; Whitlow, 1983; Windram, 1983). All of these have recognised that under an appropriate form of management dambos represent an important agricultural resource. Many have been hesitant, however, to recommend action to promote their use because data on the environmental consequences have been inadequate or ambiguous. Rattray et al (1953 p.480), for example, emphasised "that little reliable data is available on the effect of various methods of utilisation of vleis on their moisture conditions", while Elwell and Davey (1972, p.156) argued that "we have not yet proven that we can use them safely, without damage to the soil and water resources".

An attempt at monitoring the hydrological budget of dambo catchments in Grassland Research Station, Marondera, was made during the late 1950s and early 1960s (Robertson 1964, Cormack 1972). Although some results were forthcoming from these trials (see Section 2.5), this work was not completed and is consequently of only limited value. As a follow-up to this a Vlei Utilization Committee was established from 1969 to 1976 to set up an administrative and scientific framework for further field research. Perhaps the best known attempt to integrate environmental and social research on dambo cultivation was that of Theisen in the early 1970s (1975, 1976 and undated). In Chiwundura (KweKwe) communal land he sought to quantify the benefits of dambo cultivation and address concerns over environmental degradation. Although his work had influence in official circles, it was confined to one communal area and focused primarily on differences between households with and without gardens.

Since Independence there has been a renewed interest by government, the aid community and academics in agriculture, particularly in communal areas (formerly Tribal Trust Lands, see Figure 3). This is reflected in, for example, the Report of the Commission of Inquiry into the Agricultural Industry (Chavunduka, 1981), the work of Truscott (1985) and numerous studies by the Department of Land Management, University of Zimbabwe. In these, mention is made of garden cultivation but it is not the focus of the study. Research has also been carried out into the marketing of horticultural crops by Horne (1986) and Smith (1987). In the National Masterplan for Water Supply and Sanitation (1985) mention is made of garden watering though dambo gardens are not specifically identified. Both Zimcord (1981) and the Transitional Development Plans (1982, 1983) emphasise the importance of agriculture and the need to assist communal farmers with credit, extension and marketing.

In the light of this contemporary concern with agricultural development in Zimbabwe, it was felt that a further study specifically on dambo resource use was justified for the following reasons.

1. At present dambo utilisation is of interest to government.
2. Irrigation development has been given a priority since Independence.
3. Debates over carrying capacity and soil erosion continue.
4. In spite of legal restrictions, garden cultivation is widely practised on dambos. Information from aerial photographs suggests that over the last decade the area of cultivation has greatly increased.
5. Definitive empirical data on the environmental consequences of dambo utilisation are still lacking.

1.1.5 Project Aims

In this project we have sought to investigate the role played by dambo resources in communal farming. The socioeconomic constraints on and benefits of dambo use in three communal areas across the country have been considered. We have attempted to establish whether existing dambo cultivation is significantly depleting the water and soil resource base. We ask what the potential is for an expansion in dambo garden cultivation, what environmental limits should be placed upon such expansion, and what implications there are for government policy. The approach adopted has sought to complement previous studies by paying particular attention to:

- detailed analysis of a small number of dambo sites rather than an investigation of the problem in a broader but more superficial way,
- an interdisciplinary approach which combines engineering hydrology with environmental management and socioeconomic study,
- analysis of existing conditions and practices relating to dambos prior to the formulation of recommendations for the future,
- investigation of contrasting regional environments where physical and social conditions vary,
- longitudinal study which identifies and measures variations through time.

Investigations carried out include

1. Archival study of legislation relating to dambos together with how it is interpreted and implemented in particular communities.
2. Regional scale land use mapping showing the extent of dambos and, within this, the intensity of cultivation.
3. Detailed field survey of selected dambo areas in contrasting environments including
- study of village communities and individual households during the agricultural year to determine local level management of dambo resources.
- analysis of existing climatic data, regular hydrological observation in a cultivated dambo catchment and the development of a model of dambo hydrology.
- measurement of soil variations along dambo catenas, organic matter changes following cultivation and erosion rates in selected dambos.

1.2 Legislation and Policy in Zimbabwe

1.2.1 Legislation

Two pieces of legislation affect dambo use: The Natural Resources (Protection) Regulation of 1975 (commonly known as the Streambank Protection Regulation) and the Water Act of 1976.

The Streambank Protection Regulation originally enacted in 1952, prohibits cultivation within 30 metres of a streambank, and on "wetland" (Government of Rhodesia, 1975a). Wetland is defined as:

> Land that is saturated to within 15 centimetres of the surface for the major part of a rainfall season of average or above average rainfall and which may exhibit one or more of the following characteristics:
>
> (a) the presence of mottles or rustlike stains in root channels within 15 cm of the surface;
>
> (b) a black topsoil horizon very rich in organic matter overlying pale leached sands;
>
> (c) a dark grey or black heavy clay showing considerable surface cracking when dry.
>
> (Government of Rhodesia, 1975b)

Although not restricted to dambos, this definition effectively includes all potentially cultivable dambo land. Exemptions from this regulation can, in theory, be secured by farmers. However, the procedures involved are unworkable in the communal areas due to the scale of garden cultivation.

The Water Act originally passed in 1927, defines various uses of water and how these uses are regulated (Government of Rhodesia, 1976). "Primary use" is for "drinking, washing, cooking and stock watering". Usually, official permission is not needed for primary use of water. Permission is needed for "secondary use" which includes irrigation. There are also restrictions on the use of "public water" which includes water in dambos. These restrictions were imposed due to concern that use of water in dambos would affect downstream flow, and therefore, water supply in the catchment. Reduced flow from the catchment might, in turn, reduce the water supply available in the river basin as a whole, thus affecting domestic and irrigation supplies in other areas.

1.2.2 National Policy on Dambos

National interpretation of these two pieces of legislation varies between government ministries and at various levels within those ministries.

The Natural Resources Board (NRB) is most concerned with the Streambank Protection Regulation. In the 1970s, the NRB became more lenient in enforcing this legislation, partly due to the fact that maize had been grown successfully during a period of drought, without environmental damage. Work by Theisen (1976), which showed that cattle did more damage to the dambos than cultivation, was also instrumental in changing the views of NRB officials. Thus, only that part of the regulation which refers to streambank cultivation was enforced while cultivation on dambos was permitted beyond the 30 metre line. NRB policy is now one of education in proper conservation measures rather than widespread enforcement of legislation. This education is the responsibility of the Ministry of Agriculture. However, despite NRB policy, some Land Inspectorate Officers (part of the NRB) continue to enforce the regulation. In one communal area, Gutu, for example, since Independence some households have been prohibited from using their gardens.

NRB literature encourages the use of dambos for domestic water use, but states that permission to dig a well should be obtained from both the Ministry of Agriculture and the Ministry of Water Development. This is not enforced in the communal areas. NRB officials are not, at present, concerned about excessive use of water for garden irrigation. However, as garden cultivation increases they recognize that further legal clarification of these issues may be needed.

Agritex (the Agricultural Extension Service), is responsible for giving technical advice to the NRB on environmental matters. The definition of wetland in the Streambank Protection Regulation was drawn up by Agritex. However, the NRB makes the final decision on any regulations passed referring to environmental resources. In terms of land capability classification, dambo soils are in Class V, which includes all soils subject to permanent wetness (Ivy, 1981). Land classes I-IV are considered arable according to this classification, while VI-VIII are non-arable. The severe waterlogging of class V is normally considered to preclude cultivation, except with special measures. Agritex recommends that dambo land should not be drained.

While Agritex extension workers generally recognize the importance of dambo gardens to the welfare of rural households, some middle and upper-level officials remain more concerned over the environmental hazards. Top officials have nonetheless indicated that, in terms of the Water Act, as long as irrigation is done by hand and land preparation by hand or oxen, garden cultivation involves "primary use" of water, not "secondary use". Therefore permission is not needed. However, this interpretation adds to the official perception that garden watering is "domestic water use" rather than irrigation. Garden cultivation is therefore ignored in irrigation policy. Moreover, although many top officials do not disapprove of garden cultivation in communal areas, others think it should be discouraged for environmental reasons. One outcome of this lack of consensus is that, although some field officers continue to allocate new gardens more than 30 metres from the streams, they are not well-trained in safe and effective cultivation of dambos. They are also uncertain whether they should be giving extension advice on gardens.

The Agricultural Finance Corporation (AFC) which gives loans to farmers for agricultural inputs, does not give loans to farmers for gardens. This is not a result of legislation, but due to the fact that vegetables are the most common cash crops on gardens. The AFC argues that since vegetable prices are not government-regulated, it cannot be sure that farmers will repay their loans. Also, vegetables are more perishable than staple crops such as maize and rice. This sometimes results in crops spoiling before they reach the market. However, some farmers can make large profits from their gardens at less risk than those farmers depending on the rains for growing maize. After the recent drought, most of the loans given to communal farmers for dryfield crops had to be written off.

The Ministry of Energy and Water Resources Development is most concerned with dambo use as it relates to the Water Act. As with Agritex, they see dambo cultivation as primary use of water. They do not therefore consider permission to be necessary for irrigation of gardens. Officials are, however, concerned about the effects of garden watering on the water supply of the catchment. This concern persists despite the lack of evidence to prove that dambo cultivation in communal areas has a detrimental affect on stream flow.

The Ministry of Health and the Ministry of Community Development and Women's Affairs are encouraging group and individual gardens as a means of increasing family income and improving health. These gardens are often located on dambos.

In the spring of 1987, legislation was proposed by Cabinet to extend the 30m rule to 100m, ruling out much existing dambo cultivation (Johnson, 1987). If passed, NRB would be obliged to enforce this legislation, despite the fact that the Natural Resources Board and Agritex are not in favour of it.

In some areas of Zimbabwe, the government is proposing "villagization" programmes. These involve moving households closer together, providing basic services such as water and electricity, and allocating land specifically for cultivation and grazing. In Gutu these programmes will include provision for wetland cultivation, as long as gardens are located more than 30 metres from the streambank.

After the bumper maize harvests of 1985 and 1986, the Government announced that the maize price would not increase in the next year and encouraged farmers to diversify crop production. Around the same time, the Horticultural Promotion Council of Zimbabwe was formed to increase horticultural production for local consumption and export. Although the emphasis is on commercial farmers producing for export, the National Farmers Association of Zimbabwe (representing communal farmers) is represented on this council.

Active support for gardens is greatest among various development agencies working in Zimbabwe, including certain local and foreign non-governmental organizations and bilateral and multilateral aid bodies. Although by no means insignificant, most of this assistance is confined to group gardens which focus on home consumption. One known exception is a project funded by the European Economic Community (EEC), for which Z$4.4 million has been allocated to "help fruit and vegetable growers (in communal areas) to boost their production and marketing strategies" (Anon, 1986).

It is apparent that the national approach to dambo cultivation in Zimbabwe is divided both between and within ministries. Policies of the NRB, Agritex and MWD towards cultivation are not well-defined. Officials in these institutions are primarily concerned with the effects of dambo cultivation on both land and water resources, notably soil erosion, water loss in the immediate dambo catchment and in the overall river basin. By contrast, the Ministries of Health and Community Development and Women's Affairs, in their concern to improve the nutritional and economic status of farming households, support group gardens on dambos.

2. METHODOLOGY AND PRIMARY FINDINGS

2.1 Dambo site selection and land use

2.1.1 Site selection

Mapping of dambos at a national scale in Zimbabwe had previously been carried out by Whitlow (1984). It was therefore decided to focus our investigations at *district* and particularly at *local* levels. Three communal areas were selected for study, namely:

- Chiota C.A., ca. 60 km SSE of Harare, in Mashonaland E province
- Zwimba C.A., ca. 90 km W of Harare, in Mashonaland W province
- Gutu C.A., ca. 200 km S of Harare, in Masvingo province.

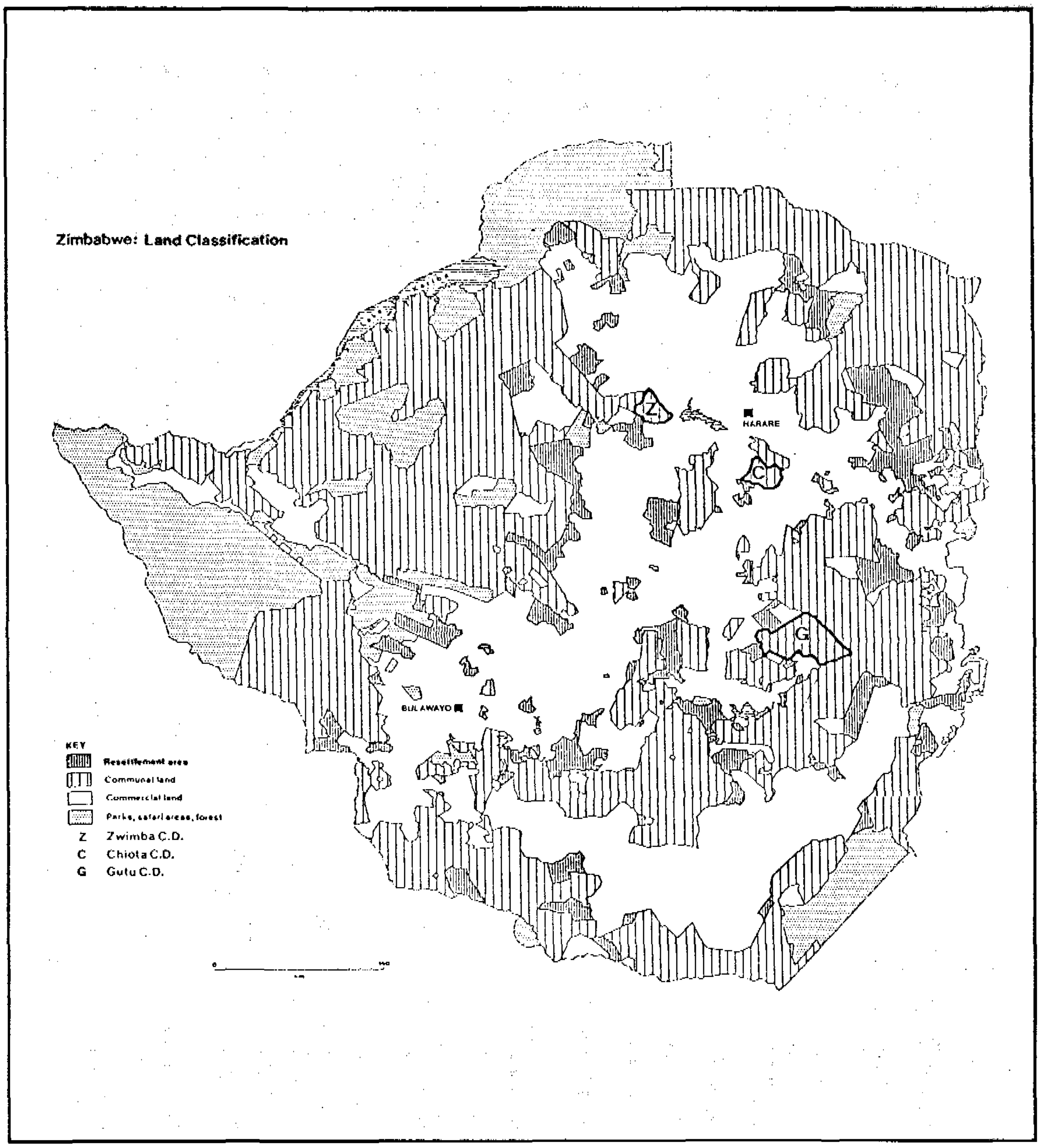

Figure 3 Zimbabwe: land classification and communal areas studied

These three areas were selected to provide contrasting examples of existing dambo cultivation. While Chiota and Zwimba are located in natural region II (intensive farming) and are within marketing distance of Harare, most of Gutu lies in drier natural region IV (semi-extensive farming) and is distant from any major urban market. The proportion of dambo land in each area varies, with Chiota having the highest proportion of dambo land and Gutu the lowest. The intensity of garden cultivation also varies considerably between the areas.

In summary the three districts can be characterised as follows:-

One communal area (Chiota) of both high *potential* and *actual* use for cultivation on dambos.

One communal area (Zwimba) of moderately high *potential* for dambo cultivation but which is as yet only partly realised.

One communal area (Gutu) of moderate potential but very limited actual use. Rainfall is less reliable than in the other two districts, and such dambo irrigation as is possible might help buffer the rain-fed agriculture.

Within the three communal areas individual dambos and/or villages were selected for detailed investigation. It was felt that only at this local scale could the crucial issues relating to hydrology, soil degradation and sociology be tackled adequately. The results of these detailed social and environmental studies make up the remainder of this part of the report (Sections 2.2 - 2.5). The analyses undertaken are summarised in Table 1.

It is important to note at this point that the study areas used for social and environmental analyses were necessarily somewhat different. Soil and water research focussed on individual dambos and their catchments as defined by the watershed. Social studies were based on villages adjacent to the dambos under study, so that for example, not all residents of Chizengeni village have their gardens on Chizengeni dambo.

2.1.2 Dambo terminology

A brief definition of dambos was presented at the start of this report (section 1.1.1); here we provide further information on their morphology and internal zones.

Dambos exhibit a range of types, varying in size, shape and soil type (Acres et al 1985). As Raunet (1985) points at, this reflects the fact that dambos themselves form but one type of Africa's 'bas-fonds' or small valley wetlands. As far as Zimbabwe is concerned, dambos vary between:

- headwater dambos (channelless, broad and sometimes coalescing)
- stream dambos (adjacent to second or third order stream channels)
- residual dambos (narrow and linear, typically along first order side streams)

Table 1 Summary of local-scale investigations undertaken

Dambo Communal Area	C Chiota	B Chiota	M Zwimba	S Gutu
Social Studies				
General and post-harvest survey (no. of families) (2 x in one year)	50	50	50	50
Detailed monthly labour survey (over period of one year) (no. of families)	20	20	N	N
Soil Studies				
Soil profiles analysed (no.)	23	4	4	5
Organic matter determinations (no.)	279	24	15	42
Erosion plots (no.)	6	N	N	N
Gully erosion studies	Y	Y	Y	N
Hydrological Studies				
Stream flow and ground-water monitoring	Y	N	N	N
Permeability tests	Y	Y	Y	Y
Meteorological data	Y	partial	partial	N

Y = Yes; N = No.
C = Chizengeni; B = Bumburwi; M = Masiyarwa; S = Shumbairerwa.

This sequence can be seen moving down valley from the watershed, and according to McFarlane (1986) it also represents an evolutionary sequence through time. Certainly in Zimbabwe, broad headwater dambos are found on the older erosion surface plateau of the highveld, whereas narrower residual dambos are typical of the steeper sloping middleveld. The pattern in the three study regions reflects these conditions; hence in Chiota (highveld) many dambos are of broad headwater type, while in Gutu (middleveld) most are narrow and linear.

As has already been noted dambos are not internally homogenous, but are zoned according to their position in the slope catena (Mackel, 1985). At the upper margin is a wash zone, typically of bleached sand, which supports only a poor cover of shrubs such as *Syzygium huillense* (mukute) and numerous termite mounds. Moving downslope the ground becomes moister and the vegetation dominated by grasses (eg *Andropogon* spp, *Eragrostis* spp) and wetland plants such as *Drosera* spp (Sundew). This band of out-seepage is termed here the upper dambo zone.

In many parts of Africa dambos continue to become wetter downslope so that the central part or 'eye' is a permanently waterlogged marsh with sedges, rushes and water-lilies. This situation is found in Zimbabwe only on peaty dambos underlain by Kalahari sand (eg near Mvuma: Whitlow, 1985). In most of Zimbabwe's dambos, conditions become drier not wetter towards the centre, as noted by Rattray et al (1953), McFarlane (1986) and other authors. Immediately downslope of the upper dambo some of the ground is saturated during the wet season, but dries out by the end of the dry season (= lower dambo zone). In broad headwater dambos the lowest part of the dambo may be dry throughout the year, except immediately after rain. This dry dambo bottom land supports vegetation of a similar density to that in the marginal wash zone, and is suitable only for grazing. A typical dambo catena with the zones as used in this report is shown in figures 4 and 5.

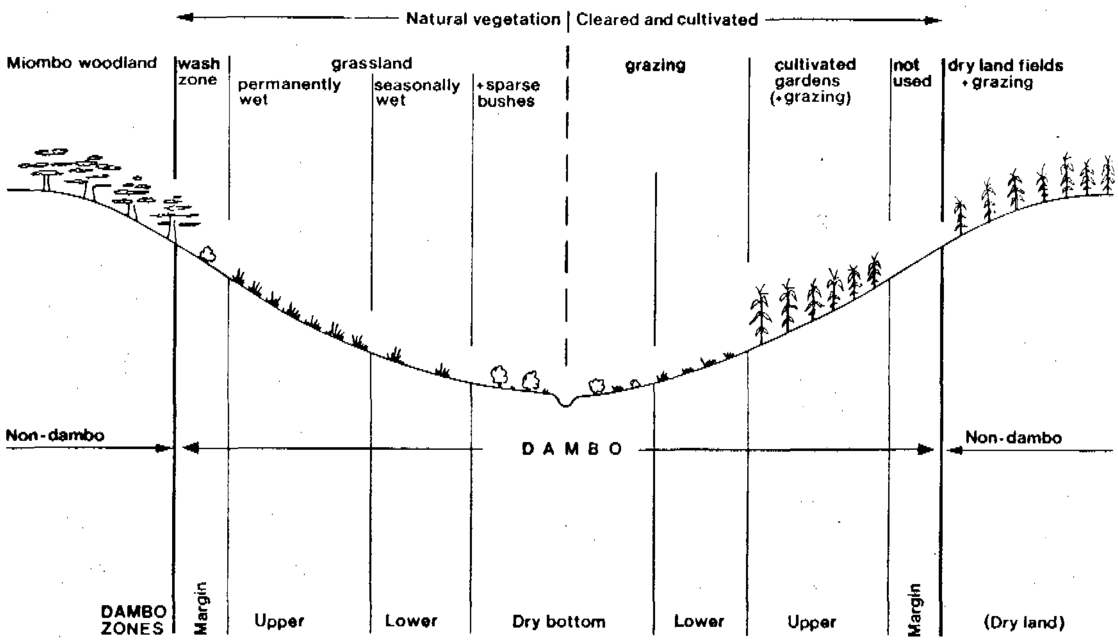

Figure 4 Schematic dambo cross-section, with zones used in this report

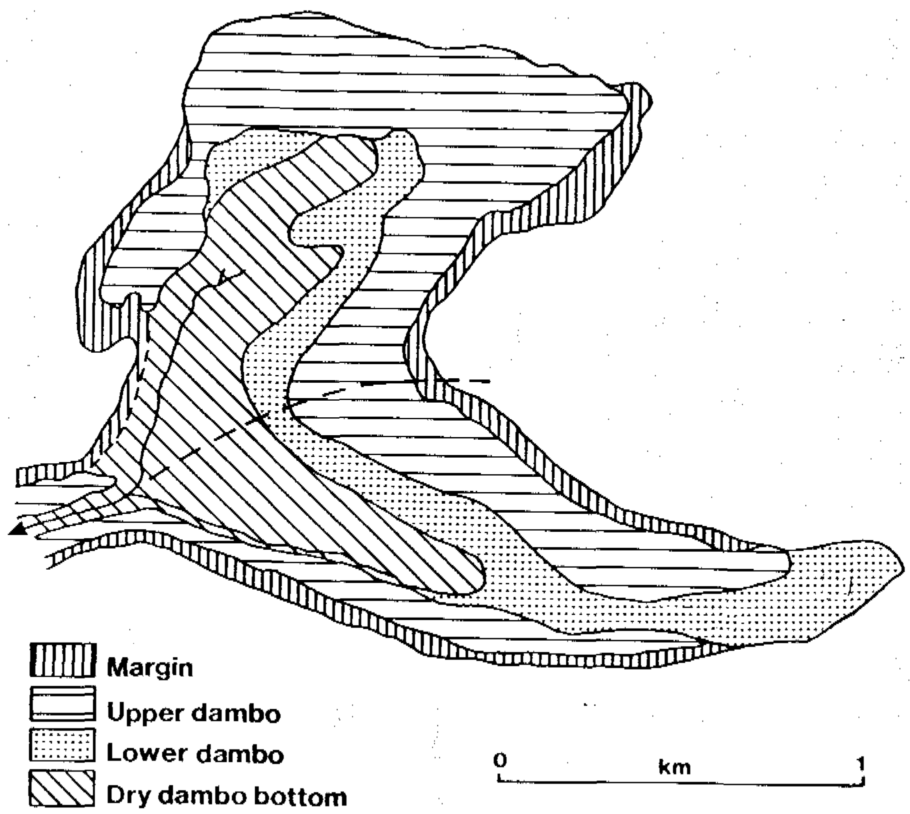

Figure 5 Dambo zones: Chizengeni and Chigwada dambos

Hydrological processes down a dambo catena are considered in detail elsewhere in this report (sections 2.5 and 3). It is clear however that at any one time there will be a part of the dambo which is wet and another which is dry. 'Wet' dambo may be considered as that where the water table is sufficiently close to the surface to permit growth of grass or crops, normally less than 2m throughout the year, and typically less than 0.5 m during the wet season. A band of darker toned grass on the upper part of dambos is conspicuous on air photographs taken near the end of the dry season (plate 1). Soil moisture is still available for plant growth when the rest of the area is dry and it is here that cultivated gardens are to be found.

2.1.3 Land use mapping

Dambo mapping was carried out for the three districts of Chiota, Zwimba and Gutu, using the most recently available air photograph cover, in all cases at 1:25,000 scale. The method adopted was as follows. A 1:25,000 scale map showing dry and wet dambo plus stream and river courses was produced by simple overlay technique on an air photograph mosaic. No attempt was made to counter parallax and other distortion, as the resulting map did not need to be of exact precision. In any case, distortion due to variable ground relief would be minimal as slopes are gentle in all three districts. Wet and dry dambo areas were easily distinguished on the basis of tone, but obviously provide only a 'snapshot view' of hydrological conditions which change seasonally in extent. In practice the air photograph cover for Zwimba and Chiota was taken in

September 1984, that is in late dry season, at the end of a period of three year drought. The area of wet dambo at that time may therefore be taken as identical to the perennially-wet upper dambo zone. The cover for Gutu was taken in August 1985 and 1986.

Although dambo gardens are visible at 1:25,000 scale, they are not sufficiently clear for direct mapping, and consequently the plotting of individual gardens was not attempted at this scale. Instead the area under cultivation on each individual dambo was calculated as a sum total. This involved use of a graticule in the eye-piece of a Wilt 'Aviopret' APT1 air photograph interpretation system, at a scale of about 1:750. Dambo gardens were defined on air photographs by the presence of *both* an open well (or other source of water; eg small reservoir) *and* a fenced margin. Not all of these gardens are in cultivation at any one time, because of fallow periods, etc, but many are double- or even triple-cropped during the year.

In CHIOTA (figure 6), dambos are found throughout the communal area, and are therefore a resource potentially available to all communities. Only along the south-western edge of the district, close to the Umfuli river, does dambo density fall significantly. Wet dambo as a proportion of total dambo area averages 43%, but this figure is higher in headwater dambos in the centre and east of Chiota, and decreases downstream to the west. The proportion of wet dambo actually under cultivation also varies significantly across the C.A., from a low of 5% to a high of 74%. In the northern half of Chiota the proportion is usually over 30%, while in the southern half it is almost always below 30% (figure 7). Altogether there are 2,500 ha of irrigated dambo gardens in this communal area. By no means all of these gardens are of recent origin: as early as 1925 the district Native Commissioner for Chiota being pleased "to note the quality and quantity of vegetables grown by natives in the reserves" (Annual Report, Marandellas, 1925)

The dambo sites studied in greatest detail were in the north-eastern part of Chiota (figure 6) at Chizengeni/Chigwada and Bumburwi. The former site lies in an area of high dambo density and numerous gardens. Taken together, Chizengeni and Chigwada have a proportion of their wet dambo land under cultivation that is close to the mean for Chiota as a whole (ca. 30%). However this gross figure disguises the fact that Chizengeni dambo is used intensively for irrigated gardens, while Chigwada dambo has few gardens and is instead given over mostly to dry season grazing.

It was known that Chizengeni dambo had been used for gardens over several decades, and included farmers with long experience of the benefits and problems of dambo cultivation for cash and subsistence. It therefore offered the possibility of assessing the effects of cultivation on soil and water resources over more than the short term. This history of cultivation is graphically illustrated in old air photographs, from which a time-series of land use maps has been produced (figure 8). As these show, cultivation was minimal in 1947, but increased dramatically between then and 1965, by which time much of Chizengeni's wet dambo area was

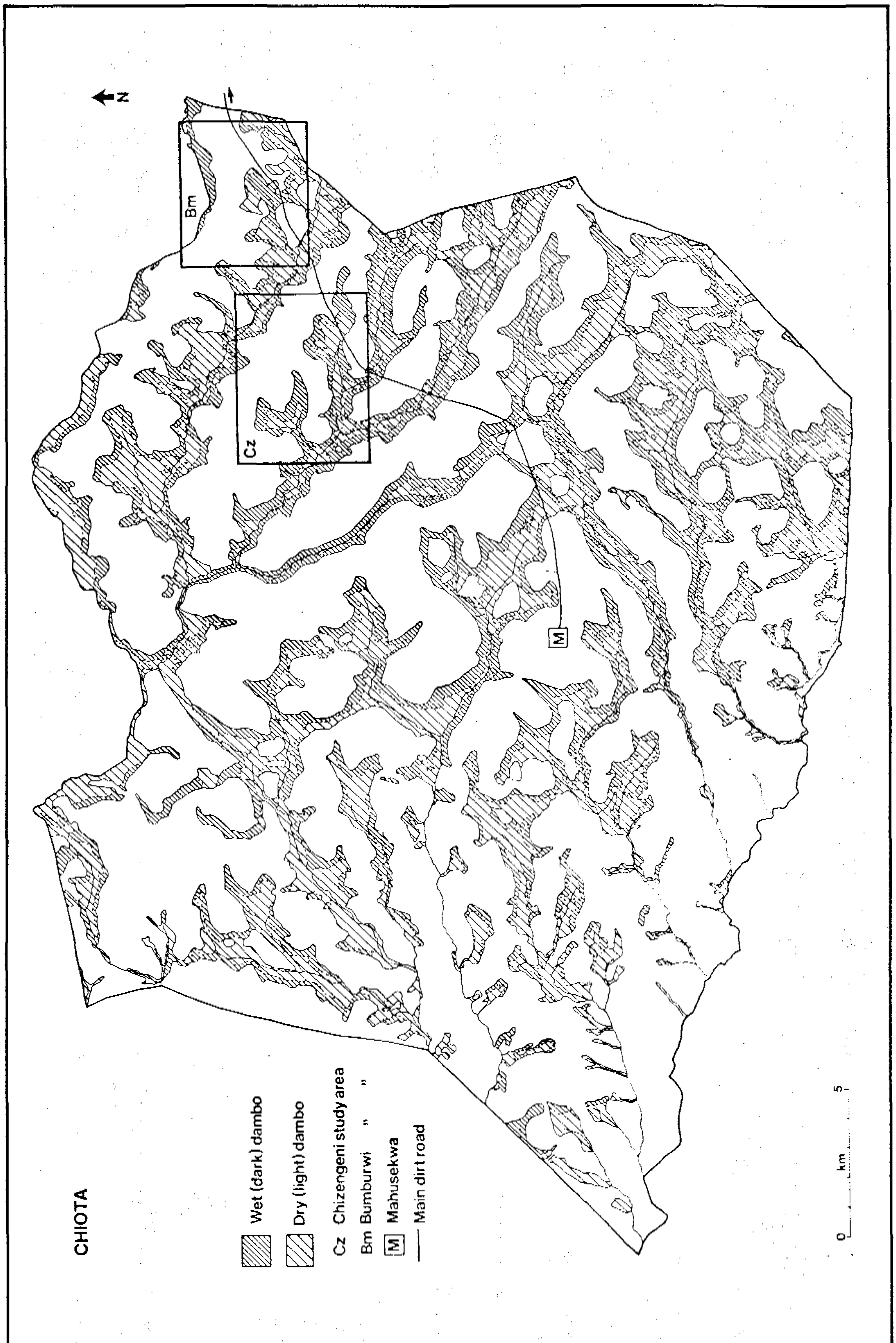

Figure 6 Wet (cultivable) and dry dambo distribution, Chiota GA

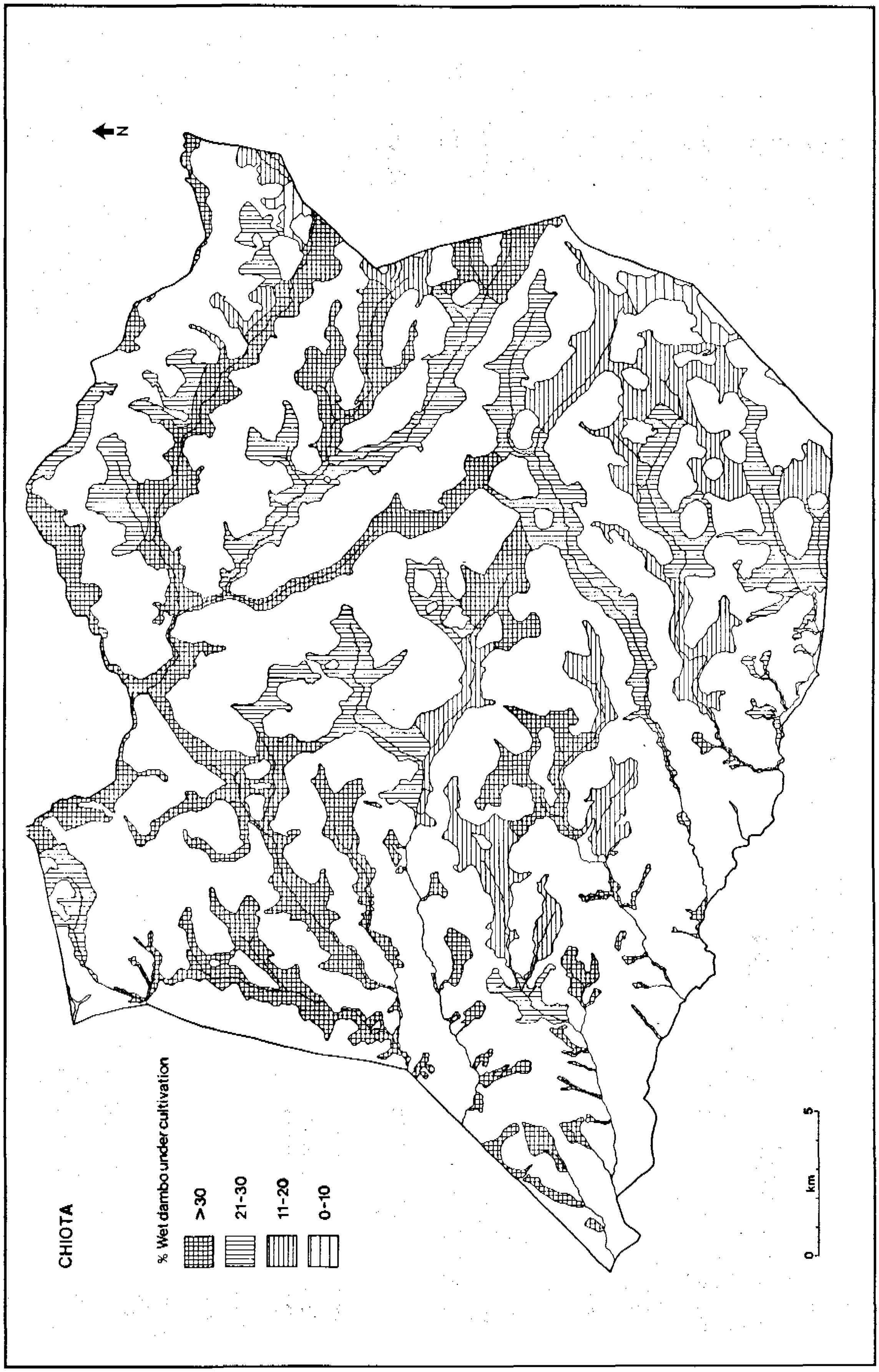

Figure 7 Proportion of wet dambo under cultivation, Chiota C.A.

under gardens. The cultivated area expanded more gradually during the 1960s and 1970s and "saturation point" was reached during the 1980s.

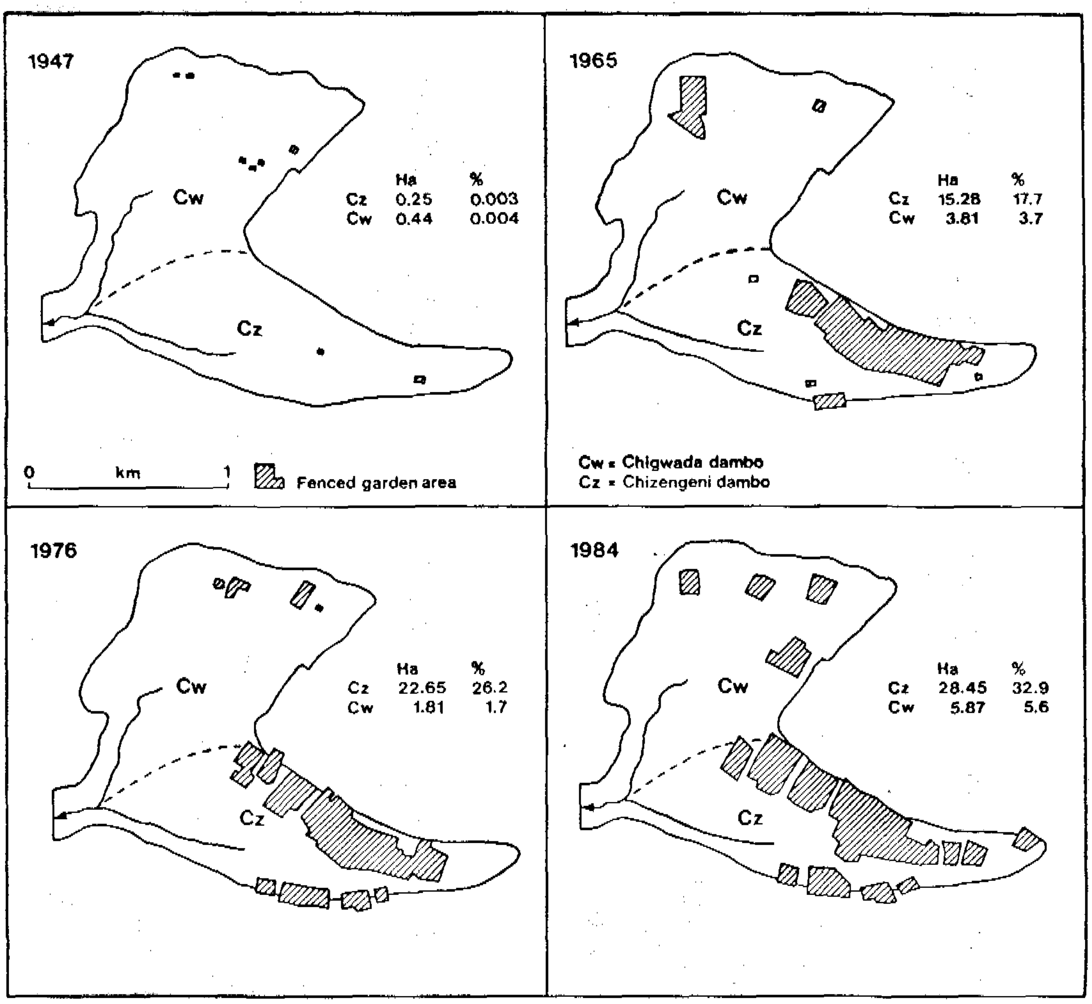

Figure 8 Changes in area of dambo garden, Chizengeni - Chigwada

In contrast to Chizengeni, Bumburwi dambo has rather few irrigated gardens. Its soils have a clayey rather than a sandy texture. These clayey soils show up as dark even when dry (see Figure 13). Bumburwi therefore offered a local-scale contrast to Chizengeni in terms of dambo utilisation and environmental parameters.

Dambos are also distributed throughout ZWIMBA communal area (Figure 9), but many are narrow linear features and dambo density is only half that in Chiota (14% c.f. 30% of total land area). The highest concentration of dambos within Zwimba lies immediately north of the main watershed, where most are of broad headwater type. Slopes are gentle (<4%) and bedrock geology granitic throughout this district. Individual gardens are smaller than in Chiota (0.25 c.f. 0.5 ha) and only 12% of the wet (cultivable) dambo area is actually under cultivation according to 1984 air photographs. The density of gardens is significantly higher in dambos draining south from the main watershed (>10% of wet dambo under gardens) than in dambos draining to the north (generally <10% cultivated). The relative paucity of gardens on the larger dambos north of the watershed is a striking feature of figure 10. These larger headwater dambos appear to be relatively under-utilised resources at present.

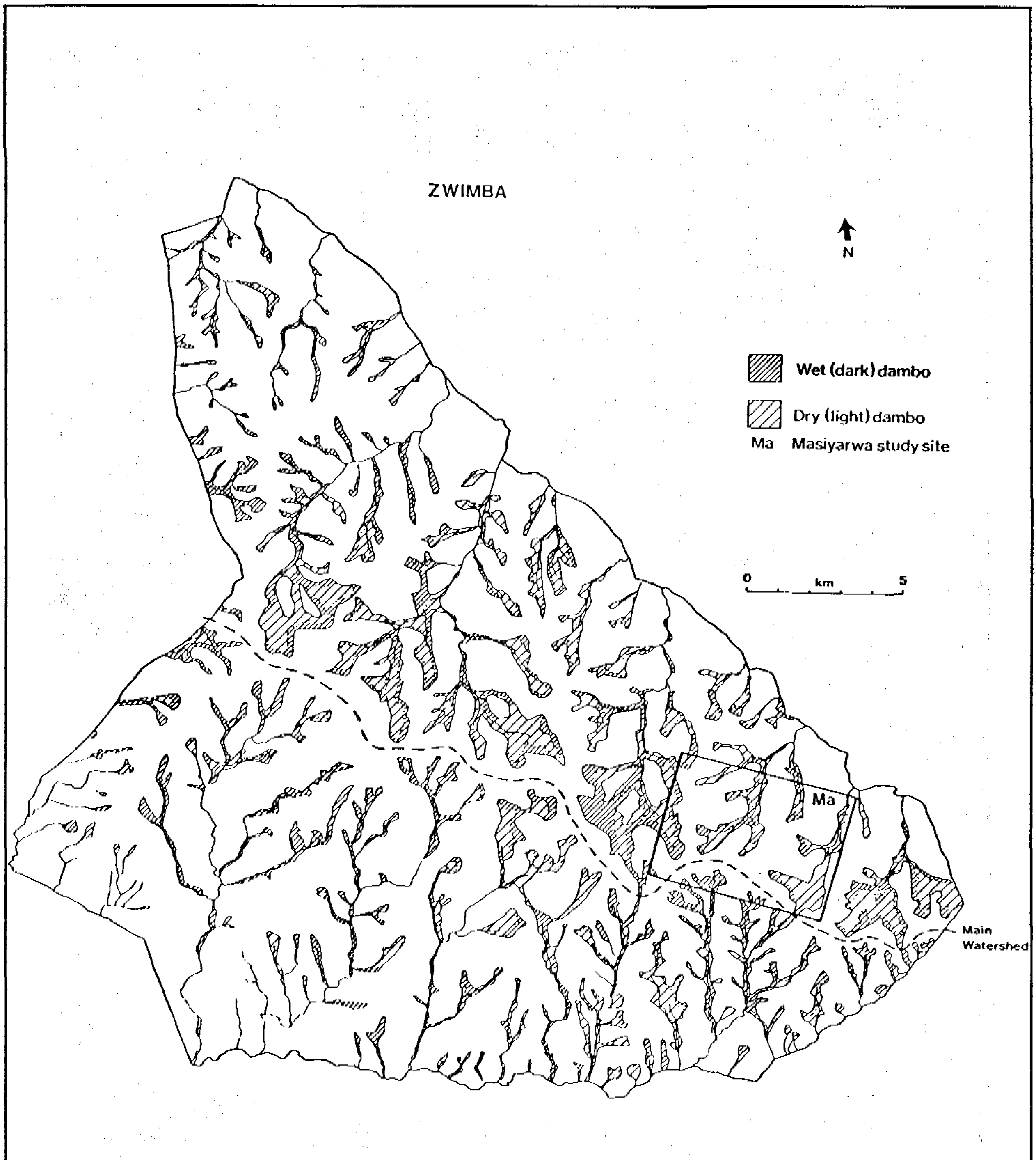

Figure 9 Wet (cultivable) and dry dambo distribution, Zwimba C.A.

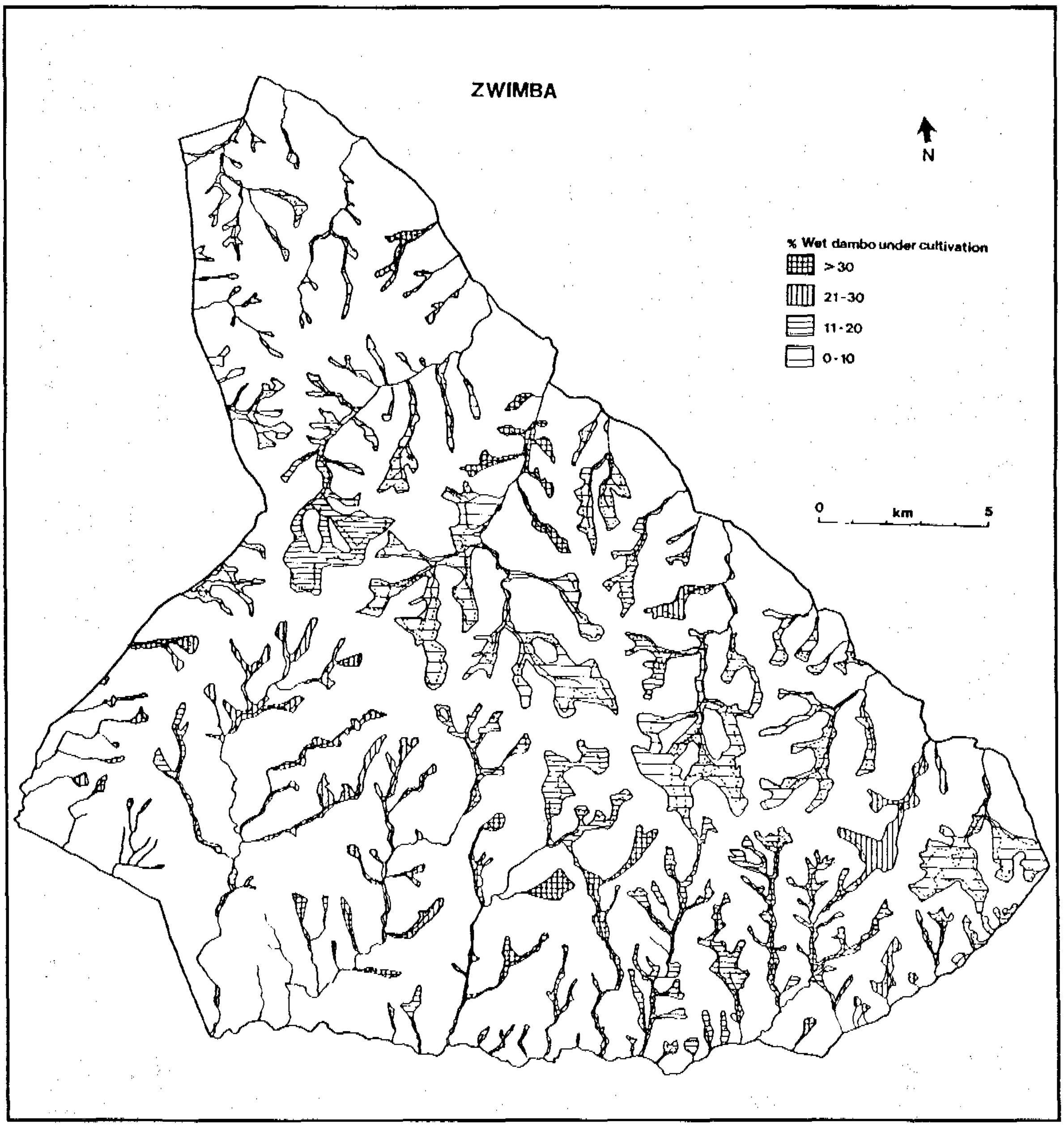

Figure 10 Proportion of wet dambo under cultivation, Zwimba C.A.

The detailed study site lay at the eastern end of Zwimba district around Masiyarwa village. The dambos adjacent to this settlement have around 6% of their wet dambo area actually under garden irrigation, a low proportion even for Zwimba. This area was chosen due to the contrast in garden size with those in Chiota and the fact that on initial visits it was clear that fewer households grew crops on the gardens for sale.

GUTU is a much larger communal area than either Chiota or Zwimba, and lies in the middleveld rather than the highveld. As Figure 11 shows, dambos are found in significant numbers only in the western half of Gutu. Here they are narrow and linear 'residual' type features, although their density is comparable to that in Zwimba at 14.1% of total area. Broad headwater dambos are rare in Gutu and perhaps because of his there is no marked dry zone at the bottom of most of its dambos. Consequently wet dambo as a proportion of total dambo area is much higher than in the other areas studied (76%). This proportion may also appear slightly higher because the years in which air photography was carried out (1985 and 1986) had better rains than 1984, the date of cover for Chiota and Zwimba. Gardens are few and far between and are even smaller than in Zwimba (generally 0.1ha in extent). The proportion of cultivable dambo actually under gardens is only 2.6% for Gutu as a whole, and in western Gutu this falls to only 1.7%. In other words, in Gutu dambos are used less for cultivation where their importance as a land resource is greater - the opposite situation to that prevailing in Chiota. In eastern Gutu the proportion of wet dambo under cultivation rises somewhat to 6.7%. This is the driest part of the communal area and the one furthest from the main commercial and administrative centre.

The site selected for detailed study was at Shumbairerwa, where dambo density is approximately 15% of the total land surface. There are 4.2 hectares of small gardens in the main dambo catchment at Shumbairerwa, representing 3.5% of the wet dambo area.

Table 2 Comparative figures on dambo area and cultivation at communal area level

Communal Area	Chiota	Zwimba	Gutu East	Gutu West	Gutu Total
Natural region	IIb	IIa	IV/V	III/IV	-
Total population (1982, thousand) **	42.8	28.5	59.2*	48.5*	107.7
Total area (km^2)	659	491	1248	1026	2274
Dambo area (km^2)	195	69	33	125	158
Dambo area/Total area	29.6%	14.1%	2.6%	12.2%	6.9%
Wet (cultivable) dambo km^2	83	35	21	100	121
Wet dambo/total dambo	43%	51%	64%	80%	76%
Total dambo garden km^2	24.5	4.3	1.4	1.7	3.1
Dambo gardens/ wet dambo area	30.0%	12.1%	6.7%	1.7%	2.6%

* assumes an even spread of population throughout the C.A.
** CSO, 1984

2.2 Socio-Economic and Agricultural Studies

2.2.1 Aims and Methodology

This part of the project sought to investigate the role of dambo utilisation in the agricultural system of households within the the four study sites. It included an assessment of the use made of dambo land and water resources together with how these resources are managed at community and household levels. The financial and welfare benefits to different household types from dambo cultivation were considered, as well as the constraints faced by farmers in cultivating dambo gardens.

A pilot study was initially carried out in Chizengeni to determine the importance of the resources of the Chizengeni dambo to households in the surrounding area. Special emphasis was given to their access to dambo land for garden plot cultivation and cattle grazing and the use of water resources in the dambo for domestic purposes, irrigation and cattle. A sampling frame was selected comprising all households with a permanent residence adjacent to the Chizengeni dambo (29 in total). Two surveys of these households were carried out: (1) Baseline survey to elicit general demographic, social, economic and agricultural information (January - March 1985) (2) Post-harvest survey (May 1985).

On the basis of the results obtained modifications were made to the questionnaires used. A more comprehensive survey was then designed which would permit comparison of dambo use both within and between communal areas. The field site in Chizengeni was extended to include the adjacent villages of Chigwada and Chiwanzamarara (See Plate 1 and Figure 12). Additional study sites were centred around the nearby village of Bumburwi, and in Masiyarwa Village, Zwimba CA, and Shumbairerwa Village, Gutu CA (Figures 13-15). Fifty households were studied in each area. Research in these four areas involved the following:

1. A baseline survey of the 200 households, carried out between October and December 1985, to determine the extent of dambo resource use, the agricultural practices employed, crops grown on dambo gardens during the dry season of 1985, and the advantages of and constraints to cultivation (see Appendix 1a).

2. A post harvest survey of the same households carried out between July and September 1986 to identify crops harvested, crop uses and the income derived from the summer planting. Comparisons were made with dryfield activities and output during the wet season 1985-86 (Appendix 1b). Since many households were away from the homestead during the period of this survey (dry season), only 155 surveys were completed as follows: 38 in Chizengeni, 38 in Bumburi, 47 in Masiyarwa, 38 in Shumbairerwa. Sufficient data were obtained, however, for comparisons to be made between the four study areas (Plate 2).

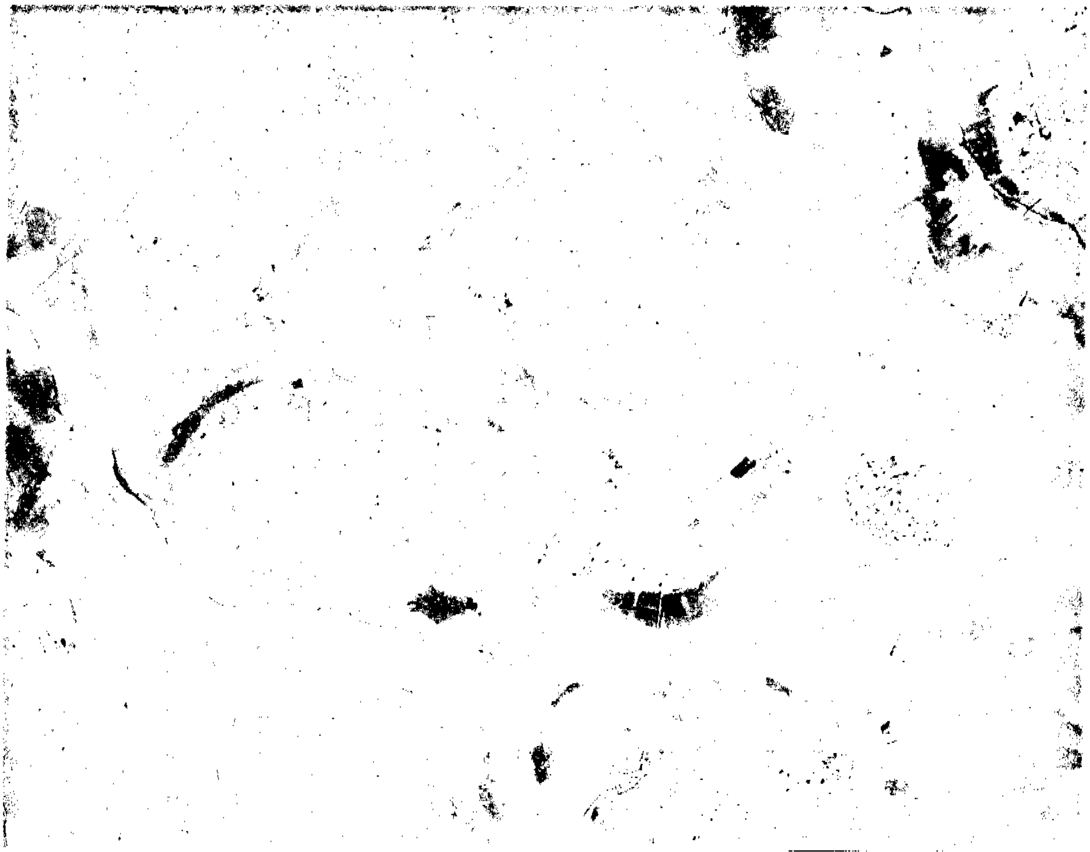

Plate 1 Air photograph of Chizengeni study site

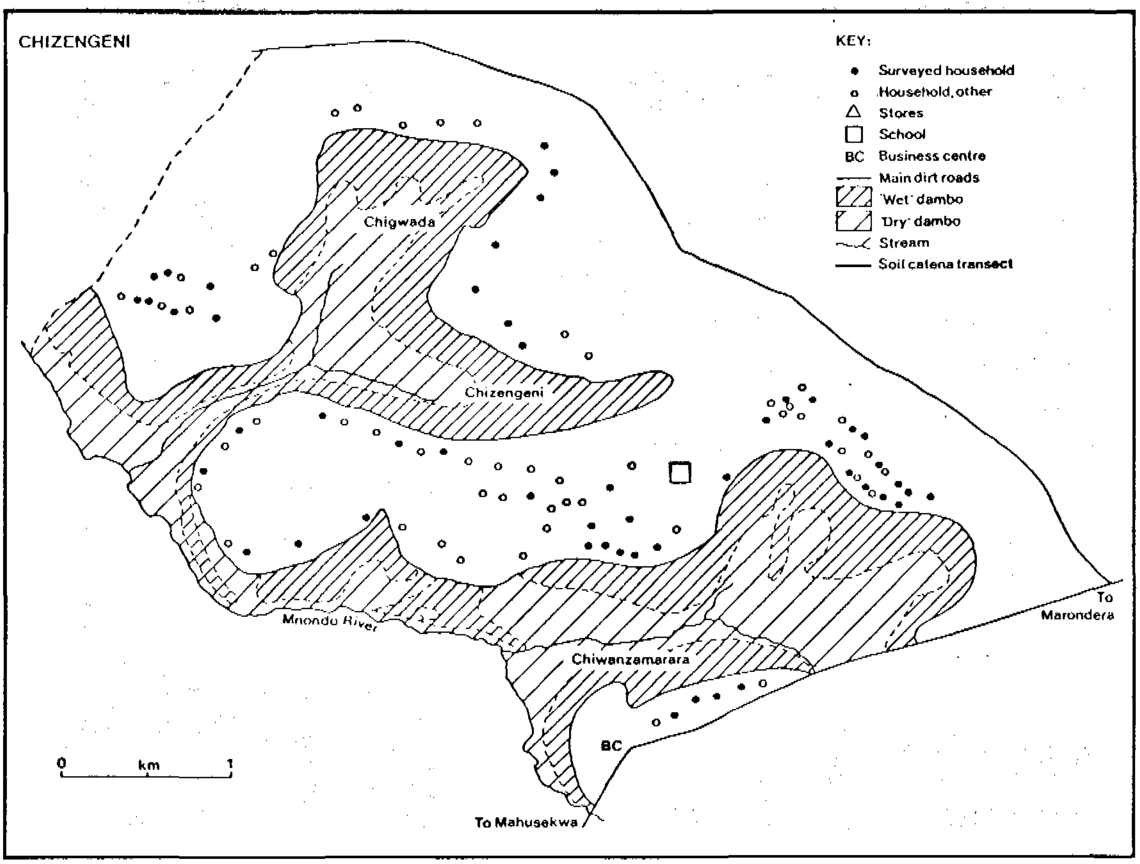

Figure 12 Chizengeni study site, Chiota C.A.

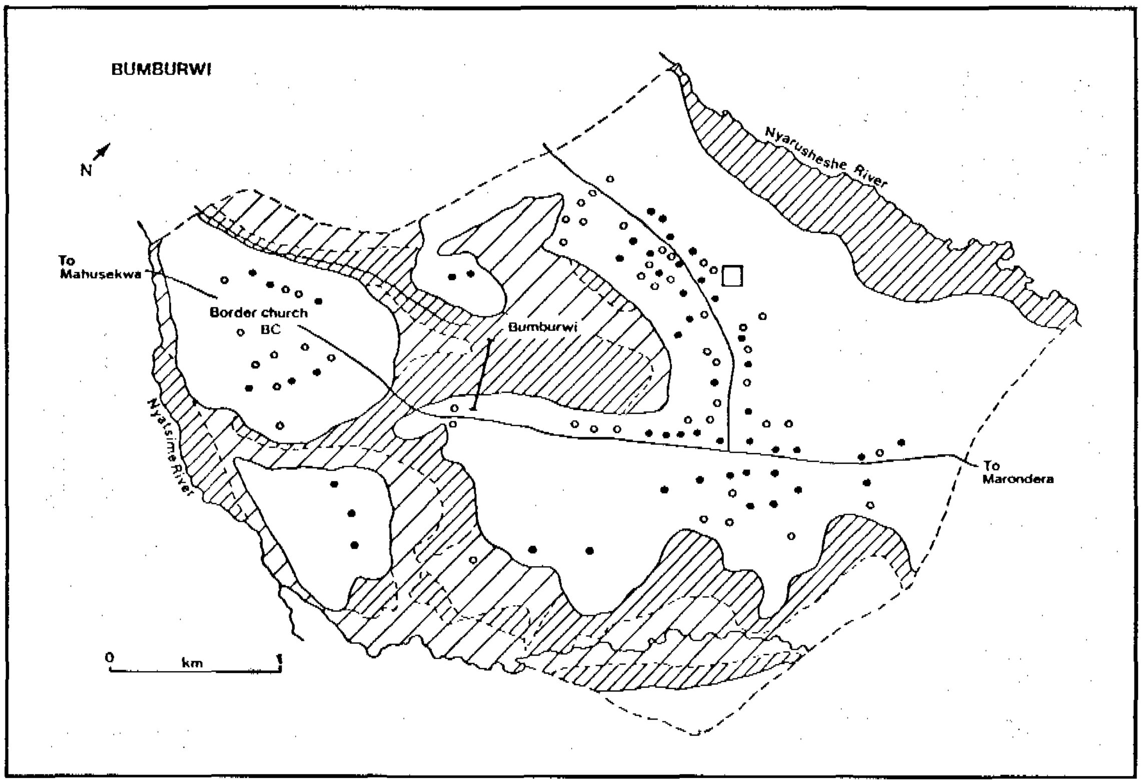

Figure 13 Bumburwi study site, Chiota C.A.

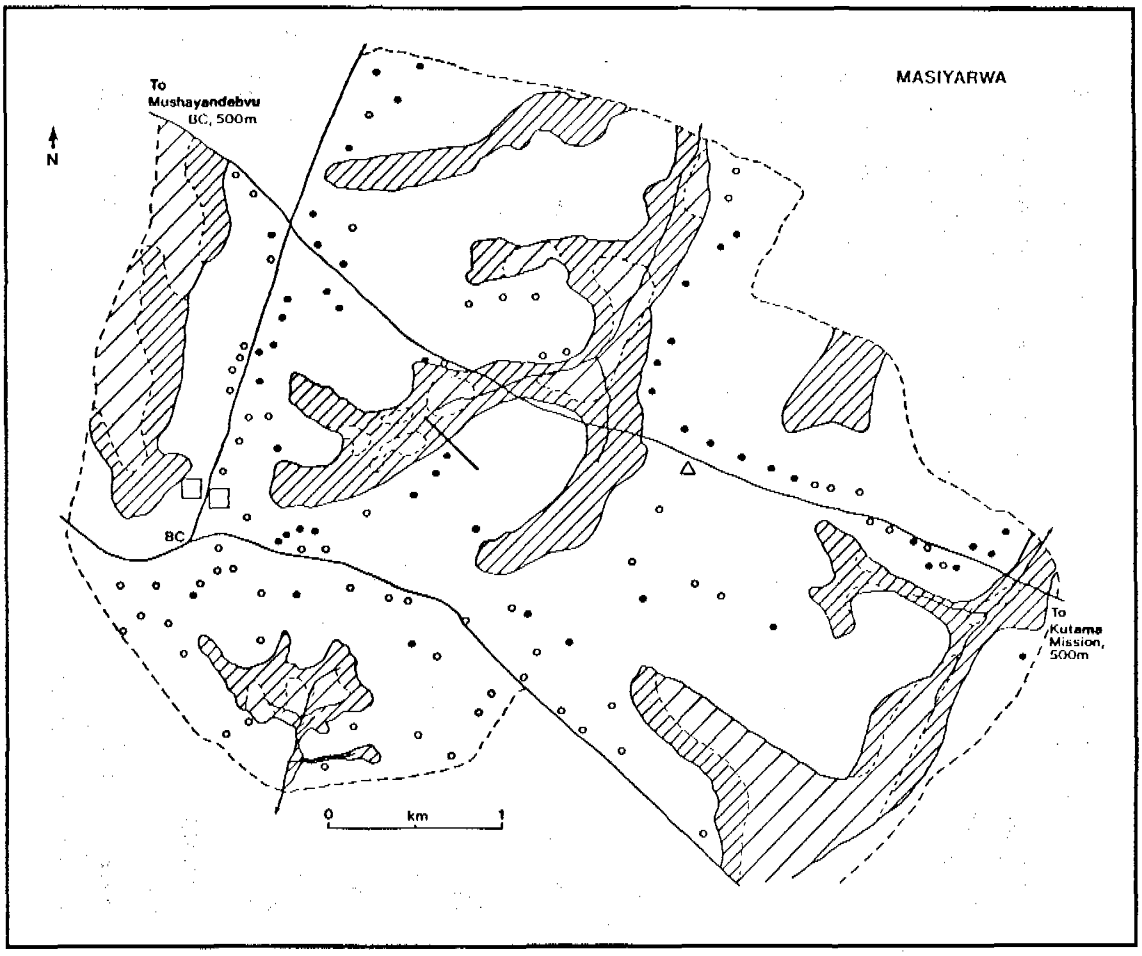

Figure 14 Masiyarwa study site, Zwimba C.A.

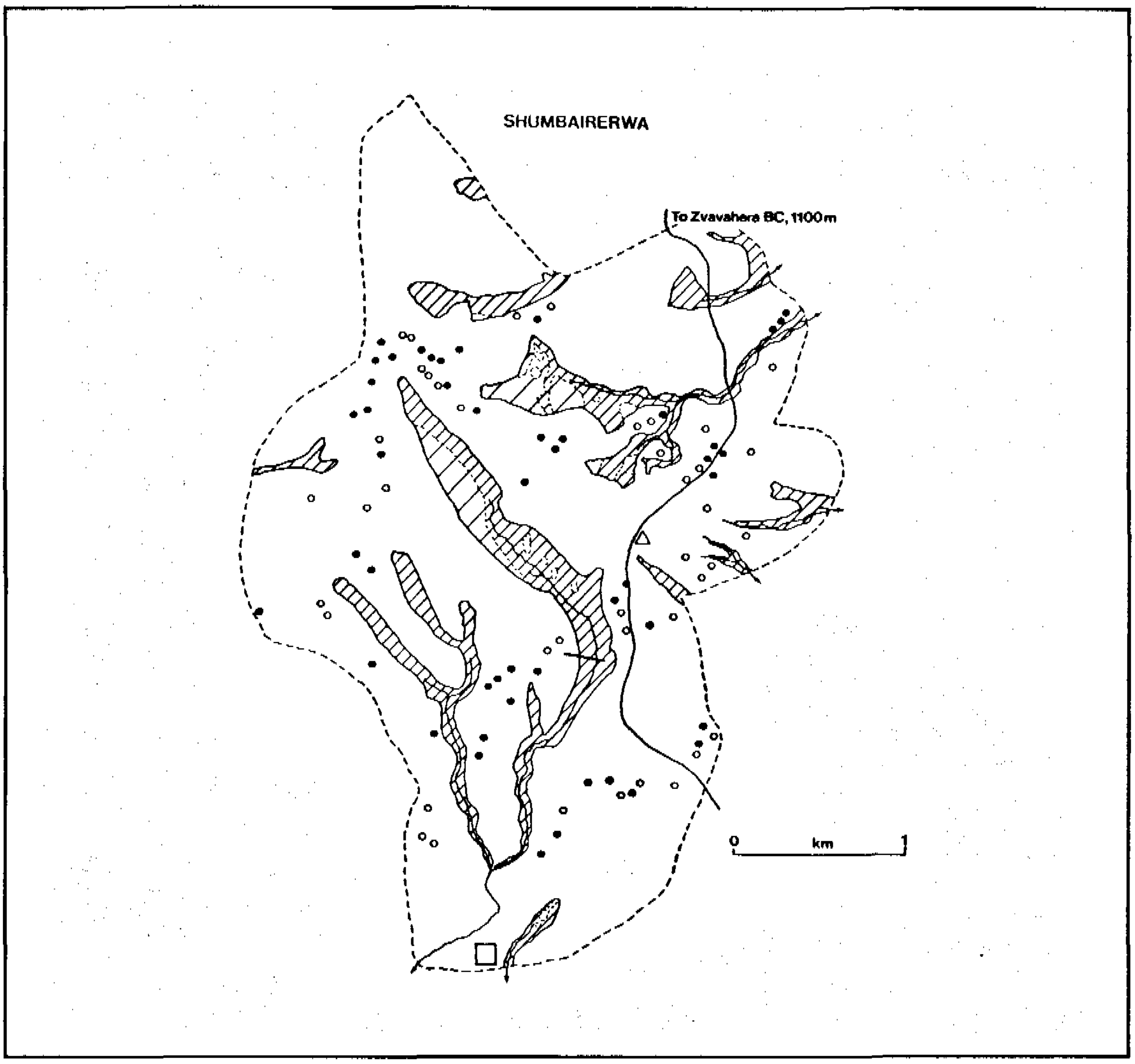

Figure 15 Shumbairerwa study site, Gutu C.A.

3. Informal discussions with local officials such as agricultural extension officers, and the Village Chairmen together with attendance at village meetings (Plate 3).

The surveys were carried out by the project team using local people as translators. In selecting sample households the dambo was defined as the centre of each study site. Air photographs were used to identify clusters of homesteads within a 2km radius of the dambo making the total area of each site betwen 12 and 18 km^2. The number of households in each cluster was calculated and estimates made of the total number of households in the study area. Sample households were selected from within each of the clusters in equal proportion to the distribution of total households.

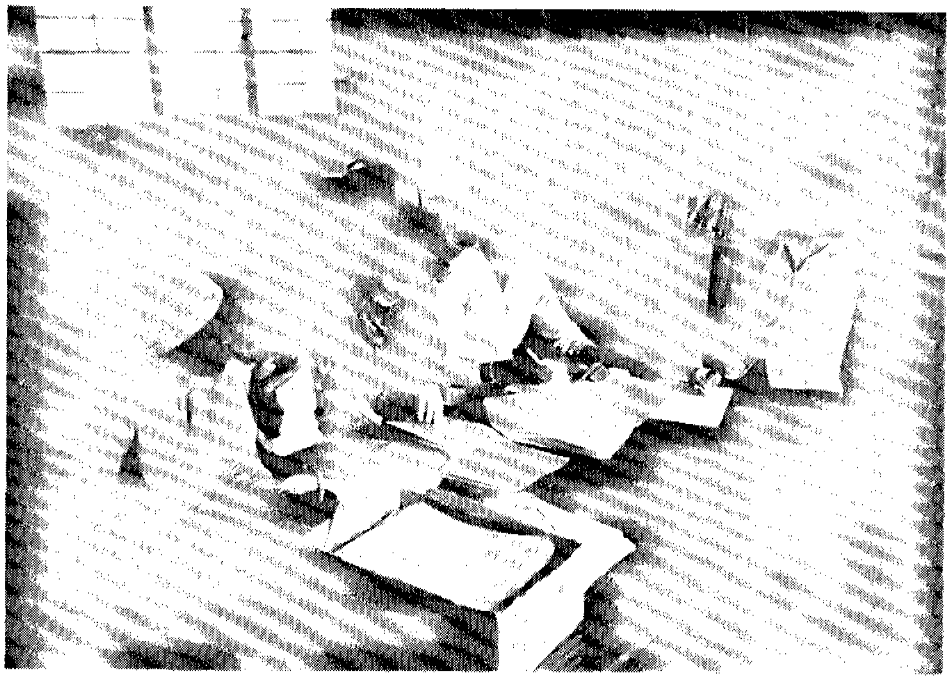

Plate 2 Organising social survey forms

Plate 3 Discussion meeting with local farmers

In conducting the surveys it was generally the household head or the wife who was questioned. In selecting the household member for interview, it was not solely those at the homestead who were questioned. Individuals working in the fields were also approached. In this way it was intended to avoid any bias in the types of interviewees (eg a bias towards wives whose husbands were in the fields or a failure to pick up widows who were also involved in tasks away from the homestead). It should also be stressed that neither survey sought to calculate output from dryfields and dambo gardens in terms of yields per hectare. Given that vegetable crops on dambo gardens must be harvested immediately after they are ripe, and that a wide variety of crops are often grown in small beds at any one time, yields could only have been determined by extremely time consuming techniques beyond the resources of this study.

2.2.2 Community Management of Dambos

Community Characteristics

In each of the four study areas some 35% of the households are headed by male migrants (Table 3). In these households (de facto female headed), due to the absence of the male head, the wife has day-to-day reponsibility for decisions concerning agriculture and for organising agricultural tasks. De jure (widowed or divorced) female-headed households (some 17%) have prime responsiblity for their family's welfare. Taking these together, slightly over 50% of households in the study areas as a whole are headed by females as either de facto or de jure household heads.The proportion is particularly high in Chizengeni.

Table 3 Type of Household Head (%)

Type	C*	B*	M*	S*	Average
Male present	30	60	54	44	47
Female Head	30	12	18	10	17.5
Male Migrant	40	28	28	46	35.5

*C-Chizengeni;B-Bumburwi;M-Masiyarwa;S-Shumbairerwa

The age and sex structure of households is characteristic of the communal areas as a whole. They comprise on average six to nine members which includes, in the majority of cases, more than one adult (that is, a member at least 15 years old) (See Appendix 2). Of those not presently attending school the overwhelming majority have only primary education or have never attended school. Household members with more advanced levels of education have not remained permanently in the study areas. All household members from a very young age provide their labour for varying tasks. However, this labour is not always available on a full-time basis due to school attendance of children and temporary absences of adults during the year. Detailed labour studies of forty families in Chizengeni on a bi-weekly basis indicated that household size fluctuated greatly throughout the year due to temporary migration. This fluidity needs to be accommodated when household tasks are organised.

Although education levels are low, some 25% of male household heads in the study areas, notably Chizengeni Village, Chiota, are Master Farmers. The colonial government initiated the Master Farmer Programme to provide training in farming practices and hence to increase yields and conserve the land. Since Independence this programme has continued as a means by which to disseminate agricultural advice. Few women are Master Farmers despite their responsibility for agriculture. However, all farmers including women are now able to gain advice from a variety of formal sources and considerable knowledge is also disseminated informally (see Section 2.2.3).

Visual differences in material wealth were apparent both within and between the communities studied. Of the three study sites Shumbairerwa, in Gutu CA, is the most marginal environmentally, relatively inaccessible to the regional capital, Masvingo, and the dambos are not intensively used. There are few visible signs of material prosperty such as European-style houses. However, considerable recent investment in social infrastructure has taken place in the form of a government programme to improve domestic water supplies and sanitation. In Bumburwi, by contrast, there are many modern houses and tractors are widely used in agriculture. In Chizengeni, Bumburwi and Masiyarwa there is little evidence of extreme poverty. Within communities, notably in Chizengeni, there was a small minority of materially wealthy households with a protected well adjacent to their homes and whose entrepreneurial skills were applied with considerable success to their agricultural activities.

Community organisation is strong in each of the study areas. Various community groups have been initiated by Government including Adult Literacy, Women's Credit Clubs and Health Committees. These supplement indigenous organisations which, although they have changed in character, are long established. A more informal type of community cooperation is "nhimbe", or work parties where community members work together in the fields of one household and are "rewarded" at the end of the day with beer and food. Most significant in all village decision-making, including dambo management, is the Village Committee presided over by the Village Chairman (like the kraalhead before him, a respected individual in the community).

Control of the land and water resources

In the communal areas land is allocated to male household heads for three main purposes:

(1) Homestead - on which a house is built and a small amount of rainfed maize is grown;

(2) Dryfields - where most rainfed crops (mainly maize) are grown;

(3) Gardens- on the dambos, where crops can be grown throughout the year.

Traditionally permission to use land for agriculture (both dryfields and dambo garden) was given by the kraalhead with the approval of the agricultural extension worker. If there was controversy over land allocation the District Commissioner and the Chief would become involved. Since Independence power to allocate land has been vested in the Village Committee comprising elected village residents. In the four areas studied it was the Chairman (VC) of the Village Committee who decided on land allocation in consultation with the extension worker. The District Council has final approval of all allocations but in practice this is usually only a formality.

It is customary for households in each of the study areas to receive their dryfields first. These are allocated to young couples when they set up their own homestead, usually within two years of marriage. By contrast, access to dambo land for garden cultivation is more restricted. It was reported by some households that they had been required to wait several years for a plot or had made many requests and had not yet received a plot. Overall access was greatest in Chizengeni and most restricted in Shumbairerwa (Table 4).

Table 4 Access to Dambo Garden (%)

Area	% of Households
Chizengeni	96
Bumburwi	64
Masiyarwa	92
Shumbairerwa	56
Average	77

This reflects the broader variations in intensity of dambo use between each of the three communal areas discussed above (Section 2.1). The Village Chairman of Chizengeni confirmed that only a few young couples in his village remained to be allocated a garden. While the figures indicate that it is more difficult to obtain a garden than dryfields, it is not uncommon in each of the study areas for households without their own garden to have use of part of a relative's plot. In Chizengeni, for example, a widow allowed her son to cultivate a small portion of her garden. This he would ultimately inherit.

Oral testimonies from households indicated that while a small minority of farmers had been cultivating for over thirty years, most households had received their plots since the 1960s (Table 5). Since Independence dambo land allocation for garden cultivation has continued in all four study areas. This evidence is reinforced by aerial photographs (Figure 8).

Table 5 Dates of Garden Allocation (%)

Decade	C	B	M	S
before 1960	15	6	7	7
1960 - 1980	42	31	52	50
since 1980	33	38	37	36
don't know	10	25	4	7

The overwhelming majority of households questioned had received formal permission to cultivate their land, either from the kraalhead, the Village Chairman or through inheritance from relatives (Table 6).

Table 6 Source of Permission for Dambo Garden (%)

	Kraalhead / VC	Obtained from relative	Took Land
Chizengeni	80	20	0
Bumburwi	68	29	3
Masiyarwa	93	2	5
Shumbairerwa	61	8	32

In all four study areas the majority of villagers were able to choose the location of their garden. This was then approved by the VC and the extension officer. Households made their own assessment based on their estimates of the availability of good soil and water conditions. The majority of gardens are located on the upper dambo. A very few households are reported to have taken their plot during the war without official permission. However, it is likely that this was the case for the majority of households who acquired gardens during the 1970s, when farmers were encouraged to take land and the power of government officials was limited. While it is not legal in the communal areas for land to be exchanged for cash, isolated cases were reported both in Chizengeni and Masiyarwa of gardens being sold. During the survey period one garden was allocated in Chizengeni and two in Shumbairerwa. There is also evidence in Chizengeni of farmers extending their gardens. This requires official permission which is not always obtained.

Plot sizes reported by the households studied varied both between and within case study areas (Plates 4 and 5). On average gardens were largest in Chizengeni and Bumburwi, ranging from 0.5-2 ha, with an average of 0.9 ha. This is higher than the average size for gardens in Chiota as a whole (0.5 ha), as calculated from air photograph surveys (this difference may be explained by the contrasting methods of measurement). One farmer was exceptional in having a garden of some 3 ha which he had received in 1948, a time when there was little land or population pressure in the area. Moreover his dryfields were relatively small. (It was customary in the past for each household to receive a similar overall amount of dambo land and dryland although the proportions of each might vary) By contrast, gardens in Masiyarwa and Shumbairerwa were generally much smaller (0.25 ha and 0.10 ha respectively, according to air photographs). Only one plot in these areas reached the average size of Chizengeni gardens. Located in Shumbairerwa, it is approximately one hectare and is cultivated by a farmer who earned a high income of over Z$1000 from cash production in 1986.

Local variations in recent land allocation highlight important differences between the four areas. These differences relate to perceived land use conflicts, notably between garden cultivation and cattle grazing and, linked with it, to local variations in the interpretation of Government legislation. Before discussing these issues reference is made to the use of dambo land for grazing.

Cattle grazing and watering

Table 7 summarises the proportion of households in each study area who owned cattle.

Table 7 Cattle Ownership (%)

No. of cattle	C	B	M	S
0	18	30	10	0
1 - 3	4	0	2	14
4 - 9	18	6	6	20
10 - 14	26	30	36	40
15+	34	34	46	26

While few goats were recorded in Chizengeni and Bumburwi (they were owned by 14% and 10% of the households respectively), they were more widespread in Masiyarwa (32%) and Shumbairerwa (68%).

Although dambos are normally considered as sources for dry season grazing (Rattray et al 1953; Young and Goldsmith, 1977), it is quite clear from Table 8 that grazing actually increases on the dambo in the wet season in Chizengeni, Bumburwi and Masiyarwa (Plate 6). This is due to the need to keep cattle away from the dryfields which are not fenced. In the dry season when cattle are not herded, grazing is more evenly spread over both the dambo and upland areas and gardens which are cultivated at this time must be protected with fencing. In Shumbairerwa the dambo is used by few households for grazing in either season. The forest areas are used during the wet season, and the dryland areas in the dry season.

Plate 4 Intensively cultivated dambo, Chinamora C.A

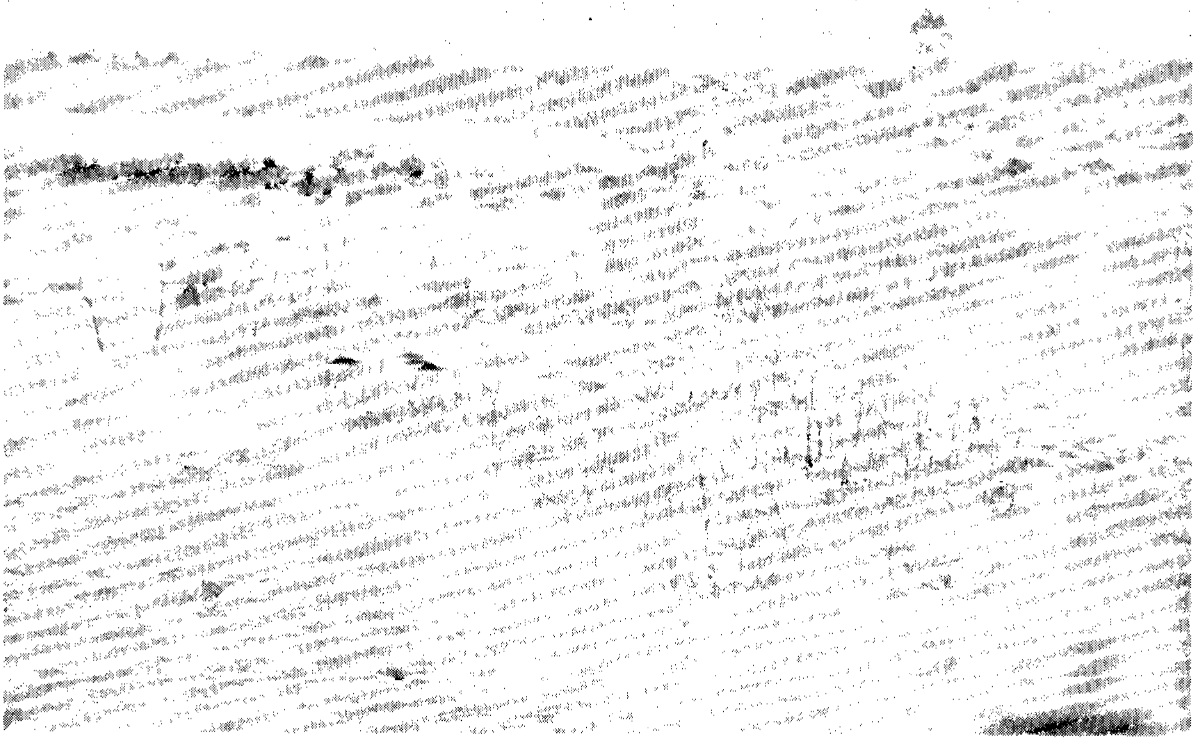

Plate 5 Small dambo garden, Seki C.A.

Plate 6 Cattle grazing on Masiyarwa dambo

Plate 7 Sisal fencing around garden, Masiyarwa

Table 8 Location of Cattle Grazing

Location	Chizengeni Wet	Chizengeni Dry	Bumburwi Wet	Bumburwi Dry	Masiyarwa Wet	Masiyarwa Dry	Shumbairerwa Wet	Shumbairerwa Dry
Dambo only	95	35	94	51	86	25	11	7
Dryland only	0	40	0	15	7	16	2	89
Both	5	20	6	34	7	59	0	0
Forest	0	0	0	0	0	0	87	4

(% of cattle owners; by season)

Although gardens must be fenced in all areas since cattle are not herded in the dry season, the prevalence of goats in Shumbairerwa and Masiyarwa creates a greater need for good fencing throughout the year. Typical fencing in these two areas comprises live bush, thorn branches, chicken wire and often a ditch around the garden (Plate 7). Sisal, which is also widely used in Masiyarwa and Shumbairerwa, is particularly effective against goats. Barbed wire fencing predominates in Chizengeni and Bumburwi. In all areas, cattle and goats generally obtain water from nearby rivers.

Land use conflicts on dambos

The transfer of plots to individual households for garden cultivation restricts the dambo area available for communal grazing. Although the dryland is also used for grazing, allocation of dryland plots appears to be considered a priority over allocation of grazing land. In each study area the need for a proper balance between dambo use for gardens and grazing is acknowledged by village officials and individual households. Maintaining this balance is recognised as a problem although its severity varies between areas as does the range of local solutions.

In Chizengeni, village officials recognise that competition exists over land for cattle grazing and cultivation. Two local solutions to this perceived land pressure have been adopted. First, as requests continue to be made for a dambo plot by newly formed households, long delays occur before they are approved and indeed young couples are encouraged to seek land in the resettlement areas. Few new gardens have been allocated since 1982 and in future they will be small in size (0.25 ha.). This decision, which has been made by the Village Chairman in consultation with local farmers, indicates that within the context of the communal system, when pressure on dambo land resources is perceived to exist, communal uses are given priority over the demands of individual households. In an interview, the VC of Chizengeni indicated his own land use preferences when he stressed that 'land is needed for cattle grazing and there must also be gaps in the slope between fields so that water can flow down to the stream'.

The second strategy involves cooperation between Chizengeni and the adjacent village of Chigwada, the boundaries of which straddle the dambo under study (Figure 12). An agreement was reached in the 1960s between these villages to allocate one lobe primarily for grazing and the other for cultivation. It was reported that this decision was made without prompting from outside officials. Efforts were therefore being made to preserve the valuable environmental resources of the dambo through cooperation between villages. In Bumburwi a similar strategy had been adopted with Bumburwi dambo used for grazing and the dambo north of the school used for cultivation (Figure 13). In Masiyarwa and Shumbairerwa problems of local conflict over land use are less important than concern over goats. The threat which they pose to crops in these villages appears to be a primary explanation for the small size of gardens (less than 0.25 ha.). Small gardens are also seen as a precaution against potential land use conflicts. In Masiyarwa, for example, it has been customary practice to allocate small plots for this reason .

Environmental concerns are much in evidence at village level. In all areas local officials and villagers are aware that gardens should be more than 30m from the streambank. In the main it is not an issue since this zone is not perceived to be the best land for cultivation. In Shumbairerwa there is evidence since Independence of farmers being moved off their gardens, ostensibly for contravening the Streambank Protection Regulation. Dambos here are narrow and linear, sometimes only 60m wide (Figure 15). If a clearly defined stream channel is present, then no dambo land will be available for cultivation outside the 30m limit. However, motives for restricting cultivation appear to be more ideological than environmental. Despite the low level of garden cultivation in this region and an apparent lack of pressure on dambo land, there has been little extension of the cultivated area since Independence. The provincial government is strongly committed to group rather than individual cultivation. In consequence, households are more likely to have a request for a garden plot approved if it is based on communal production. (For a more detailed discussion of the constraints on cultivation see section 4.5).

Water Supply

Overall, approximately 30 percent of the households studied usually obtain water for drinking and cooking from open wells in the dambo (see Table 9). Few households in any area walk more than one kilometre to obtain domestic water (Plate 9). The sources do not vary greatly between seasons, although in dry years the dambo wells become particularly important as protected wells on the topland dry out. The Ministry of Water Development recognizes this and has sited drought relief boreholes on dambos in Chiota. Wells located in gardens are used for irrigation and clothes washing, not for drinking water supply. Wells designated for drinking water are not used for clothes washing.

Table 9 Use of Dambo for Domestic Water Supply (% of households)

Season/Use	C	B	M	S	Average
Drinking/Cooking					
Dry season	34	16	50	26	31.5
Wet season	34	16	46	26	30.5
Washing clothes					
Dry season	32	6	38	14	22.5
Wet season	32	6	32	14	21.0

In all areas, the most common alternative source to dambos for drinking and cooking water is a covered well. Although in Shumbairerwa, these wells are adequately protected and fitted with the Zimbabwean "bucket pump", the covered wells in all other areas are open at the top and use a bucket and windlass for drawing water. Wells for domestic supply on the dambo are located outside the gardens and close to the homes (Plate 9). Irrigation wells are not used for domestic supply. Domestic wells are used for several years, with new ones dug when households feel the water is becoming dirty. It was expected that contamination of domestic wells on the dambo, which are uncovered and unfenced, would be much higher than that in protected wells. However, preliminary bacteriological water quality results indicate that this is not always the case (Table 10). Although a coliform count of less than 10 per 100 ml is normally acceptable, it is clear that contamination of the dambo wells tended to be less than that of the covered wells on the upland areas (IRC, 1981). Dambo wells are generally used by only two or three households, while covered wells at homes are often shared by all surrounding households. Covered well No. 2 is also used by all of the school teachers at Chizengeni School.

Table 10 Water Quality (Chizengeni)

Type of Source		Total Coliforms* per 100 ml	Month/Year
Covered well			
(1)	School	less than 10	August 1986
		0	June 1987
(2)	Household	over 1600	August 1986
		0	June 1987
(3)	Household	over 1600	August 1986
		110	September 1986
(4)	Household	20	June 1987
(5)	Household	less than 30	August 1986
Open Well on dambo (used for drinking and cooking)			
(1)	Household	less than 30	August 1986
		110	June 1987
(2)	Household	less than 10	August 1986
Open well on dambo (not used)			
(1)		less than 50	September 1986
(2)		less than 10	September 1986
Irrigation wells			
(1)		over 1800	August 1986
(2)		over 1600	September 1986
(3)		less than 10	September 1986
(4)		0	September 1986
(5)		less than 50	September 1986
Borehole w/handpump		0	September 1986
		0	June 1987

* It was not possible to test for faecal coliforms for all samples, so only total coliform count is given here.

For clothes washing, the main alternative to the dambo is covered wells at the home or a neighbour's home. In Masiyarwa and Shumbairerwa, those households not using dambo wells use the river for washing clothes.

2.2.3 Household management of dambo gardens

Although dambos are crucial as a land and water resource for cattle and for domestic water supply, the main area of conflict and misunderstanding in dambo use relates to garden cultivation. Our research has therefore concentrated on the management of dambo gardens by individual households. Since dambo cultivation is closely integrated with dryland farming, activities on the dryfields are also discussed. Garden cultivation has been practised for over one hundred years in Zimbabwe. We are not describing a new agricultural system, which has been imposed or assisted from the outside. Indeed, the successes in garden cultivation have been achieved despite discouragement by successive governments.

Cropping patterns

Since dambo cultivation is relatively independent of the rains, there are no fixed seasons for most crops. Farmers plant and harvest various crops (mostly vegetables) throughout the year. The only exceptions to this are maize and rice, which are generally planted in August/September and harvested in January/February. In drought years when dryfields are unproductive, this pattern varies, with many households growing a second crop of maize on their garden from February to May.

Although there are no fixed seasons on the garden, it is useful to look at cultivation in terms of the wet and dry seasons in order to compare with dryland cultivation which takes place only in the wet season. All households in all four areas cultivate their dryfields. Table 11 shows the percentage of households with gardens who cultivated them at various times of the year from May 1985 through April 1986. In this table, the dry season is divided into early and late dry seasons in order to distinguish between the maize and rice planted in August/September and vegetables grown throughout the year. Remaining tables simply distinguish between the wet and dry seasons.

In Chizengeni and Masiyarwa, where over 90% of the households surveyed have access to gardens, the proportion who actually cultivate them is also quite high (92% and 87% respectively). Effectively, 88% of the total sample in Chizengeni and 80% in Masiyarwa cultivate gardens, as compared with less than half in Bumburwi (46%) and Shumbairerwa (38%). Subsequent data in this section is presented as a proportion of those cultivating gardens in each area.

Table 11 Households using Dambo Garden (%)

Area	(A) Have Access	(B) Normally Use Garden (% of A)	(C) Used Garden Dry '85 (% of B)	CROPS RECORDED GROWING IN GARDEN (during periods of year): May-July 1985 (Early Dry Season) (% of C)	Aug-Oct 1985 (Late Dry Season) (% of C)	Nov.-April 1985-86* (Wet Season) (% of B)
C	96	92	82	39	100	100
B	64	72	87	70	75	83
M	92	87	98	87	82	69
S	56	68	84	81	69	54

* In the wet season, the sample size is smaller, as not all households were available for the post-harvest survey.

The main reason given in Bumburwi for lack of cultivation is that there is a great deal of pilfering of fencing and vegetables from gardens, both by local residents and by workers from nearby commercial areas. Also, the households not cultivating are generally located around a dambo which has been reported as too dry for successful cultivation and is mainly used for cattle grazing. In Shumbairerwa, insufficient water supply is given as a major reason for not cultivating a garden, even if a household has permission to use one. There is also confusion locally over the legality of gardens, with some households fined for having them (see Section 4.1).

In Chizengeni, the field survey indicates 82 % of households use their garden in the dry season and 100 % in the wet season. Cultivation in Bumburwi does not change significantly between seasons. This is partly due to the fact that, in both areas, maize and rice are grown on most gardens. In Masiyarwa and Shumbairerwa, the emphasis is upon dry season cultivation, although over half of these farmers also grow crops during the wet season. The use of gardens in the early and late dry seasons also varies considerably between areas. Chizengeni is particularly significant, with only 39 % of households growing in the early dry season, and 100 % in the late dry season. The high number in the late dry season can be explained by the fact that almost everyone in Chizengeni grows maize and/or rice on their garden at this time. The early dry season is a period of rest on many gardens due to the high level of activity on both the dryfields and gardens in the wet season. In Shumbairerwa, cultivation decreases in the late dry season due to the drying up of wells in the gardens and to the fact that very few farmers grow maize and rice on their gardens. In Chiota and Zwimba, maize planted in gardens during the late dry season has guaranteed moisture during germination as well as benefiting from rains themselves in years with adequate rainfall. In Gutu, the drier climate may make late dry season cultivation unreliable even on dambos, whereas the soil will still be moist in the early dry season.

On the dryfields, cereals and pulses are grown and form a major part of the diet for communal area households. These crops are maize, groundnuts, roundnuts, "nyemba" (dried beans), cowpeas and rapoko, which is mainly used for beer brewing. Most families grow maize and rapoko, and one or two of the other crops. Sunflowers were grown by a few families, both for cattle feed and to sell to the Grain Marketing Board. (The Government has been encouraging farmers to grow and sell sunflowers in order to make sunflower oil.)

By contrast, a greater variety of crops is grown on the gardens, with over 30 different crops recorded in the four study areas. These include the staple crops of maize and rice, numerous vegetables and several fruits. Of the staple crops, both maize and rice are grown in the gardens in Chizengeni and Bumburwi. In Masiyarwa, where the gardens are smaller, only maize is grown (Table 12). Only two families grew maize on their gardens in Shumbairerwa and none grew rice.

Table 12 Garden Maize and Rice Cultivation (%)

Area	Maize	Rice
Chizengeni	89	78
Bumburwi	67	87
Masiyarwa	81	15
Shumbairerwa	13	0

(out of those households who actually cultivated garden)

Of the vegetables grown, the most common crops are those used locally for relish (sauce) served with sadza, the staple food made from maize meal. These are tomatoes, onions, cabbage, rape and other green "leafy crops", such as "rugari" and "covo" (Table 13).

Table 13 Number of Households Growing Various Crops on Garden

	Chizengeni		Bumburwi		Masiyarwa		Shumbairerwa	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
(n=)	(36)	(37)	(20)	(15)	(39)	(27)	(16)	(7)
Crops consumed by household and sold locally								
Tomatoes	8	13	3	5	32	13	13	2
Rape	20	12	14	8	34	5	13	6
Leafy crops	0	1	5	0	16	6	2	1
Onions	6	2	4	3	20	2	12	1
Cabbage	12	12	10	5	29	12	13	8
Pumpkins	1	4	0	0	1	6	0	1
Crops usually sold in city markets								
Beans	12	14	1	0	3	2	0	0
Carrots	7	11	1	0	1	0	0	1
Cucumber	3	3	0	1	0	0	0	0
Squash	4	7	1	0	0	0	0	0
Lettuce	1	7	1	0	1	0	0	0
Peas	4	7	0	0	0	0	0	0
Shallots	4	10	0	0	2	1	0	0

NB: Due to the small sample sizes for Bumburwi and Shumbairerwa, figures in this table are not percentages.

While a greater variety of crops is grown on the gardens than the dryfields, the proportion of households growing more than four crops on the garden rarely exceeds 30% (Figure 16). Those households cultivating mainly for subsistence grow mostly crops needed for relish. Those growing some crops mainly for cash tend to grow fewer vegetables for relish, preferring to use their garden income to buy them from a neighbour (see Section 2.3).

Although a strict distinction cannot be made between crops grown for home consumption and for sale, several crops are grown mainly for sale in city markets. Chizengeni is the only area where many of these crops are grown, with a special emphasis on wet season cultivation. This emphasis on commercial production contrasts with the other areas, where gardens are fewer (Bumburwi and Shumbairerwa) or smaller (Masiyarwa). In Bumburwi and Masiyarwa, only a few cash crops were grown in the dry season, with almost none grown in the wet season. In Shumbairerwa, only one incidence of cash crops was noted, namely, the growing of carrots by one household in the wet season.

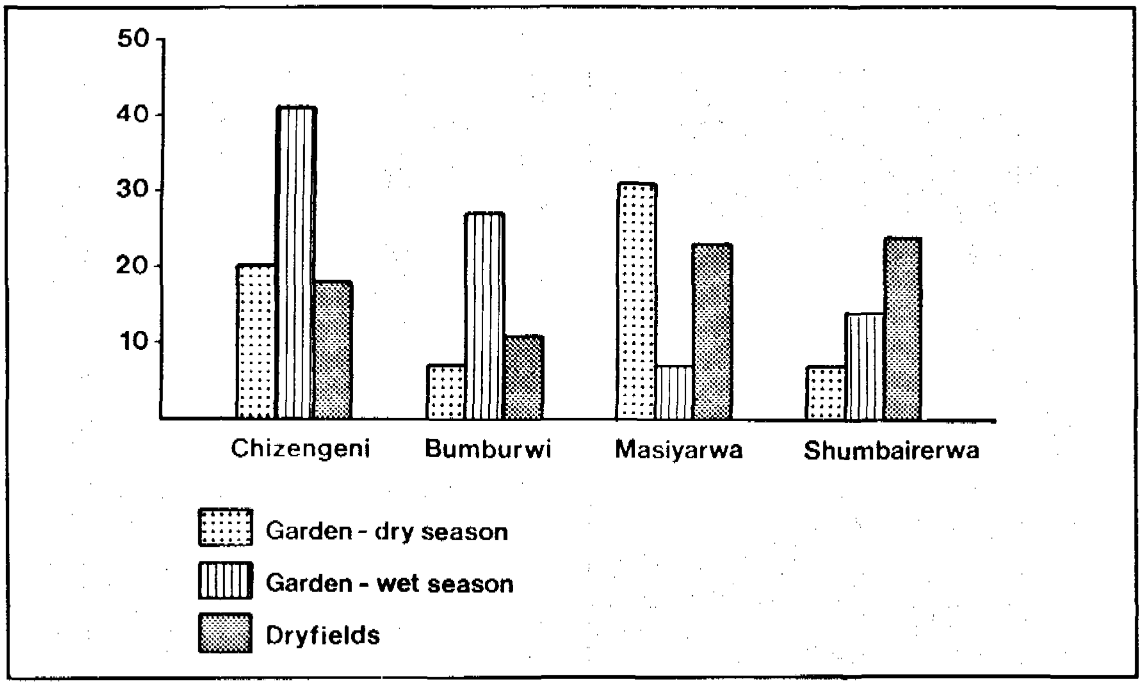

Figure 16 Number of Crops Grown

(percentage of households growing more than four crops out of those households normally cultivating garden)

Water Management

The key to successful cultivation on a dambo lies in the ability to adapt to and manage the varying soil moisture conditions. In high rainfall areas (ie Natural Regions I and II), irrigation is unnecessary for most of the year, since the soil remains moist. In wet years raised beds must be formed to prevent waterlogging of crops. Shallow drainage channels are often constructed to drain excess water. In areas with lower rainfall, irrigation is needed for a greater part of the year. In drought years it is necessary in all areas. When crops are first planted some irrigation is essential if the rains are erratic. Figure 17 summarizes the number of months during which crops were irrigated by households in each study areas.

With the exception of Chizengeni the majority of households irrigate for some 4-6 months. Field observation suggests that this was due primarily to environmental factors with the water table being closer to the surface in Chizengeni. Here crops grown in the early dry season do not usually need to be irrigated.

In Chizengeni, Bumburwi and Masiyarwa, water for irrigation is obtained from wells in the gardens (ie inside the fencing). In Shumbairerwa, where gardens are smaller and some families share wells, most wells are just outside the fence. Several households with large gardens, especially in Chizengeni and Bumburwi, had more than one well in order to reduce the time spend carrying water to distant parts of the garden (Table 14).

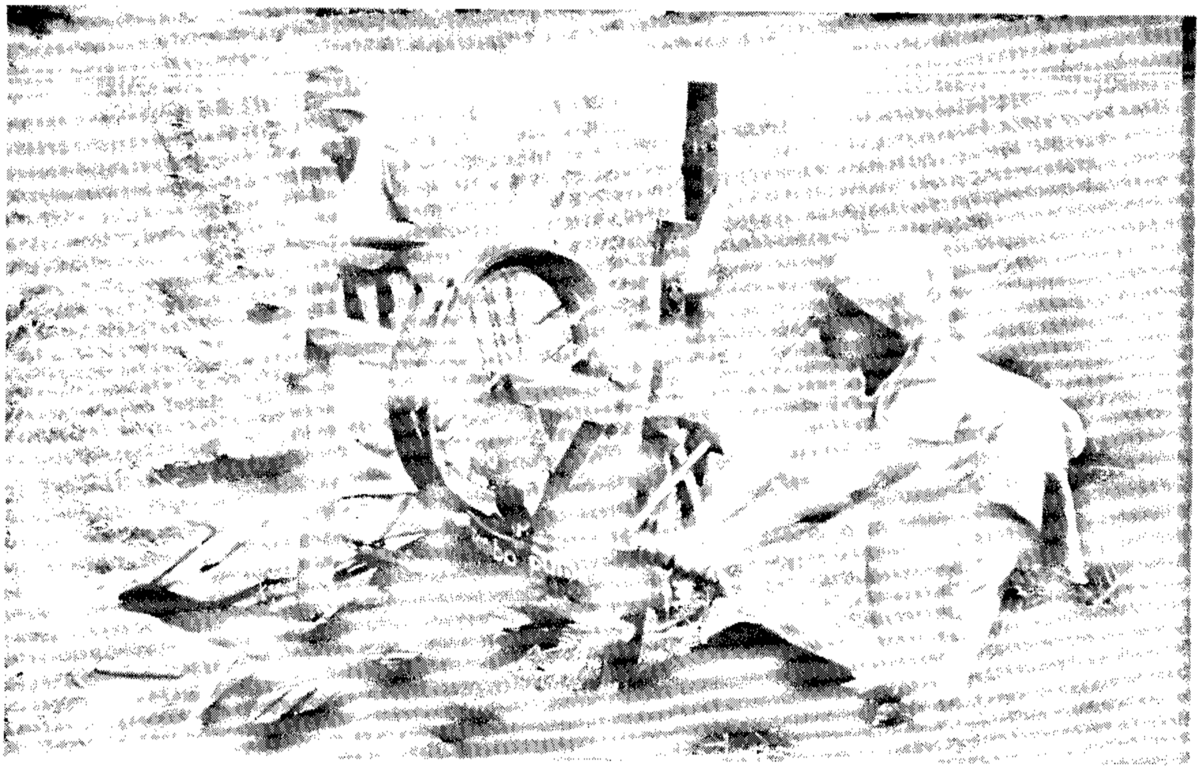

Plate 8 Dambo tambo (rope-washer) handpump

Plate 9 Well on Chizengeni dambo used for domestic water supply

Plate 10 Ox-ploughing dambo garden

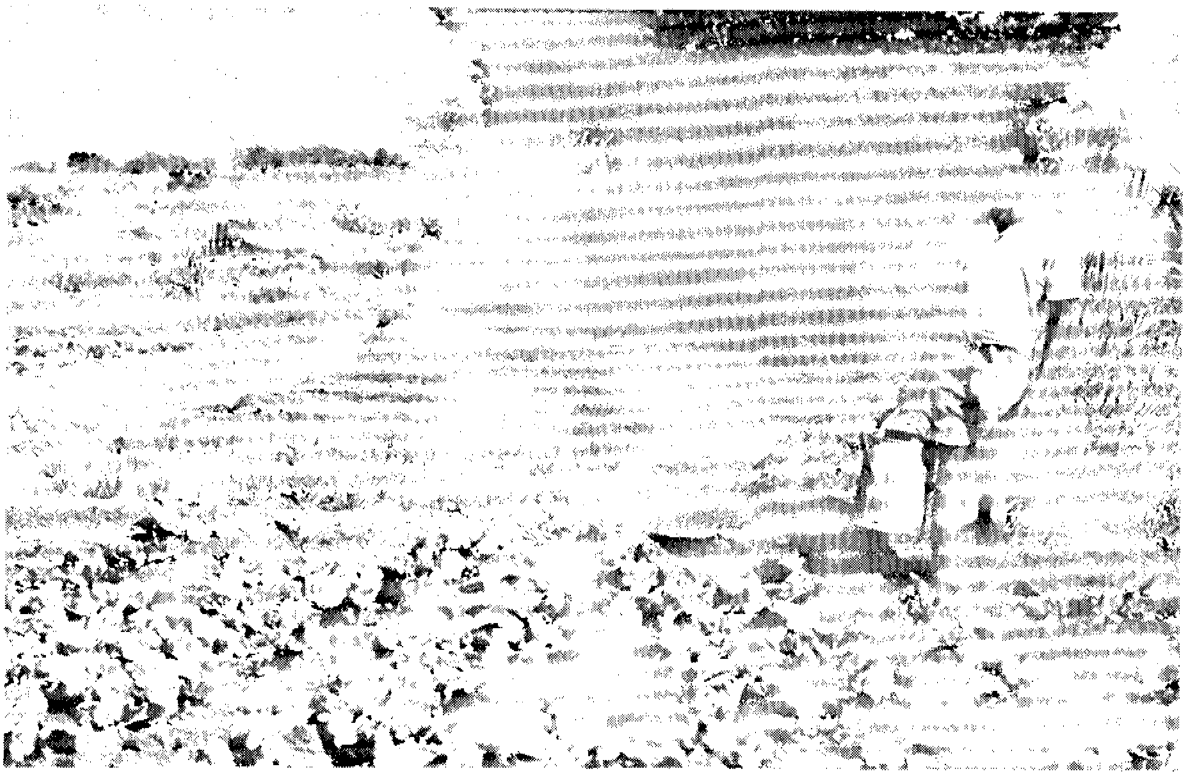

Plate 11 Garden irrigation by watering can

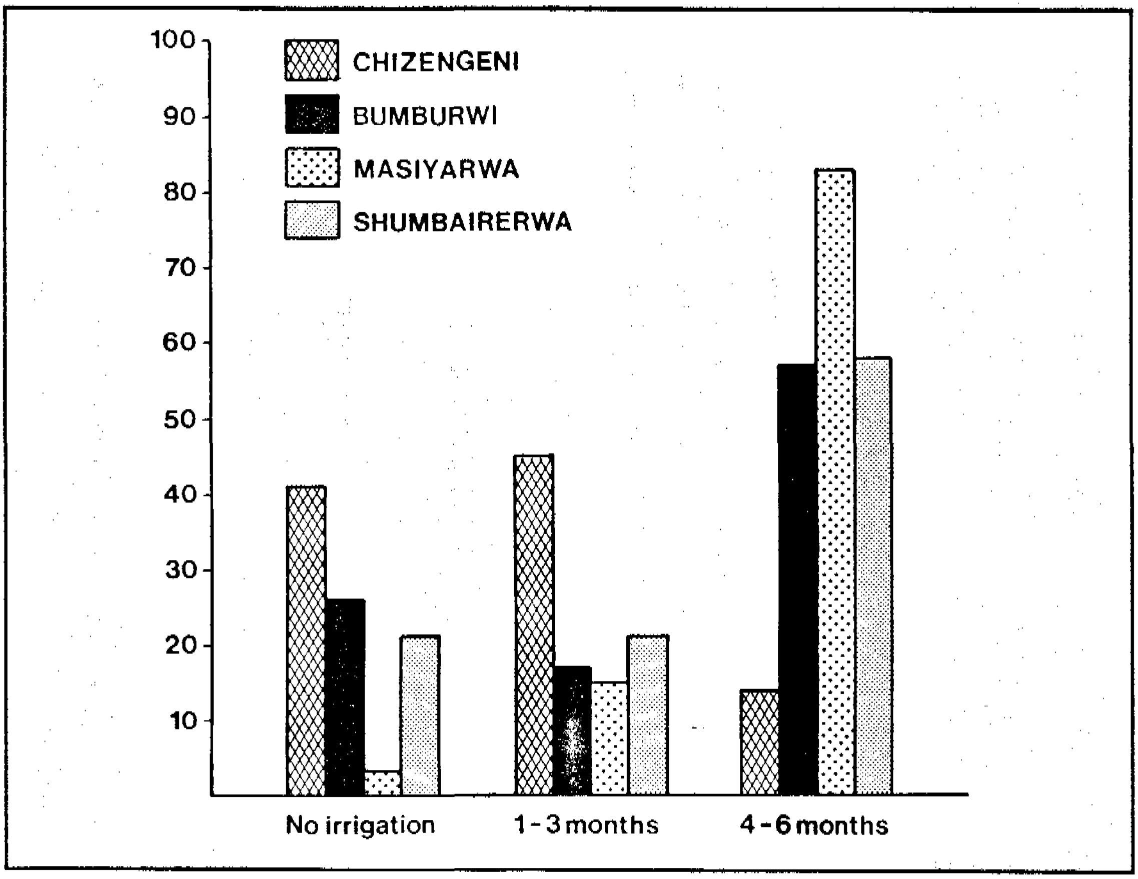

Figure 17 Irrigation of Dambo Gardens

(percentage of households irrigating dambo gardens)

Table 14 Wells in Garden (%)

Area	Percent
Chizengeni	34
Bumburwi	52
Masiyarwa	25
Shumbairerwa	11

(percentage of households with more than one well in garden out of those who actually use garden)

Even in Masiyarwa, where gardens are smaller than in Chizengeni and Bumburwi, several households found it less time-consuming to dig two wells than to carry water from one end of the garden to another. A few farmers also have small earth reservoirs for collecting water during the rainy season (Table 15).

Table 15 Small Earth Reservoirs in Garden (%)

Area	Percent
Chizengeni	23
Bumburwi	22
Masiyarwa	10
Shumbairerwa	0

(percentage of households with reservoirs out of those who actually use garden)

The simplest method of irrigation is a bucket (Plate 11). A slightly more advanced, but still inexpensive method is a watering can. These cans often have a flat, perforated spout which spreads the water more evenly on plants. They are available from stores at business centres and, in the case of Chizengeni and Bumburwi, from the local tinsmith. They cost from Z$15-50, depending on the source. Although the financial cost is low, this type of irrigation requires much time and effort.

Out of the 200 households surveyed, all but one uses a bucket and/or watering can as the main method of irrigation. Located in the Bumburwi study area, this farmer uses a diesel pump to draw water from a nearby river, although his garden is located over 30m from the streambank. He earns a relatively high income from his garden (over Z$1,000/year) and is able to cover the costs of the pump. Diesel pumps are not only expensive, but are difficult to obtain and have high operation and maintenance costs. These pumps are more common in areas such as Chinamora (15km north of Harare) where farmers earn up to Z$10,000/year from their gardens.

An intermediate method of irrigation is the use of hosepipes for distribution of water from a well or dam. Water is siphoned from an oil drum situated next to a well and filled by bucket. The hosepipe is moved to various parts of the garden, reducing the need to carry water. Earth channels are also used to distribute water, although this involves high losses due to seepage. Several farmers surveyed used a combination of these methods.

During the year of study a simple handpump was developed by the project team and installed in the garden of one of the households studied in Chizengeni (Plate 8). Another was built by a local farmer and some interest was expressed at village meetings in this intermediate level of technology (see Section 5).

Use of Agricultural Inputs

Although the agricultural extension services have greatly expanded since Independence and place more emphasis on communal farmers than before, there is still little research, training and advice in Agritex on dambo cultivation. Despite this lack of advice, those farmers who have been cultivating their gardens for many years have developed their own strategies for growing successfully on gardens. Decisions on the use of inputs on gardens are closely linked with successfully on gardens. Decisions on the use of inputs on gardens are closely linked with dryfield practices. But they are also based on knowledge of the very different environmental conditions which exist on dambos and the requirements of the particular crops grown. In Chizengeni one farmer has been cultivating his garden since 1948 with no apparent loss of soil fertility. Other farmers have followed his example, such as a widow who now grows many crops successfully for sale (see Section 2.3).

Although some farmers, especially in Bumburwi, plough their dryfields with tractors, land preparation on gardens is generally done by hand or by ox-plough (Plate 10). In Chizengeni all ploughing is done with oxen. In Bumburwi two households use tractors and the remainder use ox-ploughs. By contrast, five households in Masiyarwa and three in Shumbairerwa do their land preparation by hand; the remainder plough with oxen. On the dryfields, land preparation is primarily done by ox-plough in Chizengeni, Masiyarwa and Shumbairerwa. In Bumburwi, where several farmers own tractors, almost 50% of the households pay these farmers to plough their dryfields.

Although households rely on family members and reciprocal arrangements with neighbours for labour in agriculture, there are some cases where labour is hired for pay, either in cash or in kind. Table 16 shows the percentage of households hiring labour on their gardens and dryfields. The high percentage of labour hired in Masiyarwa and Bumburwi is mainly for ploughing. In Chizengeni, where most households do their own ploughing, more labour is hired on the gardens. Households hiring labour on the gardens are those which are growing cash crops and need extra assistance with such tasks as weeding and irrigation. The usual daily rate for work in Chizengeni is Z$2.00-2.50, although often labourers are paid by the specific job.

Table 16 Households Hiring Labour (%)

	Garden		
	Dry	Wet	Dryfields
Chizengeni	25	32	21
Bumburwi	20	20	50
Masiyarwa	15	11	34
Shumbairerwa	13	0	24

Communal farmers use four major inputs to improve soil fertility and increase yields. These are chemical fertilizer, manure (both from goats and cattle), anthills and compost. Fertilizer must be purchased at costs ranging from Z$20-Z$25 per bag and is not always available locally. Cattle manure is available from cattle kraals for 90% of all households with gardens. Twenty-three percent of the households with gardens depend on manure collected from around the grazing area to provide or supplement their supply of manure. Goat manure is generally collected from goat kraals. Although anthills (termite mounds) are widespread on dambos, digging and transporting them requires much effort and time. The raw materials for making compost (manure and plant residues) are freely available, but this process is also labour intensive.

Most farmers complained of low soil fertility on the dryfields, saying that they would have little or no maize if they did not use fertilizer. On the other hand, although dambo soils are generally more fertile (see Section 2.4.1) chemical fertilizer may be needed for specific crops. When a farmer invests time and money in growing crops for sale in Harare s/he will want to be sure of high yields and good quality crops. Also, some vegetable crops require special fertilizers not readily available for and appropriate to dryland farming. Anthills, manure and compost not only help to increase yields, but are also crucial to the maintenance of soil quality. The variation between areas in use of inputs on the gardens and dryfields is shown in Figure 18.

The majority of households in all areas still rely heavily on manure to maintain soil quality. Over 70% use cattle manure on the dryfields and garden at all times of the year. Fewer than 60% of households in all areas use anthills. The only exception is Bumburwi, where 75% of the households apply anthills to the gardens in the dry season. Compost is also more widely used in Shumbairerwa, with 60% of households applying it to both the dryfields and gardens.

Over 80% of households in all areas except Shumbairerwa used fertilizer on their dryfields. This proportion is higher than those using fertilizer on gardens. This use of purchased inputs reflects not only the lower soil quality on the dryfields, but also the fact that the dryfields are still considered crucial to agricultural production. Exceptions to this do exist, such as one farmer in Chizengeni who said that he used all purchased inputs on his garden, where he expected higher yields. However, in years with adequate rainfall most households still depend on the dryfields for the bulk of their maize production. On the gardens, fertilizer use tended to be higher in the wet season than in the dry season. This is due to the greater availability of fertilizer at this time of the year and, in Chizengeni, to the high level of cash cropping. Often, some fertilizer obtained through loans for use on the dryfields is diverted to the gardens. In Shumbairerwa, less than half of the households used fertilizer. Few households in this area had loans for purchased inputs from the Agricultural Finance Corporation or other organizations. Therefore, they rely more on locally available inputs than do households in the other three areas. Use of compost and goat manure is high, with anthills mainly used on the dryfields.

Pest control is a major problem on gardens, especially in the wet season. While some farmers own sprayers, those who cannot afford them must apply the pesticides by hand. This involves mixing the powdered chemical in a bucket with water, then using a leaf to shake the liquid over the plants. Although cheaper than a sprayer, this method is extremely hazardous. The use of pesticides on the gardens was overall much higher (58%) than on the dryfields (25%).

From the evidence above it is apparent that each case study area displays a somewhat different pattern of dambo cultivation reflecting some of the variations which exist in Zimbabwe. In

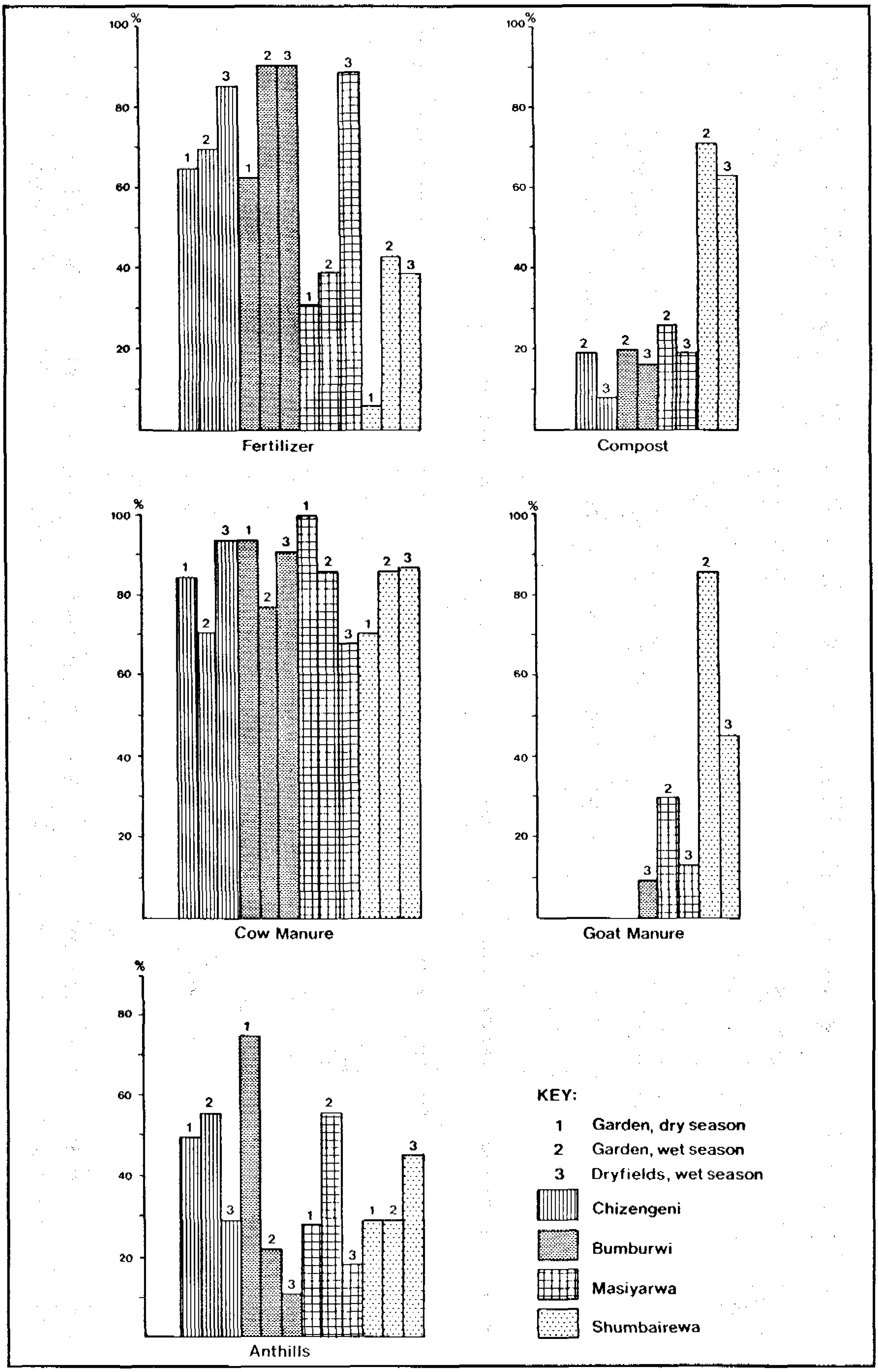

Figure 18 Use of Agricultural Inputs (% of households)

Chizengeni access to and use of a dambo garden is widespread and of comparable importance to dryfield cultivation. Households use their gardens in both dry and wet seasons, especially during the latter, and the range of crops grown is greater than elsewhere. In Masiyarwa access is also high but garden cultivation is primarily a dry season activity. It is at this time that the greatest range of crops is grown while in the wet season few households grow more than four crops since their activities are concentrated on the dryfields. Bumburwi and Shumbairerwa share characteristics in common with Masiyarwa. For example, garden cultivation is chiefly in the dry season during which time the greatest range of crops is grown. But overall, access to a garden is much more limited in Bumburwi and Shumbairerwa than elsewhere and the level of garden cultivation is relatively low in comparison to dry farming. These similarities between Bumburwi and Sumbairerwa should not, however, be allowed to mask marked differences between the two areas. Unlike Shumbairerwa, Bumburwi is a relatively prosperous village where activities other than agriculture sustain many households. Of those who do cultivate, the widespread use of tractors on dryfields and commercial inputs on gardens is evidence of this relative prosperity. Analysis of crop use in each study area reinforces the differences outlined above.

Use of Crops

In all four study areas crops grown on dambo gardens and dryfields are used for a combination of household consumption and sale. In discussing the use of crops, garden production needs to be placed in the context of dryfield production. It should also be stressed that the field survey took place during a year of good rainfall. After the dryfield harvest in April/May all households questioned stored some of their maize for the remainder of the year. In addition, some 50% sold a proportion of their surplus for a fixed price to the Grain Marketing Board in September/October when collections were made from the grain depots. Of those households who had already sold their dryfield maize by the time of the survey, several in Chizengeni, Bumburwi and Masiyarwa obtained incomes of over Z$100 and in the case of Masiyarwa they exceeded Z$500. By contrast, it was evident from visits to all study sites in May 1987 that, after a season of no rain, most households had not been able to grow enough maize to meet subsistence needs.

Crops from dambo gardens also provided for household needs. But the range of marketing possibilities was much greater than for dryfields and more flexible in terms of the times of the year at which they could be exploited. Unlike the staple crops, vegetables need to be marketed immediately after they are harvested and this enabled households to obtain a cash income at varying times in both the wet and dry seasons. The use of crops by individual households was closely related to the types of crops grown.

Vegetables for relish were grown throughout the year by some households in all areas. A supply of relish for home consumption was therefore available to supplement the staple food. Much local exchange of vegetables was also picked up in the field survey. For households without dambo gardens the purchase of a few vegetables from a neighbour's garden supplemented the staple diet during the year. The importance of vegetables in the diet to households in the communal areas is reflected in the fact that those without gardens on the dambo frequently have one by their house (Table 17). This is particularly striking in Bumburwi and Shumbairerwa, where access to a dambo garden is relatively low.

Table 17 Garden at Homestead (%)

Area	Percent
Chizengeni	10
Bumburwi	34
Masiyarwa	18
Shumbairerwa	42

These gardens by the homestead are small plots fenced off at the homestead and watered with kitchen wastewater or from wells used for domestic water supply. Unlike dambo plots, no formal permission is required for such gardens.

For most households in all study areas the local sale of produce is the primary source of income from gardens. Small amounts were being sold 'here and there' at any one time producing cumulatively an income of less than Z$100 (Table 18).

Table 18 Gross Income from Agriculture (%)

	Chizengeni			Bumburwi			Masiyarwa			Shumbairerwa		
	Garden		Dry-fields	Garden		Dry-fields	Garden		Dry-fields	Garden		Dry-fields
Income	Dry	Wet	Wet	Dry	Wet	Wet	Dry	Wet	Wet	Dry	Wet	Wet
<Z$100	14	33	26	20	20	8	49	52	4	44	71	16
Z$100-499	3	24	21	5	0	16	15	7	9	0	0	3
Z$500+	0	5	3	0	0	8	0	0	11	0	14	3
Not yet*	25	8	8	15	13	5	0	0	64	0	0	45
Total	42	70	58	40	33	37	64	59	88	44	86	67
n =	36	37	38	20	15	38	39	27	47	16	7	38

(out of percentage of households actually cultivating their gardens and dryfields by season)
*Not yet - households who plan to sell crops, but have not yet done so

In all areas garden produce provided both a supplement to the diet and a useful addition to the household income from dryfields. Although these incomes appear low, they are not insignificant. Small incomes spread throughout the year were used for incidental expenses (food, clothing) and school fees. They reduced the need to budget the income from the dryfield harvest over the entire year, an important factor in areas where banking services are nonexistent. (A detailed comparison of dryfield incomes between areas cannot be made in view of the large number of households in Masiyarwa and Shumbairerwa who had not yet sold their maize by the time of the survey. Note also that size of income is not related here to output per hectare.)

While this basic pattern of local supply and demand for relish vegetables underpins crop use, variations did occur between areas which could be related to the range of crops grown and to the intensity of cultivation at different periods of the year.

Only in Chizengeni were dambo cultivation and dryfield activity balanced. Some 96% of households had access to a dambo garden and all had access to dryfields. The proportion obtaining cash from their gardens was also broadly similar to those selling from dryfields. Those households who planted maize and/or rice in the late dry season also had a supplement to the dryfield staple in January when the food store from the previous year's harvest was becoming depleted. In 1987 when there was a drought in Zimbabwe several gardens in Chizengeni were growing two crops of maize on their gardens for home consumption.

A variety of marketing outlets are available to farmers in all areas, although the full range of possibilities is most widely used by those in Chizengeni (See Table 19).

Table 19 Methods of Marketing Vegetable Crops

LOCALLY	-	People buy directly from their neighbours gardens. Farmers sell their crops at nearby schools and business centres and some entrepeneurs come out from nearby cities to buy crops for resale directly from gardens.
WITHIN THE COMMUNAL AREA	-	Farmers sell their crops at more distant villages by going from house to house (on foot or bicycle) or selling at business centres and schools.
IN TOWNS AND CITIES	-	Crops are taken by bus or private transport to wholesale markets. Payment is either immediate or, in the case of Independent Market in Harare, one week after the crops are left for sale.

In Chizengeni there is a long tradition of the local marketing of relish vegetables (van Vulpen, 1983). In view of the high level of production in this village throughout the year, it appeared that at least village demand was being satisfied. Some households were observed selling their produce in neighbouring villages, including Bumburwi. Over and above this, in Chizengeni a wide variety of cash crops was also grown, particularly in the wet season, for distant markets, notably in Harare. One farmer reported that as far back as the 1950s he walked to Harare with his vegetable produce. Through the application of local entrepreneurial skills relatively high incomes (over Z$500) were being secured during the wet season. The success of commercial marketing close to Harare has encouraged a small minority of households in Chizengeni to concentrate on their dambo garden at the expense of the dryfields. In the case of one farmer all his purchased inputs were confined to his garden.

It should be stressed that all figures on income are likely to be conservative estimates. It is difficult to calculate with accuracy the household income derived from crop sales. Besides an understandable unwillingness to divulge such information and the difficulty of recall (see Section 2.3), households do not always report the small amounts of cash they may obtain from informal local exchange. The field survey suggested that this problem was related in part to the scale of local marketing and therefore it was to some extent place specific. In Chizengeni, for example, in view of the large scale selling which takes place, it is probable that some interviewees felt it was not worth reporting the sale of a few tomatoes or onions to neighbours. This under reporting of small amounts may be less significant in the other study areas where the scale of selling is much smaller.

Patterns of crop use in Masiyarwa, Bumburwi and Shumbairerwa contrasted sharply with those in Chizengeni. Not all the marketing possibilities could be exploited and crop sales were confined almost exclusively to the local catchment. There was also, unlike Chizengeni, a bias towards dry season production and selling. Masiyarwa stands out as an area where, for the majority of households, dryland cultivation took precedence over gardens as a source of agricultural income. Substantial incomes were secured from the sale of maize. The marketing of vegetables in small amounts took place throughout the year, but they were almost exclusively relish vegetables sold locally. Like Chizengeni there is a long tradition of local selling in this village. For many years a nearby mission school of over 500 pupils provided a regular market for many households but now it has its own garden thus reducing the local demand for vegetables. In Masiyarwa, as in Chizengeni, the local market is satisfied by present levels of production. Although these two villages are similar distances from Harare none of the farmers questioned in Masiyarwa sold crops outside the local area. Agritex officers from nearby areas knew of only one farmers growing vegetables for sale in Harare. There is, therefore, still untapped potential here for the use of gardens for cash cropping for distant markets.

While the local demand for vegetables remains constant during the year, the supply fluctuates and is therefore not always adequate. This is particularly the case in Bumburwi and Shumbairerwa where fewer households have gardens, and their level of production is much lower and more seasonal than in the other two areas. However, the impact of these conditions is very different in the two villages. In Bumburwi agriculture for cash (both dryfields and gardens) is not as significant to the livelihood of households as in Sumbairerwa. Local demand for vegetables in Bumburwi is met by neighbouring villages such as Chizengeni.

In Shumairerwa harsher environmental conditions restrict the extent of garden cultivation and largely confine it to an early dry season activity. The selling of maize remains crucial to the welfare of the majority of households. Although some local marketing of vegetables takes place by farmers with gardens, overall demand is not met and indeed several households indicated that they did not have sufficient vegetables for relish for much of the year. The surrounding area is also relatively poor agriculturally and cannot provide a buffer. The potential for local marketing is reflected in the enterprise of one farmer who cultivated crops mainly for selling in both wet and dry seasons and earned at least Z$3000 in the year of study. In July 1986 he was growing 5000 cabbages which he expected to sell to local residents and school teachers for Z$0.50 each, while in May 1987 he was selling cabbages for Z$0.75. At the same time tomatoes which had been transported from Harare were being sold in the market in Gutu (the growth point for the communal area).

2.3 Case Studies

2.3.1 Methodology

In order to obtain a more in-depth analysis of how dambo cultivation affects individual households, 40 households were chosen for more detailed studies. To simplify logistical arrangements, and also cover two different areas, the detailed studies focussed on households from only Bumburwi and Chizengeni. These studies were carried out over a one-year period (October 1985-September 1986) to assess the seasonal differences in activities. Local, trained enumerators collected the following information through bi-weekly observational studies (Appendix 3a):

1. Labour time allocation
2. Non-family labour
3. Water collection (including irrigation)
4. Foods consumed
5. Food entering cooking hut
6. Harvest and food use from dryfields and gardens

Every four weeks, households were asked additional questions about the following activities on their gardens and dryfields (Appendix 3b):

1. Ploughing
2. Planting
3. Use of inputs to improve the soil
4. Use of labour other than household members
5. Use of pesticides
6. Irrigation
7. Harvest and use of crops

2.3.2 Background

Of those households with gardens, patterns of use are similar to those identified in the general survey. In Bumburwi the seven households with gardens grow crops mainly for home consumption. Only three earned an income from their gardens, all less than Z$100. By contrast, in Chizengeni out of the eighteen households with gardens, fifteen sold crops, eight of whom had incomes exceeding Z$100 (Table 20). Those who secured high incomes did so through the sale of cash crops, mainly in Harare. As indicated below, they comprised a range of household types.

Table 20 Garden Incomes over Z$100

Income		Type of
Garden	Dryfields	Household Head
Z$2,000	NY*	Male present
903	110	Male present
850	NY*	Male present
412	0	Female
393	396	Widow
342	NY*	Male present
150	NY*	Widow
110	430	Male migrant

*NY - plan to sell maize, but not yet decided how much

In Chizengeni the three households without a garden income sold no dryfield crops either. Two of these households were headed by adults with alternative sources of income; one as a migrant labourer, the other, a widow, from local work as a seamstress. The third household was headed by a male with no outside income. Although not all households depended on agriculture for cash, they appeared to have adequate food for home consumption. Measurements made of children under five years within the 40 study households indicated that they were all within the acceptable height/weight ratio.

2.3.3 Detailed Analysis

It was not feasible to analyze thoroughly the data collected on all 40 households for the purpose of this report. Rather three households in Chizengeni were chosen for detailed analysis. All three have a garden from which two households earn more than Z$100. General characteristics of each household are outlined in Table 21. (Household members are defined as those normally resident at the homestead.)

The head of Household No. 1 is a widow who depends mainly on agriculture for cash income. Her eldest son who is a teacher lives elsewhere and is concerned primarily with his own homestead. In Household Nos. 2 and 3 the heads are carpenters who earn some income from local labour. The head of Household No. 3 and his son both obtained work as migrant labourers during the year of study, bringing a more steady income into the household. The relative importance of these outside incomes could not be ascertained due to difficulties of recall and the sensitivity of the subject. However, in the case of Household No. 3, in view of the modest incomes secured from both dryfields and dambo gardens, it can be suggested that other sources of cash such as migrant labour were more important. All three households had additional adult labour available during most of the year of study to assist with domestic and productive tasks. They also had cattle and oxen for ploughing.

Table 21 Characteristics of Case Study Households

Characteristics	HH No. 1	HH No. 2	HH No. 3
Household Head			
Type	widow present	male present	male
Age	42	40	55
Occupation	farming	farming/ carpenter	farming/ carpenter (some migrant labour)
Household			
No. of adults	4	4	4
No.of under 5's	0	0	2
Total in family	7	8	6
Cattle			
No. of cattle	17	5	4
No. of oxen	5	3	3
DRYLAND			
No. plots(ha)	5(2.3)	3(2.7)	2(1)
Total crops	4	1	4
Total income	$350-400	$110	$20
DAMBO			
No. of plots (ha)	1(0.5)	1(0.5)	1(0.5)
No. of crops	14	8	10
No. of crops sold	7	4	2
No. of months crops sold	10	5	4
Total income	$500-800	$900-1000	$70-100
Irrigation	6 months	3 months	9 months

Cropping Patterns

All three households grew a variety of crops on their gardens in addition to staple foods on their dryfields. Although garden sizes are similar, important variations occured between households in the intensity of garden cultivation and the type of crops grown. Household Nos 1 and 2 grew mainly cash crops (see below) and cultivation was concentrated in the wet season from November to April (Figure 19). These findings coincide with the general survey. By contrast Household No. 3 confined its garden activities to relish crops for home and local consumption. Cultivation was restricted during the wet season from January to March due to waterlogging of the soil.

Use of inputs

All three households used chemical fertiliser, pesticides and cow manure (from the kraal) on their gardens. Only Household No. 3 applied anthills. There are few goats in Chizengeni and goat manure was not available to the study households.

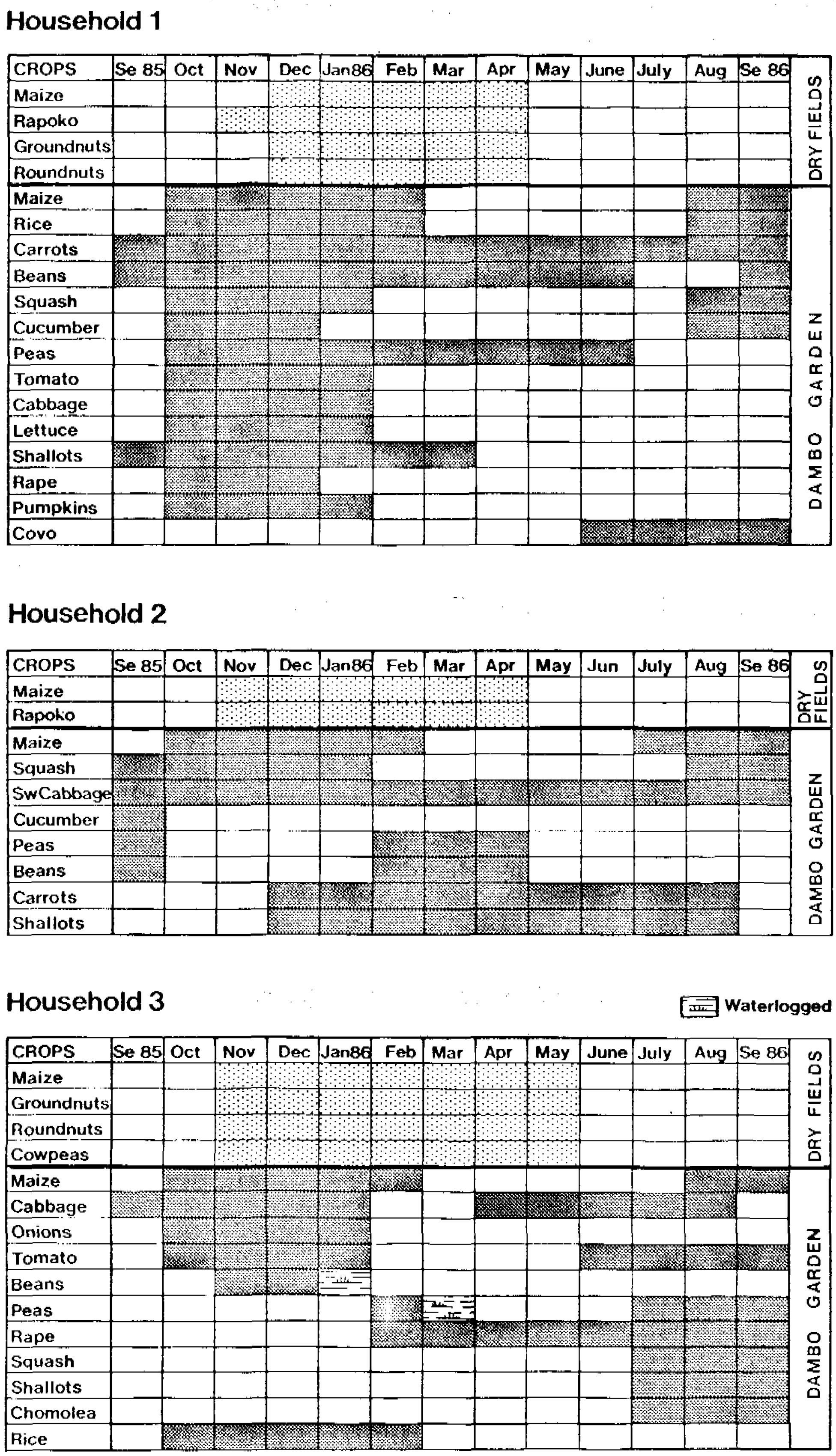

Figure 19 Cropping Patterns

Buckets and watering cans were used by all households for irrigation. In addition, Household No. 2 used a furrow system for distributing water within the carrot beds. For the households analysed here, no irrigation was observed on study days. Irrigation figures were obtained by monthly recall and must therefore must be seen as estimates. As shown in Table 22 recorded irrigation varied greatly by amounts and number of months. Overall the quantities used were minimal and relate to very small plot sizes.

Table 22 Irrigation

Month	Amount (litres/day)		
	HH No. 1	HH No. 2	HH No. 3
October 1985	60	40	50
November	30	0	390
December	13	0	240
January 1986	0	0	0
February	0	0	0
March	0	0	0
April	34	0	120
May	0	13	32
June	0	0	13
July	0	0	300
August	47	13	85
September	43	0	300

Household No. 2 irrigated the least, with fewer crops growing in the months when irrigation was needed. These figures indicate that even in the case of households which grow mainly for home consumption, the quantity of water used for irrigation, and therefore the labour time expended, can be considerable.

Food Consumption

As a rule, the households consumed three meals per day. For each household a simple tabulation was made of the foods consumed (notably maize, rice and vegetables) and their sources. No record was made of snacks between meals.

Maize was consumed at least once per day at supper and often also at lunch. It is eaten in the form of a very thick, almost hard porridge called sadza which is the staple in Zimbabwe. Sadza is served with various types of vegetable relishes or 'soup' made with chicken or meat. On occasion it is also served with insects, caterpillars, sour milk or capenta (small dried fish purchased from local stores). For breakfast, maize porridge is sometimes served or alternatively bread with margarine which is more costly but less time consuming to prepare. Rice forms a relatively small part of the staple diet. It is considered to be a sophisticated food and, unlike maize, is not a staple on which households depend.

For most of the year of study each household used dryfield maize for sadza, supplemented by 'green mealies' (maize on the cob) in January and February from the garden. Towards the end of the rainy season they began to rely on garden maize also for sadza and porridge. Household No. 1 consumed garden maize from the end of April to early June; the other two households used it from March to May. Thus garden maize provided both a supplement to the diet and a staple food in the difficult months before the dryfield maize was harvested. Rice was consumed less often than maize (Table 23). Household Nos. 1 and 3 obtained it almost exclusively from their garden while Household No. 2 acquired it from local sources including purchase from the store and a neighbour.

Table 23 Rice Consumption

HH No.	No. of Weeks	Source Dambo	Other
1	5	4	1
2	3	0	3
3	9	8	1

The main vegetables consumed by the households were tomatoes, cabbage and green leafy crops which included rape, pumpkin leaves, chomolea and rugari (Figure 20).

Although the dambo garden supplied some of these vegetables, they were also obtained from other sources. A few tomato plants and leafy crops were grown by the homestead watered with kitchen wastewater or water from nearby covered wells. Pumpkins and their leaves were obtained from dryfields. It was also apparent that not all three households chose to be self-sufficient in all vegetables. Informal local exchange and purchase of vegetables at local stores satisfied domestic food needs, making it it possible to concentrate on selected cash crops. Crop specialisation was particularly noticeable in the case of Household No. 2 which used the income from crop sales to purchase relish vegetables locally. Even in the case of Households Nos. 1 and 3, although they grew a greater range of relish crops on their garden than Household No. 2, they too supplemented their supply by purchase from nearby households and the local store. (Although cash vegetables such as carrots, lettuce, cucumber and peas, were rarely eaten at meal times by the household which cultivated them, they occasionally provided a snack for those working in the garden.)

Incomes

As noted in Table 24, Households Nos. 1 and 2 earned substantial incomes from their gardens. Household No. 3 attempted to grow one cash crop (peas) but it became waterlogged in March. A monthly breakdown of incomes for all three households (Table 24) illustrates how effectively cash returns could be spread through the year in contrast to the dryfield income which came as a lump sum (minus any government loan) several months after the maize had been sold.

It should be emphasised that crops other than maize are grown by some households on their dryfields and sold both locally and to the Grain Marketing Board (GMB). For example, the dryfield income of Household No. 1 comprised maize to the GMB and 5 buckets (approx. 40kg.) of groundnuts sold locally. While Household No. 3 sold no maize, its modest dryfield income came from the local sale of a surplus of 4 buckets (approx. 20kg.) of cowpeas.

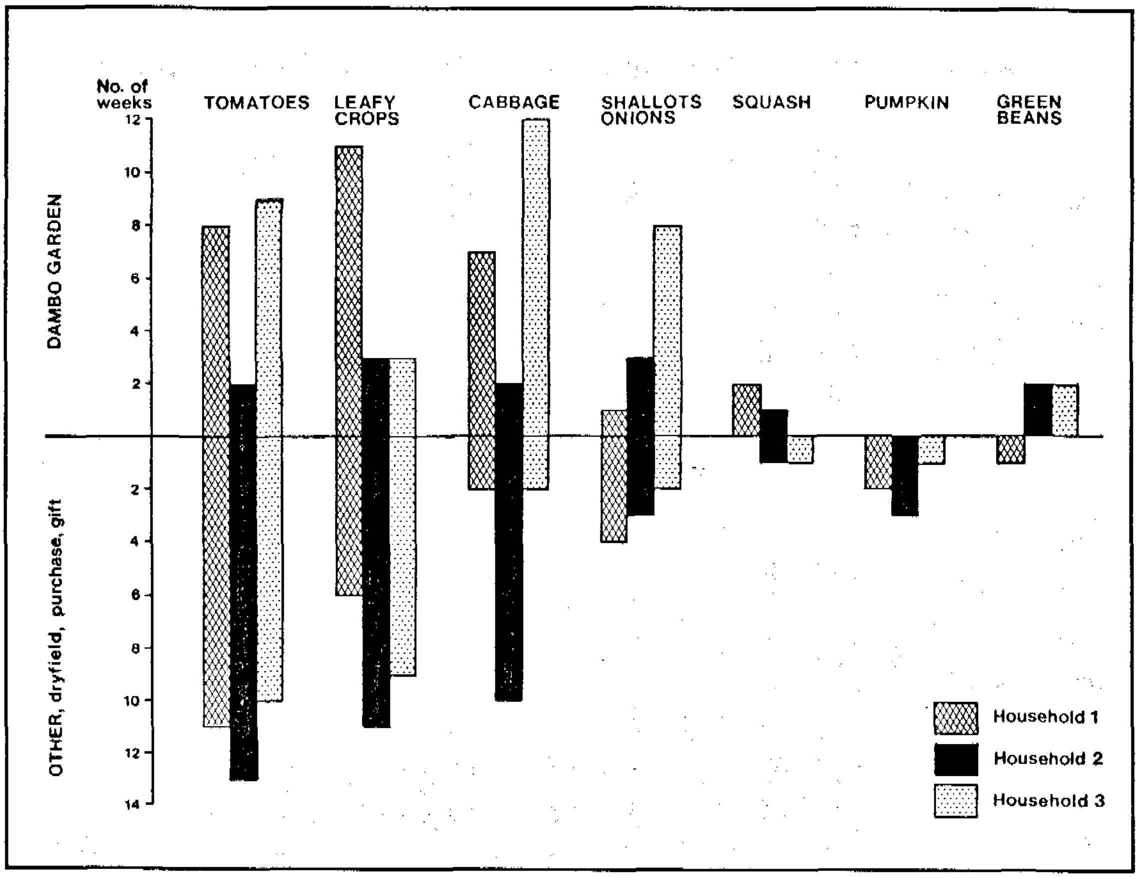

Figure 20 Frequencies and sources of Vegetables Consumed

Table 24 Gross Incomes from Gardens and Dryfields

Month	HH No. 1	HH No. 2	HH No. 3
October 1985	Z$ 40	Z$ 0	Z$ 60
November	90	0	0
December	130	250	0
January 1986	170	100	0
February	70	0	0
March	30	400	0
April	100	0	0
May	100	50	0
June	50	0	0
July	0	0	2
August	100	110	6
September	0	0	5
Total	Z$880	Z$910	Z$ 73

Household Nos. 1 and 2 had similar gross annual incomes from selling their cash crops at Independent Market in Harare. However, Household No. 1 sold a greater range of crops (Table 25) than Household No. 2 and was involved in marketing smaller quantities for twice as many months.

Table 25 Crops sold

Household No. 1	Household No. 2	Household No. 3
carrots beans squash lettuce cucumber pumpkins peas	carrots beans squash shallots	cabbage rape

Only in July and September did Household No. 1 secure no income from its garden. This regular accumulation of cash was made possible by the continuous planting and harvesting of crops such as carrots and beans and by two plantings during the year of squash and cucumber (Figure 19). In the case of Household No. 2 marketing was restricted to four cash crops, but by staggering the times of planting, harvesting and marketing were spread over five months. High incomes recorded in December and March were for a single crop of squash and carrots respectively. In the case of Household No. 3, Table 24 emphasises the relative insignificance of the dambo garden as a source of cash. For this household, the major source of garden income was obtained through local marketing of cabbages in only one month..

It should be emphasised that even these incomes, based on monthly recall, are conservative. For example, although Household No. 1 harvested cucumbers in December, peas in December and lettuce in January the cash returns from these were not picked up in the survey. Similarly for Household No. 2 the income obtained from peas harvested in April was unavailable. These omissions highlight the problem of recall when recording households incomes.

Although high incomes were obtained from garden crops, prices fluctuated greatly during the year of study even within the same month. In the case of carrots, for example, Household No. 2 earned Z$400 from two harvests in March, one from selling for Z$2.50/pocket (12kg), the other for Z$8.70/pocket (Table 26). The more usual price was around Z$3.00/pocket, although during the month of August it fell to Z$0.75.

It was reported that in the case of Household No. 1 all decisions regarding crops grown, marketing and use of income were made by the household head, a widow. In Household No. 2, although the male head determined which crops should be grown, his wife was also involved in decisions over the use of income. This is similar to the findings of Truscott (1985) who observed that women were involved in decisions on both dryfields and gardens.

Table 26 Prices Obtained for Carrots (per pocket)

Month	Household No.1	Household No.2
October	Z$ 3.00	—
November	3.00	—
December	2.60	—
March	—	2.60
March	—	8.70
April	5.00	—
August	0.75	1.00
August	3.00	—

(all crops sold at Independent Market, Harare)

Labour

Although there are nutritional and financial advantages to be gained from cultivating a garden, labour demands are high throughout the growing season, especially when cash crops are cultivated for sale in competitive markets. Table 27 summarises the average time spent on various activities by adults in each of the three households during the year of study.

Household Nos. 1 and 2, both of whom grew cash crops, spent a similar proportion of time on their garden (16.9% and 13.3% respectively), and this was considerably greater than Household No. 3 (4.1%). Time devoted to the garden by the first two households was also much greater than on the dryfields. Even allowing for the fact that the study covered 25 days throughout the year and could have missed the major days during any one month spent on the dryfields, this is still a significant difference. Only in the case of Household No. 3 was the proportion of time on the garden and dryfields broadly similar.

Although it might be assumed that labour effort on gardens would be concentrated at a time when there are not demanding activities on the dryfields, this did not appear to be the case with the households studied (Figure 21). It was during the wet season in particular, which are busy months on the dryfields, that much cultivation also took place on the gardens. This concurs with the general survey results for Chizengeni. There are no obvious explanations for this pattern of activity although several reasons where given. Both farmers and field assistants reported that much time is spent, especially in the early dry season, in preparing maize for the Grain Marketing Board. This is time-consuming in all areas. However in Chizengeni, where there is much activity in the wet season on both dryfields and dambo gardens, it is conceivable that households did use the early dry season as a period of rest on their gardens and devoted more time to maize preparation.

Table 27 Labour Time Allocation (For 25 weeks, ending mid-September 1986)

Activity	Time spent (% of total time) HHNo. 1	HH No. 2	HH No. 3	Average
Domestic (inc. water collection)	15.9	19.3	22.2	19.1
Collect food	0.6	0.0	0.0	0.2
Collect wood	0.6	1.1	0.6	0.8
Medical	0.0	4.4	0.9	1.8
Shopping	0.3 0	7 1	1 0	7
Eating/Bathing	13.7	15.3	12.9	14.0
Relaxing	9.7	12.9	11.6	11.4
Visiting	11.3	10.5	11.6	11.1
School	15.6	6.5	1.7	8.0
General agricult.	0.0	1.0	0.3	0.4
Agric/garden	16.9	13.3	4.1	11.4
Marketing/garden	0.6	0.9	0.0	0.5
Agric/dryfields	2.1	1.0	2.2	1.8
Marketing/dryf.	0.0	0.0	0.0	0.0
Ag/garden by hse	0.0	0.0	0.0	0.0
Cattle management	3.3	3.5	3.9	3.6
Local labour	0.0	9.4	6.4	5.3
Migrant labour	1.5	0.0	13.4	5.0
Seeking job	5.8	0.0	6.0	4.0
Beer brewing	2.2	0.0	0.0	0.7
Building	0.0	0.0	1.0	0.3
Other (fix bike)	0.0	0.4	0.0	0.1
TOTAL	100.1	100.2	99.9	100.2

A further reported constraint on dry season cultivation is the need for irrigation which is also time-consuming due to the low level of technology used. As mentioned above, little irrigation was observed in the three case study households, so time spent on this activity was negligible. However, Household No. 3 reported irrigation as its major constraint in terms of labour time.

Table 28 presents the various household activities in the form of five major productive tasks. The amount of time devoted to each is used as an indicator of their relative importance to the well being of the households in question.

Table 28 Labour Data, Productive Tasks

Tasks	Household 1	2	3
Domestic	17.4	21.1	23.9
Garden	17.5	14.2	4.1
Dryfields	2.1	2.0	2.5
Local labour	2.2	9.4	6.4
Migrant Labour	1.5	0.0	13.4
TOTAL	40.7	46.7	50.3

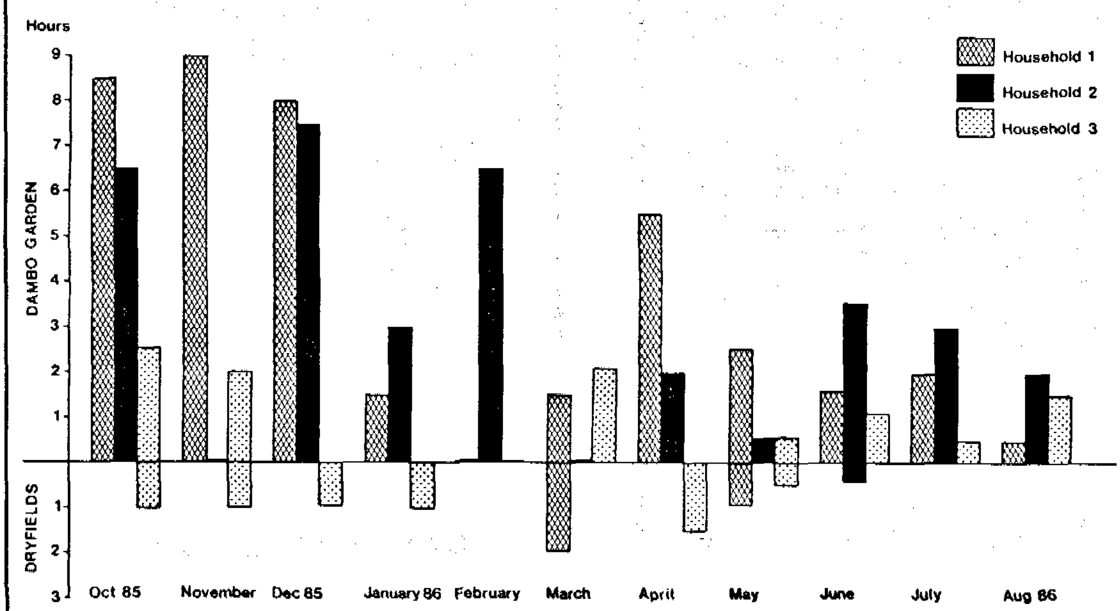

Figure 21 Average daily labour on garden and dryfields

On the basis of time spent, the dambo garden is clearly vital to Household No. 1 which lacks an alternative source of income. For Household No. 3 local and migrant labour are more important while Household No. 2 occupies an intermediate position with garden activities supplemented by local labour. A close look at the distribution of work tasks among adults within each household indicates a well marked division of labour (Table 29).

In the case of Household Nos. 1 and 2 which rely on their garden as a source of income, working on the garden is the primary task of the household head. The head of Household No. 1, a widow, is able to devote much time to her garden since her daughter is available to carry out the domestic chores. While her three adult offspring all work on the garden at various times during the year, the widow's major support comes from her eldest son for whom the garden is also his primary task. The head of Household No. 2 is assisted in his garden by his two sons although for neither of them is garden labour a primary task. It is interesting to note that in the

Table 29 Labour by Household Member

Name	Age	Sex	Major Activity (% of total time)	Time Spent on Garden
HH No. 1				
Phoebe	40	F	Garden (25.0%)	25.0%
Mavis	20	F	Domestic (37.8%)	9.7%
Victor	17	M	School (33.6%)	14.3%
Duncan	27	M	Garden (19.0%)	19.0%
HH No. 2				
Zakariah	40	M	Garden (18.8%)	18.8%
Rina*	29	F	Domestic (48.7%)	1.5%
Musekiwa	19	M	Local Labour (29.0%)	14.9%
Washington	17	M	School (26.1%)	18.1%
HH No. 3				
Samson	55	M	Migrant Labour (35.2%)	5.6%
Emily	50	F	Domestic (43.4%)	5.0%
Judith *	16	F	Domestic (43.6%)	3.7%
Albert	25	M	Migrant Labour (42.2%)	1.9%

*Had baby during study year

case of Musekiwa, on one day of the monthly survey he was reported to be at the Independent Market in Harare collecting cash for vegetables sold there during the previous week. As for Washington, 55% of the time he spent on the garden labour involved keeping cattle away from gardens (a total of 53.3 hours). This took place during the dry season when cattle were not herded. For no adult member of Household No. 3 was the dambo garden the major task and indeed for each one it was a relatively insignificant activity.

It was apparent from the monthly labour study that not only does dambo cultivation occupy the productive time of many adults within a household with access to a garden but it also generates the demand for local paid labour. For example, the widow of Household No. 1 reported that weeding was the most time-consuming activity on her garden and during the year of study she hired local labour at a rate of Z$2.00/day to help with this task. Musekiwa (Household No. 2), in addition to providing labour on his family's garden, also worked on neighbours' gardens during the year of study. This work occupied 37% of the time he spent in local employment (his major activity). Tasks performed included building a garden fence, carrying cattle manure to a garden and marketing vegetables.

Summary

The above information indicates the role played by the dambo garden in the livelihood of three households during the year October 1985 to September 1986. The conclusions are not intended to be interpreted as representative of all households in Zimbabwe, or indeed in Chizengeni. They are merely illustrations of a range of alternatives within one area of the country. Household No. 3 presents the model of a household with cash income from activities outside agriculture and for whom the dambo garden plays a relatively minor role. While it provides some relish vegetables for home consumption, inputs of labour during the year are small and similar in proportion to those on the dryfields. Cultivation of one cash crop was attempted in February but waterlogging destroyed the crop in March. This coincided with a period of paid labour for the household head and his son with the result that no further attempts at cash crop production were made during the year. Households Nos. 1 and 2 present contrasting models of households in which cultivation of a dambo garden is of considerable importance. In both cases dambo cultivation occupies much labour time and is the first priority in the productive activities of the household head. Moreover, it has a dual purpose in providing both food for home consumption and cash crops from which a substantial income, compared to that obtained from dryfields, is secured.

However, there are also important differences between these households. For Household No. 2 garden cultivation is balanced with wage labour in terms of expenditure of adult labour time and as a source of income. In addition, a more limited range of cash crops is grown while crops for home consumption are supplemented by purchase from neighbours. For Household No. 1, headed by a widow, agriculture in general and the dambo garden in particular is the primary source of cash income. The widow adopts a strategy which allows her to grow a variety of crops for household needs but also, and more particularly, a wide range of cash crops throughout the year. Her energy and effort are devoted to high value crops for distant markets and the organisation of tasks for adults within the household facilitates this commercial activity.

2.4 Soils

2.4.1 Dambo soils: general

Dambos represent the lower segment of a tropical catenary sequence (Young, 1976; Watson, 1964). In situ decomposition of grass and sedge vegetation under seasonally oxygen deficient conditions leads to a build up of organic matter and the creation of a hydromorphic, sometimes peaty, upper soil horizon. Dambos have been divided into non-calcic 'sandvlei' and calcic 'clayvlei' types, on the basis of the physico-chemical characteristics of these soils (Elwell, 1983). Of these two types the former is the more widespread in Zimbabwe, accounting for ca. 89% of all dambos (Whitlow, 1984, table 2). In addition to these two main types Whitlow recognises "perched" dambos with sodic soils and peaty dambos underlain by Kalahari sands, neither of which is suitable for cultivation. These variants are not considered in this report.

As part of this study soil catenary sequences have been investigated at five dambo sites of which three are of 'sandvlei' type developed on granitic rocks (Chizengeni, Chigwada, Masiyarwa), one of 'clayvlei' vertisolic type developed on mafic (basic) rocks (Bumburwi) and one of intermediate character (Shumbairerwa). The soils of Chizengeni dambo were studied in greatest detail, with a total of 19 soil profiles investigated. At the other sites, one profile was normally investigated for each of the four catenary positions (see Figures 12-15 & 28). Soil profiles were described and recorded in the field, and each horizon sampled for laboratory analysis. Soil analyses were undertaken by the R & SS (Research and Specialist Services) soil laboratory in Harare. The variables tested for each soil sample were: soil texture (grain-size analysis), pH, conductivity, loss on ignition and percentage organic carbon, total and individual exchangeable cations, ESP, EKP, Phosphorus, Nitrogen and base saturation. Details of the methods used and full results can be found in appendix 4. Full consideration of these data will not be attempted in this report, but some major features are summarised in figures 22 - 27. In the case of the Chizengeni catena (Figure 23) the data shown represent the average of results from several profiles.

Dry topland soils : This topmost member of the catenary sequence lies above the dambo proper, and is used for dryland maize cultivation or grazing. There are very few differences between dryland soils at the five sites, and it is likely that these analytical data are typical of kaolinitic 'sandveld' soils developed on Zimbabwe's granite/gneiss basement complex, (soil series 5G, 6G, 7G: Thompson and Purves,1978). Soils are coarse-grained sands throughout the 'A' and 'B' horizons, with less than 10% finer than 20 microns (clay and fine silt fractions). Base saturation and Cation Exchange Capacity are low, the latter due to the small clay content as well as the limited reserves of weatherable bases. Dryland soils are moderately to strongly acid (H_2O pH ~5.5).

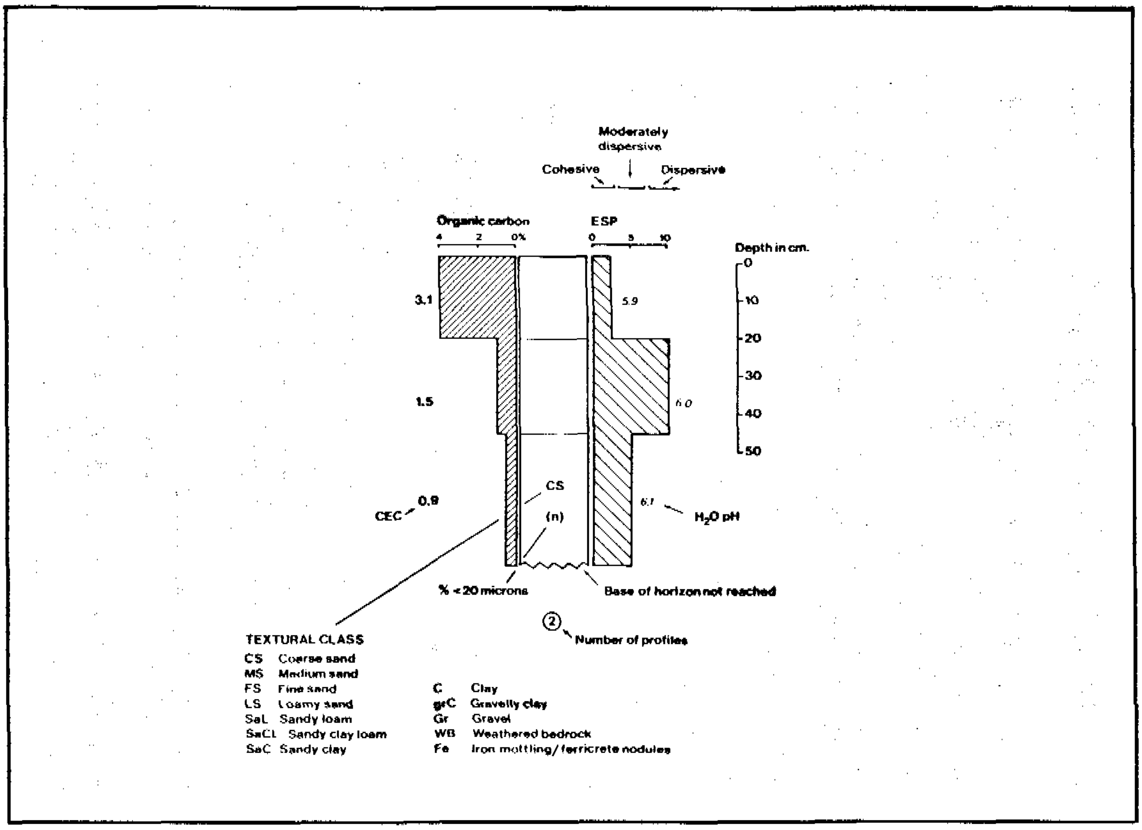

Figure 22 Key to soil catena profiles

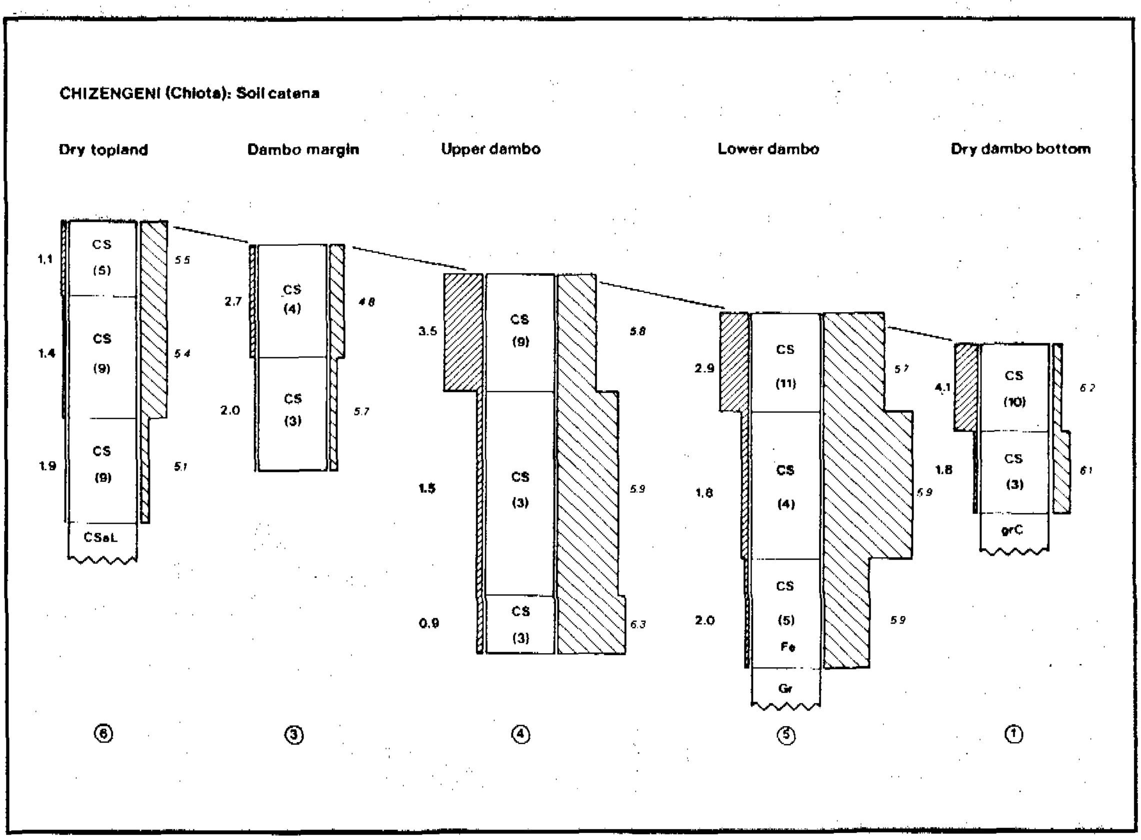

Figure 23 Chizengeni (Chiota): Soil catena

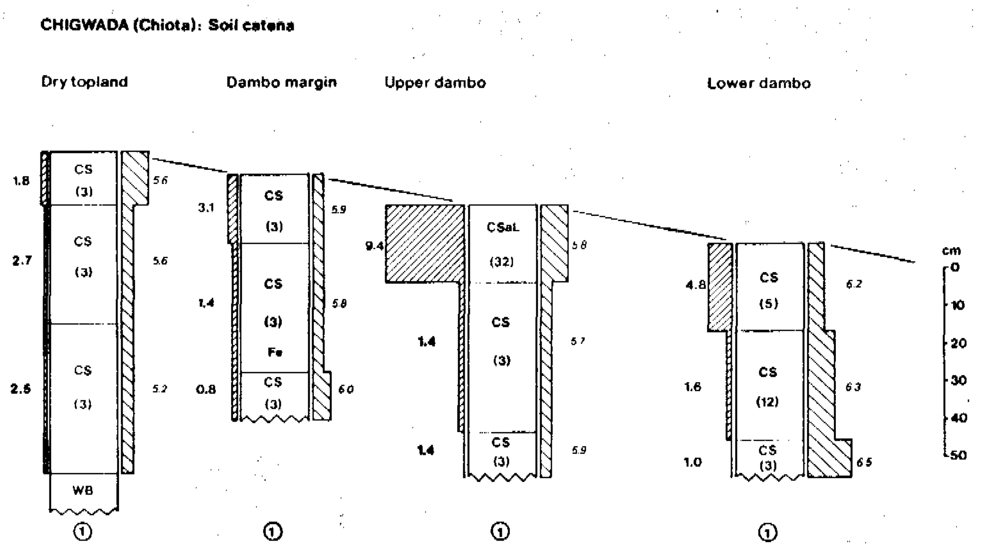

Figure 24 Chigwada (Chiota): Soil catena

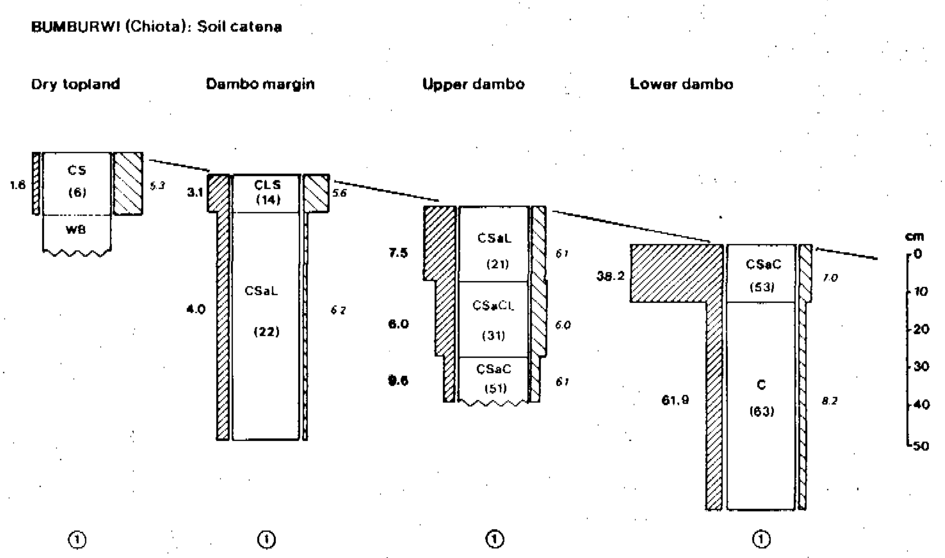

Figure 25 Bumburwi (Chiota): Soil catena

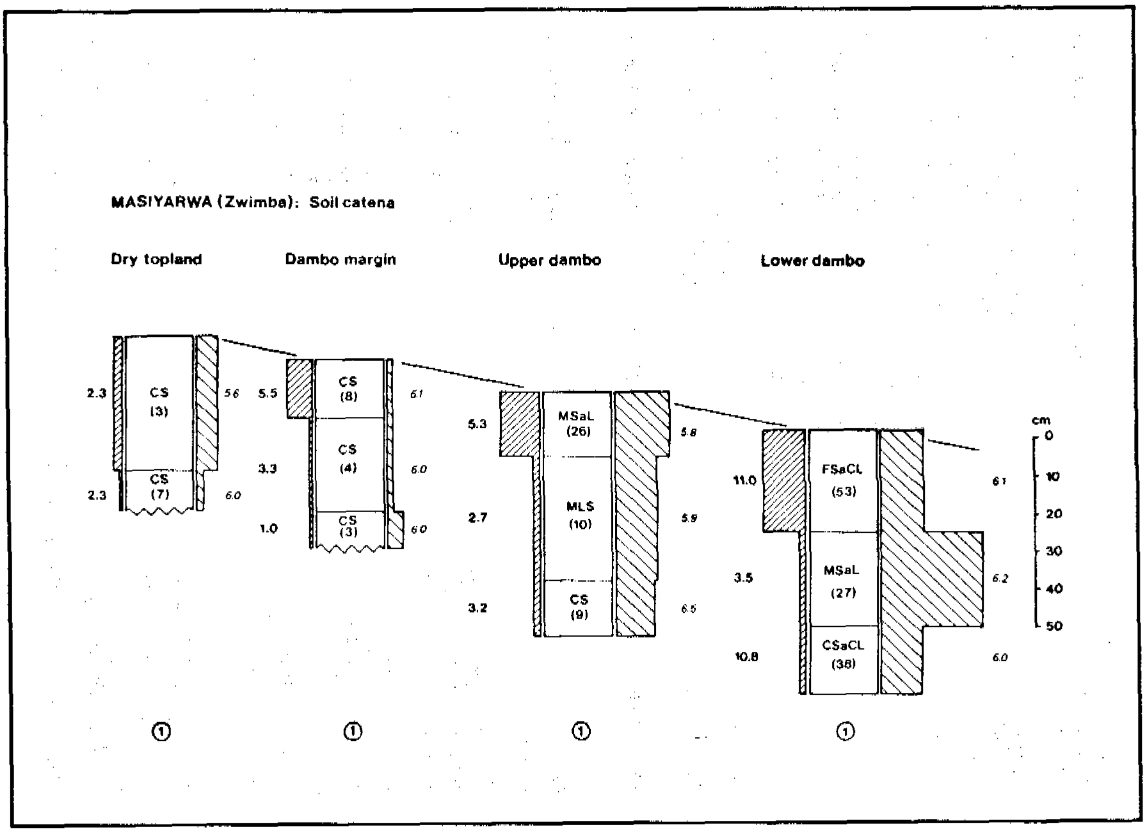

Figure 26 Masiyarwa (Zwimba): Soil catena

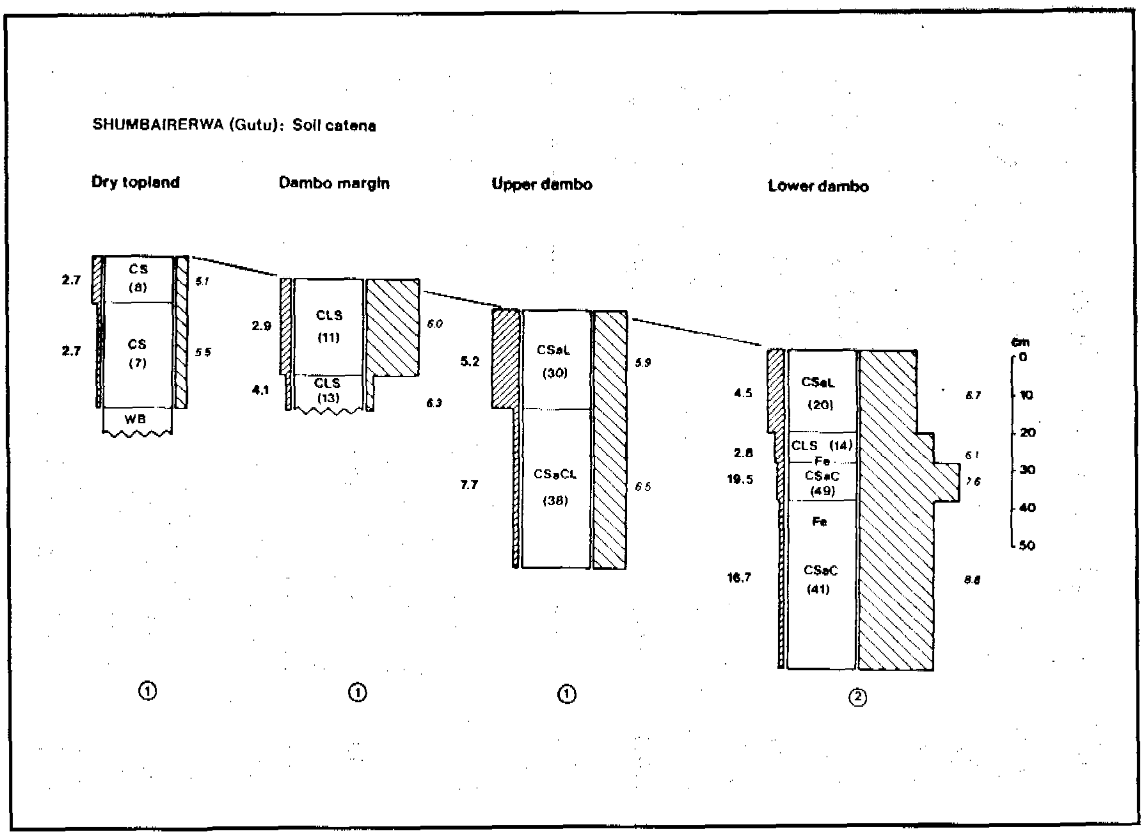

Figure 27 Shumbairerwa (Gutu): Soil catena

Dambo margin : These bleached sandy soils lie in the upper wash zone of the dambo and are normally suitable only for rough grazing. Organic matter values are often no higher than on the topland, although at their lower limit a thin (<10cm) organic topsoil is present. Dambo margin soils are somewhat less acid than topland soils (pH ~6.0).

Upper dambo : The soils of this 'seepage' zone have water tables close enough to the surface to support shallow-rooted plant growth throughout the year. They possess the clear organic 'Ao' horizon, 20-30 cm deep, that is typical of dambos. Where gardens exist, they are almost always found in this upper dambo zone, but the upper dambo is also used for grazing. The uppermost soil horizon is usually a sandy loam, with 20-30% fines, around 2% organic carbon, and CEC values between 5% and 10%. These dambo soils are not only significantly different from topland soils, but are also different from each other at the five sites investigated. In particular the profiles at Bumburwi and Shumbairerwa fine downwards to include >30% fines in their lower horizons, while the other three sites coarsen downwards from loam to sand.

Lower dambo : Superficially these soils have a certain resemblance to those of the upper dambo zone (eg presence of organic 'Ao' horizon). However this zone does not remain saturated in winter, and is almost always used for grazing land, not garden cultivation. These soils are finer grained than those upslope and show signs of ionic concentration. While this increases the availability of many cations and raises soil pH's from acid to neutral or even alkaline, it poses other problems of soil management. The 'A2 ' and 'B' horizons especially, have ESP values in the 'highly dispersive' range (>7%), making these soils potentially vulnerable to erosion (see also below, Section 2.4.3).

Dry dambo bottom : Only one profile of this type was investigated (Chizengeni). It had much lower ESP values than those in the seasonally wet lower dambo zone.

These data clearly indicate significant soil changes both within and between the five soil catenas analysed. Masiyarwa may be considered as the most typical catenary sequence, with finer-textured and more organic soils downslope. The Chizengeni catena is notably coarser-grained in its lower segment than the other sequences. The Bumburwi catena is clearly of 'clayvlei' rather than 'sandvlei' type, while the Shumbairerwa site is fine-textured but alkaline and rather sodic in its lower part.

Differences within the catena may be illustrated by comparing dryland soils with those of the upper dambo zone. The latter offers the only viable alternative for crop cultivation to dryland maize farming. In comparison with dryland soils, those in the upper dambo zone are less acid (pH ~6.0 vs ~5.5), have higher Cation Exchange Capacities (~6.2 vs ~1.9), and base saturation (~60% vs ~25%), more phosphorus (~11.0 vs ~6.0) and have a more loamy texture. These agricultural advantages are, of course, accompanied by abundant and reliable soil moisture.

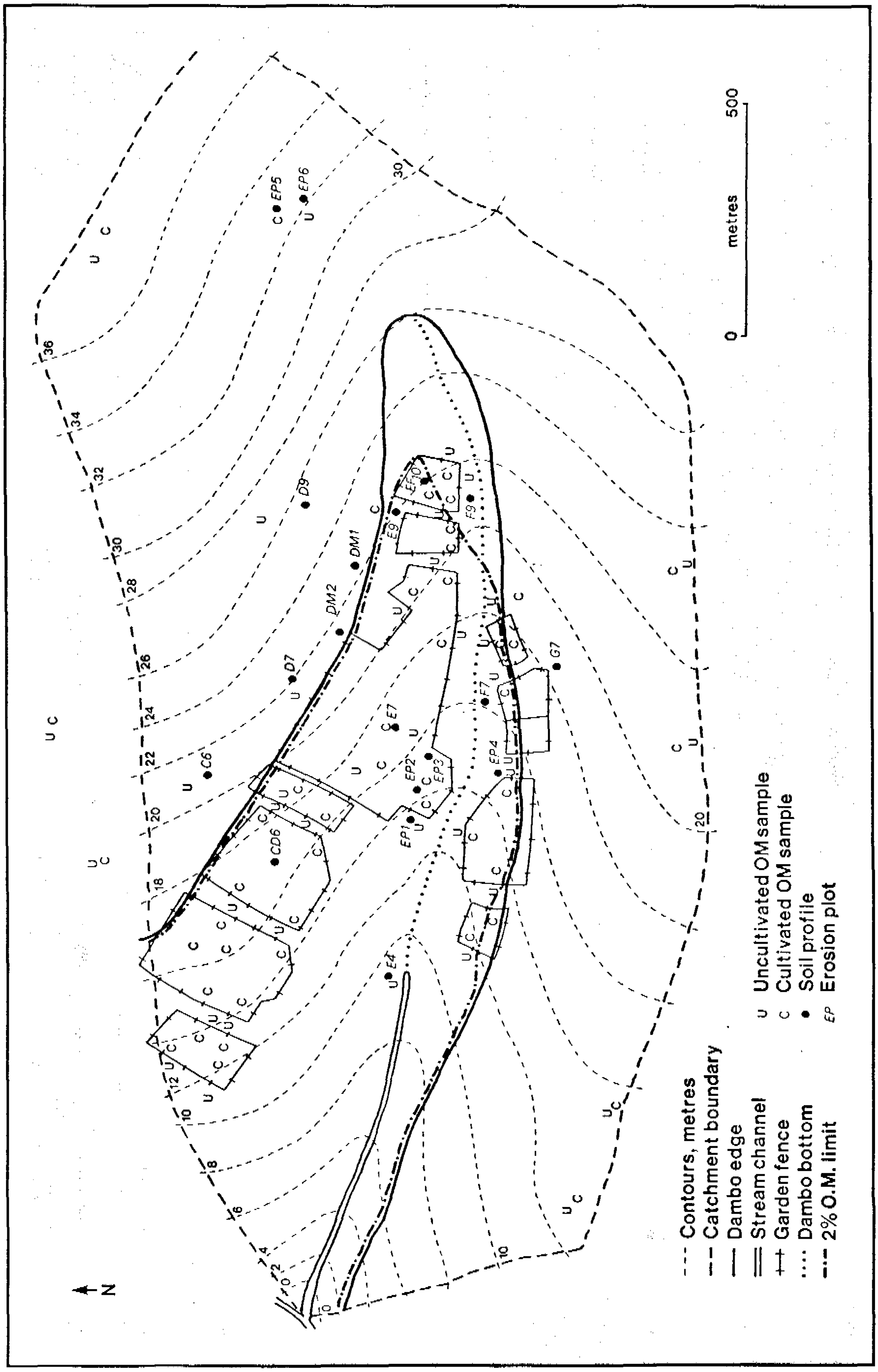

Figure 28 Location of soil study sites, Chizengeni

2.4.2 Organic Matter

Dambo soils are cultivated because they are fertile and moist, conditions which are tied to the high level of organic matter in the soil. If this high level of organic matter is destroyed, particularly in sandy dambo soils, the fertility will be seriously affected. In clay dambo soils the effect of a reduction in organic matter may not be so serious.

When soils are cultivated a drop in organic matter is to be expected as the natural root structure is broken up and exposed to greater weathering and decomposition. Dambo soils, with their high level of organic matter on which their fertility may depend, are particularly vulnerable. There is evidence in the past of dambo soils being rendered infertile due to wholesale ploughing-up and drainage by commercial farmers (Whitlow, 1983). In this research the focus has been on the effect of peasant cultivation in Zimbabwe's communal areas on dambo soils. In order to assess the effects of cultivation on dambo soils detailed investigations of organic matter content were carried out on eight dambos in Chiota, Zwimba and Gutu. A smaller number of samples was taken on dryland soils to serve as a basis for comparison.

Method of analysis

In order to assess a large number of samples to give comparative results a rapid and simple method of analysis was required. The method chosen was the loss on ignition expressed as a percentage of the dry soil mass. Samples were dried overnight at 105° C, weighed, then placed in a furnace for two hours at 550° C and weighed again. The loss in weight of the sample was then taken to be the result of the organic matter being oxidised and driven off. The precision of the results is approximately plus or minus 0.1%.

The samples were weighed and processed without being sieved, as this would have added considerably to the time required to process them. In order to check on the effects of sieving a number of samples were processed after being passed through a 2mm sieve and the results compared with the same soil analysed without sieving. The results show that for uncultivated soils the organic content of unsieved samples was 19% higher than for sieved samples and for cultivated soils, the unsieved samples exceeded the sieved by just 9%. Uncultivated soils have a higher amount of coarse roots than cultivated soils and this is reflected in the difference in values. This coarse root fraction, while being unhumified is a useful reservoir which can be utilised eventually in the form of soil humus.

Soil samples were also collected for detailed chemical and physical analysis. One of the analyses that was carried out by the Department of Research and Specialist Services (R&SS) was loss on ignition and their results gave good agreement with our own determinations.

The R&SS samples were also tested for percentage of organic carbon, so it is possible to examine the relationship between percentage loss on ignition and percentage of organic carbon. Conventionally organic carbon is assumed to be 58% of total organic matter (Landon, 1984; p

139). For topsoil samples from "wet" dambo sites (ie lower and upper dambo zones) proportions ranged between 36% and 77%, with a modal value around 50%. Loss-on-ignition values for these samples therefore correlate closely with total organic matter. On the other hand in clay-rich samples from B and C horizons, organic carbon fell to 10% or less of loss-on-ignition values. One explanation for this may be that some soil moisture remained after samples had been dried overnight at 105° C which was driven off during firing at 550° C. Topsoil samples from the dambo margin zone also gave loss-on-ignition values which overestimated total organic matter, although the former never exceeded 2%.

Loss-on-ignition best reflects total organic matter in sandy, topsoil samples. Samples for OM% determinations were consequently collected only from the top 10cm of soil, and the largest number of samples came from Chizengeni, Chigwada, Chiwanzamarara (fig 12) and a nearby dambo at Kanjanda to the North East of Chizengeni, all sites of predominantly sandy texture. The loss on ignition method measures only the quantity of organic matter. The type or quality of the organic matter may also be important and this will be affected by cultivation and soil husbandry practices.

Site selection

The aim of the organic matter investigations was to assess the effect of cultivation and to see how organic matter values changed across dambos and between dambo and dryland areas. Site selection for the variation in organic matter across the dambo and in non-dambo areas was done using air photographs to identify suitable locations. As conditions vary enormously on a dambo and between dambos it was necessary to exercise some judgement in order to get representative results. Sites were generally chosen on the upper dambo zone, where most cultivation takes place and where, as far as was possible, the adjacent cultivated and uncultivated sites represented the same local dambo soil type.

Ideally, the effect of cultivation on dambo soils would involve detailed long-term monitoring extending over five to ten years. In a short term research project another method must be found. It was decided to select paired sites of cultivated and uncultivated soils for sampling and analysis. These sites were chosen with the aid of local field assistants who had detailed knowledge of the local environment. In most cases the uncultivated sites were chosen outside but close to a garden fence with the cultivated site being nearby but inside the fence. Samples were not taken where there was evidence of past cultivation on a site which was currently uncultivated. A total of 369 sites were sampled and 381 samples analysed. The number of paired sites was 108, involving 216 analyses. A summary of the results is given in Table 30.

Table 30 Total organic matter values

Site name	Uncultivated		Cultivated	
	number of tests	average OM%	number of tests	average OM%
Chizengeni				
Dambo	37	5.3	46	3.8
Non-dambo	17	1.7	14	1.5
Chigwada				
Dambo	40	2.7	22	2.9
Non-dambo	14	0.9	0	-
Chiwanzamarara				
Dambo	30	3.3	32	3.0
Kanjanda **				
Dambo	13	3.3	14	3.6
Bumburwi				
Dambo	12	5.8	11	4.2
Non-dambo	1	1.3	0	-
Masiyarwa				
Dambo	10	5.0	2	4.8
Non-dambo	3	1.3	0	-
Shumbairerwa				
Dambo	17	4.2	6	3.5
Non-dambo	17	1.2	2	1.0
TOTAL				
Dambo	159	4.0	133	3.5
Non-dambo	52	1.3	16	1.4

** North East of Chizengeni.

Figure 28 shows the location of sites on Chizengeni dambo. Organic matter values exceeding 2% are very rare outside the dambo. Within the dambo itself organic matter values vary enormously with a value of 19.3% being recorded less than 200 metres from a site where the value was 4.3%, both sites being uncultivated grazed dambo. Only in the upper 'tail' of the dambo are values of less than 2% consistently found.

As Table 30 illustrates, mean organic matter values are consistently slightly lower for cultivated than for uncultivated dambo soils (4.0% vs 3.5%). On the other hand, only rarely does the organic content of cultivated dambo soils decline below 2.5%. Furthermore more detailed analysis of paired sites (Figures 29 & 30) shows no significant difference between cultivated and uncultivated soils in samples whose organic content was below 5%. In other words the apparently higher mean values for uncultivated soils are a product of a decline in organic content in soils with over 5% total organic matter. A fall in already relatively organic-rich soils is clearly less deleterious to soil fertility than one in soils with lower organic matter. Having declined from say 7% to 4% organic matter with initial cultivation, dambo soils subsequently seem not to decline further, but stabilise at still-adequate levels.

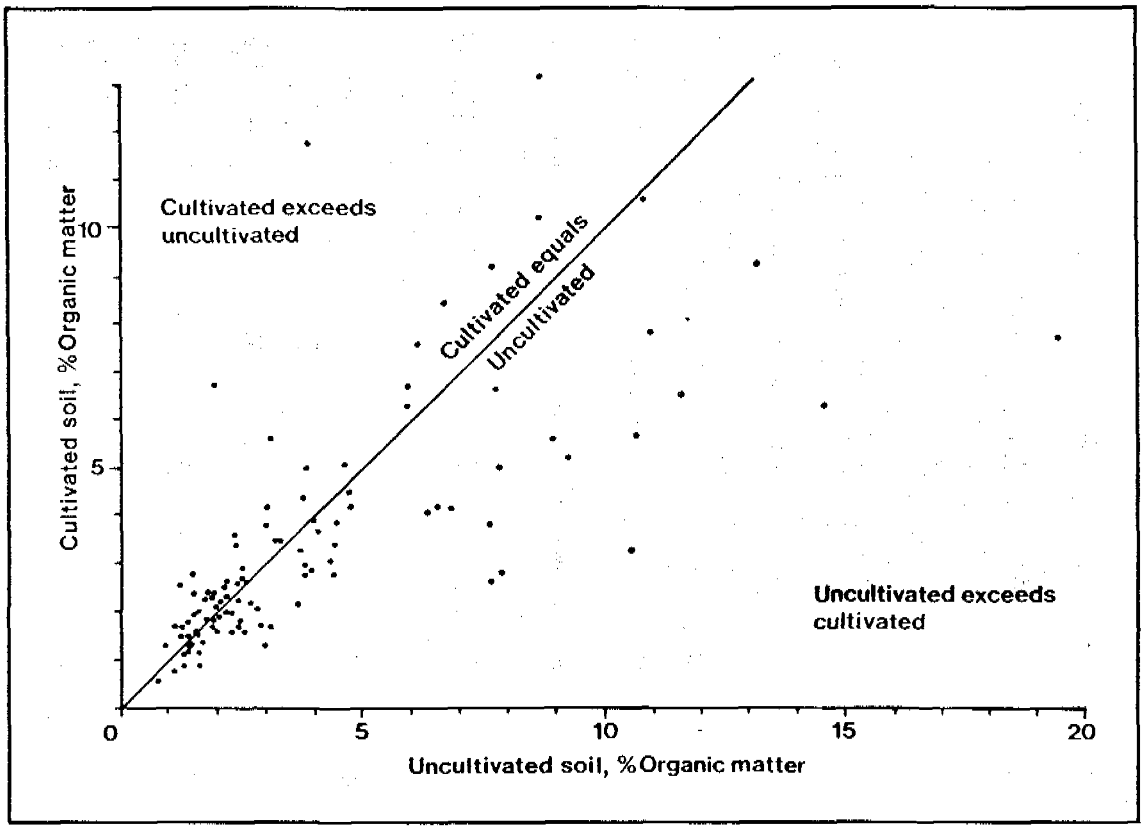

Figure 29 Correlation of soil organic matter at paired dambo sites

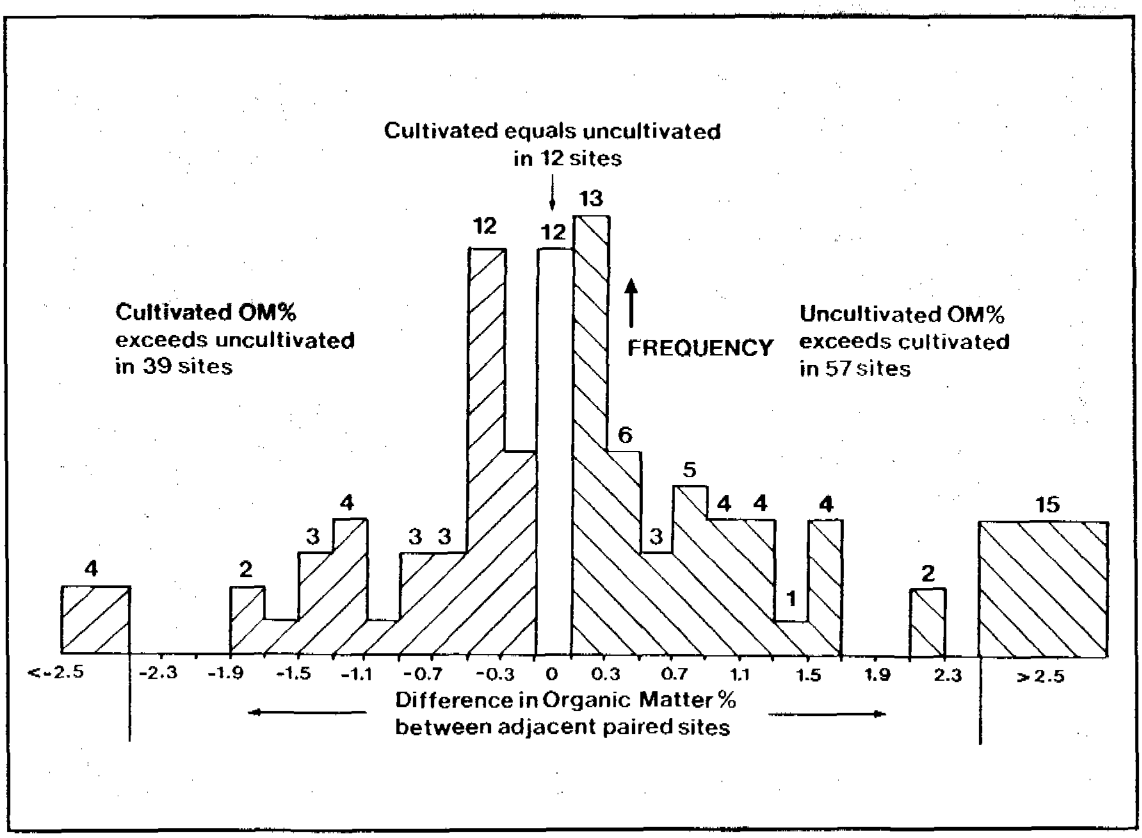

Figure 30 Differences in soil organic matter at paired dambo sites

2.4.3 Soil Erosion

Soil erosion is one of the most serious forms of land degradation that threatens African agriculture (Stocking, 1984). In their natural state dambos are well protected by dense vegetation from the effects of both sheet and gully erosion. When this vegetative cover is reduced the dambo is made more vulnerable to all forms of erosion. Casual observation suggests that overgrazing of dambos is the main factor causing gully erosion. Claims have been made that cultivation leads to sheet erosion and sometimes to gully erosion where shallow wells collapse and initiate gullying (Elwell, 1983). In order to assess the effects of cultivation on erosion field studies on both gully and sheet erosion were carried out.

Sheet erosion

A standard method for the investigation of sheet erosion is through the use of erosion plots. In Zimbabwe, work has been done at the Institute of Agricultural Engineering on erosion plots since 1974. These plots measure 30m x 10m and the total runoff is collected and analysed. The results of these plot studies show, for example, that over a 10-year period on a 4.5% slope and with a mean annual rainfall of 750 mm, soil losses on a bare slope averaged 127 tons/hectare/year (t/ha/yr), while those with a complete grass cover lost only 0.7 t/ha/yr. Dryland soils are believed to form at around 1 t/ha/yr, and acceptable target levels for soil loss are between 3 and 5 t/ha/yr (Elwell, 1984). These studies were carried out on deep, reddish brown kaolinitic clay soils, and were related primarily to commercial agricultural practices. Erosion plot studies on "sandveld" soils, where a large proportion of communal peasant farming is located, were carried out under N. Hudson between 1953 and 1963 (Barnes and Franklin, 1970). However very few have been undertaken on "sandveld" soils during the 1970s and 1980s and none at all have been done on dambo or other wetland soils.

In our field work it was necessary to adapt the standard technique due to the following constraints:

- Land Area. Plot sizes had to be standardised, and in order to locate a plot in a dambo garden that was currently being used this area had to be kept to a minimum. Many dambo gardens are small and do not always allow a 30m x 10m plot to be conveniently located.

- Materials and Cost. As the cost had to be kept low it was necessary to keep the amount of materials required to a minimum, especially as the plots would be in place for only one season.

- Waterlogging. Dambos are waterlogged during the rains and the construction of tanks large enough to collect all the water and soil running off even a small plot would have presented a major engineering challenge. Particularly difficult to overcome would have been the problem of flotation. Major engineering works in a farmer's garden, when he/she is preparing for the rains, would have been very unwelcome.

- Plot locations. Plots were sited on the basis of already existing land use, and therefore could not be placed precisely side-by-side. However, the 4 dambo plots were located within 250m of each other on slopes of similar gradient around 2%. Similarly the 2 dryfield erosion plots lay adjacent to each other (see Figure 28).

Because of these constraints it was decided to use a plot size of 10m x 5m and to use a small perforated collection tank lined with a fine-mesh cloth (plate 12). The layout of the plot is shown in Figure 31.

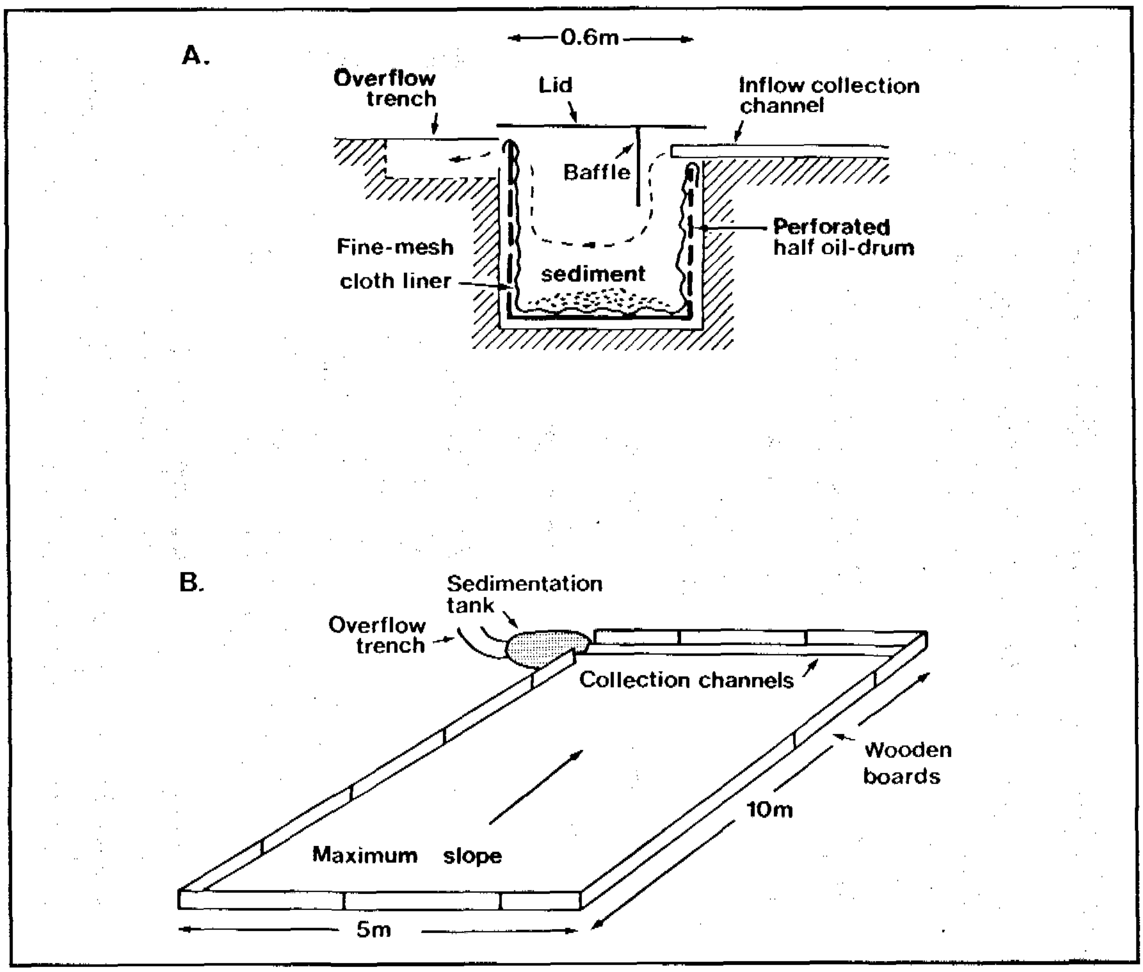

Figure 31 Erosion plot design

One of the crucial factors in sheet erosion is the length of slope over which run-off can build up. The greater the length of slope the greater the volume and velocity of water there is running off and the greater the potential for erosion. The reason for the standard plot size of 30m x 10m is that 30m is the recommended interval between contour ridges in Zimbabwe. Small plots such as were used in this study have only a short length of slope and hence this effect will not be adequately modelled. The length of slope effect is complicated by the fact that dambo gardens, being fenced, ridged and cultivated in a variety of ways will greatly change the surface runoff characteristics. Grazed dambo areas, being generally without contours, often have slope lengths in excess of 200 metres. Detailed modelling of these effects would involve detailed research over a number of years and was beyond the scope of this project, although some attempt to calibrate soil plot losses for the standard 30m slope length was made using SLEMSA (see below).

The use of a small tank and a perforated liner meant that some fine material might be carried through in heavy rain. The tanks were designed with a baffle to prevent the flow of water across the top of the tank and encourage sedimentation. In order to check the trap efficiency of the sediment tanks samples were taken of the soil on the erosion plot and the soil collected from the tanks. These samples underwent particle size analysis to determine whether there was a significant loss in fine material. In fact these analyses indicated that on the plots situated on the dryland areas the particle size distribution showed a slightly higher percentage of fine material in the tank sediment. On the dambo plots there was a marked increase in the amount of fine material in the tank sediment compared with that on the plot soil. These results show that sheet erosion on these sites led to more fine material being washed away than coarse material. Although it is not possible to quantify any possible losses of fines, the predominantly coarse-grained nature of the soils involved means that they are unlikely to significantly alter the erosion losses recorded. While the method used may be susceptible to some forms of minor systematic error we are confident that the results obtained are in the right order of magnitude.

Six plots were installed at Chizengeni, two on grazed dambo areas, two on cultivated dambo areas and two on non-dambo areas, one on a maize field and one on scrub grazing. The sediment from the tanks was collected at monthly intervals from November 1985 to April 1986, dried and weighed. The results, details of which can be found in appendix 5, are summarised in Table 31.

Table 31 Erosion plot results

Plot no	Description	Slope %	Soil loss t/ha/yr	SLEMSA prediction t/ha/yr
1	Dambo grazing	1.9	0.14	0.3-0.6
2	Dambo maize	2.3	0.36	2.0-11.9
3	Dambo weed fallow	1.5	0.18	1.0-2.5
4	Dambo grazing	2.3	0.05	0.3-0.6
5	Dryland scrub grazing	1.8	0.27	0.40
6	Dryland maize	1.8	0.71	8.3-11.0

The sediment yields from the erosion plots indicate that measured erosion never exceeded 1.0 t/ha/yr which is well within the 'acceptable' figures of 3.0 - 5.0 t/ha/yr mentioned above. The lowest rate of erosion was on a dambo plot which had the highest slope but was well covered with short grass. The highest rate of erosion on the dambo was on the maize field. On the non-dambo areas the cultivated maize field gave the higher rate of erosion, as expected.

An alternative approach to the measurement of sheet erosion involves the use of predictive soil-loss equations, such as the Universal Soil Loss Equation (USLE). A local model termed SLEMSA (Soil Loss Estimation for Southern Africa) has been developed using data from Zimbabwe (Elwell and Stocking, 1982; Elwell, 1984). SLEMSA was applied to the erosion plot sites at Chizengeni. This was easier for the non-dambo, sandveld soils, than for the azonal dambo soils, for which erodibility factors (Fb) are not provided in SLEMSA. Two further modifications were necessary for comparison with recorded erosion plot losses; firstly because rainfall during 1985-86 at Chizengeni (941mm) was above the 19-year average at the nearest meteorological station, Grassland research station (863mm); secondly because of the small plot size used, so that the slope length factor (L) required adjustment. In fact, these two modifications effectively counter-acted and cancelled out each other. Details of the SLEMSA calculations can be found in appendix 5, but summary results are shown in Table 31.

It is clear that SLEMSA gives a considerably higher value for the erosion losses on all but the non-dambo grazed areas. On the dryland maize field erosion was over-predicted by a factor of between 12 and 16 times as compared with the measured rate. We consider it unlikely that this could be accounted for by errors in the collection of samples eroded from the plots. It should be noted that SLEMSA was designed to predict long term mean soil loss and one year's data are not adequate for a rigorous comparison. Although dryland sheet erosion is not the focus of the present study the difference between the erosion plot results and the SLEMSA values, particularly on dryland maize where the difference is at least one order of magnitude, emphasises that more field research on erosion under these conditions is required. Significantly, SLEMSA values for dryland scrub grazing gives good agreement with the erosion plot results.

Gully erosion

Gully erosion is one of the most serious threats to dambos in Zimbabwe (plate 13). Serious gully erosion is most often associated with a loss of ground cover caused by overgrazing. Cattle climbing in and out of stream channels exacerbate the effect. The gully is affected by land use patterns over the entire catchment and it is very difficult to pinpoint the effects of any one feature. The rate at which gullies retreat varies hugely depending on ground cover in the catchment and soil type.

In this project a number of gullies were monitored on five dambos, four in Chiota and one in Zwimba. This was done in two ways. First, the positions of gully heads at the start and finish

Plate 12 Soil erosion plot, Chizengeni

Plate 13 Actively eroding gully heads in dambo bottom, Chiota C.A.

of the 1985-86 rainy season were recorded by survey from marker points fixed in concrete. The results of this monitoring are summarised in Table 32. The gullies in the Chigwada dambo were inactive. While there was some gullying in Chizengeni and Masiyarwa dambos it was quite minor in comparison with the rapid retreat of the gully head measured in the Bumburwi dambo.

Table 32 Gully change in selected sites

Gully	Retreat (m), pa A	Retreat (m), pa B	Volume lost (m^3), pa A	Volume lost (m^3), pa B	% of dambo under cultivation (1984)
Chizengeni	1.2	<0.4	1.0	<0.8	32.9%
Chigwada	0.2	<0.4	0.0	<0.8	5.6%
Chiwanzamarara	1.4	n.d	2.4	n.d	25.0%
Bumburwi	5.1	6.9	20.1	203.2	6.5%
Masiyarwa	0.3	1.3	0.4	21.1	2.8%

A = monitored change (1985-1986)
B = mean change on air photographs (1965-1984)

The second form of measurement involved examination of gully head positions on old air photographs. In Chizengeni and Chigwada dambos, no significant gully retreat was visible on air photographs between 1947 and 1984. Because of the accuracy of the method, there could have been some small change over this period. At Masiyarwa, there are two discontinuous stretches of gullying, both of which retreated between 1965 and 1984, the upper of which moving back by about 25m. The most rapid retreat, however, occurred in Bumburwi dambo, as can be seen in Table 32. This retreat has been investigated using historical air photographs and the results are presented below in Table 33 and Figure 32.

Figures for the rate of retreat using air photography and monitoring are comparable. The much higher volumetric losses estimated from the former technique is a result of monitoring being restricted only to one or two gully heads per site. As Figure 32 shows, there may be many more active gully heads than this and soil is also lost through side-wall collapse downstream.

Table 33 Gully retreat, Bumburwi dambo, Chiota

Period	Retreat m/yr	Volume lost (m^3)/yr
1947-1965	5.9	60.67
1965-1976	9.7	216.27
1976-1984	3.1	185.25
mean (1947-1984)	6.4	133.86

The 37-year mean of $134m^3$/yr is equivalent to 13mm lowering/100 yr over the 103 ha of the Bumburwi dambo, or 1.69 t/ha/yr.

Table 32 shows no correlation between soil loss through gully erosion and dambo land use. Intensely cultivated dambos such as Chizengeni have experienced rather insignificant gully erosion (equivalent to a soil loss of less than 0.015 t/ha/yr over the whole dambo). By far the most serious gully erosion problem exists in Bumburwi dambo, used largely for grazing, but the prime cause of the erosion is the heavy cracking clay in the dambo bottom, which breaks off in large blocks once gullying has been initiated. Interestingly this dambo has the lowest ESP values of any site investigated, so that not only dispersive soils are prone to soil degradation.

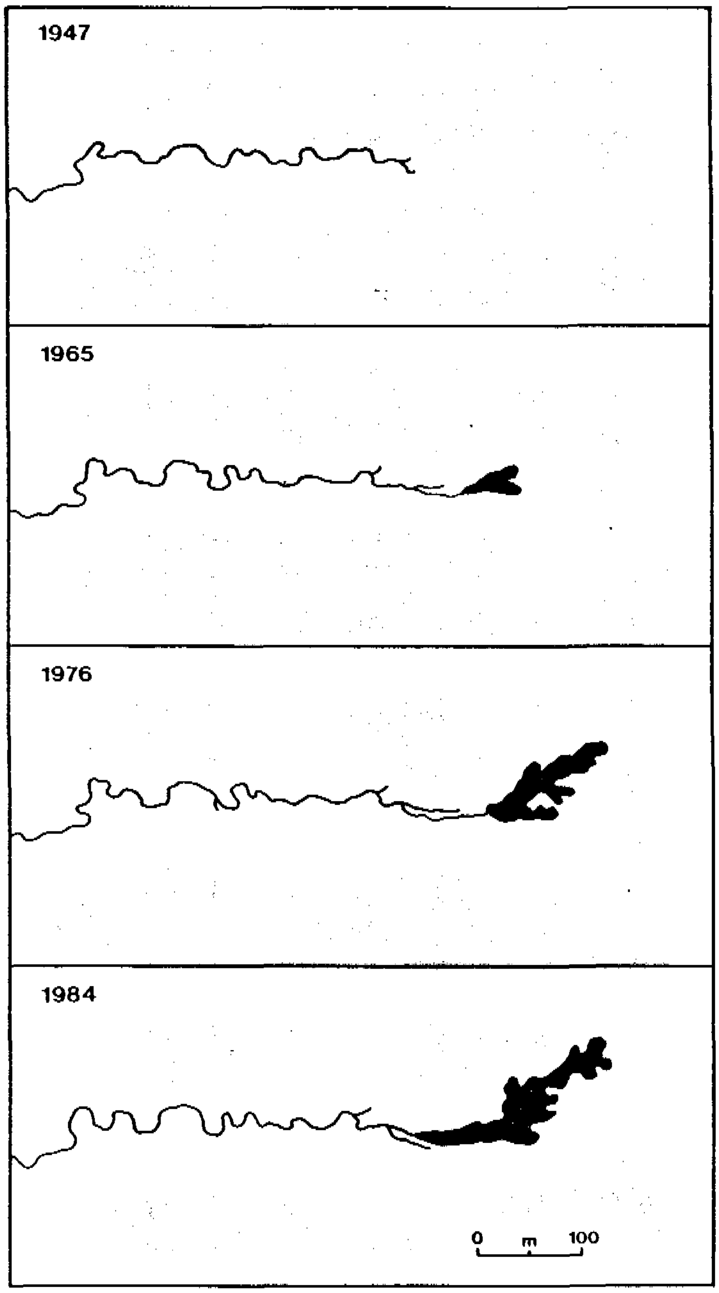

Figure 32 Changes in Bumburwi gully 1947 - 1984

2.5 Hydrology

2.5.1 General Climate

Zimbabwe lies within the tropics, from 15.5° S to 22.5° S and from 25.5° E to 33° E. From a hydrological viewpoint, the principal physical feature is the extensive high watershed area (highveld). This runs roughly from Plumtree to Marondera (South-West to North-East) and from Karoi through Harare and Marondera to Inyanga (North-West to South-East). The altitude of the highveld is generally between 1200m and 1500m. The lower lying areas of the river valleys (Zambezi, Limpopo and Sabi) are referred to as the lowveld and fall below 500m. In general the land falls away from the highveld to the lowveld on a gradual decline, the exception being the northern escarpment at the edge of the Zambezi valley where there is a dramatic drop of 1000m. The effect of altitude on temperature is shown in Figure 33, where annual mean temperatures exceed 24° C in the lowfeld but are 5 or 6 degrees less in the highveld (data source: Zimbabwe Department of Meteorological Services, 1978, 1981).

Zimbabwe is a landlocked country being at the closest point 200 km from the Indian Ocean. The predominant wind direction has an easterly component which brings moist air from this source. However, under appropriate conditions of pressure very moist air (originating from the trade winds) passes over Zimbabwe from the north-west between November and March. These physical and climatic factors are reflected in the mean annual rainfall, Figure 34. The highveld receives 600-900 mm whereas in the southern lowfeld area the mean falls below 400 mm. Only in the Eastern highlands is rainfall over 1000mm regularly recorded. Further, the dependability of rainfall decreases from north to south, with the coefficient of variation of annual rainfall doubling from 0.2 to 0.4 from the Zambezi to the Limpopo.

The sub-tropical high pressure belt lies south of Zimbabwe at an approximate latitude of 30° S. This zone of high pressure effectively shields Zimbabwe from the low pressure cyclones of middle latitudes. However, tropical cyclones originating in the Indian Ocean may have significant effects on the weather in Zimbabwe, and can cause extended drought or heavy rainfall depending on their relative position. Another consequence of being north of the sub-tropical high pressure belt is that Zimbabwe has only two seasons. The summer wet season normally runs from November to March and the winter dry season from April to October. The precise start and finish to the rains varies from year to year and between locations. Generally, the rains start and finish earlier in the south-west than in the north-east, giving a shorter wet season in the southern areas. This seasonality is quite convenient from an irrigation viewpoint as it means that during the bulk of the dry season when irrigation water is required the temperatures are at their lowest (ie the winter period) and so the evaporative demand from the crops is also comparatively low. The amount of rainfall is dependent on the position of the Inter-Tropical Convergence Zone (ITCZ), the further south the ITCZ moves the better will be the rains. The ITCZ is normally between 12 and 16°S during the summer period but may exceptionally reach the Limpopo Valley (22°S) on Zimbabwe's southern border.

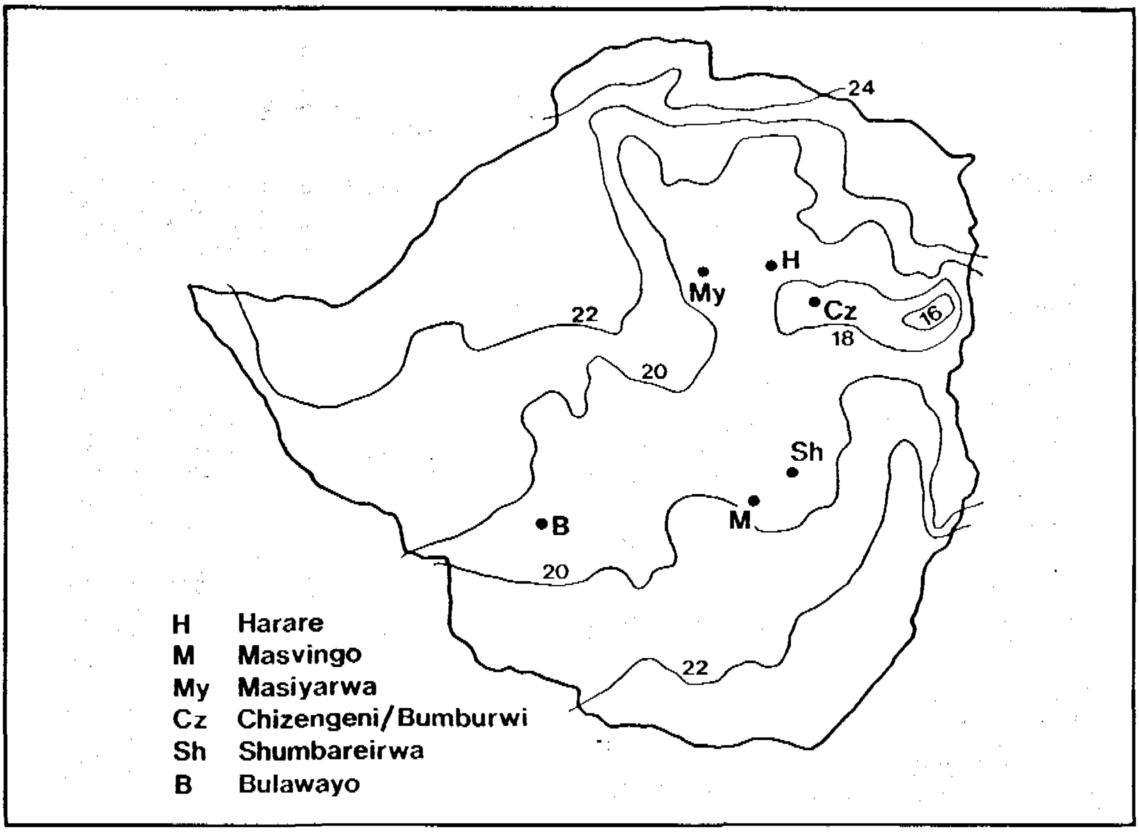

Figure 33 Annual mean temperature (°C) Zimbabwe

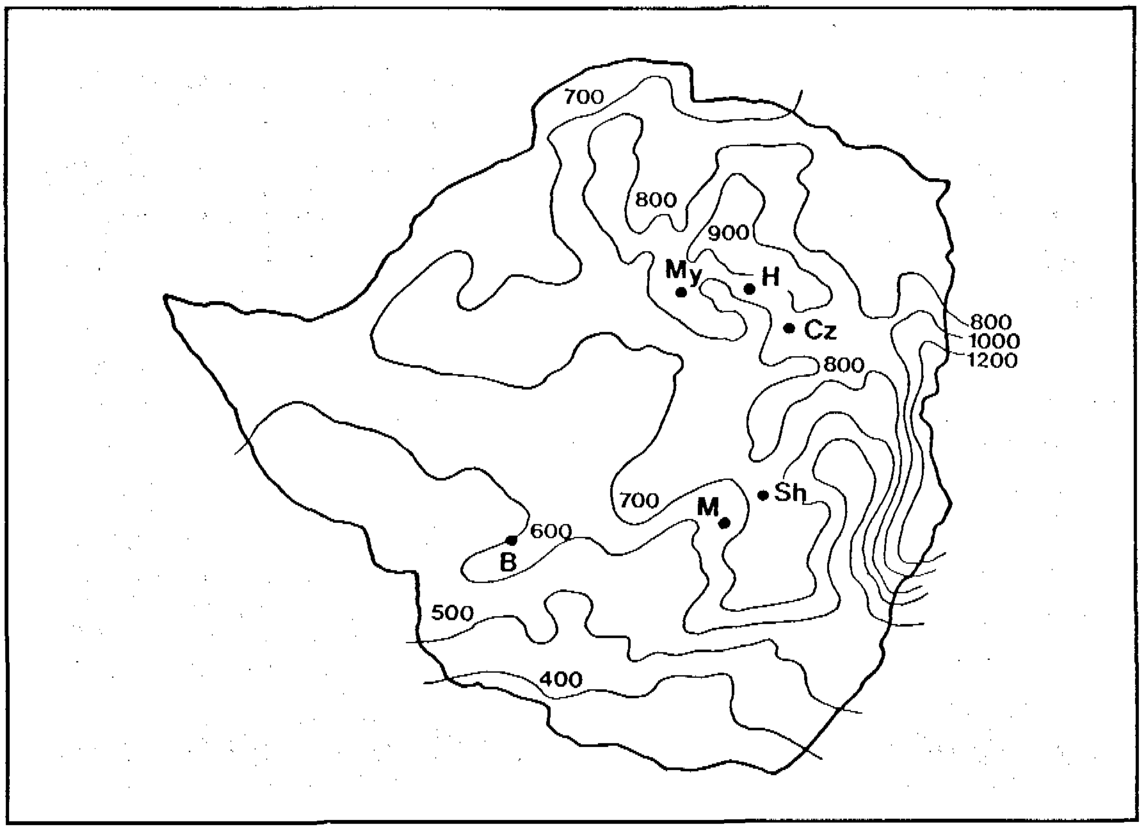

Figure 34 Mean annual rainfall (mm) Zimbabwe

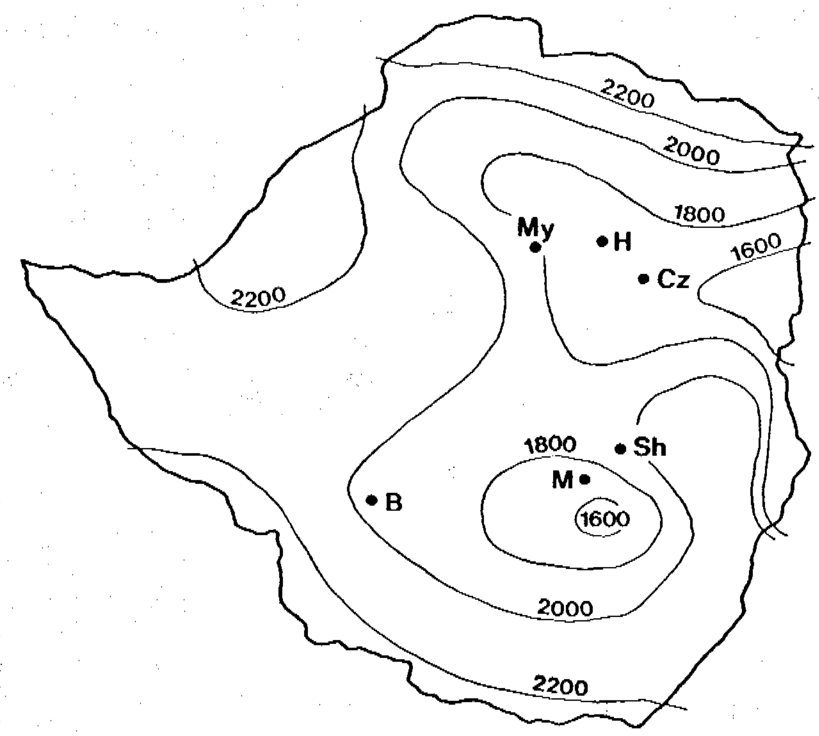

Figure 35 Annual potential evaporation (mm) Zimbabwe

The natural vegetation of Zimbabwe is largely open miombo or mopane woodland savanna. During the dry season, when leaf area and foliage persist, water is taken from groundwater to satisfy the demands of evapotranspiration. Where such foliage has been killed by frost action over appreciable areas it has been observed that seasonal streams persist longer into the dry season before drying up (Zimbabwe Department of meteorology, 1981). This emphasizes the key role of evapotranspiration in utilising groundwater which in some circumstances would otherwise contribute to streamflow. Figure 35 shows the annual potential (open water) evaporation rates for Zimbabwe, the distribution of which tends to reflect the temperature profiles, with lower values on the highveld. Crop reference evapotranspiration values will be slightly less than these values and of course actual evapotranspiration from natural vegetation will be limited by the availability of water. In some cases evapotranspiration may drop to low levels or cease during the dry months.

Considering the importance of evapotranspiration relative to groundwater levels and the influence on streamflow, particularly with regard to using groundwater sources for irrigation, the estimation of evapotranspiration formed a crucial component of the present studies.

2.5.2 Analysis of meteorological data

A complete meteorological station was set up at the principal dambo research site at Chizengeni (Plate 14). The objective was to obtain site specific data for rainfall and all the parameters from which evapotranspiration is estimated, particularly those needed for the Penman equation. Generally, data were collected over the period September 1985 to September 1986. The daily measurements taken at 0900 hrs were as follows:-

Rainfall	-	standard 125 mm gauge plus autographic gauge
Temperature	-	mercury in glass thermometer plus a thermohygrograph with weekly chart
Relative humidity	-	thermohygrograph checked with a hand held whirling pyschrometer
Wind	-	anemometer at 2 m height
Sun hours	-	Jordan sunshine recorder
Evaporation	-	Class "A" evaporation pan

Additionally, a gauging weir was constructed across the outlet stream at the bottom of the dambo (Plate 16). The principal thin gauging plate was a compound 90° "V" with a rectangular notch above (Plate 17), measuring accurately flows up to about one cubic metre per second. As dry season outflow from the dambo was the principal interest the weir was designed to measure low flows rather than wet season storm flows. A problem with only collecting one year's data is that it may not be representative of long term records. This is not so much of a problem with temperature, relative humidity, wind-run and sun hours as those are reasonably constant from year to year, but rainfall can vary considerably. However, the year 1985/86 was a reasonably typical year for rainfall (the "average" year of course never occurs precisely in practice). Figure 36 shows a comparison of the cumulative rainfall throughout the wet season at Chizengeni and the mean of the five year period 1975-80 and the nineteen year period 1961-80 for the Grasslands Research Station which is situated at Marondera about 20 km from Chizengeni. The period 1981-1984 was a period of severe drought and is not representative of the long term situation. The three profiles are similar although the monthly distribution of rainfall does vary. It is noteworthy that while Chizengeni receives almost 60 mm more rain than the 19 year mean for Marondera (1961-80) the cumulative total is less in Chizengeni until early January. Monthly rainfall totals for these periods are presented in Table 34. November's rainfall total was well below the Marondera average and it should be added that most of the rain that fell in December fell in the latter part of the month.

In order to evaluate the variation of the micro-climate at Chizengeni from that predicted using the records from nearby Marondera (1975-80)records from the two locations were compared as shown in Table 35.

The Chizengeni values given are those collected during the project period and those for Marondera are taken from published records. The daily temperatures for the two locations are close enough together to be considered as from the same population data set. However, this

Table 34 Monthly rainfall data for Chizengeni and Marondera

Month	Chizengeni 1985/86	Marondera 1975-80	Marondera 1961-80
Oct	3	32	37
Nov	44	92	135
Dec	220*	194	191
Jan	309	170	179
Feb	135	179	144
Mar	106	150	92
Apr	99	47	53
May	5	7	13
June	0	1	5
July	0	1	3
Aug	0	5	4
Sept	0	13	8
TOTAL	922	893	863

*most of this fell in latter part of month

cannot be said of the other three parameters. The relative humidity at Chizengeni is 10%-15% less for most of the year, although for the last four months of the dry season it is very close to the Marondera values. Whilst temperature is a relatively straightforward parameter to measure, relative humidity is a little more difficult. The degree of ventilation does affect the readings, and those taken at Chizengeni were taken from instruments set in a Stevenson screen. It is possible that the higher wind experienced at Chizengeni, as compared to Marondera, caused more ventilation through the screen and depressed the relative humidity values slightly.

The wind run values compared in Table 35 are both from instruments set at 2 m height, and reflect the divergence in wind values between the two locations. Chizengeni values are up to 70 km/day (40%) more than Marondera although the two stations show the same pattern of fluctuation throughout the year. Wind does vary considerably over short distances due to topographic effects and the Chizengeni values are still relatively moderate.

The sun hours for the year of data at Chizengeni are a little less than the records show for Marondera. During the months of greatest divergence, December and January, considerable rainfall was experienced which brought with it greater than average cloud cover. As reasonable control was exercised over the operation of the Chizengeni meteorological station it is considered that the records so obtained are reliable, within the limitations of the instruments themselves, and provide the best description of the climate there for the year of observation. They also provide the most reliable means of estimating potential evapotranspiration for the dambo. The evaporation pan readings are not shown in Table 35 due to leakage problems which led to an incomplete data set.

Plate 14 Meteorological station, Chizengeni dambo

Plate 15 DREAM (evaporation measurement) system

Plate 16 Gauging weir on stream draining Chizengeni dambo

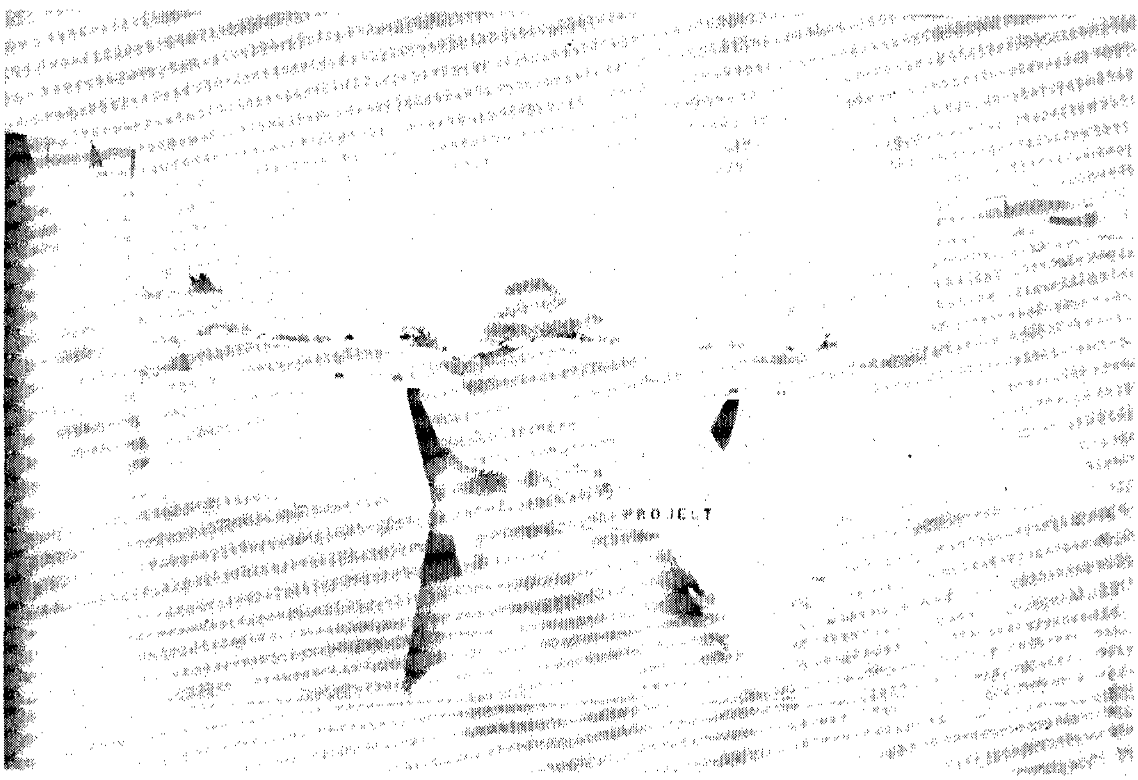

Plate 17 Detail of compound V-notch/rectangular weir plate

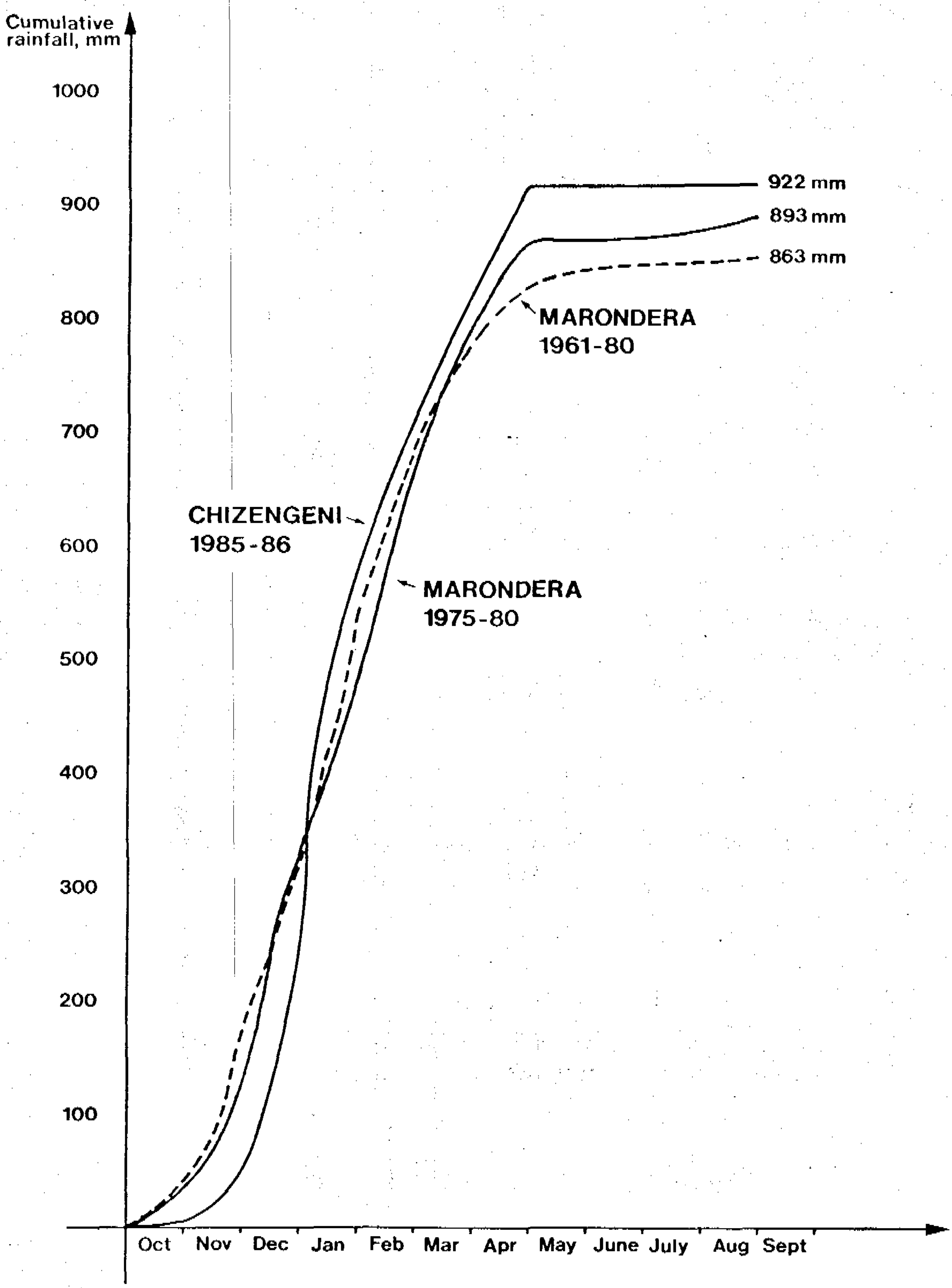

Figure 36 Comparison of rainfall at Chizengeni and Marondera

Table 35 Comparison of meteorological parameters for Chizengeni, 1985/86, (CZ) and Marondera, 1975-80, 5yr mean, (MR)

Month	Mean Daily Values							
	Temperature ^{o}C		Rel Humidity (%)		Wind Run (km)		Sun Hours (hrs)	
	CZ	MR	CZ	MR	CZ	MR	CZ	MR
Nov	18.1	18.4	57	67	248	187	6.7	6.7
Dec	18.0	18.5	65	77	230	191	4.0	5.8
Jan	17.9	18.3	69	79	231	173	4.1	6.6
Feb	18.5	18.1	64	80	221	169	5.4	5.4
Mar	17.8	17.9	62	75	209	173	7.0	7.7
Apr	17.0	16.2	67	70	262	165	6.0	8.2
May	14.4	13.9	55	66	185	156	7.8	8.7
Jun	11.2	11.5	54	65	234	165	7.8	8.1
Jul	11.6	11.7	55	61	241	169	8.8	8.5
Aug	13.8	13.9	52	54	216	182	8.4	9.1
Sep	16.7	17.0	49	50	199	200	8.7	9.6
Oct	17.7	18.4	61	52	269	218	8.6	9.1

Figure 37 shows the diurnal variation of temperature and humidity at Chizengeni for a typical day in September. The variation in temperature is moderate at 12 ° C, but there is a 62% change in relative humidity. In general the variations of the mean daily maximum and minimum temperatures from the daily mean temperatures were in the range of 4-6° C. The absolute maximum values recorded during October through to January reached 28° C and minimum values in June and July dropped to 1° C with groundfrost. The diurnal variation of relative humidity was greatest at the end of the dry winter season (September/October) with a range of 60%. During the summer period this range reduced to 40-50%.

In addition to the standard meteorological parameters already described, a dedicated suite of instruments was employed which measured (by inference) the evapotranspiration from crops and vegetation (Plate 15). This consisted of two pairs of shielded electrical resistance thermometers to measure temperature and humidity (by wet bulb depression), a net radiometer, a soil heat flux plate and a microprocessor to control the readings and log the data. The principle of the method is to measure the components of the energy budget at the earth's surface so that the only unknown is the latent heat of evaporation which can then be evaluated knowing the net radiation available. The suite of instruments are referred to by the acronym DREAM (Direct Reading Evapotranspiration Assessment Monitor). The results of this work are given in section 2.5.3.

2.5.3 Evapotranspiration Calculations

Pan Data

The Class 'A' evaporation pan situated on Chizengeni dambo yielded the results shown in Table 36. This includes an adjustment upwards of 10% to take into account the shielding effect of the protective wire mesh. The 1986 dry season monthly values are given and compared with the nineteen year mean monthly values for Grasslands Research Station situated 20 km away to the North-East. It can be seen that the 1986 Chizengeni values are somewhat lower than the Grasslands 19 year values.

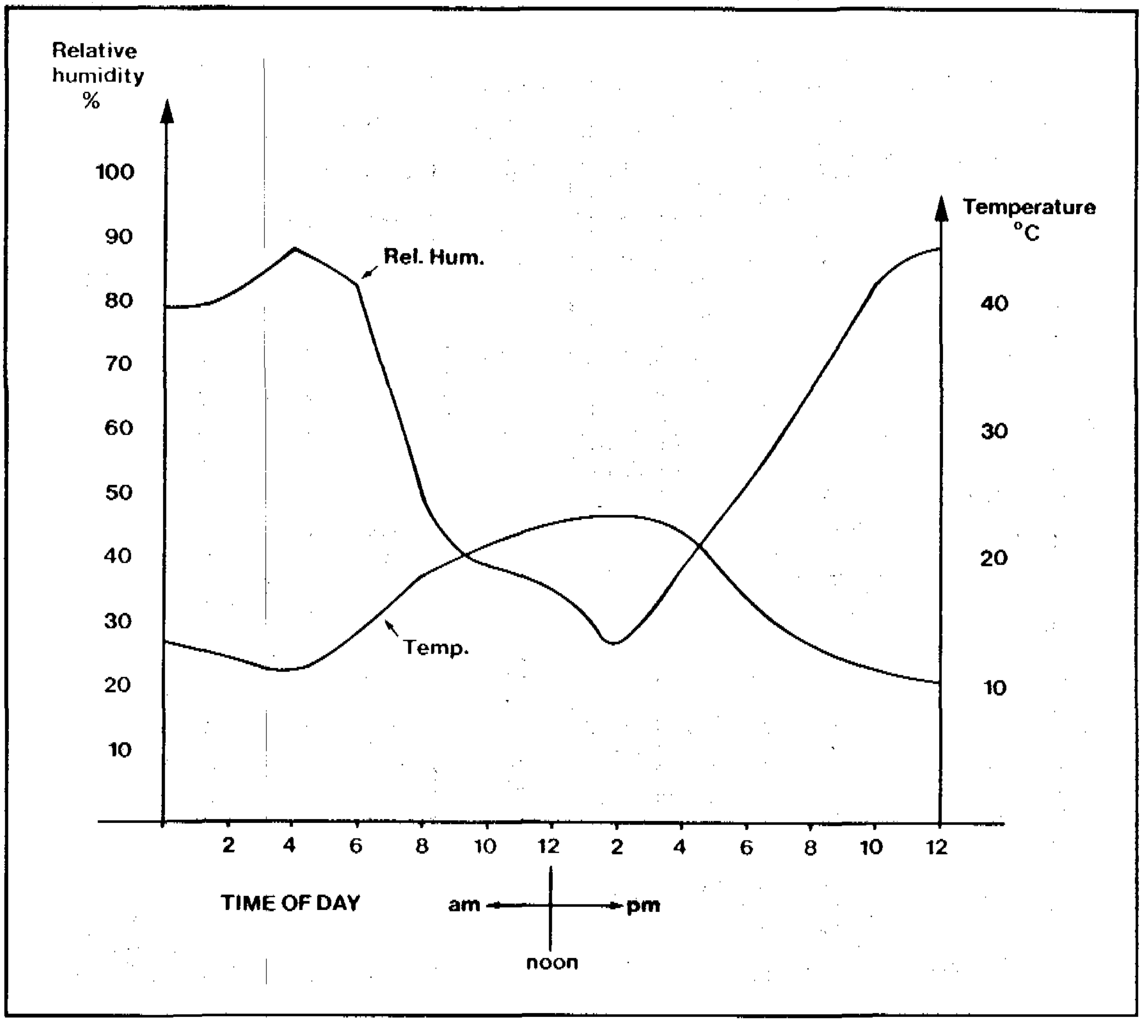

Figure 37 Diurnal variation of relative humidity and temperature, Chizengeni (September 13, 1986)

Table 36 Chizengeni Class A pan data (mm)

	May	June	July	Aug	Sept	Oct
Grasslands 19 yr	113	99	109	145	184	208
Chizengeni 1986	98	98	110	152	173	200
Daily loss, CZ	3.16	3.27	3.56	4.90	5.76	6.44
Ref crop ETo, CZ	2.61	2.45	2.67	3.67	4.32	4.83

To calculate the reference crop evapotranspiration losses (ie from a short green, actively growing crop which is not short of water) from the pan losses a correction factor must be applied (see Appendix 6). This factor depends on a number of variables including surrounding vegetation, relative humidity and daily wind-run. According to FAO paper 24 (Doorenbos and Pruitt, 1977), this factor is estimated to be 0.75 for the months June to October and was increased by 10% in May to 0.83 to account for tall grass on the dambo near the meteorological station.

Penman Data

Reference crop evapotranspiration rates (ETo) were calculated from meteorological data collected on site according to the Penman method and the FAO 24 modified method and are given below in Table 37. The rates for October were obtained by correlation with the 19-year pan data from Grasslands Research station near Marondera as meteorological data were not collected in Chizengeni for that month, field work having been completed in September. The Penman method adopted to calculate ETo is similar to that described in FAO paper 24 . However the Glover McCulloch expression is used to evaluate incident solar radiation at the earth's surface and the wind function is evaluated using the original Penman expression. (See Appendix 6 for further details). The ETo values are given in Table 37.

Table 37 Penman & FAO 24 ETo values (mm) 1985/86

Month	PENMAN Monthly	PENMAN Daily	FAO 24 Daily
Nov	149	4.96	6.01
Dec	132	4.27	4.70
Jan	128	4.14	4.49
Feb	124	4.43	5.02
Mar	131	4.23	5.06
Apr	107	3.57	4.15
May	90	2.88	3.79
June	78	2.60	3.53
July	84	2.70	3.75
Aug	103	3.33	4.46
Sept	141	4.71	6.32
Oct	183	5.90	6.96

October is the month with the highest ETo value (5.90mm/d Penman, 6.96mm/d FAO 24) June has the lowest at 2.60mm/d and 3.53mm/d respectively. This is consistent with pan data collected in various meteorological stations throughout Zimbabwe. A comparison of pan data converted to reference crop evapotranspiration and reference crop ETo, for the site at Chizengeni is given in Table 38. The Pan and Penman methods of evaluation differ on average by less than 8%, with the Penman method giving slightly higher rates at the beginning and end of the dry season. The FAO 24 method gives ETo values 40% higher than Pan values and 30% higher than the Penman values. This seems to indicate that the FAO 24 method overestimates reference crop evaporation by a possible 30 - 40% under these conditions.

Table 38 Penman/Pan/FAO comparison for 1986(mm/d)

	May	June	July	Aug	Sept	Oct	Mean
Pan ETo	2.61	2.45	2.67	3.67	4.32	4.83	3.25
Penman ETo	2.88	2.60	2.70	3.33	4.71	5.90	3.50
FAO 24 ETo	3.79	3.53	3.75	4.46	6.32	6.96	4.55

Dream Data

A selection of data collected according to the DREAM method is presented in Table 39 and compared with relevant Penman data. The Penman ET values are obtained by applying the crop coefficient to the 1-day Penman ETo value or the monthly ETo value if this is not available. The crop coefficient was obtained from tables and charts presented in FAO paper 24. The value of 0.50 for Dambo grazing was obtained by using the value of short pasture given in FAO 24. The value of 0.25 for bare ploughed soil seems to be low but this will vary according to the degree of moistness of the surface layer of the soil. FAO 24 does not allow for calculation of the crop coefficient for upland grazing, where there is no irrigation.

Table 39 DREAM/Penman data (mm/day)

Selected crops		Penman Month	ETo 1-Day	Crop coeff.	Penman ET	DREAM ET
Maize, 0.4m, Nov	P	4.96	5.85	0.40	2.34	5.33
Maize, 0.6m, Nov	P	4.96	5.11	0.50	2.56	2.57
Upland grazing, Nov	NP	4.96	4.92	-	-	1.97
Gemsquash, Nov	P	4.96	4.99	0.75	3.74	3.13
Dambo grazing, Aug	P	3.33	3.09	0.50	1.55	1.52
Dambo grazing, Aug	P	3.33	3.22	0.50	1.61	1.04
Dambo grazing, Aug	P	3.33	3.45	0.50	1.73	2.35
Bare ploughed soil,Sept	P	4.71	6.58	0.25	1.65	3.30
Irrigated garden, Sept	P	4.71	5.26	0.80	4.21	3.16
Emerging maize, Sep	P	4.71	-	0.35	1.65	1.74
Dambo grazing, Sept	P	4.71	-	0.50	2.36	2.02

P - potential evapotranspiration, NP - non-potential.

The DREAM data reflect actual evapotranspiration rates and are very site specific. In the one instance of non-potential evapotranspiration, that of upland grazing, the DREAM value seems quite high but does indicate that losses from the upland portions of the dambo catchment are likely to continue throughout much of the dry season. When one considers the depth to the water table, which varies between 2 and 6 metres, the extent of the capillary fringe and the rooting zone of plants that are established on the grazed dryland areas this is not surprising.

For crops on the dambo there are significant differences between the DREAM data and the Penman data. For the dambo grazing the individual values show considerable variation but taking average values the Penman method gives a value of 1.65 mm/d for August compared to

1.64 mm/d according to the DREAM method. This indicates that the value of 0.50 for the crop coefficient for dambo grazing is acceptable. The crucial measurements are for dambo grazing because an increase in cultivation on the dambo will be at the expense of grazing land. Therefore, the effect on the water resources must be assessed in terms of the changes in evapotranspiration rates when dambo grazing is brought into cultivation, or when existing cultivation is intensified using irrigation techniques.

2.5.4 Runoff

A weir was constructed on the Chizengeni dambo stream to measure runoff. Recording was carried out by means of a continuous chart recorder and daily manual readings. The three or four flows which overtopped the weir were not recorded and hence the figures given are somewhat less than the actual flows. However estimates of such flows have been made and are dealt with in the later part of this section. The data for the 1985/86 season are presented below in Table 40 and the 25 year mean data (1955 - 80) from the nearby Grasslands catchment near Marondera (zone ref. C43), being the longest data set, are given for comparison. The flow rates for late August and September are approximate as by then the head above the V-notch had fallen below 50 mm - the lowest level at which the calibration of the weir is valid.

Table 40 Streamflow 1985/86 (m^3 x10^3)

Catchment / Month	Chizengeni 85/86 274 ha	Grasslands ! 25yr-mean 352 ha
Nov	Nil	4
Dec	1.5	83
Jan	59.4	64
Feb	56.1	82
Mar	38.8	56
Apr	24.7	29
May	8.8	5
June	3.0	3
July	1.4	3
Aug	0.8	1
Sept	0.2	0
Total	194.7	335
% rainfall	7.7%	10.5%*
Unit Runoff(mm)	71.1	95.2
Dry season Total	14.2	12
Unit Runoff (mm)	5.2	3.4

* 19 year mean 1961 - 80

! Zimbabwe Hydrological Summaries, 1980

It will be noted that the flow in December at the Chizengeni weir was considerably less than the 25 year mean flow at the Grasslands weir. As was pointed out in Section 2.5.2 (see Table 34) there was less rainfall than normal in the early wet season in 1985/86. This explains much of the there was less rainfall than normal in the early wet season in 1985/86. This explains much of the difference although other factors such as catchment characteristics would also have an effect. The last rains were at the end of April so the dry season effectively began at the beginning of May and after August the streamflow out of the dambo was negligible. It is worth noting that the total unit runoff and the proportion of rainfall that went as streamflow were less at Chizengeni in the study period than the 19 year period at Marondera. This is in spite of the fact that vegetative cover at the Marondera site was far better than at Chizengeni. On the other hand, during the dry season (April to September) the unit runoff on Chizengeni dambo was greater than at the Grasslands site.

Infiltration tests were carried out on the dambo itself and on the dryland areas. The method used was to drive a single cylinder, 85 mm diameter, into the soil to a depth of 50 mm. Water was maintained in this cylinder at a constant head of 25 mm above the soil using a simple plastic top-up tank. The depth of water entering the soil was then plotted against time. Figure 38 gives typical plots of infiltration rates. It can be seen that the terminal rate for the upper catchment, at 230 mm/hr, is considerably higher than the value of 80 mm/hr for the dambo site which was situated on damp soil in the upper dambo zone.

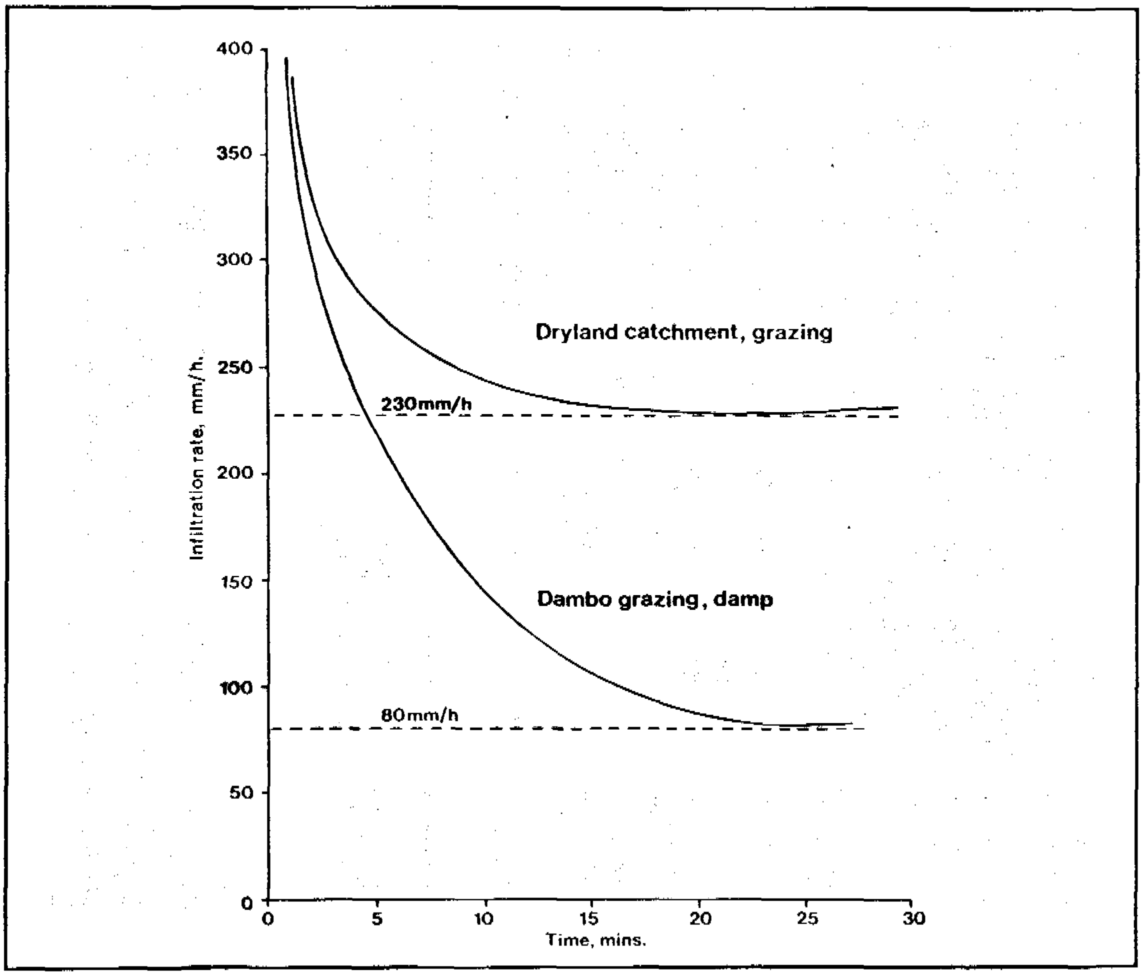

Figure 38 Infiltration rates, Chizengeni dambo

Rainfall-Runoff

The readings from the gauging weir at Chizengeni not only provide information on the runoff over the annual period but also provide an insight into the hydrological behaviour of the catchment through the response to individual storm rainfall events. The gauging weir itself was designed primarily to measure low flows accurately, and so the compound thin plate had a capacity of only 900 l/s. In order to assess the magnitude of higher flows resulting from tropical storms, a hydrological model was calibrated against the lower flows where accurate readings of flow rate are available together with the corresponding rainfall records. Once calibrated the model can be used to estimate runoff from the catchment using rainfall records only.

The problem with this approach is that as the magnitude of storm rainfall increases then the percentage of runoff resulting also increases. It is not a linear system. However, the model adopted allows for this increasing percentage of runoff by selecting a "curve number" (CN). The CN value chosen represents a plot of the relationship between rainfall and runoff in successive time increments, and includes an initial abstraction (infiltration, surface-storage etc) before runoff commences. The model is usually referred to as the SCS model and was developed by the Soil Conservation Service of the United States Department of Agriculture (USDA, 1971). The SCS model assumes the dimensions of a simple triangular shape hydrograph in terms of the dimensional parameters of the catchment.

A number of storm events were investigated, and it was found that a curve number CN of 86 predicted peak flowrates which corresponded to those recorded at the weir. The most severe rainfall event recorded was when 89 mm of rainfall fell in 3 hours (22 January 1986), and the whole weir structure was predictably overtopped. This rainfall represented a 1 in 30 year event (Zimbabwe Department of Meteorological Services). Using the SCS model a peak flow of 13.6 m^3/s was predicted. Whilst this may seem a high flow in relation to the catchment size, it nevertheless compares very well to using the simple rational formula

$$Q = CIA$$

where
- Q = peak flowrate
- C = runoff coefficient
- I = intensity of rainfall
- A = area of catchment

If C is taken as 0.6, corresponding to a total of 60% runoff from the rainfall, then this formula gives a peak flow of 13.7 m^3/s. The value of 0.6 for C is not unreasonably high when considering the severity of the event. Table 41 shows a comparison of how the SCS method can be calibrated using low flows and then used to estimate much higher flows.

Table 41 Soil Conservation Service (SCS) Flowrates

Rainfall (mm)	CN	Peak flow (m^3/s)	
		Recorded	SCS Value
7.5	86	0.011	0.011
8.4	86	0.023	0.021
27.5	86	0.73	0.72
89.0	86	(13.7 estimate)	13.6

A crucial factor brought out by this analysis is that relatively high flowrates are likely to occur several times a year with the potential for significant erosion and gully activity. However the one in thirty year event recorded did not in fact produce significant gully or sheet erosion at Chizengeni (see Section 2.4.3).

2.5.5 Geophysical and Topographical data

In order to build up a picture of the rock and soil strata underlying the Chizengeni dambo and its catchment geophysical data were collected in a variety of ways. Chizengeni is underlain by the gneiss basement complex, above which is a variable thickness of weathered bedrock (regolith). Dry catchment land use is predominantly maize fields with weed or scrub fallow (see Plate 1).

Information on the location of shallow or exposed bedrock and on the occurrence of shallow groundwater was obtained from AIR PHOTOGRAPHS combined with visual observation on the ground. A full TOPOGRAPHIC SURVEY was carried out on the Chizengeni in order to establish catchment boundaries, areas and slope angles (see Figure 28). Maximum angles did not exceed 2% in this area. The slope angles in the other study sites were similar, with the exception of Shumbairerwa (Gutu) where the maximum slope angle was 4%.

ELECTRICAL RESISTIVITY transects were performed and the results analysed. The method used for interpreting the results assumes that the underlying layers are homogenous and parallel to the surface. In dambos the underlying bedrock is characterised by its irregularities and therefore the results of the electrical resistivity survey could not be considered without reference to the other data. Figure 39 shows a section along the dambo bottom identifying changes in the underlying strata which compare well with surface observation of rock outcrops. On the catchment area above the dambo the bedrock may sometimes be found at ground level, at other times it is 10 metres or more below ground.

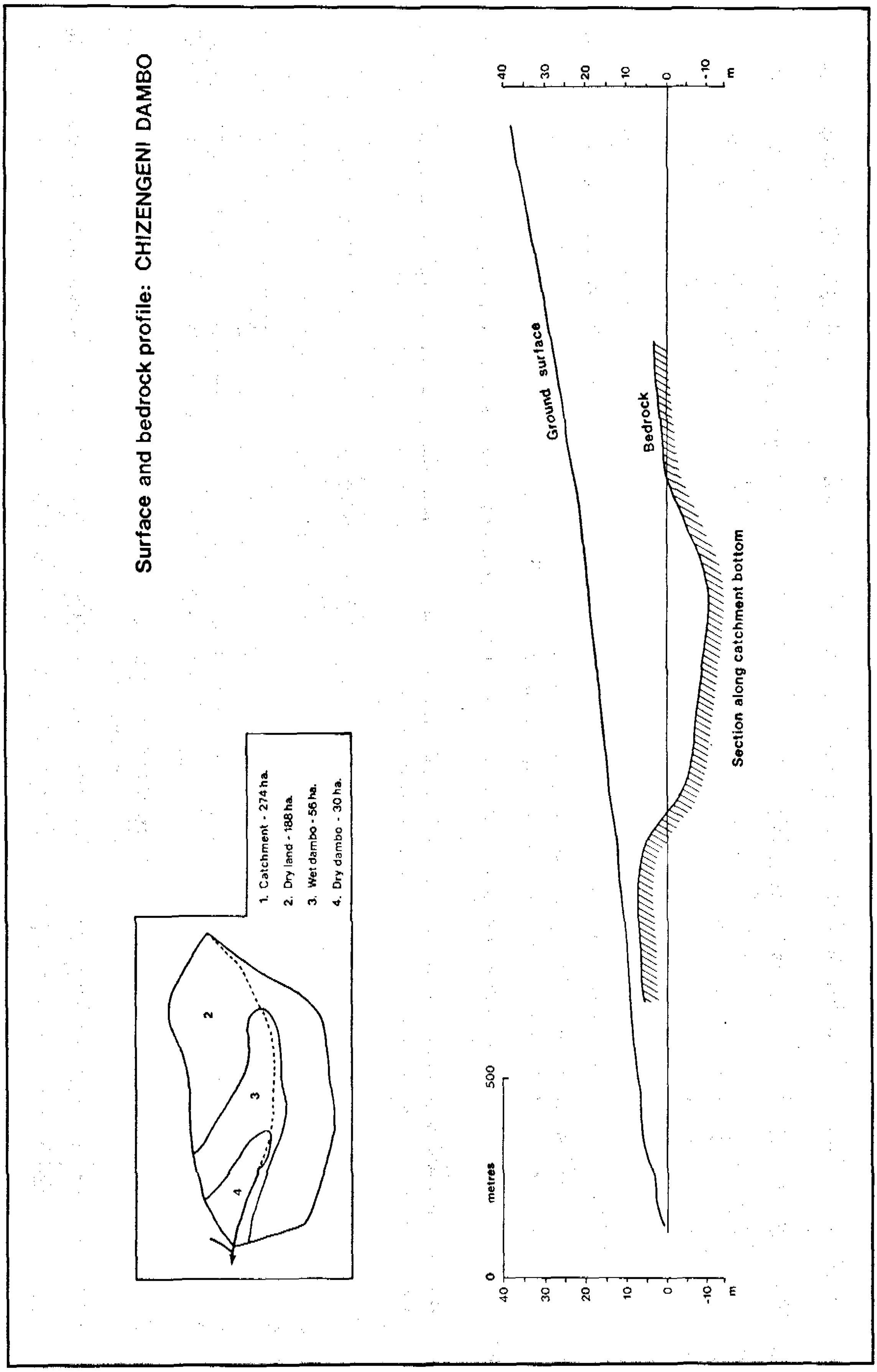

Figure 39 Surface and bedrock longitudinal profile: Chizengeni dambo

PIEZOMETERS were installed by hand auger and levelled to provide monitoring points for groundwater fluctuations. In addition holes were augered for PERMEABILITY tests. The permeability test method is the one described by van Beers (1983). These holes gave information on depth to the weathered bedrock zone and changes in soil permeability. The range in permeability values recorded according to this method was from 1 to 100 x 10^{-6} ms^{-1} with considerable local variation within the upper dambo area. For example in a distance of 10m the permeability was found to change from 0.9×10^{-6} ms^{-1} to 5.8×10^{-6} ms^{-1} . Permeability data from the other study areas have been collected.

2.5.6 Groundwater Fluctuation

Piezometers were augered at selected sites on the dambo and three hand-dug wells were constructed on the upper catchment. Regular readings were taken from these piezometers and were supplemented with readings from villagers' wells on the upper catchment.

To illustrate the manner in which the groundwater levels drop in the dry season two groundwater profiles have been drawn (see Figure 40). These profiles confirm that groundwater levels on the upper regions of the catchment undergo a significantly greater fall than on the dambo itself.
A summary of the groundwater fluctuations in the dry season, May - September 1986, with projections to the end of October, is given below in Table 42.

Table 42 Groundwater fluctuations, Chizengeni May-Sept, 1986

Region	Drop in GW level (m)
DAMBO ZONE	
Margin	0.35
Upper	0.25
Lower	0.46
Aquifer volume change	0.36(m^3 x10^6)
NON-DAMBO ZONE	
Upper regions	1.64
Mean	1.29
Projected mean drop (by October 31)	1.72
Aquifer volume change	2.43 (m^3 x 10^6)
Water volume lost (storativity = 0.1)	243 (m^3 x10^3)
Projected loss (Oct 31)	324 (m^3 x 10^3)

In estimating the volume of water lost during this period some estimate of the aquifer storage capacity is needed. Due to the heterogenous nature of the aquifer only a rough approximation can be made. The storativity of this type of aquifer can be taken as approximately 0.1. Using this figure the volume of water lost by the end of October due to the above drop in water level is in the order of 320 $m^3 \times 10^3$. This compares with the value of 14.2 $m^3 \times 10^3$ for run-off in the same period. In addition to the water lost due to the change in water level, changes in soil moisture above the water table will affect the overall water balance but these will be small in comparison to water table changes.

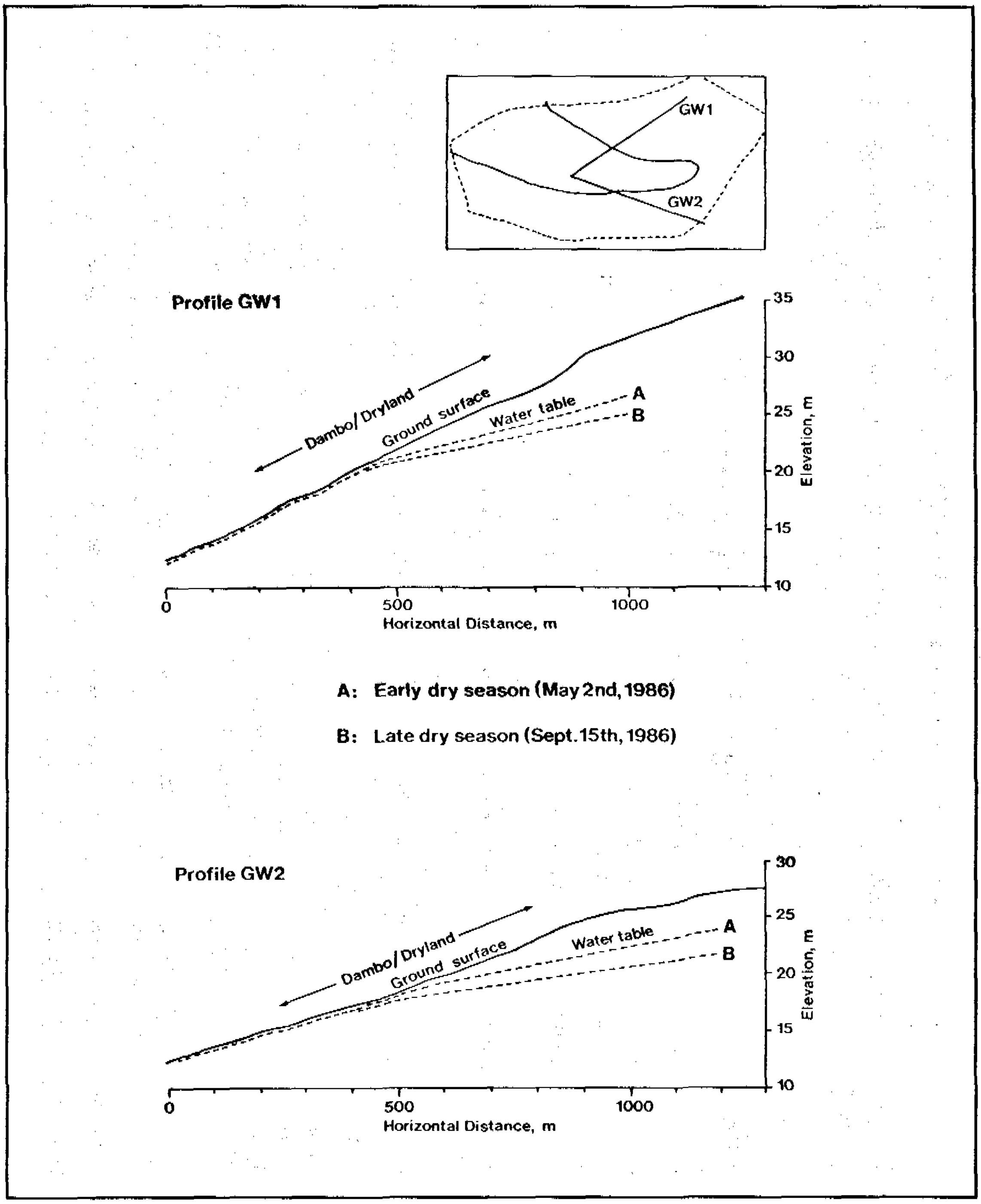

Figure 40 Changes in groundwater levels, Chizengeni, 1986

3. DAMBO HYDROLOGICAL MODEL

In this section a model of dambo hydrology is developed and is applied to data obtained from the Chizengeni dambo catchment in 1985/86 to predict the effects of cultivation and particularly dry season irrigation.

3.1 Water budget

In order to understand how the dambo operates as a hydrological entity it is important to know the quantities of water involved. When irrigation in the dry season is being considered the focus will lie with the water budget in that season. The dry season water budget is affected by the following processes:

Rainfall. During the dry season rainfall is zero and can be ignored.

Runoff. Surface runoff is zero in the dry season. Streamflow continues due to baseflow from the aquifers above the stream. For the 1986 dry season the total dry season streamflow was 14.2×10^3 m^3 or 5.2mm distributed over the catchment, all of which came from storage.

Change in groundwater storage. This will be affected by the drop in the level of the water table which is discussed in more detail below. The change in soil moisture above the water table will play a small role in the overall budget but for the purposes of this analysis may be ignored. Some of the water lost due to the drop in water level will go to deep percolation. This question is also addressed below.

Evapotranspiration. The evapotranspiration losses will vary across the catchment depending on such things as land-use, weather and availability of water. The total amount of water used has been estimated and is presented below.

Abstraction. This term covers water abstracted for domestic use. Water for irrigation will be covered by the evapotranspiration term. The amount of water extracted for domestic use is small being in the order of 2×10^3 m^3 in any one year.

To summarise the dry season water budget may be given in the form of a simple equation:

$$\text{Groundwater change} = \text{Evapotranspiration} + \text{Streamflow} + \text{Abstraction}$$

but Abstraction is negligible and may be ignored.

3.1.1 Groundwater

In Table 42, section 2.5.6, the volume of water lost due to the drop in groundwater levels, from May 1 to October 31, was estimated to be $0.324 \times 10^6\ m^3$. The average drop in the water level in the non-dambo areas of the catchment was estimated to be 1.72m. Near the top of the catchment the drop in the water level was estimated to be 2.2m on average. The drop in water level over the catchment was plotted against time for the 1986 season and is presented in Figure 41.

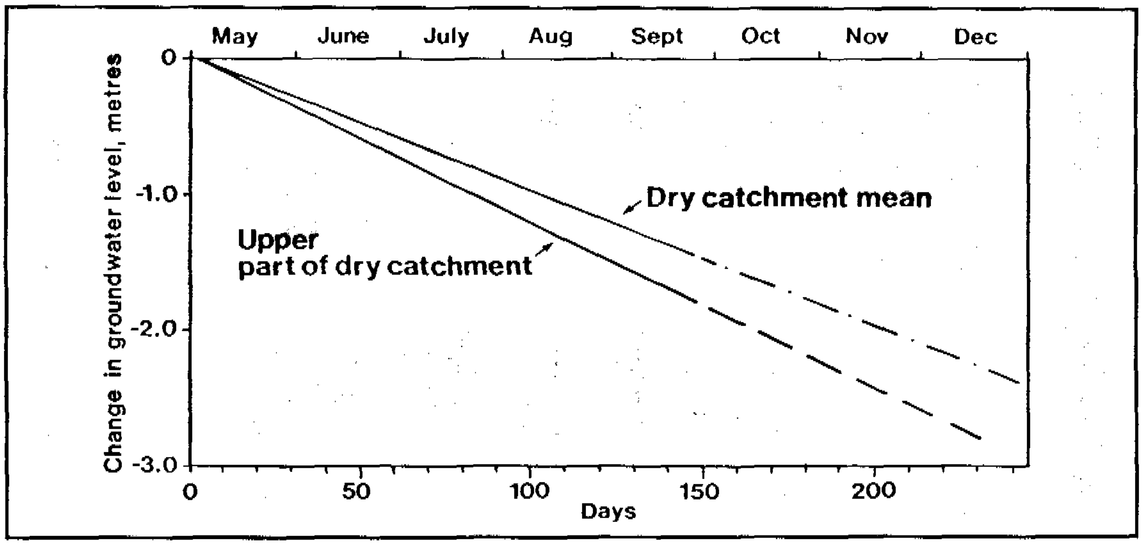

Figure 41 Dry season drop in groundwater levels on dryland portion of Chizengeni catchment 1986

3.1.2 Dry season evapotranspiration

Using the reference crop evapotranspiration values calculated in section 2.5.3 we can estimate the total amount of water lost due to evapotranspiration provided that we have a value for the ratio of actual evapotranspiration to reference crop evapotranspiration for the relevant crops. These values are presented below as 'k' values (Table 43). The validity of the 'k' values may be checked both against the 'k' values measured and by comparing the water losses calculated by groundwater measurements and by evapotranspiration estimates.

Table 43 Dry season* evapotranspiration estimates

Region	Area ha	ETo mm	k value	ETmean mm/d	Loss $m^3 \times 10^6$
Dry dambo bottom	30	679	0.15	0.55	0.03
Lower dambo	22	679	0.25	0.92	0.04
Upper Dambo	34	679	0.50	1.66	0.12
SUB TOTAL	86	679	0.33	1.22	0.18
Dryland	188	679	0.10	0.44	0.13
TOTAL	274	679	0.17	0.74	0.31

* May 1 - Oct 31

The overall loss due to evapotranspiration using these values is 0.31×10^6 m^3 which is slightly less than the loss in the groundwater storage due to a drop in the level of the water table which was calculated to be 0.324×10^6 m^3. Some water may be lost due to deep percolation but it is likely to be a small fraction of the total lost due to evapotranspiration.

It can be seen from these figures that, even in the dry season, losses due to evapotranspiration on the dryland areas of the catchment remain significant, being over 40% of the total. While the rate of evapotranspiration is low, the relatively large area causes the total volume loss to be high. Changes in land use on the dryland areas of the catchment may be as significant as changes on the dambo itself. Nonetheless, the dambo is the main surface for evapotranspiration in the dry season with the upper dambo zone being the most significant.

This particular catchment presently has a small wooded area (<5%) but there is an ongoing effort by the local people to plant gum trees, both on the dryland areas and on the dambo itself. This will lead to increased losses due to evapotranspiration. Before agricultural settlement the evapotranspiration losses due to the natural woodland would have been much higher than they are today, under maize fields and grazing land. It is likely that the removal of woodland from the dryland areas of the catchment has made more water available to the dambo.

3.1.3 Water budget summary

The dry season streamflow for Chizengeni in 1986, which followed a year of plentiful rain, was 14.2×10^3 m^3. This compares with evapotranspiration losses of 310×10^3 m^3. Clearly the dry season streamflow is very small compared to the far more significant values for both evapotranspiration and change in groundwater storage.

To summarise the water budget the values calculated above may be inserted into the dry season budget equation with very small terms such as abstraction ignored:

Groundwater change	=	Evapotranspiration	+	Streamflow
0.324	=	0.31	+	0.014 ($\times 10^6$ m^3)

Our study did not allow for the precise calculation of a water budget for the complete season as this would need data on the amount groundwater levels at the end of the 1985 dry season and hence the groundwater storage that was replenished with the onset of the rains in late 1985. However in order to appreciate the relative orders of magnitude involved an approximate calculation of the water budget for the whole year may be done as follows. The total rainfall for the 1985/86 season was 922mm which amounts to a volume of water falling on the Chizengeni dambo catchment of 2.53×10^6 m^3. Of this 0.195×10^6 m^3 went in runoff (see Table 40, section 2.5.4) and 0.324×10^6 m^3 went in dry season evapotranspiration leaving a balance of 2.01×10^6 m^3. The two major remaining terms to be estimated are the wet season evapotranspiration and the replenishment of groundwater storage.

The reference crop evapotranspiration for the wet season is 771mm which amounts to 2.11×10^6 m^3 over the catchmnent, which is greater than the amount available (2.01×10^6 m^3). The actual evapotranspiration will be less than this. If we assume that there was a net increase in groundwater storage, this being a wet year and there having been drought between 1981 and 1984, the figure for evapotranspiration must be less than 2.01×10^6 m^3. Working with an increase in groundwater storage of 0.5×10^6 m^3, equivalent to a rise in the water table of 1.8 metres over the whole catchment, then the figure for evapotranspiration is 1.51×10^6 m^3 or 551 mm over the whole catchment. This gives a 'k' value of 0.71 relative to the reference crop evapotranspiration figure of 771 mm. A smaller value for the increase in groundwater storage would give a correspondingly higher value for evapotranspiration. This is considerably higher than the dry season evapotranspiration losses. Wet season evapotranspiration losses are expected to be higher than dry season losses because in the wet season there is more water available as soil moisture content and because temperatures are higher.

Despite the tentativeness of these figures it is clear that evapotranspiration is the greatest single component in the water balance (after rainfall). Changes in dryland catchment land use which reduce vegetative cover, such as deforestation and cultivation (and hence evapotranspiration) will, depending on land preparation, increase runoff or groundwater storage. Thus more water becomes available for streamflow or, in catchments with dambos, for evapotranspiration from the dambo.

3.2 Hydrological Mechanisms

In addition to data on the volumes of water entering, being stored in and leaving the dambo catchment, it is important to understand the mechanisms by which the water moves through the catchment. The primary concern of this section is the mechanism that affects the dambo and how cultivation may interfere with that mechanism.

One very simple storage model of a dambo is that of a sponge which stores water during the rainy season and releases it slowly both as streamflow and as evapotranspiration. Dambos were described as sponges as long ago as 1874 by Livingstone: "one has to watch carefully in crossing them to avoid plunging into deep water holes made by the feet of elephants and buffaloes" (MacNair,1956 p298). The sponge model assumes that the dambo soaks up water during the rains and releases it as streamflow during the dry season.

The sponge model of a dambo does not explain many of the hydrological phenomena associated with dambos, especially the headwater and stream dambos in Zimbabwe's highveld. In particular the model fails to explain the persistence of a high water table in the upper areas of the dambo while those lower down have a much lower water table. That dambos do not behave as simple sponges has been stated by various researchers in this field (Balek and Perry, 1973; Pereira pers. comm., 1987) A more sophisticated model is proposed below. This model has been described to some extent in previous papers on dambo hydrology (Rattray et al 1953; Elwell and Davey, 1972). Because dambos vary considerably the components of this model may vary in significance for any particular dambo.

3.2.1 Storage/seepage mechanism

Although regular wet zones are easily identified in dambos a striking feature at a detailed scale is the irregular pattern with which this water lies close to the surface. One may encounter heavily waterlogged areas which are only a matter of metres from quite dry areas. This is reflected in the sharp variations in soil organic content which are closely associated with waterlogging (eg Whitlow, 1985 p 129). Inspection of air photographs and field investigations show that the waterlogged dambo areas are often several hundred metres or more from the head of the nearest stream (Plate 1).

In the upper dambo area water appears close to the surface and remains there throughout the dry season. The lower parts of the dambo dry out as the dry season progresses. In Figure 42 a model of the dambo is proposed based on geophysical investigations, augering of piezometers, water table level observations and air photography interpretation carried out on the Chizengeni dambo.

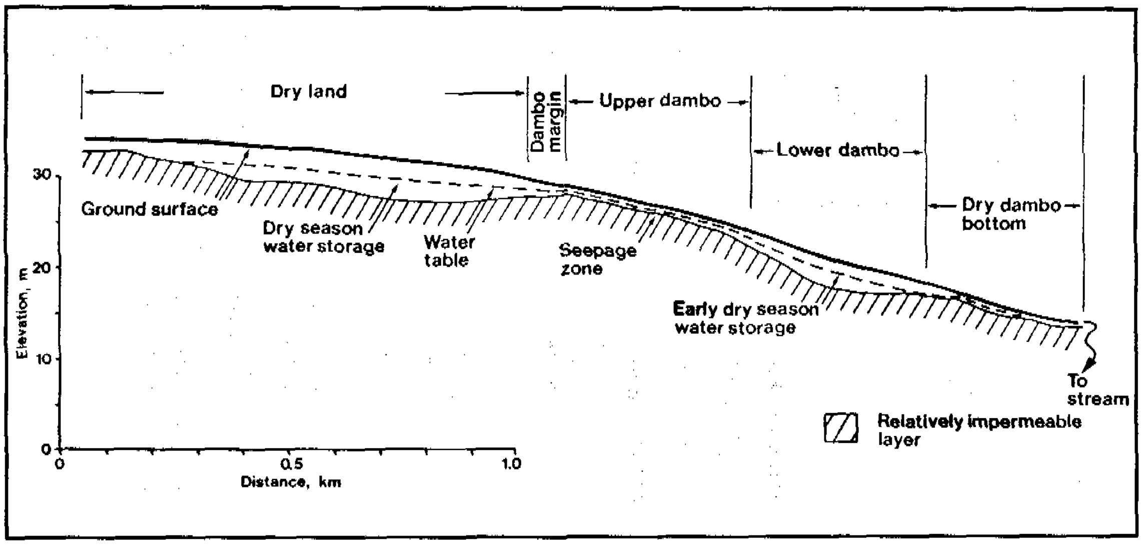

Figure 42 Dambo hydrogeological model, based on Chizengeni catchment

The existence of a permanently wet dambo zone upslope from drier dambo zones implies that groundwater is being forced to ground level under the influence of the hydraulic gradient and variations in sub-surface permeabilities. Permeability tests clearly indicate that there are significant changes over relatively short distances within the dambo (see Section 2.5.5). It appears that the dambo is underlain by an undulating and relatively impermeable layer which comes close to the surface in the upper dambo zone. In some cases this impermeable layer may be in the form of bedrock and be clearly visible at the surface. In other cases it may comprise clay-rich or lateritic layers within the weathering profile (McFarlane, 1986). The dryland catchment must also be underlain by a relatively impermeable horizon.

During the early part of the dry season water from the replenished aquifer above the dambo will enter the upper dambo area. Here plant growth will be vigorous and evapotranspiration high. Some of the water from the upslope will pass through into the lower dambo zone where there will be further losses due to evapotranspiration. A certain amount will go into the dry dambo bottom and the rest will go into the stream as the catchment baseflow.

As the dry season proceeds, the depletion of the non-dambo aquifer reduces the hydraulic gradient and hence the amount of water leaving that aquifer. Because evaporative losses on the upper dambo area will continue there will be reduced replenishment of the lower dambo storage. Thus the lower dambo, where any localised shallow storage is limited, will begin to dry out. As this happens the amount of water reaching the stream as baseflow will be reduced until the stream dries up as it did in 1986 in August after a year of good rains. After a year of poor rains the stream dries up much earlier. The dry dambo bottom, with minimal storage and bedrock close to the surface will have dried out already.

Towards the end of the dry season the flow from the upper aquifer will only be sufficient to provide for evapotranspiration on the upper dambo. There will be no surplus to be passed on to the lower dambo which will now be very much drier than the upper dambo zone. With the onset of the rains surface runoff and sub-surface flow from the upper catchment will ensure that all the dambo areas become saturated during the early part of the wet season. As this happens, base flow in the stream will resume as it did at the end of December at Chizengeni in 1985 - 86.

Using this model it is clear that the principal aquifer storage during the dry season lies beneath the upper, dryland area of the catchment. The dambo itself has only limited aquifer storage which is depleted quite early in the dry season. The simple sponge model is clearly inappropriate in this case.

3.3 Effect of cultivation on dambo hydrology

In most of Zimbabwe's communal areas only a small proportion of the land is now covered by indigenous miombo woodland. The removal of this woodland has undoubtedly reduced the dryland evapotranspiration losses. Thus the amount of groundwater stored has increased and may have contributed to a re-activation of the dambo systems. This is worth noting as Zimbabwe lies at the low rainfall end of the spectrum of regions in which dambos are found. Most other parts of Southern Africa with dambos receive 1000 - 1500 mm of rain per year. In looking at the effects of an increase in water use on a small area of dambo it is important to keep in mind that changes in land use on the dryland areas, particularly the removal or addition of trees, may be a more important influence on evapotranspiration losses than cultivation on dambos.

Land use on dambos is divided here into four basic categories. Ungrazed or lightly grazed dambos are rare in Zimbabwe's communal areas. Most dambos are relatively heavily grazed. Some dambos are cultivated and within these cultivated areas some land is under irrigation. Irrigation is a dry season activity, rarely involves the whole garden area at any one time and usually involves simple technology. For example it can be calculated from the amounts of irrigation water applied by households under study (Table 22, Section 2.3.3), that in Chizengeni in 1986 the irrigated dambo area never exceeded 2 ha in total at any one time. With current technology, being in the main hand watering of gardens using watering cans and buckets, irrigation is very labour intensive. Labour is a scarce resource and hence the area of dambo garden that is irrigated is limited.

Dambo cultivation without irrigation is unlikely to alter significantly the evaporative water use compared with dambo grassland under intensive grazing. This agrees with observations made by Elwell and Davey (1972). The direct measurement of specific crop water use is difficult. However results calculated according to the DREAM and Penman method indicate that this was the case in our study site. Therefore the rest of this analysis is concerned with the predicted change in water use when heavily grazed dambo land is brought into irrigated cultivation.

A limited amount of work has been done on the design of suitable low-cost pumps for use by peasant farmers and it is likely that interest in this area will grow as the potential for food production on dambos is recognised. Several pumps show promise and it is likely that there will be a range of options open to the peasant farmer if research and development efforts are successful (Lambert, 1987). With the introduction of different technology that allows greater amounts of water to be pumped, the potential for increasing the area of land irrigated in the dry season will increase. This increase in water use will affect both the aquifer storage and the stream flow to some extent. Depletion of storage must be made good by recharge during the rains. The effects on storage and recharge are discussed below.

3.3.1 Effect on aquifer storage

Increasing water use on the dambo will affect the aquifer above the dambo. Dryland vegetation and wells for domestic use obtain water from this aquifer and will be affected by a drop in its level. To assess this drop in level an equation has been developed based on the storage-seepage model described earlier. The equation gives the drop in the water table and is as follows:

WTdrop = (dK x ETo) (Acult/Aaq) (1/S)

where:	WTdrop	=	drop in water table of the aquifer affected
	dK	=	factor for change in evapotranspiration
	ETo	=	reference crop evapotranspiration
	Acult	=	cultivated area
	Aaq	=	area of aquifer affected
	S	=	storativity of aquifer, taken as 0.1

In this analysis, the dry season is divided into two periods for which the drop in water table is calculated and then summed. The two periods are:

- an early period extending from May 1 to June 30 when a depletion in aquifer water table level occurs over the total catchment area, which in this case is 274 ha. The reference crop evapotranspiration for this period is 168mm;

- a late period extending from July 1 to October 30. In this period it is assumed that evapotranspiration on the upper areas of the dambo is maintained primarily by water entering the dambo from storage in the upper catchment aquifer, extending in this case over 188 ha. Because this aquifer area is smaller than in the early period the effect on the water level is more marked. The reference crop evapotranspiration for this period is 511mm.

The change in evapotranspiration, denoted by 'dK', is estimated by comparing the crop coefficient of a grazed area of the upper dambo, which remains wet through most of the dry season, with a selection of crop coefficients. Our data give a figure of 0.50 for the crop coefficient in these circumstances. Using data available from FAO 24 and the Farm Management Handbook of Agritex, Zimbabwe a selection of average crop coefficients has been prepared. These coefficients are presented below in Table 44.

Table 44 Crop coefficients for selected crops

Crop	Coefficient
Green beans	0.73
Carrots	0.77
Onions (green)	0.66
Cabbage	0.70
Spinach	0.49
Tomato	0.57
CROP AVERAGE	0.65
Dambo grazing	0.50

For this selection of vegetable crops, typical of those commonly grown on dambo gardens, the overall average crop coefficient is 0.65. Therefore the increase in crop coefficient over dambo grazing is 0.15 or 30%. To allow for circumstances in which the crop coefficient may be increased by a larger amount, such as in a drought where the grazed areas would be short of water or where crops with a high crop coefficient predominate, the calculation is also carried out using an increase of 0.30 or 60%.

The analysis is carried out for irrigated areas of 10 ha and 27.4 hectares respectively. The figure of 27.4 hectares represents 10% of the dambo catchment area and approximates to the present total area of gardens in Chizengeni dambo. The results of the calculations are presented graphically in Figure 43. A summary of the results is presented below in Table 45.

Table 45 Predicted drop in Chizengeni catchment water table due to projected dambo irrigation

Irrigated area (ha) (% of catchment)		10.0 (3.6%)		27.4 (10%)	
Increase in crop coeff., dK		0.15	0.30	0.15	0.30
Dry season* period		Drop in Water Table (mm) (assumes storativity of 0.1)			
Early: 61 days, ETo=168mm Aquifer area =274ha		9	18	25	50
Late: 123 days, Eto=511mm Aquifer area =188ha		41	82	112	223
'Natural' drop (1986) = 1720 mm	TOTAL DROP	50	100	137	274
% of 'natural' drop		2.9	5.8	8.0	15.9

* May 1 to October 31

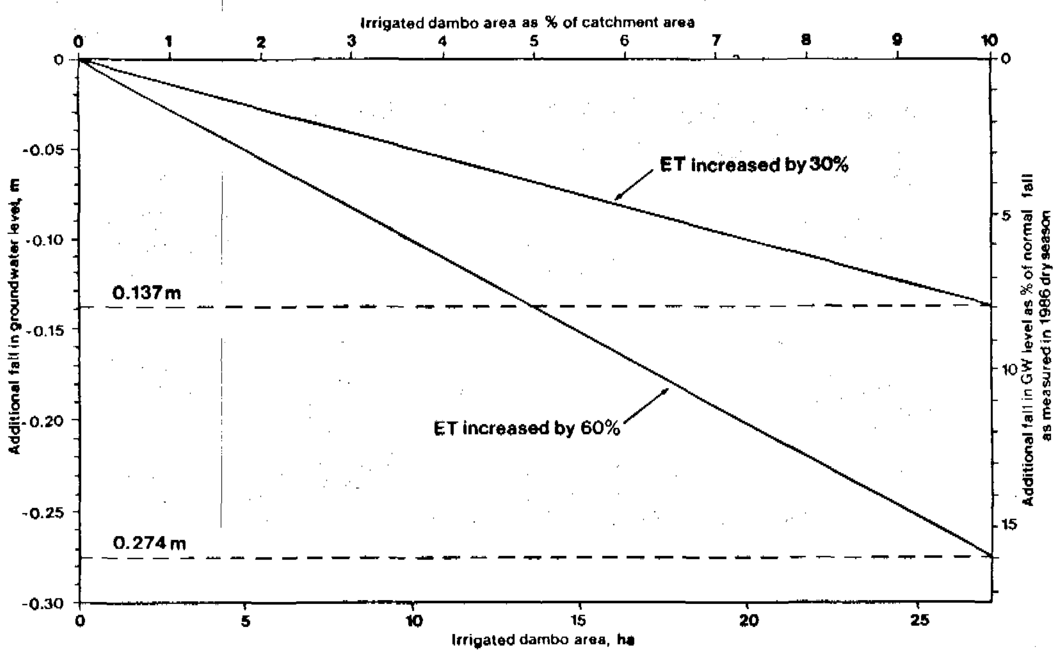

Figure 43 Predicted drop in groundwater level due to dambo irrigation, Chizengeni

Monitoring of wells and piezometers in Chizengeni dambo catchment for the 1986 dry season indicates that the water table in the non-dambo area of the catchment drops by 1.72m on average between May and the end of October. If 10 ha were intensively cultivated with irrigation then the additional drop in the water table is estimated to be 50mm or 2.9% of the drop recorded in 1986. In years when the increase in evapotranspiration, denoted by a change in the 'K' value of 0.30 is larger, such as in drought years, the effect on the water table is correspondingly greater. This corresponds to an increase in evapotranspiration of 60%.

If the whole of the upper dambo zone, 34 ha, were to be irrigated in a year when the increase in evapotranspiration was 30% the effect on the water table in the aquifer above the dambo would be an additional drop of 20%. In dambo catchments where the specific yield is very much less than 10% then the effect on the upper aquifer of intensive irrigation on large areas of dambo may become significant.

Intensive irrigation would require the use of high powered pumps, eg diesel pumps. Even with such pumps the rate at which water could be extracted from a dambo well is limited by the permeability of the soil around the well. Where the permeability permits large rates of extraction and high powered pumps are used then the effect on the aquifer above the dambo may become important.

During the dry season the level of the water table in the dambo itself is determined by the degree of replenishment from the dryland aquifer above it and the level of water loss on the dambo. If the rate of water loss increases then for equilibrium the rate of replenishment must also increase. The rate of replenishment is controlled by the hydraulic gradient of the upper aquifer. Consideration of Figure 40 in Section 2.5.6 shows that a hydraulic gradient equivalent to 5 in 500 or 1% is to be expected at the end of the dry season. Depletion of the level of the aquifer by 0.1 metres as would be the case with extensive irrigated cultivation (Table 45) would change the hydraulic gradient to 4.9 in 500 - an insignificant change. From this analysis it seems that the water table in the dambo itself is unlikely to be significantly affected by cultivation so long as the upper aquifer which replenishes it is not seriously depleted. During the wet season the water table in the dambo will rise quickly unless drainage has been installed.

3.3.2 Effect on aquifer recharge

Recharge of the aquifers by rainfall will be affected by how much they have been depleted in the dry season. Thus any further depletion in the non-dambo aquifer due to increased water use will mean that it will require more water to recharge than normal. The additional amount needed has been calculated and is presented below in Table 46.

Table 46 Effect of dambo irrigation on aquifer recharge

Irrigated area (hectares)	Increased recharge requirements (mm water)*	
Increase in crop coeff	K=0.15	dK=0.30
2.0	0.7	1.5
10.0	3.7	7.4
27.4	10.2	20.4

* Rainfall in 1987 = 922mm

The effect of the area of irrigation in 1986 in Chizengeni, less than 2 ha, on the recharge requirements appears minimal never exceeding 1.5 mm of water. With greater areas of cultivation the recharge requirements increase and with intensive irrigation over the whole upper dambo area and a high increase in evapotranspiration the increase in recharge requirements reaches just over 20mm. This compares with a rainfall total of 922mm in the 1985/86 season.

Using this model it appears that the effect of dambo cultivation on the wet areas of the dambo during the dry season will have but a small effect on the aquifer of the dambo catchment. If cultivation takes place on areas of the catchment that would otherwise be dry then there will be a greater increase in evapotranspiration and hence the effect on the aquifer will be greater. To minimise the effect on the aquifer it is necessary to keep the increase in evapotranspiration due to cultivation to a minimum. This can be done by ensuring that dambo cultivation does not take place outside the upper dambo zone. Figure 44 shows the scale of the predicted change in groundwater levels. The fall in the catchment aquifer of 1.72m which was measured in 1986 is represented by 'A' and the predicted additional falls due to irrigation over the whole cultivated dambo area are represented by the 8% and 16% lines (see Table 45).

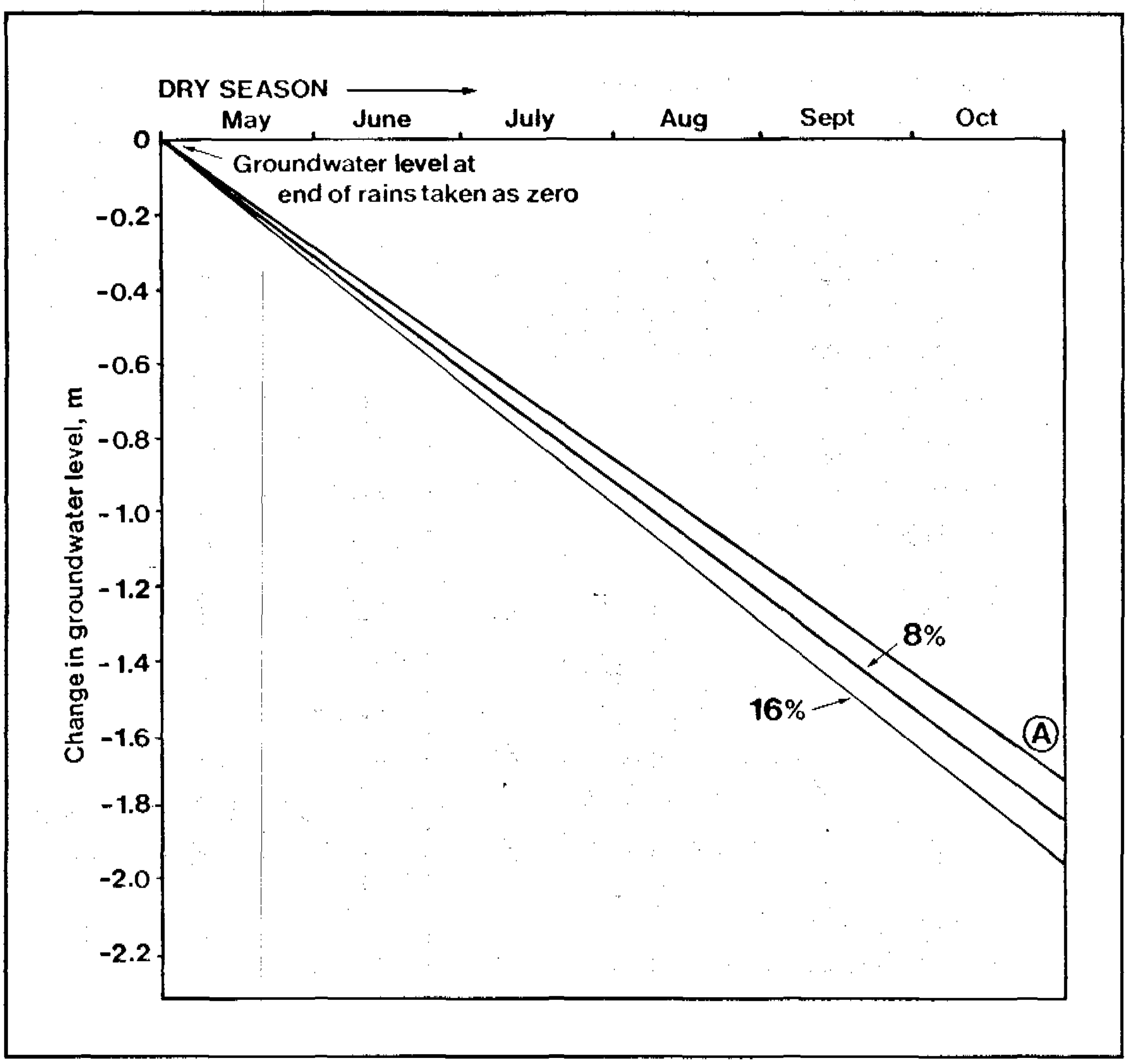

Figure 44 Predicted monthly change in dry season groundwater levels due to dambo irrigation:
(A) non-dambo aquifer fall in 1986 at Chizengeni

3.3.3 Dry season flows

The simple sponge model of a dambo assumes that water stored in the dambo is slowly released as evapotranspiration and stream base flow in the dry season. Hydrological investigations on a heavily wooded catchment in Zambia, reported by Balek and Perry (1973), indicate that this flow reduces rapidly early in the dry season. Our research in Zimbabwe, indicates that this also holds true on a far less heavily wooded catchment.

The amount of water stored in the dambo itself is relatively small and is held close to the surface within reach of crops and vegetation so permitting high rates of evapotranspiration. Without replenishment from aquifers higher up in the catchment the dambo storage is depleted early in the dry season and hence streamflow ceases.

The upper dambo zone remains moist long after the stream has dried up, indicating that water is stored in the upper catchment aquifer. Because of the undulating impermeable layer this water is forced to the surface where high rates of evapotranspiration ensure that no water passes down to contribute to streamflow. In effect, these moist areas break the link between the upper aquifer and the stream. Increasing evapotranspiration losses on these areas, by pumping for irrigation, will directly affect the level of the aquifer in the upper catchment but will not affect the dry season flow in the stream. The late dry season is the time when the increase in evapotranspiration will be most significant. At this time the stream will have already dried up and hence cannot be affected by water use on the upper dambo area.

The lower dambo zone has more direct links with the stream and its moisture status directly affects streamflow. Practices which cause this zone to dry out earlier, such as abstraction of water for irrigation, will lead to an earlier cessation in streamflow.

When the rains begin, streamflow will occur as a result of surface runoff and baseflow from the recharged aquifers. Surface runoff will be affected by landuse and vegetative cover. Dry season cultivation, where it increases ground cover above what would be available in an overgrazed dambo, may even reduce surface runoff. Recharge of the lower dambo storage must take place before baseflow begins. Recharge here will be a result of rain falling directly on the lower dambo, plus surface runoff and sub-surface flow from the upper areas of the catchment.

The effect of depleting the non-dambo aquifer will be to reduce slightly the contribution of only the sub-surface flow to the recharge of the dambo storage. This will be affected by the change in the hydraulic gradient of the aquifer above the dambo. The change in the hydraulic gradient due to an increase in irrigated area is very small (see above). Therefore early wet season baseflow may be affected by a depletion in the non-dambo aquifer but this effect is likely to be small. It is notable from Table 40 (Section 2.5.4) that streamflow at Chizengeni in the early dry season was very low. It is unlikely that the level of irrigation in 1986 could have alone produced this effect. The most likely cause is the unusually dry period at the beginning of the wet season (see Section 2.2.2).

In short, although there may be a small effect on the early wet season baseflow (itself but one part of streamflow) increased water use on the moist upper dambo is unlikely to affect dry season streamflow.

3.3.4 Implications for downstream river hydrology

The storage/seepage model has implications for our understanding of the role that dambos play in river system hydrology. The model implies that there is a barrier between the water stored in the catchments above many dambos and downstream river systems. This is clearly seen in air photographs in the Chiota area of Zimbabwe. The water held up behind that barrier seeps into the dambo and is used by vegetation or crops in evapotranspiration. Thus it can be argued that the presence of this type of dambo, with a dry lower zone, within a river system may actually reduce the amount of water that would otherwise be available for streamflow particularly in the dry season. Without the underground barrier that forces water to the surface where it is available for evapotranspiration, the water would be able to slowly percolate down to the stream.

4. DISCUSSION

4.1 Dambos as a land and water resource

4.1.1 Regional analysis of dambo use

Dambos provide a land resource for grazing and cultivation, and a water resource for domestic uses, livestock watering and irrigation. Both household and air photograph surveys indicate that these different activities vary regionally in their importance across Zimbabwe. According to the household surveys, the extent of dambo cultivation is high in Chizengeni (Chiota CA) and Masiyarwa (Zwimba CA), and low in Bumburwi (Chiota CA) and Shumbairerwa (Gutu CA). This is confirmed from mapping of the area under gardens at each study site. On Chizengeni dambo 33% of dambo land is used for cultivation, although when considered together with neighbouring Chigwada dambo which is used mainly for grazing, this figure falls to 18%. At other study sites the garden area is much less: 6% at Bumburwi and Masiyarwa, and 3.5% at Shumbairerwa. These figures reflect not only the number but also the size of individual gardens (Table 47). At a regional scale, air photograph-based land use mapping shows a comparable pattern, with Chiota having 12.5% of dambo land under gardens, followed by Zwimba (6%) and Gutu (2%). Gardens as a proportion of cultivable or 'wet' dambo land show a similar gradation.

Table 47 Summary of Dambo Use in Communal Areas Studied

	Chiota	Zwimba	Western Gutu
Dambo area/total land area	29.0%	14.1%	12.2%
Dambo gardens/cultivable dambo area	30.0%	12.1%	1.7%
Mean garden size (ha)	0.5	0.25	0.1
(Illustrative study sites)	Chizengeni	Masiyarwa	Shumbairerwa
Dambo gardens/cultivable dambo area at study sites	29.6%	6.1%	3.5%

Of the four study sites three appear to be broadly typical of the communal areas in which they are situated as far as dambo cultivation is concerned. Bumburwi is the 'odd man out' for reasons discussed in Section 4.2, while Shumbairerwa can only be considered to illustrate conditions in the western half of Gutu, as dambos are rare in the eastern half of this communal area.

Making the link between three of the study sites and their communal areas, we may attempt to use socioeconomic survey data from each to help explain broader regional differences in dambo use. At Chizengeni, gardens are used both in dry and wet seasons, and crops include staples, such as maize and rice, and vegetables for sale (eg carrots, peas), as well as relish vegetables (eg cabbage, leafy crops). Dambo cultivation is an integral part of the agricultural system, and not simply supplementary to dryland farming as it is at Masiyarwa and Shumbairerwa. The existence of numerous and relatively large gardens throughout Chiota suggests that what is true of Chizengeni may also be true of the communal area as a whole. At Chizengeni, about one-third of households with gardens obtained a cash income of over Z$100 from the sale of wet season garden crops, in many cases being sold in distant markets, notably Harare. It is difficult to know whether this commercial activity is repeated elsewhere in Chiota, but the distribution of dambo gardens in this communal area does not appear to be significantly influenced by the position of the main dirt road towards Harare or by the location of the business and market centre at Mahusekwa, the major town in Chiota.

Dambo gardens are available to most households in Masiyarwa, but they fulfill a somewhat different role to those at Chizengeni, being cultivated mainly during the early part of the dry season for relish vegetables. Although some selling of garden vegetables takes place, it is entirely local and provides only a small (<Z$100) income. As Masiyarwa is one of the more accessible parts of Zwimba to Harare, long-distance sale of vegetable crops is possible. Despite the relatively low incomes obtained from gardens, dambos are an important resource in Zwimba, not only for gardens, but also, as in Chiota, for cattle grazing. It may be noted that the different relative importance of dambo gardens in Chiota and Zwimba are not due to environmental causes, as the two communal areas lie in the same natural region, and have similar rainfall and soil types.

This is not the case, however, in Shumbairerwa. Here many fewer of the households surveyed cultivate gardens (38% as compared to 88% in Chizengeni), and dambos were even reported to be largely unused for grazing. This may be due to the existence of wet season woodland grazing which is unavailable in highveld communal areas such as Chiota and Zwimba. Gardens in Gutu are the smallest of the three communal areas studied, and at Shumbairerwa are used mainly for early dry season vegetable crops for household consumption and local sale. The other main use of the dambo here is for domestic water supply, a use shared by the two other study areas. Overall, around 30% of all households surveyed obtained their domestic water supply from wells on dambos. In Western Gutu dambos are potentially as important a resource as they are in Zwimba, but if the study site at Shumbairerwa is at all typical it can be concluded they are substantially under-utilised at present.

The extent and distribution of dambo gardens has not been mapped for the whole of Zimbabwe as part of this survey. Nonetheless, the three district-level garden surveys that have been carried out using recent air photograph cover give some indication of existing dambo garden area and the potential for its expansion at national level. Taken together Chiota, Zwimba and Gutu Communal Areas contain approximately 42,000 ha of dambo land, of which some 24,000 ha is cultivable (wet) dambo. Of this 3,200 ha is actually under garden cultivation. Whitlow (1984) has estimated the total dambo area in Zimbabwe's communal lands as 263,000 ha. Although this may possibly overestimate the true extent, a cautious estimate of cultivable dambo land in the communal areas would still be 110-150,000 ha. If the three communal areas studied in detail are representative of the national spectrum of dambo cultivation, the total extent of existing gardens in Zimbabwe would be 15-20,000 ha.

Current dambo use for gardens is limited by both technical and socioeconomic constraints. Technical constraints are affected by soil quality and water table levels, normally limiting actual cultivable dambo area to 30-50% of the total dambo. However, the main reason why dambo cultivation is not higher lies in social, legal and institutional constraints. These are affected by attitudes towards and management of dambos, both by local people and by government at all levels. These attitudes vary between and within communal areas, affecting the extent and intensity of dambo use.

4.1.2 Local Level Conflict over Dambo Use

There is no conflict at local level over the dambo as a water resource; there is no fear of the dambo "drying up" or of people extracting too much water for irrigation or domestic use. The level of water in the rivers, which are used for livestock watering, is not perceived locally to be influenced by use of water for irrigation and domestic supply. Domestic wells are small and scattered, only used by a few households at a time. They are generally located close to the homes, higher up the slope than the gardens, so are not in danger of chemical contamination from pesticides and fertilizer used in the gardens.

The main conflict at local level over dambo use relates to its function as a land resource. Lack of adequate grazing space is seen as a problem by a majority of households in all of the study areas except Shumbairerwa. However only in Chizengeni do some people relate this problem to the number and size of gardens. Both cattle and gardens are not only important to communal households, but are of mutual benefit. Cattle, in addition to providing financial security and social status to a household, provide manure and draught power for the gardens and dryfields. Plant residues and maize stover from the fields and gardens provide fodder for cattle, which are often allowed to graze in the uncultivated fields.

Although allocation of land for gardens is, in effect, a community decision, once allocated activities on gardens are controlled completely by individual households. By contrast, grazing areas must be managed communally, since all households have access to this land. Households have a direct interest in maintaining the soil quality of their own gardens, while their efforts on the grazing area would only be effective if carried out by a majority of households. Therefore proper environmental management of dambos may be more difficult if it is used as a common property resource for grazing (Blaikie and Brookfield, 1987). There has been some experimentation with the organization of communally-managed cattle paddocks in Zimbabwe, but this is still in the early stages of development. In Shumbairerwa it was reported in July 1986 that a paddock scheme was starting at the end of the month. This scheme had still not begun in May 1987, and local people were reluctant to discuss the reasons for the delay.

The communal need for adequate grazing space must be balanced with the household's need for a garden plot. In the 1960's a decision was made by villagers in Chizengeni and Chigwada (an adjacent village) to allocate one dambo mainly for grazing and one for cultivation. In the 1980's the Village Chairman for Chizengeni reported that he would not allocate any additional gardens in order to preserve the grazing area. However, he later qualified this, saying that some small plots (0.25 hectares) might be allocated to those in need. Thus, a conscious decision was made to give priority to the communal need for grazing land.

It is important to note that dambo land is used for grazing throughout the year in all study areas except Shumbairerwa, but for many households is the only land used for grazing in the wet season. To put the "grazing/garden conflict" into perspective, we must remember that since not all dambo land is suitable for cultivation, the area cultivated will usually be far less than the area grazed. Even Chizengeni dambo, the most heavily cultivated of all the study sites, only has gardens on 33% of the dambo.

4.1.3 Government Policy

Government policy on dambo use varies between ministries, at different levels within ministries and between and within communal areas. Strict interpretation of the Streambank Protection Regulation makes it illegal to cultivate on dambos unless an exemption has been granted by the government. As a further deterrent, new legislation was proposed by the Cabinet in the spring of 1987, making it illegal to cultivate within 100 metres of a stream, which would rule out some existing dambo cultivation, especially on narrow, linear dambos such as those found in Gutu. By contrast, top officials of the Natural Resources Board and Agritex accept that dambo cultivation does not cause a major environmental hazard.

In government, environmental concerns relate to the dambo both as a land and a water resource. As a land resource, officials are concerned about erosion and other forms of soil degradation, as well as shortage of land for grazing. The concern about dambos as a water resource relates to fears of reducing water levels in the dambo, reducing streamflow into the river basin and siltation of reservoirs. The only one of these concerns which is also shared by local people is the issue of adequate space for grazing. This is the least-mentioned concern of government officials, who, in our experience, raise it only after long discussion of the other environmental factors.

The importance of dambos is not fully recognized by most government officials, who have personal rather than professional knowledge of how they are actually used in the communal areas. Almost everyone in government, when asked, says "yes, my mother has a garden". They are also aware that many of the vegetables they buy have been brought to the Harare markets by communal farmers. However, due to the lack of attention paid to gardens by government, official knowledge of the various strategies of garden use and the constraints on farmers is limited. Gardens are not included in irrigation or crop production statistics and are not directly assisted or controlled by any one ministry. They are left out of government policy, partly due to lack of detailed knowledge, partly due to lack of clear guidelines relating to the legislation. Even the experience of ministries such as Health and Community Development and Women's Affairs relates only to group gardens, which, although similar, operate under different constraints from individual gardens.

Only limited research has previously been available to assist officials in policy making and implementation. In an attempt to help fill this information gap, the following questions about the environmental hazards and the type and extent of dambo use, addressed by our research, are discussed below:

a) How important are dambos to the rural population, and how do they fit into the overall agricultural and social system in communal areas? (Section 4.2)
b) What are the constraints on dambo use and how are these affected by local and national management of this resource? (Section 4.2)
c) Does dambo cultivation constitute a serious threat to water and soil resources? (Section 4.3 and 4.4)

4.2 Advantages of and Constraints to Dambo Cultivation

4.2.1 Household Strategies

Dambo cultivation has been successfully integrated with dryland farming in the communal areas of Zimbabwe for many years. Several household strategies for using gardens and dryfields have been identified by our research. These can be divided broadly into two groups: households relying on agriculture to meet subsistence needs only; and those relying on agriculture as a source of income, as well as subsistence.

Households relying on agriculture only for subsistence fall into two categories:

(a) those with access to dryfields only
(b) those with access to dryfields and garden

These households may sell a few vegetables locally or a few bags of maize to the GMB if they have excess.

Households depending on agriculture as a source of income may employ any one of several strategies in order to obtain the highest financial returns:

(a) those with access to dryfields sell only dryfield crops
(b) those with access to dryfields and garden -
- sell only from dryfields, with garden crops used mainly for home consumption; or
- sell only from garden, with dryfield crops used only for home consumption; or
- sell from both the dryfield and gardens.

Although these strategies vary between individual households, some generalizations can be made about the four areas studied in this survey. In Shumbairerwa and Bumburwi, most households obtain incomes only from their dryfields. With few exceptions, those who do have access to gardens still sell dryfield crops as their main source of agricultural income. However, it appears that in Bumburwi, unlike Shumbairerwa, other sources of income are more important than agriculture. In Masiyarwa, while most households have gardens, they only sell a few crops locally. Although information on dryfield incomes was not available for many households in this area at the time of the survey, even with only 36 percent reported, it was clear that households in Masiyarwa were obtaining higher incomes from their dryfields than in other areas. In Chizengeni, where more households grow cash crops on their gardens, the gardens and dryfields appear to be of equal financial importance in a year of good rains. This strategy provides the most flexibility and spreading of risk for households.

Our studies have shown that all types of household are able to use dambo land resources for agriculture. However, important variations occur in their ability to exploit these resources and their degree of dependence upon them during the agricultural year. The agricultural strategy chosen by an individual household depends upon a variety of factors including the quality of the land resources available, access to adult labour during the year, knowledge of land and soil husbandry, and access to cattle and an outside income.

It is also apparent that a household may change its strategy from year to year depending on changes in these factors. The major advantage of having a dambo garden is that it gives the household an element of choice. Assuming that the necessary adult labour is available, cultivating a garden can increase the options and spread the risk to the farmer who is normally completely dependent on adequate rains to grow crops. Unlike certain other types of farming (such as cooperatives and irrigation schemes), because the household has control over how the garden is used, it has considerable autonomy in deciding when and how its strategy might change.

Since garden cultivation is not solely a dry season activity and there are no fixed planting seasons, vegetables can be grown as needed. A household can decide on a monthly basis whether to grow crops for sale or home consumption or both. In areas with dambo gardens, even those households without access to gardens can obtain vegetables through local exchange.

4.2.2 Advantages of dambo cultivation

Dambo gardens help to improve **nutritional status** in three ways:

(a) by providing a ready supply of vegetables to households throughout the year;
(b) by providing at least one staple crop of maize and rice in January/February, which is often the time when stocks of dryfield maize begin to run out;
(c) by providing an income to the household throughout the year which can be used to buy necessary foods.

In drought years, gardens are especially important. In 1986/87, Zimbabwe had the worst maize harvest in 40 years (Raath, 1987). During this year, the only maize harvested in Chizengeni came from gardens. Some farmers were even able to grow two crops of maize in their gardens, one from September to February, another from February to May. Thiesen (no date) reported that in Qwe Qwe Tribal Trust Land (now Chiwundura CA) "during the 1969/70 drought season, 84% of vlei land cultivators produced sufficient crops for subsistence requirements, while only 21% of dryland cultivators produced subsistence requirements."

Incomes from the sale of garden crops can be as high as Z$600 per month in areas close to the markets in Harare. In Chizengeni, those earning high incomes received Z$500-2,000 per year, exceeding incomes from many irrigation schemes in Zimbabwe. These high incomes can be secured by many different types of household, including those headed by women. More commonly, in all four areas, farmers grow vegetables mainly for home consumption, selling a few "here and there" for reported incomes of less than $Z100 per year. Small incomes spread throughout the year can be used for incidental expenses and reduce the need to budget the income from the dryfield harvest (assuming there is one) to last an entire year. This is especially important for families with little or no income from wage labour.

Some crops are grown mainly for selling, while others can be sold both locally or in city markets. Although farmers usually have the end use of the crop in mind when planting, they can, with these latter crops, decide at the time of harvest whether to sell them or use them for home consumption, depending on whether their need for cash or food is greater. Since, in our study areas, there is always at least some demand locally for a few vegetables, excess crops can usually be sold not far from the household--or even from the garden itself. One farmer studied even sold his garden maize in order to pay off his AFC (Agricultural Finance Corporation) loan and thereby avoid interest payments.

Although there are some problems involved with **marketing** of vegetable crops (see below), the present system offers many advantages. Farmers are able to sell these crops at any time throughout the year. This is in contrast to dryfield crops which are generally sold to the GMB at one time during the year. Marketing with the GMB (Grain Marketing Board), although done locally, often involves long delays in transport and payment. A greater range of marketing possibilities is available to farmers with gardens. Many of them use several market outlets depending on the particular crop and time of year. Income from vegetable crops is earned either immediately or, in the case of Independent Market in Harare, a week after delivering the crop. Prices do fluctuate, but farmers generally are able to offset losses on one crop with a high price on another. Farmers who have been selling cash crops for several years soon learn which crops are best to sell at various times throughout the year. With the increased government emphasis on nutritional and horticultural production, the demand for vegetables should continue to rise.

Although work on the garden is time-consuming, **labour** time on the dambo can be spread throughout the year, depending on other demands on the time of household members. Losses from the labour force due to illness or other commitments are not as disruptive to garden production as dryfield production since planting and harvesting times are not completely dependent on the rains. Only in Chizengeni did intensive dambo garden cultivation coincide with dryland farming. The fact that households spend so much time on the gardens indicates the measure of importance which they attach to this form of agriculture. What is critical is that household members are able to organise and divide up various productive and domestic tasks between themselves in order to make this cultivation possible. In addition, our studies showed that dambo cultivation can provide a source of local paid labour. This is particularly the case in households which grow cash crops and require extra assistance with time consuming tasks such as weeding and irrigation.

Traditionally, **women** have had more control over garden activities and incomes than they have over dryfields. Although the pattern varies greatly due to the effect of migrant labour and cash cropping, in households with dambo gardens, women generally have an additional option and element of control not otherwise open to them. In the case of households headed by women, which are often the poorest households, there is an opportunity to increase their financial and nutritional status.

The cost of setting up a dambo garden is minimal, being the cost of a fence and watering can, generally much less than Z$1,000/ha. Even where a diesel pump is installed the cost is unlikely to exceed Z$5,000/ha. This compares with the cost of conventional irrigation schemes which start at Z$10,000/ha. As the technology used in dambo gardens is simple, maintenance and repair costs and delays are minimal. This reduces the pressure to earn a high income which is often required of those participating in conventional irrigation schemes.

In comparison with conventional irrigation schemes, cultivation of dambo gardens does not entail expensive **infrastructure** requiring outside management and the associated risks. With the small, dispersed development of dambo gardens progress can be gradual with infrastructural investment taking place piecemeal and only when warranted. The risks of failure are thus far less than with conventional schemes. Since gardens are allocated to individual households through the existing land tenure system, there is no need for expensive and socially disruptive population relocation and changes in land tenure if garden allocation were to increase. Moreover, in contrast to large-scale, centrally managed agricultural schemes, cultivation does not conflict with indigenous agricultural practices and social organization.

4.2.3 Constraints on dambo cultivation

The ambiguous government policy on dambo use creates constraints to dambo cultivation in all communal areas in Zimbabwe. With the exception of a few experimental grazing schemes, there is no government control over grazing on dambos. Boreholes for domestic water supply have been installed on dambos. The constraints on dambo use relate primarily to garden cultivation. As with the benefits (see above) they vary between households, villages and communal areas. Table 48 lists the main constraints and the areas in which they affect dambo cultivation. These have been identified through informal discussion and village meetings with farmers and Agritex extension workers. It should be pointed out that several of the constraints also apply to dryland cultivation, although to a different extent.

Access to land for cultivation is a problem throughout the communal areas of Zimbabwe. These communal areas have long been deemed to be overcrowded and young couples are encouraged to join resettlement schemes in order to relieve population pressure. However, this pressure is not uniform throughout the communal areas and is the outcome not only of population increase, but also of environmental constraints and legislation. The constraints posed by unsuitable soils is one which applies to dryfields as well as dambo gardens. In Bumburwi, where only 64% of the households have gardens, one of the main reasons given is the

Table 48 **Locally Identified Constraints on Dambo Cultivation**

Constraints	C*	B*	M*	S*
Access to land				
Unsuitable dambo soils	N	Y	N	N
Prohibition due to legislation	N	N	N	Y
Land needed for grazing	Y	N	N	N
Lack of labour (some families)	Y	Y	Y	Y
Technology	Y	Y	Y	Y
Lack of adequate extension advice	Y	Y	Y	Y
Access to inputs				
Credit to purchase inputs	Y	Y	Y	Y
Fencing, seeds, fertilizer, pesticides	N	N	N	Y
Marketing				
Limited local markets	Y	N	Y	N
Transport to distant markets	Y	Y	Y	N
Uncontrolled prices	Y	Y	Y	N
Theft of fencing and crops	N	Y	N	N

Key: Y-yes; N-no
*C-Chizengeni;B-Bumburwi;M-Masiyarwa;S-Shumbairerwa

unsuitable, heavy clay soil in the main dambo under study. Households with gardens live closer to other dambos which have more suitable sandy soils. Soil quality on dambos varies locally but overall our research suggests that it has the agricultural potential to complement dryland farming.

The legislation on dambo cultivation is a major constraint everywhere upon access to land for gardens, but implementation varies between regions, eg in Shumbairerwa, Gutu, where only 56% of households have access to gardens. In this province, which has a strong conservation policy, legislative and environmental constraints come together. Although there appears to be a lack of pressure on dambo land, the type of dambo is somewhat different from in Chiota and Zwimba. Moreover, the Streambank Protection Regulation is more strictly enforced, which has resulted in people being prohibited from using their gardens. There is some debate over the real reasons for this action. Government officials have reported that only households with gardens within 30m of a streambank have been fined. However, these households report that their gardens were not within 30m of the streambank and proper permission had been obtained for their use. According to other local residents, these gardens were being cultivated without permission and were in the grazing areas (although cattle generally do not generally graze on the dambos in this village). This confusion has resulted in some households voluntarily giving up their gardens for fear of prosecution. It should be noted that two households surveyed received permission for new gardens in the year between the first and second surveys indicating that there is not a complete restriction on garden cultivation. Overall, however, it appears that the provincial government is strongly committed to group rather than individual gardens. Several of these have been allocated on dambos in preference to allocation of individual plots.

One problem which varies more between households than between areas is lack of labour . Although dambo cultivation is beneficial to the household and more flexible in terms of utilizing labour, it can still require more time and energy than dryfield farming. This was clear from the labour studies (Section 2.3), where even the household growing crops only for home consumption spent twice as much time on the garden as on the dryfields. With present farming methods and levels of technology the availability of labour is crucial to the success of garden cultivation. One of the most time-consuming tasks is weeding. Irrigating with a watering can is also highly labour intensive and inefficient in terms of labour effort. It can occupy several hours per day in the dry season, thus limiting the area of cultivation at this time of the year. Little research has been conducted into appropriate pumping technologies for garden cultivation.

Although Agritex does not on the whole discourage dambo cultivation, some **extension** workers are hesitant to give advice on gardens due to confusion over their legality. Training of officers focusses on dryland crops and conditions, so that the specialist advice needed for growing vegetable crops on dambos is not available. This is a particular problem with pest control, which is a greater problem on dambos due to the type of crops grown and the wetter soils.

Financing for inputs needed for cultivation is more of a constraint on dambo cultivation than dryland farming. The Agricultural Finance Corporation (AFC) and other private organizations do provide some funding for seeds, fertilizer, fencing and other inputs used for growing dryfield crops sold through the Grain Marketing Board (GMB). These loans are available to the majority of communal farmers. By contrast, finance for garden cultivation is only available, in principle, to farmers who have successfully paid off their AFC loans for several years running. In practice, no farmers we studied had been able to obtain loans from the AFC specifically for garden inputs. This poses particular problems in Masiyarwa and Shumbairerwa where elaborate and expensive fencing is needed to keep out goats. In Shumbairerwa, local purchase of the specialized inputs needed was more difficult than in the other three areas, where they were available from the nearest business centres. Farmers in Shumbairerwa had to travel to the distant town of Gutu, or sometimes even Masvingo, to obtain these inputs.

Marketing is perceived to be a problem in all areas, although the specific constraints vary greatly. In Shumbairerwa and Bumburwi, the local markets for vegetable crops are not, as yet, satisfied by local production. Households in Bumburwi often buy vegetable crops from those in Chizengeni. In Shumbairerwa, only one farmer grows crops on a large scale for selling locally. Households which do not buy vegetable crops from this farmer must go to other areas where there are gardens or to Gutu, where vegetables sold in the market often come from as far away as Harare. By contrast, in Masiyarwa and Chizengeni, there is considerable local trade in vegetables and local demand appears to be satisfied. The modest amounts grown on the small gardens in Masiyarwa at present do not justify marketing in Harare.

In Chizengeni, discussions with farmers about marketing and transport revealed that the most useful change in the present system would be to improve security at the bus stations so that garden produce was not stolen from farmers as it can be at present. Farmers must transport their produce from the station to the Independent Market (the one most used by farmers in Chizengeni) which is time-consuming and expensive. An additional, relatively simple, improvement would thus be to ensure that buses coming from areas where gardens are used for commercial production stop at Independent Market before arriving at the bus station. Farmers in Chizengeni were not interested in organizing transport cooperatives, preferring to pay government to organize transport. However, it is unrealistic to expect government to manage all transport and marketing for vegetable crops when the marketing system for dryfield crops does not always run smoothly. A government-managed marketing system would almost certainly require controlled prices, which would reduce the marketing options. At present, price fluctuations do make marketing difficult, but most farmers have adapted to the system. Given that a major advantage of gardens is that they increase the element of control and choice for the communal farmer, it would be undesirable to reduce that control by the direct management by government of marketing and transport of horticultural crops.

The above constraints can be linked, in part, to the ambiguous government policy on dambo cultivation. Since Independence, the Government has reorganized agricultural institutions in order to place more emphasis on communal farming. The focus has been on dryland farming, with only a few new irrigation schemes implemented. Owing to fears over the environmental consequences of dambo cultivation and an ambivalence over its importance, dambo cultivation has been ignored. Thus, as yet no changes have been made which would facilitate the access of communal farmers to loans, marketing and transport.

4.3 The effects of cultivation on dambo water resources and streamflow

In order to assess the effects of dambo cultivation on water resources, one must consider the situation prior to this cultivation. In their original ungrazed or lightly grazed state dambos would have been covered with dense long grass as is the case with many of the dambos in Zimbabwe's commercial farming areas. The original state would have coincided with different land use patterns on the dryland areas of the catchment immediately above the dambo probably including a far greater coverage of indigenous woodland. This woodland would use more groundwater for evapotranspiration and hence there would be less reaching the dambo. These land use patterns have changed irrevocably in the communal areas of Zimbabwe. Here the main alternative form of dambo use to cultivation is now cattle grazing. This means that the dambo is covered with short grass for most of the year and in dry years often very poorly covered due to grazing pressure. While reafforestation may restore some of the dryland woodland it is unlikely to cover a significant area of the drylands. Thus in communal areas the hydrology of the undisturbed dambo and its catchment is a less important model for comparison than that involving dambo grazing.

The effects of cultivation on water resources may be addressed in terms of the effects on the quantities of water involved and of the consequences for surface runoff and streamflow.

4.3.1 Effects of present extent of cultivation

Where irrigation is not practised cultivation is unlikely to have a significant effect on the amount of water used and may in fact reduce usage. The dambo at Chizengeni is comparatively intensively cultivated, but the area that is irrigated throughout the dry season is considerably less than the total area of cultivation. This is related to the present level of technology and the availability of labour and in some cases access to a good water source. The area under irrigation varies throughout the dry season but did not exceed 2 ha in 1986. The effect on the level of water in the catchment aquifer due to this level of irrigation is to lower it by between 10 and 20mm (0.6% - 1.2%) - an insignificant amount.

Surface runoff is affected by the degree of roughness of the soil, the length of run of water flowing over the surface and such factors as concentrating or dispersing effects. Closely grazed dambos without gardens allow great lengths of run thereby increasing the volume and velocity of runoff. Infiltration is reduced and the erosion hazard is increased. The degree of roughness depends on the soil and crop husbandry practices in operation. Where crops are planted and become established before the rains begin, where ploughing is across rather than down the slope and where there are numerous physical barriers such as small ditches and dykes (all of which occur at present in the dambo in Chizengeni) the degree of roughness is likely to be considerably greater than on closely grazed uncultivated dambo.

Dambos that are intensively cultivated must have alleys between the gardens to allow runoff from the contour ridges on the dryland areas to pass down to the stream. It is inevitable that some of these alleys will also serve as footpaths or cattle tracks. The concentrating effects on surface runoff of the contour ridges can be carried down to the dambo area and exacerbated by the use of these alleys as tracks. In order to mitigate these effects the alleys need to be of sufficient width, and good ground cover must be maintained. The width will depend on slope angle, intensity of traffic and local soil erodibility but we would suggest not less than 5 metres in areas such as Chiota and Zwimba where slopes average 2%.

Streamflow will be affected both in quantity and quality by the above factors. On balance dambo gardens would seem to have an attenuating effect on surface runoff in comparison with close grazing and certainly with over-grazing. Thus the peakiness of storm flows is reduced. Dambos are areas where water from the aquifer beneath the dryland catchment is interrupted in its passage to the stream, forced to the surface and used in evapotranspiration. When streamflow has ceased, as it usually does in the late dry season, increased evapotranspiration on the dambo will have no effect on that streamflow. It seems most likely that the early dry season streamflow is affected by storage in the lower parts of the dambo where cultivation does not and should not take place. Our calculations indicate that with crop production on the upper dambo zone the relatively small increase in water use will have a negligible effect on early dry season streamflow.

A decrease in the level of the aquifer will mean that it will take longer to recharge. Thus the portion of streamflow that is caused by seepage from this aquifer will be delayed until this recharge takes place. The amount of recharge is small and will only affect early wet season baseflow in the stream which in any case is only one part of total streamflow.

4.3.2 Predicted effects of an increase in irrigated cultivation

An increase in irrigation will directly affect the level of the water in the dryland aquifer. Applying our model to the Chizengeni catchment, if an area of upper dambo equal to 10% of the total catchment area, 27.4ha in this case, were irrigated throughout the dry season this could lower the water table in this aquifer by an additional 140 to 270mm (8 - 16%), a small drop compared to the natural drop of over 1700mm. The effect on the hydraulic gradient, which is the driving force behind water moving down from the upper areas of the catchment, is negligible. Such an increase in irrigation represents an approximate fifteen-fold expansion compared with the present area. This would only be possible with the introduction of diesel pumps and methods of increasing the "abstractablility" of the water. Introducing manual powered pumps is unlikely to increase the irrigated area by more than a factor of five. The primary limitation on the "abstractability" of the water is the permeability of the aquifers in which the wells are situated.

The effect on streamflow will be similar to that described above. The only significant difference will be the amount of time needed to recharge the aquifer which has been drawn down by abstraction for irrigation. This may have some effect on early wet season baseflow.

In years of drought the increase in irrigated crop water requirements over water use on grazed areas where there is no irrigation will be higher than in normal years. Thus the water table in the dryland areas, already low due to drought conditions, will be depleted still further, affecting those wells on the dryland areas that have not already dried up. The additional fall in groundwater levels will not, however, be more than the 140-270 mm outlined above. These effects must be weighed against the benefits of crop production at a time when this production is most needed.

4.3.3 Variations between different areas

Dambos vary considerably between and within communal areas. The components of the storage - seepage model will have different degrees of significance depending on the particular dambo in question.

Hydrologically, the dambo that differs most from Chizengeni is the dambo at Shumbareirwa in Gutu communal area. The dambos are smaller and lack a clear "dry dambo bottom" zone . The mean annual rainfall is slightly less, being approximately 750mm in Shumbareirwa and 890mm in Chizengeni (figure 34), but is more variable. The runoff is similar and the percentage potential evaporation is slightly higher. The water table falls to a much lower level in Shumbareirwa than in the other areas making irrigation in the late dry season more difficult.

The present extent of cultivation varies considerably between the areas in our study. However the area of irrigated cultivation in all the four study sites is small.

4.4 The effect of cultivation on dambo soils

4.4.1 Are dambo soils suitable for cultivation?

The existing soil classification and legislation in Zimbabwe categorises wetland soils, including dambos, as Class V being normally unsuitable for cultivation (Ivy, 1981). Yet these soils support many thousands of hectares of gardens in the communal lands. How can this apparent contradiction be explained? We would suggest that two considerations are especially relevant. Firstly, the classification relates to attempts at cultivating dambo wetlands using commercial mechanised methods rather than indigenous African methods . Dambo soils are easily broken down when subjected to crop monoculture, deep ploughing and drainage using heavy machinery. These practices, which took place on commercial farms in the first half of this century, led to soil erosion and environmental deterioration (Whitlow, 1985). Indigenous African techniques for managing wetland soils are fundamentally different in approach from commercial ones. Lacking large power sources, they are labour intensive, small in scale and have evolved over a long period. Water management involves both the removal of excess water by superficial drainage or the construction of raised beds in the wet season, and simple irrigation in the dry season with conservation of scarce water by practices such as mulching . The need for sensitivity to seasonal or local variations in environmental conditions is related to the second consideration - soil differences within the dambo catena.

While dambo wetlands have been treated as a single soil category according to the existing classification it is clear both from our analyses and the work of others (Watson, 1964; Whitlow, 1985) that there is considerable variation both within and between dambos.

There are crucial differences in dambo soils down the catenary sequence:

- dambo margin
- upper (wet) dambo
- lower (seasonally wet) dambo
- dry dambo bottom

Soils on the dambo margin and on the dry dambo bottom are not suitable for cultivation. In the upper dambo zone topsoils are rich in organic matter and groundwater normally remains within two metres of the surface throughout the year. In comparison with the dryland "sandveld" soils these upper dambo soils are less acid, have a richer nutrient base and have more reliable soil moisture. In short they provide a more suitable soil environment for crop growth. Significantly, land-use mapping indicates that it is within the upper dambo zone that over 90% of all gardens are located showing that most dambo gardeners have correctly identified the most suitable dambo agro-ecological zone - and this without the help of outside specialist advice. Because this upper dambo zone is normally situated well away from nearby watercourses, it is rare for there to be conflict with the "30 metre rule" of existing legislation.

Cultivation may also be possible on the seasonally wet lower dambo zone but our data indicate that cultivation here may be problematic, even hazardous. Soils in this zone may be sodic and therefore both prone to erosion and unsuitable for certain crops. Being located at the bottom of the slope in the catchment means that run-off from the upper slopes must pass over this zone which again increases the erosion hazard.

It is important to note that there are variations in dambo soils across Zimbabwe and elsewhere. The above discussion relates primarily to dambos based on sandy soils ("sandvleis") typical of the highveld. Sandy dambo soils account for an estimated 89% of dambos found in Zimbabwe according to Whitlow (1985). Soil conditions found in basic, clayey dambos, such as Bumburwi, are rather different although at least some parts of these may also be cultivable.

4.4.2 How does garden cultivation on dambos affect soil conditions?

As with the equivalent question on water resources the effects of cultivation must be compared with the effects of grazing as well as with the undisturbed "natural" state. The soil on the dambo may be affected both directly and indirectly by cultivation. Direct effects include the exposure to sheet erosion of the cultivated soils which have less ground cover than that provided by natural dambo vegetation and the changes in soil organic matter in cultivated gardens. Indirect effects on erosion include the susceptibility of the cultivated plots to sheet erosion caused by run-off from the dryland part of the catchment above the dambo, and the concentrating effects of diverting this run-off into alleys between the gardens, so increasing the gully erosion hazard. An indirect effect on organic content is the transfer of organic material, in the form of cattle manure, from the grazing areas to the gardens.

As with any natural resource the standards of management and the technology used will play a vital role in the effects of cultivation on dambo soils. The most intensively cultivated dambos studied were in Chiota Communal Area which has a long history of garden cultivation. Good soil husbandry practices such as ploughing across the slope and applying cow manure, anthill and compost are common.

The organic matter of dambo soils, especially those that are sandy, is vital and must be maintained. It is this organic matter which gives the soil its fertility and is a direct result of seasonal waterlogging. Our research considered the effects of cultivation on the amount of organic matter in cultivated plots compared with that in adjacent grazed areas. Some drop in organic content is to be expected with any soil that is cultivated as the roots and vegetation of the natural vegetation are broken down. Our results show that there is a drop in organic matter related to cultivation of dambo soils but that this drop is most marked where organic content was originally very high, ie above 10%. When the organic content is below 5% there is no significant difference between organic matter values on cultivated and uncultivated sites. Cultivation appears to reduce the high values considerably but to have little effect on the medium and lower values. This fall in the high values of organic content is clearly less harmful than a decline in the lower values would be. The organic content in cultivated areas stabilises at levels above 2%, an acceptable level, and appears capable of maintaining the soil as a fertile resource.

It is clear from the social survey that the fertility of the gardens is being partly maintained with organic matter that is obtained in the form of cow manure from other areas. There is no doubt that farmers who depend on the gardens for food and income take care of them - whereas care expended on grazed areas which are held as common property will not have similar direct benefits to the individual.

4.4.3 Does dambo cultivation increase erosion?

In assessing the effects on erosion of garden cultivation it is important to note that land use on the dambos cannot be separated from land use on the catchment as a whole. This is especially true of gully erosion. However Zimbabwe's dambos are a fragile resource and require special care in the prevention of erosion whatever the land use.

Dambos in their natural state, covered with thick vegetation, are well protected from the effects of direct rainfall and run-off from the dryland part of the catchment. When dambos are heavily grazed they lose this protection. Poor ground cover and long uninterrupted slope lengths provide little impediment to run-off from the upper areas of the catchment. As a result both sheet erosion and gully erosion may become a hazard.

Garden cultivation exposes the soil much more than would be the case in the natural state. However where crops are well established before the rains begin, as is the case with most of the dambos we have studied, they are likely to provide better cover than overgrazed dambo areas. In addition dambo gardens are bounded by ditches and fences, in some cases being completely surrounded by elaborate earthbanks covered in sisal. Surface run-off inside the gardens will experience frequent interruptions in flow, reducing the velocity and discharge and hence the erosive power. If there are a large number of protected gardens runoff from the upland areas must be directed along alleys. These alleys are susceptible to erosion, if not of sufficient width and properly protected. Small well dispersed gardens will not be a problem in this respect.

Cultivation along the bottom of the dambo could have undesired consequences for erosion. This type of cultivation was not observed on any dambo in the three communal areas studied here.

The effects of garden cultivation on sheet erosion were investigated on six erosion plots at Chizengeni, each measuring 5 x 10m. The investigations were carried out during the 1985/86 wet season - a season of above average rainfall. These show that while sheet erosion on the cultivated areas of the dambo was higher than on the grazed areas, which were quite well covered with short thick grass, it was below 0.5 t/ha/yr - still well within acceptable limits. It is clear that sheet erosion on cultivated dambo soils is not a significant problem at any of the sites studied.

Gully erosion was investigated by historical analysis of air photography and by the use of surveyed erosion pegs. The results show that gully erosion could not be correlated with the level of cultivation - other factors such as soil type seemed to play a far greater role. On the most intensively cultivated dambo at Chizengeni gully erosion was under 1 m^3 per year while at Bumburwi which is used mainly for grazing, gully erosion rates were over $100m^3$ per year, indicating that there is no direct link between cultivation and increased gullying.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The extent of present dambo cultivation in the communal areas of Zimbabwe is in the order of 15-20,000 ha. This is a much greater area than that which has been brought under irrigation via government-sponsored smallholder schemes since Zimbabwe became independent in 1980. It must be emphasized that this does not refer to streambank cultivation. Almost none of the gardens recorded in the air photograph survey were less than 30m from a streambank.

Dambos in Zimbabwe vary in their physical characteristics as well as in their present use. In the highveld, we find broad, headwater dambos with clearly defined dry and wet zones. Dambos in the middleveld are more usually narrow and linear, with less distinct dry areas. Sandy soils are found on approximately 89% of all dambos in Zimbabwe. Our research and recommendations apply to this type of dambo.

In communal areas of Zimbabwe where dambos are found, they provide an invaluable source of land for cultivation and grazing, as well as water for irrigation, livestock and domestic use. There are significant differences between and within communal areas in terms of the density and size of gardens, the seasonality of cultivation and the type of crops grown. However, in all areas where they are used, dambo cultivation is successfully integrated with dryland farming in Zimbabwe. The additional choice available to the communal farmer who has access to a garden is one of its key advantages. With a garden, there are more options available for providing the family with an adequate and varied diet and an increased income. Gardens provide a hedge against starvation in drought years, and a surplus for sale in good years. They are individually managed, so that the farmer can decide as the year goes on how best to allocate his/her labour and other inputs. Development costs are minimal, yet higher incomes can be earned from dambo gardens than from conventional irrigation schemes. In addition to their importance to agriculture, the water resources available in dambos are crucial as a source of domestic water supply for households in all areas. Dambos are also important for livestock grazing in Chiota and Zwimba, but less so in Gutu.

In the communal areas, the management systems for controlling dambo use are well-established and effective. Policy within the Government is more divided. Most officials recognize the advantages of dambo cultivation and there has been a recent move to encourage horticultural production in the country (with the main focus on commercial farmers). However, there is still concern about environmental effects of dambo use. Micro-scale irrigation, as practised on dambos, is not considered of sufficient importance to be included in agricultural or irrigation policy and is not the prime responsibility of any one ministry. The effects of this lack of clear policy vary between regions, but include limited access to gardens due to legislation, limited Agritex advice, and lack of finance for garden cultivation.

To aid clarification of policy, environmental studies have been carried out which show that cultivation has a minimal effect on dry season streamflow. By cultivating that portion of the dambo that is wettest and which naturally evapotranspires freely during the dry season (under grassland), existing cultivation does not significantly increase water loss. A much greater effect would be produced if gardens were placed in drier parts of the catchment--in this case evapotranspiration would be considerably increased. Soil conditions are much less favourable in these drier zones and the irrigation technology required would be far more complex. There is good reason to keep gardens where they are located at present, ie., in the upper wet zone of dambos.

It is clear that dambo gardens in Zimbabwe are an important form of cultivation to rural farmers. This cultivation rarely, if ever, has direct harmful environmental effects. At present, gardens occupy only one-fifth of the dambo area that could be safely brought under cultivation in the communal areas. The potential for expansion obviously varies regionally. In Chiota Communal Area for example, where garden cultivation is already well developed, the cultivated area could be doubled, while in Zwimba it could be increased five-fold. It should be stressed that this potential expansion could take place within the prescribed acceptable environmental limits for soil and water use. These environmental limits and some recommendations for encouraging dambo cultivation in Zimbabwe are given below.

5.2 Recommendations

5.2.1 Environmental recommendations

In order to ensure that cultivation of dambos may be carried out in a sustainable way we make the following recommendations. These recommendations apply to sandy dambos which can be divided into four internal zones: the dambo margin; the upper or permanently wet dambo zone; the lower or seasonally wet dambo zone and the dry dambo bottom.

The dambo should not be allowed to dry out permanently. Therefore permanent drainage of dambos is not recommended. Superficial drainage or the use of raised beds which protect crops from waterlogging may be permitted.

On the basis of our experience in the three communal areas studied, it is proposed that cultivation should take place only on the upper dambo zone (Figure 45). This is the zone which is permanently wet, the water table being close enough to the surface to allow plant growth throughout a "normal" rainfall year. Cultivation should not take place where the organic topsoil layer is less than 10 cm thick. As the boundary between the upper and lower dambo zones may not always be very clear, cultivation in the boundary area should be guided by the recommendations below.

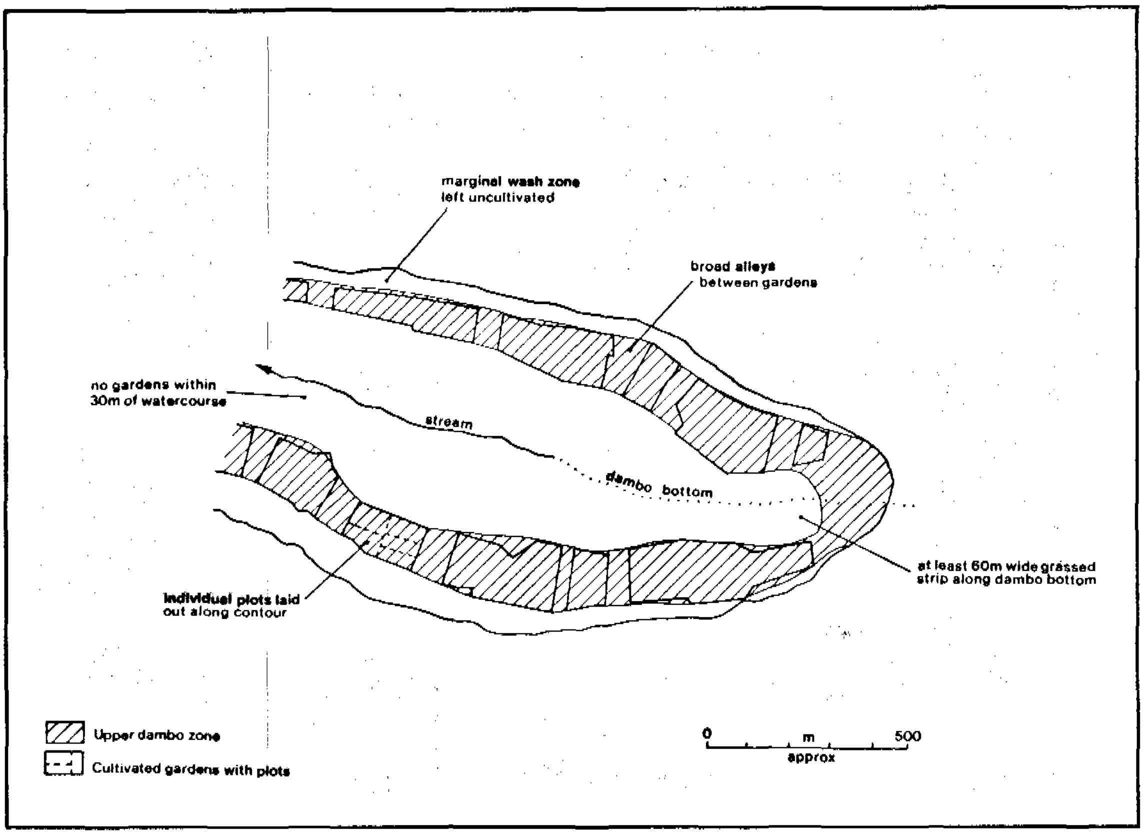

Figure 45 Model illustrating dambo land use recommendations

Cultivation on the dambo margin or on the dry dambo bottom is not recommended, firstly because of the poor fertility or shallow depth of the soils and secondly because the increase in evaporatranspiration would be greater in these areas than on the wet dambo.

On intensively cultivated dambos it is recommended that a grassed strip, at least 60 m wide, running along the bottom of the dambo should be left uncultivated. This is to provide a protected drainage line for runoff from the upper areas of the catchment and to prevent erosion in this most vulnerable part of the dambo. This strip should not be overgrazed or heavily trampled by cattle when the soil surface is wet. The head of actively eroding gully heads must be adequately protected against erosion : for example tracks should be discouraged close to the stream head. The existing 30m guideline of the Streambank Protection regulation should be respected.

In terms of the dambo water resources, the area of the dambo that may be safely cultivated should, in general, not exceed 30% of the dambo area or 10% of the total dambo catchment area, whichever is the smaller. Cultivation of areas in excess of this may begin to significantly affect groundwater levels in the dambo catchment aquifer or streamflow and before such cultivation is allowed a hydrological survey of the catchment should be carried out to ascertain what such effects would be.

Broad alleys between the gardens must be maintained with good ground cover. The spacing and width of these alleys will depend on the intensity of cultivation on the dambo and on the soils and relief of the catchment. For example in Chizengeni where the soils are sandy and slopes are gentle at 2%, the alleys should be a minimum of 5 metres wide.

Individual plots should be laid out along the contour to discourage ploughing up and down the slope. Beds or ridges and the direction of ploughing should also be along the contour.

The application of cow manure or compost and the ploughing in of crop residues should be encouraged so as to maintain the organic content of the dambo soil.

While indigenous technologies such as the hoe and the ox-plough are being used successfully it is considered likely that the use of heavy machinery for dambo cultivation may have undesirable consequences. Similarly the watering can and handpump can be used safely for dambo irrigation, within the limits on area discussed above. However diesel or electric powered pumps greatly increase the amount of water that may be abstracted and hence the amount of land that may be irrigated. The use of such pumps could be regulated under existing controls on abstraction for "secondary use". The use of diesel pumps should not affect water resources provided that irrigation is kept within the limits recommended.

These recommendations, while intended for the communal areas of Zimbabwe also have relevance for commercial and resettlement areas.

5.2.2 Policy Recommendations

Dambo gardens presently allocated should be encouraged and extended within the environmental limits prescribed above. The main goal of any change in policy and/or legislation should be to facilitate successful and safe cultivation of dambos by communal area farmers. There are various ways of achieving this goal:

(a) encourage increased intensity of cultivation on gardens presently allocated and/or encourage allocation of additional gardens taking into account the need for adequate grazing land. This would require a well-advertised change in policy which would include dambo cultivation in budgeting and development plans;
(b) within the existing legislation, streamline the system for granting exemptions to farmers;
(c) review the present designation of dambos as Class V (wetland) as non-arable;
(d) modify the present legislation to incorporate safe levels of cultivation as agreed upon by the ministries concerned with natural resources, agriculture and water development.

A decision on the most effective way to encourage safe dambo cultivation can only be made by the ministries involved. A clear and consistent policy through all ministries is required. Once a clear policy is defined, several measures could be implemented at the national level in order to assist farmers in cultivating dambo gardens:

(a) credit facilities could be made available to farmers, either through the Agricultural Finance Corporation or through local farmers' groups and savings clubs;
(b) additional training of Agritex officers on all aspects of dambo utilisation, with particular emphasis on horticultural production and environmental protection;
(c) providing better security at bus stations to reduce theft of vegetables at regional markets.

Our research suggests that the preferred method of assisting farmers is through indirect measures. In the case of more formal garden projects, local conditions should be taken into account in their formulation and any such development should be small in scale.

5.3 Research needs

Further research is undoubtedly needed on many aspects of dambo cultivation. We do not propose to lay out an exhaustive list of research requirements. Rather, arising from our experiences in this project, we point to some areas that we believe merit further investigation. Some of these areas are already being investigated by individuals and institutions inside and outside Zimbabwe and some are about to be investigated in the near future.

Agritex is currently considering dambos in relation to existing soil classifications and we would encourage this.

Existing crop trials, such as those being carried out at Makaholi Research Station in Zimbabwe, could be expanded to cover a wide range of crops and different locations. Particular attention needs to be paid to crop rotations that preserve or improve soil fertility and to improved pest management. There is a need for long term monitoring of soil fertility and particularly of soil organic matter in cultivated plots.

Data on the extent of gardens in the communal areas are incomplete. While good data on three communal areas have been obtained in this study through air photography analysis, this work needs to be expanded to cover the whole country. Similarly the nature and extent of dambos as a resource elsewhere in Southern and Central Africa have yet to be assessed.

It is clear that there is a gap in water abstraction technology between the bucket or watering can and the diesel pump. The identification and development of suitable manual or animal powered pumps to fill this gap sould greatly increase the potential for utilising dambos (and other shallow groundwater resources) for micro-scale irrigation. Research on this topic, funded by the ODA, commenced in October 1987.

While there are many advantages to the present system of marketing dambo crops, there is a need to investigate how the system could be improved. Some issues relating to marketing and transport are currently under study.

One of the aims of increasing vegetable production is the associated benefits of improved nutrition. However the expansion of cash cropping may have implications for family nutrition which need further investigation.

5.4 Broader implications of this study

Cultivation on dambos in Zimbabwe is being carried out successfully using indigenous techniques. It represents one form of micro-scale irrigation largely unrecognised by irrigation planners. Micro-scale irrigation is widespread in many other parts of Africa (Underhill, 1984; Kay et al, 1985; Lambert et al, 1987).

An important outcome of our research in Zimbabwe is the recognition of the great variations that exist at local, regional and national level in the utilisation of a similar resource. Just as the successes in one part of Zimbabwe may not readily be repeated elsewhere, so the successes in Zimbabwe may not be directly replicable in other parts of Africa. Recognising the importance of these variations, we believe that micro-scale irrigation, of which dambo cultivation provides one example, has significant potential in much of Africa. It is vital that micro-scale irrigation is recognised by governments and is accorded due weight in rural development plans.

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APPENDICES

APPENDIX 1a: DAMBO UTILIZATION SURVEY

DAMBO UTILIZATION SURVEY - SEPT. - DEC. 1985

Day/Date: ____________

Area (1) ________ HH. No. (2-3) ____________ Record No. (4) 1

Respondent (5) ______

FAMILY DATA

TYPE OF HH. HEAD (6) ________ FAMILY NAME ____________

ADULT MEMBERS OF HOUSEHOLD:

	(HH Head)	(Wife)	Other Adult	Other Adult	Other Adult
Name:					
Relation to HH Head:	(7)	(16)	(25)	(34)	(43)
Sex:	(8)	(17)	(26)	(35)	(44)
Age:	(9)	(18)	(27)	(26)	(45)
Marital Status:	(10)	(19)	(28)	(37)	(46)
Date Married:	(11)	(20)	(29)	(38)	(47)
Occupation:	(12)	(21)	(30)	(39)	(48)
Highest Education:	(13)	(22)	(31)	(40)	(49)
Master Farmer?:	(14)	(23)	(32)	(41)	(50)
Member of Local Group:	(15)	(24)	(33)	(42)	(51)
(List)					

(ADD OTHER ADULTS ON REVERSE SIDE - COLS. 52-80)

CLUSTER LOCATION:

1 | | | | 2 |

Number of your children living at home, age 5-15 (born 1970-80): (5) ______

Number of your children under 5 (born 1980+): (6) ______

Number of grandchildren age 5-15 living at home: (7-8) ______

Number of grandchildren under 5 living at home: (9-10) ______

TOTAL NUMBERS:

ADULTS: (11-12) ______

CHILDREN 5-15: (13-14) ______

CHILDREN <5: (15-16) ______

CHILDREN: (17-18) ______

TOTAL FAMILY SIZE: (19-20) ______

Comments:

CODES FOR INFO. ON P. 1:

Location:
1-Chizengeni
2-Bumburwi
3-Zwimba
4-Gutu

Type of HHead:
1-Male
2-Male Migrant
3-Female

Education:
1-No education
2-Primary School
3-Form 4
4-O-levels
5-Form 6
6-A-levels
7-Post-secondary
8-Post-Primary

Age:
1-under 5
2-5-14
3-15+

Rel. to HH Head:
1-HHHead
2-wife
3-son/daughter
4-grandchild
5-daughter-in-law
6-niece/nephew/cousin

Marital Status:
1-Married
2-Widowed/Divorced
3-Single

FOR ALL OF SURVEY -

1-YES
2-NO
3-No answer, don't know

Sex: 1-Male, 2-Female

Occupation:
1-Farmer only
2-Migrant Labour
3-Farmer and Other
Local (Specify)

1 | | | | 3 |

PHYSICAL CHARACTERISTICS

Main Housing Type: (5) ____ 1-Modern, 2-Traditional, 3-Mixed

Number of granaries: (6) ____

Latrine?: (7) ____ 1-Yes, 2-No, 3-Pit dug, no lining or superstructure

Possessions:

- Plough (gejo) (8) ____
- Bicycle (basikoro) (9) ____
- Radio (waiseri) (10) ____
- Scotch Cart (ngoro) (11) ____
- Cultivator (karuveti) (12) ____

GARDENS

Do you have access to a garden on the bane/dambo? (13) ____

If yes, is it your own, or part of someone else's? (14) ____ 1-own plot, 2-relative's

Location (use air photo) (15) ____ 1-dambo, 2-vlei, 3-within 30 m of stream (0.5 cm on large photo)

Does anyone in the family besides the HHead have their own plot within the garden? (16) ____

If yes, who? ____________ (17) ____ 1-wife, 2-son, 3-daughter, 4-female relative, 5-male relative

Do you have a garden by your house? (18) ____

LIVESTOCK

Number of cattle: ________	(19-20) ____	1-0, 2-1-3, 3-4-9, 4-10-14, 5-15+
Number of goats: ________	(21-22) ____	(code later)
Number of sheep: ________	(23-24) ____	"
Number of small ruminants (goats + sheep)	(25-26) ____	"
Total Livestock Units: ________	(27-28) ____	"
Number of chickens: ________	(29-30) ____	"
How many of the cattle are for ploughing?	(31-32) ____	
Do you do your own ploughing?	(33) ____	
If not, what is major reason?	(34) ____	1-lack of cattle, 2-lack of plough, 3-lack of labour, 4-combination of 1/2/3
Where do your cattle graze: in winter:	(35) ____	1-dambo, 2-dryland, 3-both
in summer:	(36) ____	
Do you think there is enough grazing area?	(37) ____	

Comments:

IRRIGATION OF DAMBO GARDEN:

How many wells do you have in your garden?	(38) ____	
Do you have a dam in your garden?	(39) ____	
Does anyone else use the well in the garden?	(40) ____	
If so, for what purpose?	(41) ____	1-HH, 2-IRR
For how many months this winter have you watered your garden?	(42) ____	
How often did you water it?	(43) ____	1-once/day, 2-twice/day, 3-every other day
Did your well in the garden become dry during the drought a year ago?	(44) ____	

1			4

DOMESTIC/CATTLE WATER USE

USE	NORMAL DRY SEASON Usual W. Source	NORMAL DRY SEASON Distance fr Use Point	NORMAL WET SEASON Usual W. Source	NORMAL WET SEASON Distance fr. Use Point
DRINKING/ COOKING	(5-6)	(7)	(8-9)	(10)
WASHING CLOTHES	(11-12)	(13)	(14-15)	(16)
CATTLE WATERING	(17-18)	(19)	(20-21)	(22)

SOURCES:
01-Piped WS
02-Protected Well
03-Protected Well (neighbour)
04-Borehole
05-Unprotected Well/Dryland
06-Unprotected Well/Dambo/Unfenced
07-Unprotected Well/Dambo/In own Garden
08-Unprotected Well/Dambo/Neigbour's Garden
09-River
10-Dam
11-Other (specify)

DISTANCES:
1-less than 30m
2-30m - 1 km
3-more than 1 km

Comments:

LAND

	DRYLAND	DAMBO/VLEI
Number of plots	(23)	(34)
Total acres	(24-25)	(35-36)
Distance from HH	(26)	(37)
Date obtained	(27)	(38)
Decade obtained	(28)	(39)
(If dambo and dry obtained in different years, see p. 6)		
Permission from	(29)	(40)
Is the plot fenced?	(30)	(41)
If not, why not?	(31)	(42)
Yes-type of fencing	(32)	(43)
Do you have problems with animals getting into the field?	(33)	(44)

CODES:
Distance:
1-less than 1 km
2-1-3 km
3-more than 3 km

Acres: (code later)

Decade obtained:
1-before 1950
2-1950-1959
3-1960-1969
4-1970-1979
5-since 1980

Type of fencing:
1-wire; 2-bush; 3-other (specify)

No fencing, why?:
1-cost; 2-not available;
3-no need; 4-other (specify)

Permission from:
1-kraalhead/Village Chair/Agtex
2-Relative
3-Other (specify)

If dambo and dryland not obtained at the same time:

Which was obtained first?: (45) ______

Why?: (46) ______

1-dambo
2-dry
(code later)

Comments:

AGRICULTURE WINTER 1985 - CROPS/INCOME

On your dambo/bane garden this past winter
(not your garden by the house):

Did you cultivate the garden this winter? (47) ______

If yes, did you cultivate all or part of it? (48) ______

If part, why didn't you cultivate all of it? (49) ______

1-all; 2-part

1-lack of inputs
2-lack of labour
3-no need
4-

1 | | | | 5 |

CROPS GROWN:

Name	When Planted	When Harvested	Amount Harvested local m.	Converted	Use of Crop	Where Sold Gen.	Speci.	If sold, Income
(5-6)	(7-8)	(9-10)		(11-13)	(14)	(15)	(16)	(17)
(18-19)	(20-21)	(22-23)		(24-26)	(27)	(28)	(29)	(30)
(31-32)	(33-34)	(35-36)		(37-39)	(40)	(41)	(42)	(43)
(44-45)	(46-47)	(48-49)		(50-52)	(53)	(54)	(55)	(56)
(57-58)	(59-60)	(61-62)		(63-65)	(66)	(67)	(68)	(69)

CROP NAMES:

01-Beans
02-Bush Marrows
03-Cabbage
04-Carrots
05-Cauliflower
06-Cucumber
07-Eggplant
08-Gem Squash
09-Lettuce
10-Onions
11-Peas
12-Peppers
13-Potatoes
14-Pumpkins
15-Rape
16-Shallots
17-Spinach
18-Sugarloaf
19-Sweet potatoes
20-Tomatoes
21-Turnips
22-Watermelon

Month codes:
03-March
04-April
05-May
06-June
07-July
08-August
09-September
10-October
11-November

Amt. Harvested:
(code later)

Income:
1-less than $20
2-$20-49
3-$50-99
4-$100-199
5-$200-499
6-$500+

Use of Crop:
1-Mainly for household
2-Mainly for selling
3-Selling and Household

Where sold:
General:
1-Harare in market
2-nearby town
3-Harare-other
4-locally

Specific:
1-Independence Market
2-Mbare Musika
3-

(Leave Record 6 for additional crops)

1 | | | | 6 |

1

			7

(Line 04, Col. 1,2 -- Leave 52 extra spaces for more crops - Line 04, Col. 36-80; Line 05, Col. 5-12)

Total number of crops: (5-6) ______ Total income: (7) ______

Main use of income: (8) ______

If you did not grow any crops for sale on the dambo garden, why not? (9) ______

______

______

Did you grow any crops for sale in the garden by your house? (10) ______

If so, list crops: ______ (11-20) ______

Income from garden by house: (21) ______

(Total income from both gardens - (7 + 21) (22) ______

AGRICULTURAL INPUTS

On your garden this winter:

Did you use fertilizer?	(23) ______	
If yes, what type?	(24) ______	1-D;2-S,3-AN, 4-
Did you use cattle manure?	(25) ______	
Collected from the cattle kraal?	(26) ______	
Collected from around grazing area?	(27) ______	
Did you use anthills?	(28) ______	
Did you leave maize stalks or other parts in the field to be ploughed back into the soil?	(29) ______	
Did you use herbicides? Type ______	(30) ______	
Did you use pesticides? Type ______	(31) ______	
Did you use insecticides? Type ______	(32) ______	
How many weeks after the summer harvest did you plough?	(33-34) ______	
Did you hire anyone to work in the fields in the winter season?	(35) ______	
If yes, how many days did they work?	(36-37) ______	
What was the daily rate paid? ______	(38) ______	(code later)
(Total cost of labour: ______)	(39) ______	(code later)
What activities did they help with?		
Ploughing	(40) ______	(1-Yes, 2-No)
Planting	(41) ______	
Weeding	(42) ______	
Irrigating	(43) ______	
Harvesting	(44) ______	
Other (spec.)	(45) ______	
Who in the family decides what will be grown on the garden?	(46) ______	1-Husband 2-Wife 3-Other family member (male) 4-Other family member (female)
Who in the family decides what will be done with the income from the garden?	(47) ______	

AGRITEX ADVICE

Have you received Agritex advice on: (48) ______ 1-Dryland only 2-Dambo only 3-Both

Dryland ______

Dambo ______

Has the soil been tested on: (49) ______

Dryland ______

Dambo ______

If yes, do you have the results?

EROSION/SOIL QUALITY

Has the soil gotten worse in the last few years on: (50) ______ 1-Dryland only 2-Dambo only 3-Both

Dryland ______

Dambo ______

If the quality of the soil has gotten worse, do you know why? (51) ______ (code later)

What can you do to improve the quality of the soil? (52) ______ (code later)

Have you tried this? (If not, why; if so, what were results?) (53) ______ (54) ______

Gully erosion - describe gully - Do you know what causes this? (55) ______

Do you know how it can be prevented? (56) ______

To improve the amount and quality of grazing land, would you support any of the following solutions, if everyone followed them?

Cattle paddocks? (57) ________

Controlled burning? (58) ________

Planting new and better grasses? (59) ________

Control of cattle numbers? (60) ________

Do you have any other suggestions for improving the amount and quality of grazing land? (61) ________

END

APPENDIX 1b: POST-HARVEST SURVEY

Area-______

HH-______

POST-HARVEST SURVEY

DAY/DATE ....

HOUSEHOLD NAME ....

AREA NO.	☐	1
HOUSEHOLD NO.	☐☐	2 - 5
RECORD NO.	0 8	
RESPONDENT	☐	6
Does family have garden? (Confirm)	☐☐	7 - 8

If they do have a garden and are previously recorded as not having a garden, ask following:

Plots	☐	9 - 14
Acres	☐	
When obtained	☐	
From	☐	
Fenced?	☐	
Problems with animals?	☐	
Why not listed before?	☐	15
Were you able to choose the location of your garden?	☐	16
Why did you choose to have your garden plot where it is now?	☐	17

Area-______

HH-______

Did you cultivate your garden this summer? (October - May) ☐ 18

Did you cultivate the whole garden? ☐ 19

If only part, why? ☐ 20

Did you water the garden during this time? ☐ 21-22

Which months?
(How many months?) ☐

How often (times/week)? ☐ 23

How many buckets each time? ☐☐ 24-28

Total buckets per week ☐☐☐

Total number of hours per week ☐☐ 29-30

Have any changes been made in the garden since I last saw you?
(For example, dug well, added fencing) ☐ 31

If YES, what changes? ☐ 32

CROPS GROWN ON GARDEN

Area-
HH-

Area / HH No. / Record No. | | | | 0 | 9 | 1 - 5

Name		When Planted		When Harvested		Amount Harvested				Use of Crop	Where sold		If sold, Income
						Local m	Converted				Gen.	Spec.	

6 - 44

45 - 70

1-food
2-selling
3-food and selling
4-livestock
5-local exchange
6-beer brewing
7-gift
8-other
9-combination of above

| | | | 1 | 0 | 1 - 5

Name		When Planted		When Harvested		Amount Harvested				Use of Crop	Where sold		If sold, Income
						Local m	Converted				Gen.	Spec.	

6 - 44

45 - 70

Area-______

HH-______

			/	/	1 - 5

Name		When Planted		When Harvested		Amount Harvested				Use of Crop	Where sold		If sold, Income	
						Local m	Converted				Gen.	Spec.		
														6 - 44
														45 - 70

Area-_____

HH-_____

ON THE GARDEN

| | | | / | 2 | 1-5 |

Were any of these crops intercropped? If yes, which ones? ☐ 6

Were any of these crops grown for the first time? If yes, which ones? ☐ 7

(Total number of crops) ☐☐☐ 8-10

(Total number of crops sold)

(Total income to date) ☐ 11

Do you still plan to sell some of these crops? ☐☐ 12-13

If yes, which crops? (1-maize, 2-other, 3-maize and other)

Have you given any crops from the garden to friends or relatives? ☐☐ 14-15

If YES, is there a reason (just to help out, exchange for labour, etc.)

Who in the family decided this summer what would be grown on the garden? (1-household head, 2-wife, 3-both, 4-other male family member, 5-other female family member, 6-combination of above) ☐ 16

What will the income from the garden be used for? ☐☐ 17-18

Who in the family decided this summer what the income from the garden would be used for?

Do you eat or sell food from your garden as soon as it is ready - or do you preserve it in some way? ☐☐ 19-20

If you preserve it - which crops and what method do you use?

Area-______

HH-______

AGRICULTURAL INPUTS ON THE GARDEN

On your garden this summer:

Did you use fertilizer?	[ ][ ]	21-22
If yes, what type? 1-D; 2-S; 3-AN; 4-other;4-more than one		
Did you use cattle manure?	[ ]	23-28
Collected from the cattle kraal?	[ ]	
Collected from around grazing area?	[ ]	
Did you use goat's manure?	[ ]	
Did you use anthills?	[ ]	
Did you use compost?	[ ]	
Did you leave maize stalks or other parts in the field to be ploughed back into the soil?	[ ]	29
Did you use herbicides? Type	[ ]	30
Did you use pesticides? Type	[ ]	31
Did you use insecticides? Type	[ ]	32
If you grew maize in the garden, How many weeks after the summer harvest did you plough?	[ ]	33
What ploughing method did you use? 1-hand; 2-oxen; 3-tractor	[ ]	34
Did you hire anyone to work in the garden in the winter season?	[ ]	35-38
If <u>YES</u>, how many days did they work?	[ ]	
What was the daily rate paid?	[ ]	
(Total cost of labour: ....)	[ ]	

Area-_____

HH-_____

What activities did they help with?
1 - YES   2 - NO

Ploughing		39-44
Planting		
Weeding		
Irrigating		
Harvesting		
Other (please specify)		

Area-______

HH-______

CROPS GROWN ON DRYFIELDS

					1	3

1 - 5

Name		When Planted		When Harvested		Amount Harvested				Use of Crop	Where sold		If sold, Income	
						Local m	Converted				Gen.	Spec.		
														6 - 44
														45 - 70

1-food
2-selling
3-food and selling
4-livestock
5-local exchange
6-beer brewing
7-gift
8-other
9-combination of above

					1	4

1 - 5

Name		When Planted		When Harvested		Amount Harvested				Use of Crop	Where sold		If sold, Income	
						Local m	Converted				Gen.	Spec.		
														6 - 44
														45 - 70

Area-_____

HH-_____

ON THE DRYFIELDS

| | | | / | 5 | 1-5

Were any of these crops intercropped?
If YES, which ones? 6

Were any of these crops grown for the first time?
If YES, which ones? 7

(Total number of crops) 8-9

(Total number of crops sold) 10

(Total income to date) 11

Do you still plan to sell some of these crops? 12-13

If YES, which crops?
(1-maize, 2-other, 3-maize and other)

Have you given any crops from the garden to friends or relatives? 14-15

If YES, is there a reason (just to help out, exchange for labour, etc.)

Who in the family decided this summer what would be grown on the dryfields? 16

What will the income from the dryfields be used for? 17-18

Who in the family decided this summer what the income from the dryfields would be used for?

Area-_____

HH-_____

AGRICULTURAL INPUTS ON THE DRYFIELDS

On your dryfields this summer:

Did you use fertilizer? [ ] 19-20

If YES, what type? [ ]
1 - D; 2 - S; 3 - AN;
4 - other;5-more than one

Did you use cattle manure? [ ] 21-26

Collected from the cattle kraal? [ ]

Collected from around grazing area? [ ]

Did you use goat's manure? [ ]

Did you use anthills? [ ]

Did you use compost? [ ]

Did you leave maize stalks or other parts in the field to be ploughed back into the soil? [ ] 27

Did you use herbicides? [ ] 28
Type ....

Did you use pesticides? [ ] 29
Type ....

Did you use insecticides? [ ] 30
Type ....

How many weeks after the summer harvest did you plough? [ ] 31

What ploughing method did you use? [ ] 32
1 - hand 2 - oxen 3 - tractor

Did you hire anyone to work in the dryfields in the winter season? [ ] 33-36

If YES, how many days did they work? [ ]

What was the daily rate paid? .... [ ]

(Total cost of labour: ....) [ ]

Area-_____

HH-_____

What activities did they help with?
1 - <u>YES</u> 2 - <u>NO</u>

Ploughing	☐	37-42
Planting	☐	
Weeding	☐	
Irrigating	☐	
Harvesting	☐	
Other (please specify)	☐	

Area-_____

HH-_____

AGRICULTURAL PRODUCTION

(Add up total income from all crops to date) 43

Do you have an AFC loan? 44-45

If NO, is there a reason?

If YES - for which crop(s) 46-49
(1-maize, 2-other, 3-maize and other)

for how many acres?

(Total cost of loan)

Do you think you will be able to pay back the loan?

Did you run out of stored grain/maize for food before the last harvest? 50-51

Do you normally run out of grain/maize for food before the last harvest?

How many months do you think this year's harvest will last? 52-53
(Will it last until the next harvest?)

If the maize will not last until next year's harvest, how will you obtain enough food? 54

If you will buy food, what sources of income will you use? 55-61

___ 1-cash from members of the household working away somewhere

___ 2-selling livestock

___ 3-selling local crafts

___ 4-local labour

___ 5-selling garden crops

___ 6-selling dryfield crops

___ 7-other (specify)

Which one of these is the most important source of income for your family? 62

APPENDIX 2: HOUSEHOLD CHARACTERISTICS

NUMBER OF HOUSEHOLD MEMBERS (%)				
Number	C	B	M	S
1-5	38	36	30	38
6-9	56	54	54	52
10+	6	8	16	10

NUMBER OF ADULTS PER HOUSEHOLD (%)				
Number	C	B	M	S
1	10	6	4	6
2	44	46	44	48
3-5	44	42	44	46
6+	2	6	8	0

NUMBER OF CHILDREN PER HOUSEHOLD (%)				
Number	C	B	M	S
1-4	68	52	48	66
5-8	22	32	38	24
9-13	2	4	4	4

EDUCATION OF HOUSEHOLD HEAD (%)				
	C	B	M	S
None	18	14	12	12
Primary*	66	76	74	70
Form 4 and above	16	10	14	18

*This includes those who attended only a few years of secondary school, but did not pass Form 4

Area	MEMBER OF LOCAL GROUP (%) Household Head	Wife	MASTER FARMER (%) Household Head	Wife
C	34	48	18	6
B	28	40	24	10
M	50	56	28	22
S	32	48	36	36

APPENDIX 3a: Detailed Study, Observational Data

TIME ALLOCATION

p. 2

Day/Date: ______________

Hours observed: ______________

Name of Household Head: ______________

Week ______

HH No. ______

TIME	ACTIVITIES											
	Name	Code	Act Code	Name	Code	Act Code	Name	Code	Act Code	Name	Code	Act Code
4:30-5:00 a.m.												
5:00-5:30 a.m.												
5:30-6:00 a.m.												
6:00-6:30 a.m.												
6:30-7:00 a.m.												
7:00-7:30 a.m.												
30-8:00 a.m.												
8:00-8:30 a.m.												
8:30-9:00 a.m.												
9:00-9:30 a.m.												
9:30-10:00 a.m.												
10:00-10:30 a.m.												
10:30-11:00 a.m.												
11:00-11:30 a.m.												
11:30-12 noon												
12noon-12:30p.m.												
12:30-1:00 p.m.												
1:00-1:30 p.m.												
0-2:00 p.m.												
2:00-2:30 p.m.												
2:30-3:00 p.m.												
3:00-3:30 p.m.												
3:30-4:00 p.m.												
4:00-4:30 p.m.												
4:30-5:00 p.m.												
5:00-5:30 p.m.												
5:30-6:00 p.m.												
6:00-6:30 p.m.												
6:30-7:00 p.m.												
7:00 p.m. until ????												

Week No. _____

HH No. _____

NON-HOUSEHOLD LABOUR

If anyone is working who is not a member of the household (as listed in Section 1), please note the hours worked on the time allocation sheet (Section II.1) and collect the information below:

For each person:

1. Name ....

Type of person	☐	16–17
Relation to household head	☐	

Activity done (write activity on line - do not fill in boxes)

________ 1	☐	☐	18–25
________ 2	☐	☐	
________ 3	☐	☐	
________ 4	☐	☐	

Compensation: (Put check in one or more box)

meals	☐	26–29
cash (amount ....)	☐	
crops	☐	
reciprocal labour	☐	

Comments ....

....

....

....

Type of person code:

1 = M 15 +

2 = F 15 +

3 = M 5 - 15

4 = F 5 - 15

Relation to head code:

1 = Relative

2 = Non-relative

NON-HOUSEHOLD LABOUR continued

2. Name ....

Type of person	☐	30-31
Relation to household head	☐	

Activity done (write name of activity, do not fill in boxes)	1 ______	☐☐	32-39
	2 ______	☐☐	
	3 ______	☐☐	
	4 ______	☐☐	

Compensation: (put check in one or more boxes)	meals	☐	40-43
	cash (Amount ....)	☐	
	crops	☐	
	reciprocal labour	☐	

Comments ....

....

3. Name ....

Type of person	☐	44-45
Relation to household head	☐	

Activity done (do not fill in boxes)	1 ______	☐☐	46-53
	2 ______	☐☐	
	3 ______	☐☐	
	4 ______	☐☐	

Compensation: (put check in one or more boxes)	meals	☐	54-57
	cash (Amount ....)	☐	
	crops	☐	
	reciprocal labour	☐	

Comments ....

....

Week No.

HH No.

WATER COLLECTION

Survey No. [ ][ ][ ] 1- 3

Household No. [ ][ ] 4- 7

Record No. [0][2]

*Person Collecting	Code	*Time Spent	Time code		Type of source code*	Type of container code*	*Number of Containers	Litres code	Purpose code*	
										8-42
										43-77

Instructions Fill in: Person collecting (name)

Type of source
1-Borehole
2-Protected (covered well)
3-Open well on dryland
4-Open well on bane (not in garden)
5-Open well in garden
6-River

Type of container
1-Large bucket
2-Small bucket
3-Open well on dryland
4-Olivine can
5-Other (write exactly what it is)

Number of containers - write exact no.

Purpose
1-Cooking/washing dishes/bathing at house/drinking
2-Washing clothes
3-Irrigation
4-Other (write exactly what it is)

MEALS SERVED

Week No. ________

HH No. ________

Survey No.	[ ][ ][ ]	1- 3
Household No.	[ ][ ]	4- 7
Record No.	0 3	

After a meal has been eaten (or as close to the time as possible), complete the appropriate table. If the evening meal is not observed, ask what will be served, who will eat it, and where the food will come from.

List each food separately.

Remember: record all foods used; including all of the foods in the relish for sadza or rice. Do not just put "relish"; put the ingredients of the relish.

Fill in name of food and source.

1. MORNING MEAL

*Type of food prepared	Food code	Source*	
			8-22
			23-31

Codes for food sources:

1-From garden on bane
2-From garden by house
3-From dryfield
4-Purchased from store or neighbour
5-Gift
6-Payment for labour
7-Other (specify)

*People eating meal (write names)

....
....
....
....
....
....
....

(do not fill in this box)

People eating meal:

	code	
Adults		32-35
Ages 5-15		
Under 5		
Visitors		

Week No. __

HH No. __

MEALS SERVED continued

2. MIDDAY MEAL

*Type of food prepared	Food code		Source*

36-50

51-59

*People eating meal (write names)

....

....

....

....

....

....

....

(do not fill in this box)

People eating meal:

	CODE
Adults	
Ages 5-15	
Under 5	
Visitors	

60-(

Source Codes:

1-From garden on bane
2-From garden by house
3-From Dryfields
4-Purchased from store or neighbour
5-Gift
6-Payment for labour
7-Other (specify)

MEALS SERVED continued

Week No. ____

HH No. ____

Survey No.	[ ][ ][ ]	1- 3
Household No.	[ ][ ]	4- 7
Record No.	0 4	

3. EVENING MEAL

*Type of food prepared	Food code		Source*	
				8-22
				23-31

*People eating meal (write names)

....

....

....

....

....

....

....

(do not fill in this box)

People eating meal:	code	
Adults		32-35
Ages 5-15		
Under 5		
Visitors		

Source Codes:

1-From garden on bane
2-From garden by house
3-From Dryfields
4-Purchased from store or neighbour
5-Gift
6-Payment for labour
7-Other (specify)

Week No. ____

HH No. ____

FOOD ENTERING COOKING HUT

Survey No.				1- 3

Household No.			4- 7
Record No.	0	6	

* Food Name	Food code		* Amount in local terms	Amount coded and converted	Source code *	
						8–27
						28–39
						40-59

Source codes:

1-from garden on bane
2-from garden by house
3-from dryfields
4-purchased from store or neighbour
5-gift
6-payment for labour
7-other (specify)

HARVEST AND FOOD USE

Week No. ______

HH No. ______

Survey No. [| |] 1- 3

Household No. [|] 4- 7

Record No. [0 | 5]

Weigh or measure all crops taken from garden on bane and dryfields and ask what the food will be used for. All but kitchen store.

There are separate sections for harvest from garden on bane and dryfields; make sure you put the right harvest in the right section.

Do not fill in the code next to crop name; codes for end use of crop are below. If a crop will be used for more than one purpose, please put all uses

A. HARVEST FROM DRYFIELDS

*Crop name	Crop code		*Amount harvested local terms	Amount coded and converted	End use of crop coded *

8-31

End Use Codes

1-Storage
2-Sale
3-Gift
4-Labour payment
5-Other (specify)

Comments ....

....

....

....

Week No. ______

HH No. ______

B. HARVEST FROM GARDEN ON BANE

*Crop Name	Crop code		*Amount harvested local terms	Amount coded and converted	End use of crop coded *

35-58

Comments ....

....

....

....

End Use Codes:

1-Storage
2-Sale
3-Gift
4-Labour Payment
5-Other (specify)

APPENDIX 3b: Detailed Study: Activities in Past Month

p. 5

Week No. ______

ACTIVITIES IN PAST MONTH -

HH No. ______

Survey No. [| |]

Household No. [|]

Record No. [|]

Household No. [|]

No. of Adults [|]

No. of children under 5 years [|]

Type of household head [ ]

Dambo or non-dambo [ ]

1) PLOUGHING

Measure of area (paces)	Area	Crop to be planted	Cost of ploughing	Comments

2) PLANTING

Area (paces)	Area	Crop Name	Source of seed	Cost of seeds	Method of planting

Week No. ______

HH No. ______

ACTIVITIES IN PAST MONTH continued

3) ANYTHING USED TO IMPROVE THE SOIL?

Area (paces)	Area	Crop	Commercial Fertilizer			Manure amount	Anthills amount	Plant residue Compost Left on
			Type	Amount	Cost			

4) LABOUR

Did you hire anyone to work in your fields in the past month?
If yes, please fill in the chart below:

Type of person hired	Relation to HH head	No.of days worked	Type of work	Amount paid/day	Total cash payment

Comments:

5) ADDITIVES

Did you use any pesticides, insecticides or herbicides?
If yes, fill in the chart below:

Note whether: Pest/Insect/Herb	Type	On which Crop(s)	Cost	Comments

6) IRRIGATION

Did you water any crops in the past month?
If yes:

Which crops? ____________________

How often? ____________________

What type of container do you use? ____________________

How many containers each time you water? ____________________

APPENDIX 4: SOIL PROFILE DESCRIPTIONS AND ANALYTICAL DATA

Profile descriptions : R.Lambert

Laboratory analyses: Research and Specialist Services, Harare

Texture

CS : coarse sand (2.0-0.5 mm)
MS : medium sand (0.5-0.18 mm)
FS : fine sand (0.18-0.053 mm)
coarse silt (or very fine sand) (0.053-0.02 mm)
fine silt (0.02-0.002 mm)
clay (under 0.002 mm)

grain-size analyses carried out by sieving and hydrometer methods.

soil textural classes :

Sand (S) less than 8% clay, more than 85% sand
Loamy sand (LS) less than 12% clay, 75-92% sand
Sandy loam (SaL) less than 20% clay, more than 50% sand
Sandy clay loam (SaCL) 20-35% clay, more than 45% sand, less than 35% fine silt
Sandy clay (SaC) 35-55% clay, more than 45% sand, less than 20% fine silt
Clay (C) more than 40% clay, less than 50% sand or 40% fine silt

pH ($CaCl_2$)

determined from 1 : 5 suspension of soil in 0.01 M $CaCl_2$.
on average calcium chloride pH is ca.0,7 units lower than water pH.

EC (mhos)

electrical conductivity of a suspension of 1 part soil to 5 parts distilled water, providing a measure of soluble salt content (ie. salinity)

organic matter

% weight loss on ignition of dry soil sample at 550°C for 2 hours.
% organic carbon determined by Walkley-Black method; organic C conventionally assumed to be 58% of total organic matter.

cations

Cation exchange capacity (CEC) in milligram equivalents per cent.
E/C value denotes CEC per 100 gm of clay.

Exchangeable calcium (Ca), magnesium (Mg) and sodium (Na) determined by atomic absorption spectrophotometry, exchangeable potassium (K) by emission spectrophotometry. All reported in milligram equivalents per cent.

	exchangeable potassium sands	sandy loams
deficient	below 0.05	below 0.1
marginal	0.05 - 0.1	0.1 - 0.2
adequate	0.1 - 0.25	0.2 - 0.3
rich	above 0.25	above 0.3

Total exchangeable bases (TEB) in milligram equivalents per cent
= sum of exchangeable cations.
S/C value denotes TEB per 100 gm of clay

Base saturation = TEB as a percentage of CEC

ESP/EKP

Exchangeable sodium and potassium percentages
= 100 (Ex. Na/K (m.e.%) - water soluble Na/K) / CEC (m.e.%)

For ESP 0 - 3% : cohesive
3 - 7% : moderately dispersive
over 7% : dispersive

Phosphorus and nitrogen

initial mineral nitrogen is the amount of nitrate-nitrogen plus ammonia-nitrogen in parts per million in received sample.

mineral nitrogen after incubation is the amount of nitrate-nitrogen plus ammonia-nitrogen in parts per million after 2 weeks incubation under optimum conditions for mineralisation.

available phosphorus in parts per million, as determined after agitation with an anion exchange resin.

	N after inc.	P_2O_5
deficient	below 15	below 15
marginal	15 - 30	15 - 30
adequate	30 - 40	30 - 50
rich	above 40	above 50

A) CHIZENGENI (TOPLAND SOILS)

PROFILE : G7, Chizengeni, Chiota, Zimbabwe.
site : dry topland
date described : 5/3/86
slope : ca.2%
landuse : scrub grazing

DESCRIPTION :

0-40 cm : dark greyish brown (2.5Y 4/2) sandy loam, friable crumb structure, moderate root density, gradual indistinct transition to...
40-65 cm : light olive brown (2.5Y 5/4) silty sand, dense crumb structure, low root density, clear transition to...
>65 cm : weathered bedrock

ANALYTICAL DATA :	G7A	G7B
depth (cm)	0-40	40-65
texture	CS	CLS
coarse sand %	24.70	23.23
medium sand %	41.90	34.00
fine sand %	22.13	15.30
coarse silt %	6.67	7.60
fine silt %	2.00	5.00
clay %	3.00	5.00
pH (H_2O)	5.70	5.10
pH ($CaCl_2$)	4.30	4.20
EC (mhos)	7.00	8.00
loss on ignition	.79	1.51
carbon %	.03	.15
TEB m.e. %	.26	.24
CEC m.e. %	1.02	2.05
base saturation %	25.50	11.80
exchangeable Ca	.10	.10
exchangeable Mg	.10	.10
exchangeable Na	.04	.02
exchangeable K	.02	.02
ESP	3.90	1.00
EKP	2.00	1.00
available P (ppm)	4.00	4.00
E/C value	36.40	42.50
S/C value	9.30	5.00

PROFILE : D7, Chizengeni, Chiota, Zimbabwe.
site : Dry topland, just above dambo margin.
date described : 5/3/86
slope : 2%
landuse : scrub grazing

DESCRIPTION :

0-23 cm : Dark greyish brown (2.5Y 4/2) sandy loam, moderate root density, very weak blocky crumb structure, homogenous, gradual indistinct transition to...

23-45 cm : Light olive brown (2.5Y 5/3) silty sandy loam, few roots, weak crumb structure, homogenous, gradual transition to...

45-80 cm : Greyish brown (2.5Y 5/2) silty sand, few roots, rust mottling, dense very weak crumb structure, homogenous.

ANALYTICAL DATA :	D7A	D7B	D7C
depth (cm)	0-23	23-45	45-80
texture	CS	CS	CS
coarse sand %	41.10	35.00	35.50
medium sand %	30.90	32.10	32.90
fine sand %	17.61	20.96	22.57
coarse silt %	8.69	2.14	7.33
fine silt % / clay %	3.00	6.00 / 4.00	3.00
pH (H_2O)	5.60	5.40	5.30
pH ($CaCl_2$)	4.30	4.50	4.60
EC (mhos)	9.00	6.00	7.00
loss on ignition	.92	.70	.40
carbon %	.17	.10	.03
TEB m.e. %	.40	.24	.24
CEC m.e. %	1.64	2.25	2.25
base saturation %	24.00	10.70	10.70
exchangeable Ca	.23	.10	.10
exchangeable Mg	.09	1.00	1.00
exchangeable Na	.05	.02	.02
exchangeable K	.03	.02	.02
ESP	3.00	.90	.90
EKP	2.00	.90	.90
available P (ppm)	5.00	4.00	2.00
E/C value	54.60	59.10	80.10
S/C value	13.30	6.30	8.60

PROFILE : C6, Chizengeni, Zimbabwe
site : Dry topland, north of dambo, next to small group of trees
date described : 5/3/86
slope : ca. 2%
landuse : Fallow dry field

DESCRIPTION :

0-20 cm : olive brown (2.5Y 4/4) sandy loam, weak crumb-cum-blocky structure, some fine roots, gradual transition to...
20-65 cm : light olive brown (2.5Y 5/4) sandy loam, weak crumb structure, some roots, gradual transition...
65- cm : olive yellow (2.5Y 6/6) silty sandy loam, weak crumb structure, some deep roots

ANALYTICAL DATA :	C6A	C6B	C6C
depth (cm)	0-20	20-65	>65
texture	CS	CS	CS
coarse sand %	33.80	25.10	27.60
medium sand %	34.60	25.10	32.40
fine sand %	20.22	19.76	20.12
coarse silt %	8.48	28.64	14.08
fine silt %	3.00	2.00	3.00
clay %			3.00
pH (H_2O)	5.40	5.40	5.40
pH ($CaCl_2$)	4.60	4.50	4.30
EC (mhos)	7.00	5.00	6.00
loss on ignition	.90	.70	1.71
carbon %	.16	.14	.03
TEB m.e. %	.36	.60	.26
CEC m.e. %	1.23	1.84	1.64
base saturation %	29.40	32.60	15.90
exchangeable Ca	.20	.10	.10
exchangeable Mg	1.00	.20	1.00
exchangeable Na	.04	.20	.02
exchangeable K	.02	.10	.04
ESP	3.30	10.90	1.20
EKP	1.60	5.40	2.50
available P (ppm)	3.00	2.00	4.00
E/C value	43.70	92.00	58.30
S/C value	12.90	30.00	9.30

PROFILE : D9, Chizengeni, Zimbabwe
site : dry topland, north of dambo
date described : 5/3/86
slope : ca. 2%
landuse : dry field cultivation

DESCRIPTION :

0-20 cm : brown, dark-brown (10YR 4/3) sandy loam, weak crumb structure,
homogenous, rooting zone, gradual indistinct transition to...
20-50 cm : brown, (10YR 5/4) sandy loam, weak crumb structure, gradual indistinct transition to...
50 cm - : yellowish brown sandy loam, weak crumb structure, slightly sticky, very few roots.

ANALYTICAL DATA :	D9A	D9B	D9C
depth (cm)	0-20	20-50	>50
texture	CS	CS	CSaL
coarse sand %	26.40	28.30	35.00
medium sand %	40.90	36.20	32.00
fine sand %	19.52	16.52	15.11
coarse silt %	8.38	11.08	11.49
fine silt %	2.00	3.00	1.00
clay %	3.00	5.00	13.00
pH (H_2O)	5.30	4.90	4.70
pH ($CaCl_2$)	4.40	4.30	4.20
EC (mhos)	10.00	13.00	12.00
loss on ignition	1.41	1.41	1.91
carbon %	.13	.11	.05
TEB m.e. %	.24	.24	.24
CEC m.e. %	1.02	1.03	1.44
base saturation %	23.50	23.50	16.80
exchangeable Ca	.10	.10	.10
exchangeable Mg	.10	.10	.10
exchangeable Na	.02	.02	.02
exchangeable K	.02	.02	.02
ESP	2.00	2.00	1.40
EKP	2.00	2.00	1.40
available P (ppm)	7.00	4.00	3.00
E/C value	36.40	21.30	11.20
S/C value	8.60	5.00	19.00

PROFILE : EP5, Chizengeni, Chiota, Zimbabwe.
site : Dry topland
date described : 14/1/86
slope : ca. 2%
landuse : Scrub grazing.

DESCRIPTION :

0-20cm : Dark greyish brown (10YR 4/4) loamy sand, crumbly, friable, top 2cm mainly sand, gradual transition to...
20-60cm : Yellowish brown (10YR 5/6) sandy loam, some clay, crumbly, slightly sticky, gradual transition to...
60-->cm : Yellowish brown (10YR 5/8) clayey sandy loam, crumbly, sticky.

ANALYTICAL DATA :	EP5/1	EP5/2
depth (cm)	0-20	20-60
texture	CS	CSaL
coarse sand %	25.20	26.50
medium sand %	39.90	29.60
fine sand %	19.80	15.56
coarse silt %	8.50	7.54
fine silt %	7.00	4.00
clay %		17.00
pH (H_2O)	5.60	5.30
pH ($CaCl_2$)	4.20	4.10
EC (mhos)	9.00	6.00
loss on ignition	1.52	2.72
carbon %	.26	.18
TEB m.e. %	.28	.38
CEC m.e. %	.82	2.26
base saturation %	34.30	16.90
exchangeable Ca	.10	.20
exchangeable Mg	.10	.10
exchangeable Na	.04	.04
exchangeable K	.04	.04
ESP	4.90	1.80
EKP	4.90	1.80
available P (ppm)	6.00	3.00
E/C value	12.00	13.40
S/C value	4.10	2.30

PROFILE : EP6, Chizengeni, Chiota, Zimbabwe.
site : Dry topland
date described : 14/1/86
slope : ca. 2%
landuse : Cultivation - dry land maize.

DESCRIPTION :

0-19cm : Dark brown (7.5YR 3/4) loamy sand, weak crumb structure, homogenous, distinct transition to...
19-50cm : Dark brown (7.5YR 4/4) loamy sand, weak crumb structure, homogenous, gradual transition to...
50-->cm : Brown (7.5YR 5/4) sticky sandy loam, sticky crumb structure, homogenous.

ANALYTICAL DATA :	EP6/1	EP6/2
depth (cm)	0-19	19-50
texture	CS	CS
coarse sand %	35.30	31.00
medium sand %	43.00	42.00
fine sand %	11.32	11.88
coarse silt %	5.78	10.52
fine silt %	2.00	6.00
clay %	3.00	
pH (H_2O)	5.20	5.40
pH ($CaCl_2$)	4.20	4.20
EC (mhos)	6.00	9.00
loss on ignition	1.32	1.90
carbon %	.21	.21
TEB m.e. %	.26	.36
CEC m.e. %	1.02	1.85
base saturation %	25.50	19.60
exchangeable Ca	.10	.20
exchangeable Mg	.10	.10
exchangeable Na	.04	.04
exchangeable K	.02	.02
ESP	3.90	2.20
EKP	2.00	1.10
available P (ppm)	15.00	7.00
E/C value	36.40	31.70
S/C value	9.30	6.20

(DAMBO MARGIN SOILS)

PROFILE : E9, Chizengeni, Chiota, Zimbabwe.
site : Dambo margin, upper wash zone.
date described : 5/3/86
slope : ca. 1%
landuse : Cultivated unfenced, with poor rapoko growing.

DESCRIPTION :

0-30cm : Very dark brown (10YR 3/1) organic but infertile sand, few roots, almost no crumb structure, homogenous, indistinct transition to...

30-60cm : Greyish brown (10YR 5/2) sandy silt, densely packed homogenous. Water table <50cm down.

ANALYTICAL DATA :	E9A	E9B
depth (cm)	0-30	30-60
texture	CS	CS
coarse sand %	36.00	33.40
medium sand %	37.20	34.00
fine sand %	17.69	21.06
coarse silt %	6.11	9.74
fine silt % clay %	3.00	3.00
pH (H_2O)	4.90	5.70
pH ($CaCl_2$)	4.00	4.70
EC (mhos)	16.00	4.00
loss on ignition	1.10	.50
carbon %	.41	.03
TEB m.e. %	.28	.54
CEC m.e. %	2.87	2.04
base saturation %	9.80	26.50
exchangeable Ca	.10	.40
exchangeable Mg	.10	.10
exchangeable Na	.06	.02
exchangeable K	.02	.02
ESP	2.10	1.00
EKP	.70	1.00
available P (ppm)	5.00	4.00
E/C value	102.00	72.90
S/C value	10.00	19.30

PROFILE : DM1, Chizengeni, Chiota, Zimbabwe
site : Dambo margin
slope : ca.2%
landuse : Rough scrub
(no profile recorded)

ANALYTICAL DATA :	DM1
depth (cm)	0-20
texture	CS
coarse sand %	35.40
medium sand %	35.40
fine sand %	18.52
coarse silt %	7.68
fine silt % clay %	3.00
pH (H_2O)	4.80
pH ($CaCl_2$)	4.00
EC (mhos)	13.00
loss on ignition	.75
carbon %	.25
TEB m.e. %	.26
CEC m.e. %	2.25
base saturation %	11.60
exchangeable Ca	.10
exchangeable Mg	.10
exchangeable Na	.04
exchangeable K	.02
ESP	1.80
available P (ppm)	6.00
E/C value	80.10
S/C value	9.30

PROFILE : DM2, Chizengeni, Chiota, Zimbabwe
site : Dambo margin
slope : ca.2%
landuse : Rough scrub
(no profile recorded)

ANALYTICAL DATA :	DM2
depth (cm)	0-20
texture	CS
coarse sand %	32.20
medium sand %	35.70
fine sand %	18.45
coarse silt %	9.05
fine silt %	2.00
clay %	3.00
pH (H_2O)	4.80
pH ($CaCl_2$)	4.00
EC (mhos)	12.00
loss on ignition	.90
carbon %	.17
TEB m.e. %	.26
CEC m.e. %	2.87
base saturation %	9.10
exchangeable Ca	.10
exchangeable Mg	.10
exchangeable Na	.04
exchangeable K	.02
ESP	1.40
available P (ppm)	5.00
E/C value	102.00
S/C value	9.30

(UPPER DAMBO ZONE SOILS)

PROFILE : E7, Chizengeni, Chiota, Zimbabwe.
site : Upper dambo, near well, close to small reservoir.
date described : 4/9/86
slope : ca.2%
landuse : Garden

DESCRIPTION :
0-30 cm : Black (10YR 2/1) sandy organic loam, homogenous crumb structure, clear transition to...
30-90 cm : Dark greyish brown (10YR 4/2) slightly loamy sand, weak homogenous crumb structure

ANALYTICAL DATA :	E7A	E7B
depth (cm)	0-30	30-90
texture	CLS	CS
coarse sand %	35.48	48.10
medium sand %	27.68	27.74
fine sand %	13.98	12.68
coarse silt %	9.89	6.67
fine silt %	7.97	4.81
clay %	5.00	
pH (H_2O)	6.10	6.20
pH ($CaCl_2$)	4.50	4.70
EC (mhos)	20.00	15.00
loss on ignition	4.80	.80
carbon %	2.70	.22
TEB m.e. %	1.50	1.20
CEC m.e. %	3.70	1.20
base saturation %	41.00	100.00
exchangeable Ca	1.00	.40
exchangeable Mg	.30	.20
exchangeable Na	.26	.64
exchangeable K	.06	.04
ESP	7.00	53.30?
EKP	1.60	3.30
available P (ppm)	13.00	1.00
N (ppm) initial	8.00	2.00
N (ppm) after inc	9.00	2.00
E/C value	74.00	24.90
S/C value	30.00	24.90

PROFILE : CD6, Chizengeni, Chiota, Zimbabwe.
site : Upper dambo, close to 2 shallow wells.
date described : 4/9/86
slope : ca.2%
landuse : Garden

DESCRIPTION :
0-25cm : Black (10YR 2/1) organic sand, crumb structure, homogenous with clear transition to...
25-85cm : Greyish brown (10YR 5/2) sand, weak crumb structure, homogenous, with indistinct transition to...
85-100cm : Light brownish grey (10YR 6/2) sand.

ANALYTICAL DATA :	CD6A	CD6B	CD6C
depth (cm)	0-25	25-85	85-100
texture	CS	CS	CS
coarse sand %	54.82	64.99	60.56
medium sand %	22.59	24.71	28.78
fine sand %	5.90	4.39	5.13
coarse silt %	5.77	3.10	2.72
fine silt % clay %	10.92	2.81	2.81
pH (H_2O)	5.60	6.00	6.30
pH ($CaCl_2$)	4.70	5.00	5.10
EC (mhos)	30.00	15.00	15.00
loss on ignition	3.70	1.00	.30
carbon %	2.57	.34	.22
TEB m.e. %	4.50	.50	.60
CEC m.e. %	5.40	1.90	.90
base saturation %	83.00	28.00	68.00
exchangeable Ca	3.00	.30	.30
exchangeable Mg	1.00	.20	.20
exchangeable Na	.16	.06	.08
exchangeable K	.28	.02	.02
ESP	3.00	3.20	8.90
EKP	5.30	1.10	2.20
available P (ppm)	14.00	1.00	1.00
N (ppm) initial	6.00	3.00	3.00
N (ppm) after inc	24.00	4.00	4.00
E/C value	49.50	67.90	32.10
S/C value	41.30	17.90	21.40

PROFILE : EF10, Chizengeni, Chiota, Zimbabwe.
site : upper dambo, north side.
date described : 5/3/86
slope : ca. 1%
landuse : fallow garden

DESCRIPTION :

0-38 cm : black (7.5 YR 2/0) organic sandy loam, weak block/crumb structure, clear but gradual transition to...

38 cm - : brown/dark brown (10YR 4/3) fine sand, homogenous densely packed, not very permeable

ANALYTICAL DATA :	EF10A	EF10B
depth (cm)	0-38	>38
texture	CS	CS
coarse sand %	33.10	29.70
medium sand %	35.30	38.60
fine sand %	15.00	19.88
coarse silt %	9.90	10.02
fine silt %	4.00	
clay %	3.00	3.00
pH (H_2O)	6.10	5.70
pH ($CaCl_2$)	4.90	4.50
EC (mhos)	25.00	10.00
loss on ignition	2.53	.60
carbon %	1.35	.10
TEB m.e. %	2.46	.36
CEC m.e. %	3.08	1.43
base saturation %	79.70	25.20
exchangeable Ca	1.71	.20
exchangeable Mg	.60	.10
exchangeable Na	.08	.04
exchangeable K	.06	.02
ESP	2.60	2.80
EKP	2.00	1.40
available P (ppm)	16.00	3.00
E/C value	109.30	51.00
S/C value	87.10	12.90

PROFILE	: EP4, Chizengeni, Chiota, Zimbabwe.
site	: Upper dambo, near lower limit.
date described	: 4/9/86
slope	: ca. 2 %
landuse	: Grazing, old raised beds visible nearby.

DESCRIPTION :

0-30cm	: Black (10YR 2/1) organic sandy loam, weak crumb structure, homogenous, clear but gradual transition to...
30-80cm	: Brown dark brown (10YR 4/3) sand, homogenous.

ANALYTICAL DATA :	EP4A	EP4B
depth (cm)	0-30	30-80
texture	CS	CS
coarse sand %	47.10	57.66
medium sand %	35.47	28.95
fine sand %	7.52	6.27
coarse silt %	5.10	4.32
fine silt % clay %	4.81	2.80
pH (H_2O)	5.40	5.50
pH ($CaCl_2$)	4.10	4.20
EC (mhos)	16.00	20.00
loss on ignition	2.00	.90
carbon %	1.54	.39
TEB m.e. %	1.50	.80
CEC m.e. %	1.90	1.30
base saturation %	81.00	61.00
exchangeable Ca	1.10	.40
exchangeable Mg	.30	.20
exchangeable Na	.14	.24
exchangeable K	.02	.04
ESP	7.40	18.50
EKP	1.10	3.10
available P (ppm)	5.00	4.00
N (ppm) initial	5.00	3.00
N (ppm) after inc	18.00	5.00
E/C value	39.60	46.40

(LOWER DAMBO ZONE SOILS)

PROFILE : F7, Chizengeni, Chiota, Zimbabwe.
site : Lower dambo
date described : 4/9/86
slope : ca.2%
landuse : Grassland grazing

DESCRIPTION :
0-25 cm : Black (10YR 2/1) organic silty clay loam, fine crumb structure, homogenous with clear transition to...
25-42 cm : Dark brown (10YR 3/3) sandy loam, soft crumbly and homogenous with indistinct transition to...
42-62 cm : Dark yellowish brown (10YR 4/4) sandy loam, slightly blocky, some crumb structure evident with indistinct transition to...
62-80 cm : Yellowish brown (10YR 4/4) sand, slightly crumbly with rust mottling. Water table at 80 cm.

ANALYTICAL DATA :	F7A	F7B	F7C	F7D
depth (cm)	0-25	25-42	42-62	62-80
texture	CSaL	CS	CLS	CS
coarse sand %	46.60	55.75	48.38	57.85
medium sand %	18.96	27.88	32.08	28.80
fine sand %	5.63	3.93	4.88	3.86
coarse silt %	9.71	6.62	5.82	4.67
fine silt %	9.75	5.82	2.61	4.82
clay %	9.35		6.23	
pH (H_2O)	5.40	5.40	5.30	5.40
pH ($CaCl_2$)	3.70	3.80	4.00	4.10
EC (mhos)	18.00	13.00	15.00	15.00
loss on ignition	6.40	1.50	1.60	.70
carbon %	2.90	.63	.04	.31
TEB m.e. %	1.70	.90	2.20	1.30
CEC m.e. %	3.80	2.60	3.00	2.50
base saturation %	45.00	35.00	73.00	53.00
exchangeable Ca	1.00	.50	1.00	.70
exchangeable Mg	.50	.30	.90	.50
exchangeable Na	.10	.08	.22	.10
exchangeable K	.06	.04	.08	.04
ESP	2.70	3.10	7.30	4.00
EKP	1.60	1.50	2.70	1.60
available P (ppm)	4.00	5.00	5.00	3.00
N (ppm) initial	7.00	3.00	3.00	3.00
N (ppm) after inc	27.00	4.00	4.00	4.00
E/C value	40.60	44.70	48.20	51.90

PROFILE : F9,Chizengeni, Chiota, Zimbabwe.
site : Lower dambo, but at upper (eastern) end.
date described : 5/3/86
slope : ca.1%
landuse : Formerly cultivated, now under grass

DESCRIPTION :

0-30cm : Black (10YR 2/1) organic sand, weak crumb structure, few roots, homogenous, clear transition to...

30-75cm : Brown dark brown (10YR 4/3) silty sand, homogenous, weak crumb structure, indistinct transition to...

75- cm : Homogenous sand ; water table at 105 cm

ANALYTICAL DATA :	F9A	F9B	F9C
depth (cm)	0-30	30-75	75-105
texture	CS	CS	CS
coarse sand %	42.40	39.60	50.63
medium sand %	33.10	34.30	31.79
fine sand %	10.73	14.18	6.93
coarse silt %	9.17	10.12	5.85
fine silt %	2.00	3.00	4.80
clay %	3.00		
pH (H_2O)	5.30	5.50	5.90
pH ($CaCl_2$)	4.10	4.50	4.40
EC (mhos)	14.00	9.00	13.00
loss on ignition	2.68	.50	1.20
carbon %	.95	.27	.17
TEB m.e. %	.80	.66	.80
CEC m.e. %	1.84	1.84	1.20
base saturation %	43.60	35.90	67.00
exchangeable Ca	.50	.30	.50
exchangeable Mg	.20	.30	.20
exchangeable Na	.06	.04	.10
exchangeable K	.04	.02	.02
ESP	3.30	2.20	8.30
EKP	2.20	1.10	1.70
available P (ppm)	7.00	3.00	2.00
E/C value	65.60	65.60	25.00
S/C value	28.60	23.60	16.70

PROFILE : EP1, Chizengeni, Chiota, Zimbabwe.
site : Lower dambo
date described : 4/9/86
slope : ca.2%
landuse : Grazing.

DESCRIPTION :

0-22cm : Very dark grey (10YR 3/1) organic silty loam, slightly blocky weak crumb structure, homogenous, clear sharp transition to...

22-65cm : Brown dark brown (10YR 4/3) silty sand, weak crumb structure, clear sharp transition to...

>65cm : Gravel and stones, weathered bedrock

ANALYTICAL DATA :	EP1A	EP1B
depth (cm)	0-22	22-65
texture	CS	CS
coarse sand %	39.48	49.85
medium sand %	30.06	28.65
fine sand %	12.73	10.61
coarse silt %	8.91	8.09
fine silt % clay %	8.82	2.80
pH (H_2O)	6.10	6.30
pH ($CaCl_2$)	4.60	4.80
EC (mhos)	15.00	10.00
loss on ignition	2.30	.80
carbon %	.85	.33
TEB m.e. %	2.20	1.10
CEC m.e. %	2.20	1.60
base saturation %	100.00	67.00
exchangeable Ca	1.60	.50
exchangeable Mg	.40	.20
exchangeable Na	.46	.30
exchangeable K	.06	.04
ESP	20.90	18.80
EKP	2.70	2.50
available P (ppm)	3.00	1.00
N (ppm) initial	6.00	4.00
N (ppm) after inc	15.00	4.00
E/C value	25.00	55.60

PROFILE : EP2, Chizengeni, Chiota, Zimbabwe.
site : Lower dambo
date described : 4/9/86
slope : ca. 2%
landuse : Garden.

DESCRIPTION :

0-28cm : Black (10YR 2/1) organic fine silty loam, crumb structure, homogenous, clear transition to...

28-65cm : Dark greyish brown (10YR 4/2) silty sand, densely packed, homogenous, indistinct transition to...

65-100cm : Brown dark brown (10YR 4/3) sand, homogenous, some iron mottling.

>100cm : Gravel.

ANALYTICAL DATA :	EP2A	EP2B	EP2C
depth (cm)	0-28	28-65	65-100
texture	CS	CS	CS
coarse sand %	38.95	50.60	33.70
medium sand %	28.87	27.03	30.62
fine sand %	10.66	10.24	17.05
coarse silt %	10.65	8.32	11.82
fine silt % clay %	10.87	3.81	6.81
pH (H_2O)	6.10	6.20	5.80
pH ($CaCl_2$)	5.20	5.30	4.40
EC (mhos)	25.00	15.00	16.00
loss on ignition	2.50	.80	.40
carbon %	1.20	.32	.08
TEB m.e. %	3.30	1.10	.70
CEC m.e. %	3.60	1.70	1.70
base saturation %	91.00	62.00	39.00
exchangeable Ca	2.20	.50	.40
exchangeable Mg	.80	.20	.20
exchangeable Na	.32	.34	.10
exchangeable K	.04	.02	.04
ESP	8.90	20.00	5.90
EKP	1.10	1.20	2.40
available P (ppm)	6.00	2.00	1.00
N (ppm) initial	9.00	2.00	2.00
N (ppm) after inc	16.00	2.00	2.00
E/C value	33.10	44.70	25.00

PROFILE : EP3, Chizengeni dambo, Chiota
site : Lower dambo
date described : 4/9/86
slope : ca. 2%
landuse : Garden.

DESCRIPTION :

0-25cm : Black (10YR 2/1) organic sandy loam, very weak crumb structure, homogenous, clear sharp transition to...
25-55cm : Dark greyish brown (10YR 4/2) sand, homogenous, indistinct transition to...
55-90cm : Greyish brown (10YR 5/2) sand, homogenous.
90- cm : Gravel

ANALYTICAL DATA :	EP3A	EP3B	EP3C
depth (cm)	0-25	25-55	55-90
texture	CS	CS	CS
coarse sand %	37.72	46.21	46.81
medium sand %	29.19	33.57	31.82
fine sand %	14.15	9.69	12.23
coarse silt %	10.10	7.73	6.24
fine silt % clay %	8.84	2.80	2.90
pH (H_2O)	5.80	6.30	6.30
pH ($CaCl_2$)	5.00	4.90	5.00
EC (mhos)	25.00	10.00	11.00
loss on ignition	2.50	.80	.60
carbon %	1.57	.03	.07
TEB m.e. %	2.20	.60	.50
CEC m.e. %	3.30	1.00	2.40
base saturation %	66.00	63.00	22.00
exchangeable Ca	1.60	.30	.20
exchangeable Mg	.40	.20	.20
exchangeable Na	.10	.12	.14
exchangeable K	.10	.02	.02
ESP	3.00	12.00	5.80
EKP	3.00	2.00	.80
available P (ppm)	10.00	3.00	1.00
N (ppm) initial	6.00	4.00	3.00
N (ppm) after inc	14.00	3.00	3.00
E/C value	37.30	35.70	82.80

(DRY DAMBO BOTTOM SOILS)

PROFILE : E4, Chizengeni, Zimbabwe
site : Dry dambo bottom 10m from rock outcrop, 15m from anthill.
date described : 5/3/86
slope : ca.1%
landuse : Grassland grazing

DESCRIPTION :
0-23 cm : black (10YR 2/1), organic sandy loam, friable crumb structure, clear transition to...
23-45 cm : brown dark brown (10YR 4/3), silty sand, crumbly, densely packed homogenous, clear transition to...
>45 cm : dark grey (10YR 4/1), sticky stoney clay,

ANALYTICAL DATA	E4A	E4B
depth (cm)	0-23	23-45
texture	CS	CS
coarse sand %	36.00	38.90
medium sand %	32.10	31.70
fine sand %	13.25	15.06
coarse silt %	8.95	11.54
fine silt %	7.00	3.00
clay %	3.00	
pH (H_2O)	6.20	6.10
pH ($CaCl_2$)	5.10	5.20
EC (mhos)	20.00	10.00
loss on ignition	2.10	.50
carbon %	1.21	.11
TEB m.e. %	2.45	1.06
CEC m.e. %	4.13	1.84
base saturation %	59.30	57.70
exchangeable Ca	1.72	.70
exchangeable Mg	.61	.30
exchangeable Na	.04	.04
exchangeable K	.08	.02
ESP	1.00	2.20
EKP	2.00	1.10
available P (ppm)	8.00	4.00
E/C value	145.70	65.60
S/C value	86.40	37.90

B) CHIGWADA

PROFILE : CW4, Chigwada, Chiota C.A., Zimbabwe.
site : Dryfields, just above dambo margin.
date described : 4/3/86
slope : ca. 1.5%
landuse : Scrub grazing

DESCRIPTION :

0-14cm : Very dark greyish brown, (10YR 3/2) sandy slightly organic loam, friable loose crumb structure, few roots, indistinct transition to ...

14-45cm : Brown dark brown (10YR 4/3) sandy loam, very loose crumb structure, some dark mottling, indistinct transition to...

45-85cm : Yellowish brown (10YR 5/6) sand, indistinct transition to...

>85 cm : weathered bedrock

ANALYTICAL DATA :	CW4A	CW4B	CW4C
depth (cm)	0-14	14-45	45-85
texture	CS	CS	CS
coarse sand %	30.40	34.30	28.70
medium sand %	36.50	34.60	33.40
fine sand %	20.76	18.62	23.05
coarse silt %	10.64	10.68	12.15
fine silt % / clay %	3.00	3.00	3.00
pH (H_2O)	5.60	5.60	5.20
pH ($CaCl_2$)	4.50	4.40	4.40
EC (mhos)	16.00	7.00	7.00
loss on ignition	1.50	.80	.70
carbon %	.37	.12	.13
TEB m.e. %	.50	.46	.26
CEC m.e. %	1.84	2.66	2.46
base saturation %	27.20	17.30	10.60
exchangeable Ca	.30	.30	.10
exchangeable Mg	.10	.10	.10
exchangeable Na	.06	.04	.04
exchangeable K	.04	.02	.02
ESP	3.30	1.50	1.60
EKP	2.20	.80	.80
available P (ppm)	4.00	4.00	3.00
E/C value	65.60	94.70	87.40
S/C value	17.90	16.40	9.30

PROFILE : CW1, Chigwada, Chiota C.A., Zimbabwe.
site : Dambo margin, mukute bushes nearby.
date described : 4/3/86
slope : 1.5%
landuse : Scrub grazing

DESCRIPTION :

0-18 cm : Very dark greyish brown (10YR 3/2) sandy organic loam, loose homogeneous crumb structure, with indistinct transition to..

18-52 cm : Brown (10YR 4/3) sand, very weak crumb structure, low root density, spotted rust brown patches, homogenous, indistinct transition to...

>52 cm : Greyish brown (10YR 5/2) sand, homogenous.

ANALYTICAL DATA :	CW1A	CW1B	CW1C
depth (cm)	0-18	18-52	>52
texture	CS	CS	CS
coarse sand %	40.80	39.60	35.00
medium sand %	39.30	38.00	38.80
fine sand %	14.10	15.20	18.50
coarse silt %	2.90	5.30	6.00
fine silt % clay %	3.00	3.00	3.00
pH (H_2O)	5.90	5.80	6.00
pH ($CaCl_2$)	4.50	4.90	5.20
EC (mhos)	11.00	12.00	7.00
loss on ignition%	.90	.30	.40
carbon %	.43	.28	.20
TEB m.e. %	.37	.34	.34
CEC m.e. %	3.14	1.43	.82
base saturation %	11.80	23.80	53.90
exchangeable Ca	.21	.20	.30
exchangeable Mg	.10	.10	.10
exchangeable Na	.04	.02	.02
exchangeable K	.02	.02	.02
ESP	1.30	1.40	2.50
EKP	.70	1.40	2.50
available P (ppm)	12.00	4.00	2.00
E/C value	109.30	51.00	29.10
S/C value	12.90	12.10	15.70

PROFILE : CW2, Chigwada, Chiota C.A., Zimbabwe.
site : Upper dambo
date described : 4/3/86
slope : ca. 2%
landuse : Grassland grazing

DESCRIPTION :

0-20cm : Black (7.5YR 2/0) organic sandy loam, strong crumb-cum-block structure, homogenous, many roots, dense organic soil, clear abrupt transition to ...

20-60cm : Dark brown (10YR 4/2) very sandy loam, some roots, weak crumb structure, homogenous, gradual transition to...

>60 cm : Brown (7.5YR 5/2) silty sand, densely packed, homogenous

ANALYTICAL DATA :	CW2A	CW2B	CW2C
depth (cm)	0-20	20-60	>60
texture	CSaL	CS	CS
coarse sand %	23.40	37.10	35.80
medium sand %	19.20	35.40	35.10
fine sand %	9.70	16.80	19.90
coarse silt %	15.80	8.90	7.50
fine silt %	14.00	3.00	3.00
clay %	18.00		
pH (H_2O)	5.80	5.70	5.90
pH ($CaCl_2$)	4.40	4.80	4.90
EC (mhos)	21.00	12.00	11.00
loss on ignition%	11.05	.90	.40
carbon %	4.20	.26	0.00
TEB m.e. %	5.81	.64	.64
CEC m.e. %	9.37	1.43	1.43
base saturation %	61.90	44.80	44.80
exchangeable Ca	3.86	.40	.40
exchangeable Mg	1.46	.20	.20
exchangeable Na	.33	.02	.02
exchangeable K	.15	.02	.02
ESP	3.60	1.40	1.40
EKP	1.60	1.40	1.40
available P (ppm)	14.00	4.00	2.00
E/C value	53.40	51.00	51.00
S/C value	33.10	22.90	22.90

PROFILE : CW3, Chigwada, Chiota, Zimbabwe.
site : Lower dambo zone (upper edge of..)
date described : 4/3/86
slope : ca. 2%
landuse : Grassland grazing

DESCRIPTION :

0-23cm : Black (10YR 2/1) organic sandy loam, many roots, strong crumb structure, fairly distinct transition to...

23-52cm : Brown dark brown, (10YR 4/3) sandy loam, gradual transition to...

>52 cm : Brown (10YR 5/3) silty sand, dense and homogenous

ANALYTICAL DATA :	CW3A	CW3B	CW3C
depth (cm)	0-23	23-52	>52
texture	CS	CS	CS
coarse sand %	35.40	37.60	41.70
medium sand %	28.60	31.70	29.30
fine sand %	13.96	16.96	16.37
coarse silt %	17.24	1.84	10.83
fine silt %	2.00	9.00	3.00
clay %	3.00	3.00	
pH (H_2O)	6.20	6.30	6.50
pH ($CaCl_2$)	4.90	5.00	n.d
EC (mhos)	21.00	12.00	13.00
loss on ignition%	1.93	.50	.10
carbon %	1.27	.21	0.00
TEB m.e. %	2.84	1.00	.88
CEC m.e. %	4.75	1.64	1.02
base saturation %	59.70	61.30	86.30
exchangeable Ca	1.92	.60	.50
exchangeable Mg	.71	.30	.30
exchangeable Na	.10	.06	.06
exchangeable K	.10	.04	.04
ESP	2.10	3.70	5.90
EKP	2.10	2.50	2.00
available P (ppm)	4.00	4.00	4.00
E/C value	167.60	58.30	36.40
S/C value	100.00	35.70	31.40

C) BUMBURWI

PROFILE : Bb1, Bumburwi, Chiota C.A., Zimbabwe.
site : Dryfields, just above dambo margin.
date described : 3/86
slope : 2%
landuse : Scrub grazing

DESCRIPTION :
0-17cm : Dark brown (10YR 3/3) silty loam, loose weak crumb structure, homogenous, clear transition to...
>17cm : Weathered bedrock.

ANALYTICAL DATA :

	Bb1A
depth (cm)	0-17
texture	CS
coarse sand %	26.50
medium sand %	34.30
fine sand %	24.90
coarse silt %	8.50
fine silt %	3.00
clay %	3.00
pH (H_2O)	5.30
pH ($CaCl_2$)	4.20
EC (mhos)	10.00
loss on ignition	1.25
carbon %	.37
TEB m.e. %	.32
CEC m.e. %	1.64
base saturation %	19.60
exchangeable Ca	.10
exchangeable Mg	.10
exchangeable Na	.06
exchangeable K	.06
ESP	3.70
EKP	3.70
available P (ppm)	5.00
E/C value	58.30
S/C value	11.40

PROFILE : Bb2, Bumburwi, Chiota, Zimbabwe.
site : Wash zone at dambo margin
date described : 3/86
slope : 2%
landuse : Scrub grazing

DESCRIPTION :
0-10cm : Very dark greyish brown (10YR 3/2) organic sand, homogenous clear transition to...
10-70cm : Dark greyish brown (10YR 4/2) clayey gravel.

ANALYTICAL DATA :	Bb2A	Bb2B
depth (cm)	0-10	10-70
texture	CLS	CSaL
coarse sand %	28.50	28.00
medium sand %	29.50	25.50
fine sand %	18.37	14.93
coarse silt %	9.63	9.37
fine silt %	7.00	7.00
clay %	7.00	15.00
pH (H_2O)	5.60	6.20
pH ($CaCl_2$)	4.50	4.70
EC (mhos)	25.00	14.00
loss on ignition	2.14	2.78
carbon %	1.09	.52
TEB m.e. %	1.92	2.55
CEC m.e. %	3.12	3.96
base saturation %	61.40	64.50
exchangeable Ca	1.12	1.43
exchangeable Mg	.61	1.02
exchangeable Na	.10	.02
exchangeable K	.08	.08
ESP	3.30	.50
EKP	2.60	2.10
available P (ppm)	7.00	6.00
E/C value	45.00	26.20
S/C value	27.60	16.90

PROFILE : Bb3, Bumburwi, Chiota C.A., Zimbabwe.
site : Upper dambo, seepage zone.
date described : 3/86
slope : 2%
landuse : Grazing, some former field ridges adjacent

DESCRIPTION :

0-20cm : Black (10YR 2/0) silty organic loam, friable blocky, clear transition to...

20-40cm : Dark greyish brown (10YR 4/2) clayey silt, sticky, non-homogenous, indistinct transition to...

>40 cm : Yellowish brown, (10YR 5/6) clay, non-homogenous sticky.

ANALYTICAL DATA :	Bb3A	Bb3B	Bb3C
depth (cm)	0-20	20-40	>40
texture	CSaL	CSaCL	CSaC
coarse sand %	29.00	24.00	18.90
medium sand %	24.10	20.80	13.30
fine sand %	15.90	20.27	8.60
coarse silt %	10.10	3.73	7.90
fine silt %	13.00	9.00	4.00
clay %	8.00	22.00	47.00
pH (H_2O)	6.10	6.00	6.10
pH ($CaCl_2$)	4.50	4.50	4.70
EC (mhos)	10.00	10.00	7.00
loss on ignition	2.83	2.30	n.d
carbon %	1.78	1.06	.58
TEB m.e. %	3.57	3.65	6.57
CEC m.e. %	7.54	5.99	9.60
base saturation %	47.30	60.90	68.40
exchangeable Ca	2.01	1.78	3.17
exchangeable Mg	1.37	1.68	3.17
exchangeable Na	.13	.10	.11
exchangeable K	.06	.08	.11
ESP	1.70	1.80	1.10
EKP	.80	1.40	1.10
available P (ppm)	7.00	5.00	4.00
E/C value	91.50	27.50	20.50
S/C value	43.30	16.70	14.00

PROFILE : Bb4, Bumburwi, Chiota C.A., Zimbabwe.
site : Dambo bottom, 150m above gully head.
date described : 3/86
slope : <1%
landuse : Grassland grazing

DESCRIPTION :

0-15cm : Black (10YR 2/1) organic clay, cohesive, clear transition to...

15-70cm : Black (7.5YR 2/0) clay, sticky cohesive homogenous

ANALYTICAL DATA :	Bb4A	Bb4B
depth (cm)	0-15	15-70
texture	CSaC	C
coarse sand %	18.10	12.90
medium sand %	10.80	10.40
fine sand %	7.35	7.04
coarse silt %	10.75	6.46
fine silt %	17.00	9.00
clay %	36.00	54.00
pH (H2O)	7.00	8.20
pH ($CaCl_2$)	6.00	6.90
EC (mhos)	70.00	90.00
loss on ignition	17.80	5.85
carbon %	4.85	.83
TEB m.e. %	32.80	46.32
CEC m.e. %	38.22	61.91
base saturation %	85.80	74.80
exchangeable Ca	21.63	33.46
exchangeable Mg	10.52	12.23
exchangeable Na	.56	.58
exchangeable K	.09	.05
ESP	1.50	.90
EKP	.20	.10
available P (ppm)	29.00	7.00
E/C value	107.30	114.60
S/C value	92.12	85.80

D) MASIYARWA, ZWIMBA

PROFILE	: Z4, Masiyarwa/Kutama, Zwimba C.A., Zimbabwe.
site	: Dryfields above dambo margin
date described	: 17/3/86
slope	: 2%
landuse	: Rough grazing

DESCRIPTION :

0-35cm	: Dark greyish brown (10YR 4/2) silty loam, loose grained, very weak crumb structure, homogenous, clear transition to...
>35 cm	: Yellowish brown (10YR 5/4) fine sand, some pockets of darker soil.

ANALYTICAL DATA :	Z4A	Z4B
depth (cm)	0-35	>35
texture	CS	CS
coarse sand %	32.00	27.50
medium sand %	33.40	34.00
fine sand %	19.84	21.71
coarse silt %	11.96	11.89
fine silt %	2.00	
clay %	3.00	3.00
pH (H_2O)	5.60	6.00
pH ($CaCl_2$)	4.60	4.90
EC (mhos)	20.00	12.00
loss on ignition	1.20	.10
carbon %	.39	.08
TEB m.e. %	.94	.57
CEC m.e. %	2.25	2.28
base saturation %	41.90	25.00
exchangeable Ca	.70	.41
exchangeable Mg	.10	.10
exchangeable Na	.06	.02
exchangeable K	.08	.04
ESP	2.70	.90
EKP	3.60	1.80
available P (ppm)	5.00	2.00
E/C value	80.10	80.10
S/C value	33.60	20.00

PROFILE	:	Z3, Masiyarwa/Kutama, Zwimba C.A., Zimbabwe.
site	:	Dambo margin, upper wash zone
date described	:	17/3/86
slope	:	2%
landuse	:	Grazing close to maize fields

DESCRIPTION :

0-15cm	:	Very dark grey (10YR 3/1) organic sandy loam, friable crumb-cum-block structure, clear transition to...
15-40cm	:	Dark greyish brown (10YR 4/2) loamy sand, loose grained weak crumb structure, homogenous, clear transition to...
>40 cm	:	Light brownish grey (10YR 6/2) loose sand.

ANALYTICAL DATA :	Z3A	Z3B	Z3C
depth (cm)	0-15	15-40	>40
texture	CS	CS	CS
coarse sand %	34.00	36.10	35.20
medium sand %	31.30	33.90	34.50
fine sand %	15.43	16.73	18.39
coarse silt %	11.67	9.47	10.11
fine silt %	5.00	1.00	3.00
clay %	3.00	3.00	
pH (H_2O)	6.10	6.00	6.00
pH ($CaCl_2$)	5.00	5.30	5.10
EC (mhos)	21.00	25.00	15.00
loss on ignition	2.85	.60	.40
carbon %	1.30	.10	.11
TEB m.e. %	3.32	.54	.54
CEC m.e. %	5.54	3.27	1.02
base saturation %	59.90	16.50	52.90
exchangeable Ca	2.92	.40	.40
exchangeable Mg	.30	.10	.10
exchangeable Na	.04	.02	.02
exchangeable K	.06	.02	.02
ESP	.70	.60	2.00
EKP	1.10	.60	2.00
available P (ppm)	94.00	14.00	6.00
E/C value	196.70	116.60	36.40
S/C value	117.90	19.30	19.30

PROFILE : Z2, Masiyerwa/Kutama, Zwimba C.A., Zimbabwe.
site : Upper dambo
date described : 1/9/86
slope : 2%
landuse : Grassland grazing

DESCRIPTION :

0-17cm : Black (10YR 2/1) organic loam, crumbly homogenous, clear transition to...

17-50cm : Brown (10YR 4/3) silty loam, homogenous fine crumb structure, clear transition to...

50-65cm : Greyish brown (10YR 5/2) homogenous sand.

ANALYTICAL DATA :	Z2A	Z2B	Z2C
depth (cm)	0-17	17-50	50-65
texture	MSaL	MLS	CS
coarse sand %	7.20	14.10	50.37
medium sand %	22.90	27.40	32.91
fine sand %	29.33	33.13	3.97
coarse silt %	14.27	15.37	3.91
fine silt %	13.00	5.00	3.60
clay %	13.00	5.00	5.24
pH (H_2O)	5.80	5.90	6.50
pH ($CaCl_2$)	4.00	4.30	4.40
EC (mhos)	17.00	10.00	12.00
loss on ignition	6.56	1.22	2.30
carbon %	2.12	.35	.33
TEB m.e. %	1.75	.57	1.00
CEC m.e. %	5.25	2.70	3.20
base saturation %	33.30	21.10	32.00
exchangeable Ca	1.24	.30	.70
exchangeable Mg	.10	.10	.20
exchangeable Na	.37	.14	.16
exchangeable K	.04	.02	.02
ESP	7.10	5.30	5.00
EKP	.80	.80	.60
available P (ppm)	8.00	5.00	3.00
N (ppm) initial	n.d.	n.d.	4.00
N (ppm) after inc	n.d.	n.d.	4.00
E/C value	39.80	55.20	61.10
S/C value	13.30	11.70	19.10

PROFILE : Z1, Masiyarwa/Kutama, Zwimba C.A., Zimbabwe.
site : Dambo bottom, 15m above gully
date described : 1/9/86
slope : ca.1 %
landuse : Grassland grazing

DESCRIPTION :

0-27cm : Black (10YR 2/1) organic clayey loam, fine crumb structure, homogenous, clear gradual transition to...

27-52cm : Greyish brown (10YR 5/2) silty loam, weak crumb structure, clear irregular transition to...

52-70cm : Grey (10YR 5/1) and Dark yellowish brown (10YR 4/6), two distinct colours, sticky clay.

ANALYTICAL DATA :	Z1A	Z1B	Z1C
depth (cm)	0-27	27-52	52-70
texture	FSaCL	MSaL	CSaCL
coarse sand %	1.00	12.35	25.56
medium sand %	5.70	29.99	16.96
fine sand %	21.64	14.58	10.63
coarse silt %	19.16	18.12	9.11
fine silt %	21.00	18.71	8.82
clay %	32.00	8.25	28.92
pH (H_2O)	6.10	6.20	6.00
pH ($CaCl_2$)	4.50	4.80	4.80
EC (mhos)	29.00	21.00	15.00
loss on ignition	8.87	2.30	6.70
carbon %	2.23	.29	.33
TEB m.e. %	7.87	2.60	10.80
CEC m.e. %	11.01	3.50	10.80
base saturation %	71.50	73.00	100.00
exchangeable Ca	5.50	1.50	8.00
exchangeable Mg	1.66	.50	2.60
exchangeable Na	.60	.46	.57
exchangeable K	.10	.08	.10
ESP	5.50	13.10	5.30
EKP	.90	2.30	1.00
available P (ppm)	11.00	4.00	2.00
N (ppm) initial	n.d.	5.00	3.00
N (ppm) after inc	n.d.	5.00	4.00
E/C value	34.40	42.40	37.40
S/C value	24.60	31.50	37.40

E) SHUMBAIRERWA, GUTU

PROFILE : GM2d, Shumbairerwa, Gutu C.A., Zimbabwe.
site : Dryfields, above dambo
date described : 11/3/86
slope : 2%
landuse : Maize field

DESCRIPTION :

0-12cm : Dark yellowish brown (10YR4/4) sandy loam, crumbly slightly cohesive, homogenous, clear transition to...

12-40cm : Yellowish brown (10YR 5/6) sandy loam, weak block/crumb structure,
homogenous, clear transition to...

>40cm : Yellowish brown (10YR 5/4) stony weathered bedrock.

ANALYTICAL DATA :	GM2d/A	GM2d/B
depth (cm)	0-12	12-40
texture	CS	CS
coarse sand %	38.40	37.30
medium sand %	24.90	27.10
fine sand %	16.80	17.68
coarse silt %	12.20	11.22
fine silt %	5.00	4.00
clay %	3.00	3.00
pH (H_2O)	5.10	5.50
pH ($CaCl_2$)	4.30	4.30
EC (mhos)	35.00	11.00
loss on ignition	.91	.45
carbon %	.41	.12
TEB m.e. %	.72	.60
CEC m.e. %	2.67	2.67
base saturation %	27.10	22.60
exchangeable Ca	.50	.30
exchangeable Mg	.10	.20
exchangeable Na	.04	.04
exchangeable K	.08	.06
ESP	1.50	1.50
EKP	3.00	2.30
available P (ppm)	62.00	6.00
E/C value	94.70	94.70
S/C value	25.70	21.40

PROFILE : GM2c, Shumbairerwa, Gutu C.A., Zimbabwe.
site : Dambo margin
date described : 11/3/86
slope : ca. 2%
landuse : Maize field

DESCRIPTION :

0-25cm : Dark grey (10YR 4/1) organic sandy loam, loose grained, weak crumb structure, homogenous, clear transition to...

>25 cm : Greyish brown (10YR 5/2) silty sand, homogenous, very loose texture. Water table too high to continue

ANALYTICAL DATA :	GM2c/A	GM2c/B
depth (cm)	0-25	>25
texture	CLS	CLS
coarse sand %	37.10	40.00
medium sand %	23.80	23.80
fine sand %	19.31	13.79
coarse silt %	10.09	9.61
fine silt %	4.00	2.00
clay %	7.00	11.00
pH (H_2O)	6.00	6.30
pH ($CaCl_2$)	4.70	5.00
EC (mhos)	20.00	16.00
loss on ignition	1.31	1.56
carbon %	.51	.21
TEB m.e. %	1.81	1.91
CEC m.e. %	2.88	4.14
base saturation %	62.80	46.10
exchangeable Ca	.91	1.12
exchangeable Mg	.40	.71
exchangeable Na	.20	.04
exchangeable K	.30	.04
ESP	6.90	1.00
EKP	10.00	1.00
available P (ppm)	7.00	7.00
E/C value	41.00	37.80
S/C value	25.90	17.40

PROFILE : G7, Shumairerwa, Gutu C.A., Zimbabwe
site : Upper dambo
date collected : 1/86
slope : ca. 2%
landuse : grassland grazing

(no profile recorded)

ANALYTICAL DATA :	G7/A	G7/B
depth (cm)	0-ca.25	>25
texture	CSaL	CSaCL
coarse sand %	26.40	29.00
medium sand %	15.70	13.80
fine sand %	16.81	9.57
coarse silt %	10.79	9.33
fine silt %	15.00	4.00
clay %	15.00	34.00
pH (H_2O)	5.90	6.50
pH ($CaCl_2$)	4.80	5.20
EC (mhos)	30.00	17.00
loss on ignition	4.05	3.04
carbon %	1.41	.32
TEB m.e.	4.07	6.10
CEC m.e. %	5.21	7.69
base saturation %	78.00	79.20
exchangeable Ca	2.45	3.77
exchangeable Mg	1.33	1.99
exchangeable Na	.22	.31
exchangeable K	.06	.02
ESP	4.30	4.10
available P (ppm)	7.00	4.00
E/C value	34.50	22.40
S/C value	26.90	17.70

PROFILE : GM2b, Shumbairerwa, Gutu C.A., Zimbabwe.
site : Lower dambo
date described : 11/3/86
slope : Almost flat
landuse : Seasonal grassland grazing

0-25cm : Very dark greyish brown (10YR 3/2) organic sandy loam, dense cohesive, some crumb, homogenous, clear transition to...

25-30cm : Dark greyish brown (10YR 4/2) silty loam, dense, homogenous, clear transition to...

>30 cm : Grey (10YR 5/1) clay with coarse sand and gravel, dense cohesive.Ferricrete pockets evident in these two layers.

ANALYTICAL DATA :	GM2b/A	GM2b/B	GM2b/C
depth (cm)	0-25	25-30	>30
texture	CSaL	CLS	CSaC
coarse sand %	36.80	32.80	21.80
medium sand %	17.70	20.30	22.50
fine sand %	14.94	21.54	10.03
coarse silt %	13.66	12.66	9.97
fine silt %	8.00	6.00	6.00
clay %	9.00	7.00	42.00
pH (H_2O)	6.80	7.10	8.50
pH ($CaCl_2$)	5.10	5.30	6.80
EC (mhos)	30.00	24.00	110.00
loss on ignition	2.38	.92	5.37
carbon %	.88	.48	.58
TEB m.e. %	4.09	1.76	18.94
CEC m.e. %	5.82	2.47	23.62
base saturation %	70.40	71.10	80.20
exchangeable Ca	2.55	1.01	7.83
exchangeable Mg	1.12	.51	6.76
exchangeable Na	.41	.22	4.29
exchangeable K	.02	.02	.06
ESP	7.00	9.00	18.20
EKP	.40	.80	.30
available P (ppm)	6.00	7.00	7.00
E/C value	64.90	36.00	56.80
S/C value	45.70	25.60	45.50

PROFILE : GM2a, Shumbairerwa, Gutu C.A., Zimbabwe.
site : Lower dambo
date described : 11/3/86
slope : Almost flat
landuse : Seasonal grassland grazing

DESCRIPTION :

0-18cm : Very dark greyish brown (10YR 3/2) organic sandy loam, strong crumb structure, homogenous, clear transition to...

18-30cm : Dark greyish brown (10YR 4/2) sandy silty loam, slightly sticky, rust specks, dense non-homogenous, variable clear transition to...

30-40cm : Dark yellowish brown (10YR 4/6) sticky clay, with grey patches, dense, homogenous, variable clear transition to...

40-85cm : Grey (10YR 5/1) clay with some coarse sand, dense, fairly homogenous.

ANALYTICAL DATA :	GM2a/A	GM2a/B	GM2a/C	GM2a/D
depth (cm)	0-18	18-30	30-40	40-85
texture	CLS	CLS	CSaC	CSaC
coarse sand %	41.30	45.80	28.00	22.80
medium sand %	20.10	17.20	9.60	9.90
fine sand %	12.58	11.43	6.02	7.15
coarse silt %	11.32	11.87	6.58	19.55
fine silt %	6.00	5.00	4.00	5.00
clay %	9.00	9.00	46.00	36.00
pH (H_2O)	6.50	5.00	6.70	8.80
pH ($CaCl_2$)	4.60	4.50	5.10	7.20
EC (mhos)	20.00	300.00?	25.00	150.00
loss on ignition	1.72	.63	3.98	3.45
carbon %	.80	.48	.23	.24
TEB m.e. %	2.21	2.62	11.76	53.83
CEC m.e. %	3.10	3.09	15.29	16.73
base saturation %	71.20	85.00	76.90	100.00
exchangeable Ca	1.22	.81	3.96	41.74
exchangeable Mg	.71	.71	6.53	10.30
exchangeable Na	.24	.30	1.22	1.62
exchangeable K	.04	.81	.04	.17
ESP	7.80	9.80	8.00	9.70
EKP	1.30	26.10	.30	1.00
available P (ppm)	5.00	5.00	5.00	6.00
E/C value	34.80	34.80	33.40	46.50
S/C value	24.80	29.50	25.70	46.50

APPENDIX 5: SOIL EROSION STUDY DATA

a) SLEMSA CALCULATIONS

DRY FIELD SLEMSA (applied to Chizengeni erosion plots)

Erosivity :

17,000 J/m 2 - main annual rainfall, Grasslands (863 mm)

18,000 J/m 2 - recorded rainfall, Chizengeni, 1985-86 (941 mm)

Fb : = 6G Top Soil texture = A (sand)

= (4,5)

Fm : EP5 : = >3 years fallow

= (6,5)

EP6 : = Conventional tillage, no ridging, level ploughing

= (4,5)

L = 10 m (+30 m) [plot + normal]

S = 1.75% (EP5), 1.83% (EP6)

EP6 i = Emergence 15th November, yield 500 - 1000 kg/ha maize.

= 15-20% crop cover

EP5 i = weed fallow

= 93% crop cover. [in fact observations show much lower figure for start of rain; ~50%]

	EP5		EP6	
	(plot condition)	(normal condition)	(plot)	(normal)
Derived parameters:				
K (soil loss)	35t/ha	(25t/ha)	120t/ha	(95t/ha)
X (slope factor)	0.23	(0.35)	0.23	(0.35)
C (crop factor)	0.05	-	0.3-0.4	-
Z	0.40t/ha	(0.44t/ha)	8.3-11.0	(10.0-13.3)
actual observed	0.27t/ha		0.71t/ha	
	[1.5x]		[12x - 15.5x]	

DAMBO SLEMSA (applied to Chizengeni erosion plots)

Erosivity:

17,000 J/m ^{2}: m.a. rainfall, Grasslands (863 mm)

18,000 J/m ^{2}: recorded rainfall, Chizengeni, 1985-86 (941 mm)

Fb = 6C/6E : Top soil texture : Sand (A)

No specific data but range = 4.0 - 5.5

Fm = EP1 + EP4 = 6.0 - 7.5

EP2 (0.5 for rough tilth : -0.5 for irrigation)

= 4.0 - 5.5

EP3 = 4.0 - 5.5

L = 10 m (+30 m) [plot + normal]

S = ~2% [EP1 = 1.94%

EP2 = 2.27%

EP3 = 1.52%

EP4 = 2.28%]

i = EP1 + EP4 = grazing land

= 70 - 90%

EP2 (maize field; emergence 1-15 September, yield 2000-4000 kg/ha)

= 24 - 38%

EP3 (weed fallow; 1st year fallow)

= est. ~50%

	EP1/4		EP2		EP3	
	(plot)	(normal)	(plot)	(normal)	(plot)	(normal)
Derived parameters:						
K (soil loss)	20-45t/ha	(15-30)	65-165	(45-135)	65-165	(45-135)
X (slope factor)	0.25	(0.40)	0.3	(0.45)	0.3	(0.45)
C (crop factor)	0.05	-	0.10-0.24		0.05	
Z	0.25-0.56t/ha	(0.3-0.6)	1.95-11.88	(2.0-14.6)	1.0-2.5t/ha	(1.0-3.0)
actual observed	0.05-0.14t/ha [5x - 4x]		0.36t/ha [5x - 33x]		0.18t/ha [5x - 14x]	

b) EROSION PLOT RESULTS

Monthly data from plots on Chizengeni catchment, Chiota Communal Area Zimbabwe for the season 1985/86

PLOTS			Nov	Dec	Jan	Feb	Mar/Apr	Total
DAMBO	Slope	Yield						
1	1.9%	g/plt	213	36	258	138	59	704
Grazing		*t/ha	0.04	0.05	0.10	0.13	0.14	0.14
2	2.3%	g/plt	145	675	683	150	141	1794
Maize		*t/ha	0.03	0.16	0.30	0.33	0.36	0.36
3 Weed	1.5%	g/plt	337	227	208	85	59	916
Fallow		*t/ha	0.07	0.11	0.15	0.17	0.18	0.18
4	2.3%	g/plt	77	54	60	39	41	271
Grazing		*t/ha	0.02	0.03	0.04	0.05	0.05	0.05
NON-DAMBO								
5 Scrub	1.8%	g/plt	203	298	421	347	105	105
Grazing		*t/ha	0.04	0.10	0.18	0.25	0.27	0.27
6	1.8%	g/plt	224	555	1469	933!	369	369
Maize		*t/ha	0.04	0.16	0.45	0.64	0.71	0.71

* cumulative totals ! Estimate

g/plt = grammes per plot

APPENDIX 6: EVAPOTRANSPIRATION CALCULATIONS

REFERENCE CROP EVAPOTRANSPIRATION (ETo) CALCULATIONS

The reference crop evapotranspiration is defined as "the rate of evapotranspiration from an extensive surface of 8 to 15 cm tall, green grass cover of uniform height, actively growing, completely shading the ground and not short of water" (FAO Paper 24).

The reference crop evapotranspiration calculations were carried out by three methods, described in our text as:

- the FAO 24 method
- the Penman method
- the Pan method

The basic form of the FAO 24 method and the Penman method is:

ETo = c(W.Rn + (1-W).f(u).(ea-ed))

where ETo is the reference crop evapotranspiration in mm/day
c is an adjustment factor for day/night conditions
W is a temperature related weighting factor
Rn is net radiation expressed in mm/day
f(u) is the wind function
(ea-ed) is the vapour pressure term in mb

FAO paper 24 describes in detail how to use this method referred to in our text as the FAO 24 method. It is, in fact a modification of the original Penman method. A computer programme was developed to calculate ETo values. A copy of the programme is included in the Apendix. It was developed to run on BBC Basic.

The Penman method , as mentioned in our text, involves changes to both the wind function and the radiation term of the FAO 24 method. The original Penman wind function is used which is compared below with the FAO 24 wind function:

f(u) = 0.27(1 + 0.01xU) FAO 24
f(u) = 0.26(1 + 0.0062xU) Penman

where U is the daily wind run in km.

The net radiation, Rn is the algebraic sum of of net shortwave and net longwave radiation:

Rn = Rns - Rnl
where Rns = Rs (1 - α) and α is taken as 0.25.
and Rnl = f(T).f(ed).f(n/N)

The Glover McCulloch radiation term is used in the evaluation of the incident shortwave solar radiation at the earth's surface Rs. It compares with the FAO 24 method as follows:

Rs = Ra(0.25 + 0.50 x n/N) FAO 24

Rs = Ra(0.29 cos 'Latd' + 0.52 x n/N) Penman (Glover McCulloch)

where Ra is the extra terrestrial radiation (mm/day)
n is the actual hours of sunshine
N is the maximum possible hours of sunshine
Latd is the latitude of the site

The long wave radiation term consists of a temperature function, f(T); a sun hours function, f(n/N); and a vapour pressure function, f(ed). The original Penman and the FAO 24 method differ only in the vapour pressure function, f(ed), as follows :

f(ed) = (0.34 - 0.044x√(ed)) FAO 24

f(ed) = (0.56 - 0.08x√(ed)) Penman (Brunt)

where ed is the actual vapour pressure.

The Pan method is the method described in FAO paper 24, where

ETo = kp. Epan

where Epan is the evaporation in mm/day from a pan
kp is the pan coefficient

This coefficient is 0.75 for the months June to November at the site in Chizengeni, Chiota, Zimbabwe and was increased by 10% to 0.83 in the month of May to take into account the effects of the tall grass surrounding the site at that time. In addition an extra 10% was added to the raw data to allow for the wire mesh screen that was on the Class A pan at Chizengeni.

THE DREAM METHOD OF CALCULATING ACTUAL EVAPOTRANSPIRATION

The DREAM method (Direct Reading Evapotranspiration Assessment Monitor) is based on the energy balance at the earth's surface (Faulkner and Evans, 1981).

Neglecting small terms such as photosynthesis, the energy balance can be expressed by the equation:

$$Rn = H + Le + G \qquad (1)$$

where Rn is the net radiation, H is the sensible heat transfer between the earth's surface and the air, L is the latent heat of vaporisation, e is evaporation and G is the heat flux in the surface layer of the ground. (In this context evaporation refers both to direct evaporation and transpiration through plants).

Net radiation and ground heat flux may be measured directly and L is known. In order to evaluate the amount of evaporation it is necessary to measure 'H', the sensible heat transfer between surface and air. However H is very difficult to measure directly but may be evaluated using the Bowen ratio:

$$B = H / Le \qquad (2)$$

Substituting in (1) we get the equation:

$$e = (Rn - G) / L(1 + B) \qquad (3)$$

The Bowen ration, B, may be evaluated as follows:

$$B = y\, dT/dq \qquad (4)$$

where y is the psychometric constant and is known, dT is the temperature gradient above the crop surface and dq is the specific humidity gradient above the crop surface.

In order to evaluate the temperature and humidity gradients above the crop surface accurate measurements of wet and dry bulb temperatures at and above the crop surface are necessary.

Therefore the actual evaporation, e, may be evaluated from the measurement of four parameters, net radiation, heat flux in the ground surface, and wet and dry bulb temperatures at crop surface and 0.5 - 1.0m above it.

PROBLEMS

Aside from operational problems with the instrumentation the most serious problem was in the evaluation of the wet bulb temperatures. Ideally an aspirated wet bulb thermometer should be used. However the package of instruments that we were using included only non-aspirated wet bulb thermometers. Thus in conditions of high wind this could lead to some errors due to the velocity gradient above the crop. However in Zimbabwe wind speeds are generally low.

The instrumentation included a microprocessor which acted as a data logger and processor. The microprocessor was directly linked to all the instruments. However the microprocessor was unreliable , which meant that data had to be logged by hand and analysed later on. The microprocessor had to be brought into the office to print out the results which limited its flexibility in the field.

It was clear from our experience with these instruments that future field work using this method would be far better served by a suite of instruments that could be read directly with analysis of the results being done later on in the office. Accurate dry and aspirated wet bulb thermometers could be used with the net radiation and the heat flux being measured seperately and directly using integrating voltmeters.

In field situations such as those experienced in this project the instruments will need supervision by an attendant. Choosing and training a suitable attendant or technician would solve the supervision and data logging problems in one step.

Despite these problems we believe that we obtained useful data on comparative actual evapotranspiration rates on dambos and their catchment. However there is no doubt that much more work could be done in this area.

APPENDIX 7: PROJECT PUBLICATIONS

Project Reports

Interim Reports to the Overseas Development Administration:

Number 1, October 1984

Number 2, January 1985

Number 3, September 1985

Number 4, June 1986

Number 5, November 1986

Utilisation of Dambos in Rural Development , Discussion Document prepared by the Dambo Research Unit, April 1987.

Published Articles

Bell, M. and Roberts, N 1986 Development theory and practice in human and physical geography. *Area* 18, 3-8.

Drive to develop dambos 1986 *World Water* March, 13.

Hotchkiss, P. and Bell, M. (in press) *Dambo resource use in Zimbabwe* . Paper presented at the 13th WEDC Conference, Malawi, 7-10 April, 1987.

Lambert, R. et al (in press) *Micro-scale irrigation in Africa* . Paper presented 13th WEDC Conference, Lilongwe, Malawi, 7-10 April, 1987.

Lambert, R. 1987 Rope-pump whips dambo drought. *World Water* , May 35-37.

Roberts, N. (in press) Dambos in development: management of a fragile ecological resource. *Journal of Biogeography* .

Windram, A.F. 1983 Small sources have a large potential. *World Water* , June, 36-37.

Windram, A.F. et al 1985 *The use of dambos in small scale rural development* . Proceedings of the 11th WEDC Conference, Dar es Salaam, Tanzania, 15-19 April, 114-117.

Published References to the Project

Consider alternatives to conventional irrigation *The Farming Gazette* , Zimbabwe, 3 October, 1987.

Varsity develops low-cost device for drawing water *Sunday Mail* , Zimbabwe, October, 1986.

Vital for government to realise that vlei-land is an important resource and can be cultivated carefully *The Farming Gazette* , Zimbabwe, 8 May, 1987.

Workshop and Conference Papers

Bell, M., Faulkner, R.D. and Roberts N. 1986 The use of dambos in small scale irrigation. Paper presented to the Meeting of the Institution of Civil Engineers Appropriate Development Panel on Small Scale Irrigation, 15 May.

Hotchkiss, P. and Bell, M. 1986 Dambo cultivation in Zimbabwe: the need for a coherent policy. Paper presented to Seminar on Irrigation Policy in Kenya and Zimbabwe, Harare, April.

Hotchkiss, P. 1986 Socioeconomic aspects of dambo cultivation. Paper presented at Workshop on Dambo Utilisation in Zimbabwe, University of Zimbabwe, 7-8 August.

Hotchkiss, P., Lambert, R. and Roberts, N. 1986 The use of dambos in Zimbabwe's communal areas. Report of a Workshop held at the Univerity of Zimbabwe, 7-8 August.

Lambert, R. 1986 Ecological and practical aspects of dambo cultivation: preliminary findings. Paper presented at Workshop of Dambo Utilisation in Zimbabwe, University of Zimbabwe, 7-8 August.

Lambert, R. and Hotchkiss, P. 1987 Shallow groundwater for micro-scale irrigation. Paper presented to seminar on Irrigation Policy in Kenya and Zimbabwe, Nyanga, Zimbabwe, May.

Windram, A.F. 1987 Alternatives to conventional smallholder irrigation. Paper presented at the African Water Technology Conference, Nairobi, Kenya, 24-26 February.