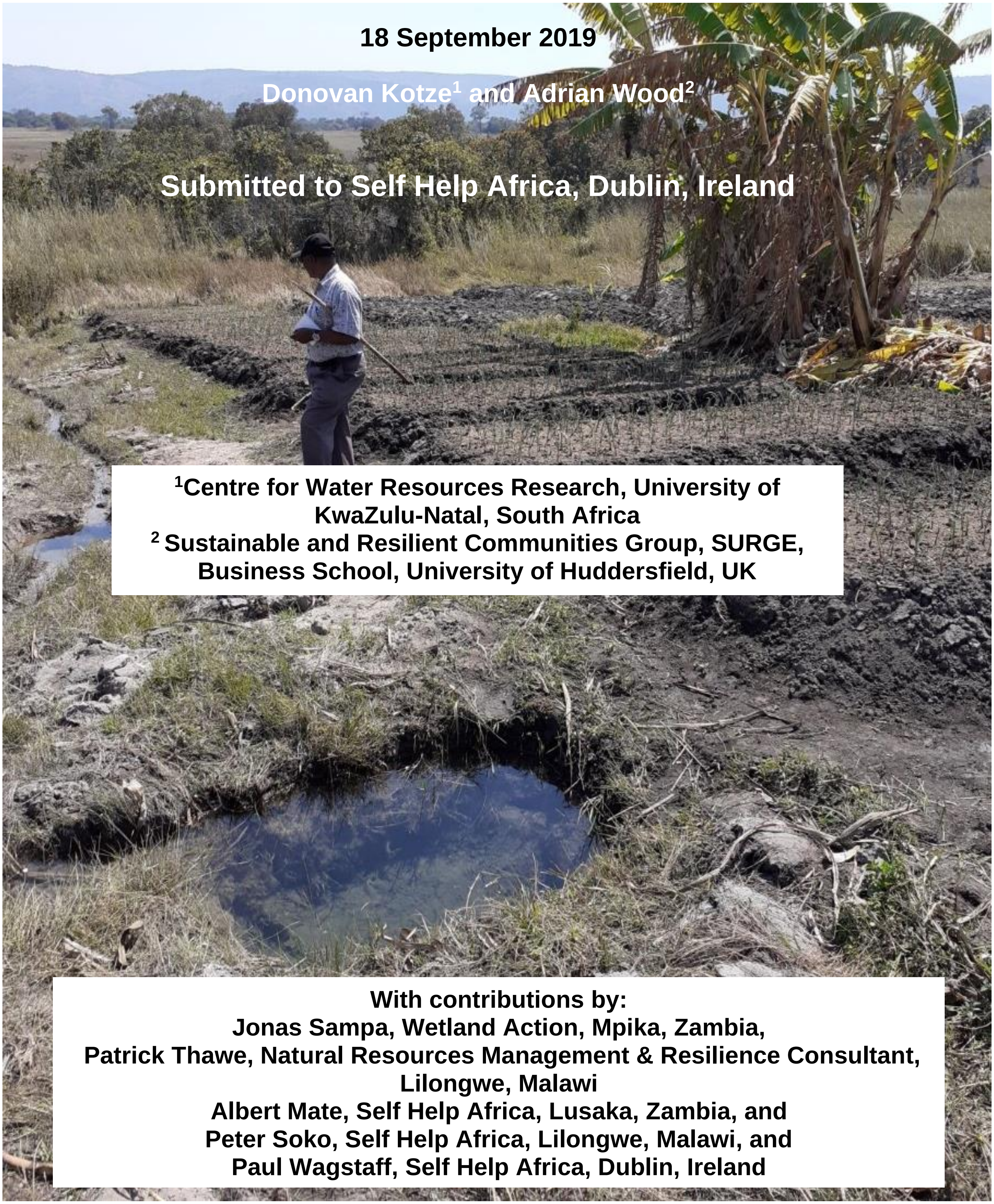
An assessment of the sustainability of use of selected dambos in the Mpika District, Zambia and Kasungu District, Malawi



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Cover Photograph: shows observations being made by Albert Mate of ridges cultivated with onions and hand-watering "stations", which reveal the currently high water table on this seepage slope of the Mwansabamba dambo

Executive summary

Setting

Dambos, which are seasonally waterlogged wetlands at or near the head of valleys, have long played a critical role in the livelihoods of many people across Africa's tropical savannas. The Striking a Balance (SAB) project was undertaken in selected wetlands in Malawi and Zambia from 2006 to 2008 to explore how to reconcile the growing demands of local people - in terms of wellbeing and livelihoods through using the provisioning services of dambos, and the long-term ecological health and other ecosystem services of these areas. Central to the project was the Functional Landscape Approach (FLA) which promotes sustainable land management practices with a perspective that links catchments and wetlands, and proposes local institutions and bylaws for managing these areas.

Methods and Purpose

In July 2019 the WET-SustainableUse method was applied to four dambos where the Striking the Balance project had been active between 2006 and 2008 and which had been assessed with WET-SustainableUse in 2008 (Kotze et al., 2008; Kotze, 2009). Two of the wetlands, Chikakala and Mwansabamba, were in Mpika district, northern Zambia and the other two, Katema and Chiotha, were in the Simlemba Traditional Authority of Kasungu district in central Malawi. These dambos represent a diversity of hydrogeomorphic settings as well as varying with respect to land-cover (Table ES1).

Table ES1: Key biophysical features and key land-cover trends of the four dambos and their catchments

Dambo name	**HGM (Hydrogeomorphic) setting of the dambo**	**Dambo size (ha)**	**% of the dambo currently cultivated[1]**		**% of dambo under natural vegetation**		**% of dambo's catchment under natural vegetation**	
			2008	**2019**	**2008**	**2019**	**2008**	**2019**
Chikakala	Lateral seepage grading gradually into a valley bottom (predominantly unchanneled)	254 ha	2%	3%	87%	82%	39%	35%
Mwansa-bamba	As above, but valley bottom predominantly channeled and located somewhat downstream of the headwaters	369 ha	2%	6%	88%	76%	30%	25%
Katema	Lateral seepage grading gradually into a valley bottom (predominantly unchanneled) located in the headwaters	33 ha	29%	26%	45%	36%	24%	29%
Chiotha	Valley bottom, channeled in the uppermost and lowermost portions but predominantly unchanneled, located well downstream of the headwaters	17 ha	23%	22%	42%	40%	28%	19%

[1]This excludes fallow lands and old abandoned lands, which after accounting for natural vegetation, generally make up most of the remaining area of the dambo.

The primary purpose of the study reported here is to describe the current ecological health of the dambos based on the WET-SustainableUse assessment and assess how this compares with the baseline assessment at the end of the SAB project in 2008. It also sought to identify potential drivers influencing the observed ecological health trends. This study contributes a number of reflections on the long-term impacts of the Striking a Balance project. The report focuses particularly on the impact of cultivation as this is the primary use made of all four of the dambos. Sustainability is widely recognized to encompass both an environmental and social/institutional dimension. Thus, the investigation of ecological sustainability was complimented by a summary assessment of the social/institutional sustainability of the management of the four dambos. The study involved one day of extensive fieldwork with two or more knowledgeable local farmers within most areas of each dambo for field observations and assessments, as well as ground truthing for the remote sensing images. A second day involved focus group discussions with community groups of between 10 and 20 people including both men and women. The study also drew on previous investigations of these sites from the SAB Project period and subsequently (Dixon & Carrie, 2015; McElwee & Wood, 2017; Mbewe & Sampa, 2018).

Findings

The results of the ecological health assessment (Table ES2) show that for Chikakala (Zambia) and Katema (Malawi) dambos there was only a slight decline in ecological health from 2008 to 2019, in Mwansabamba (Zambia) the decline was somewhat greater, and in Chiotha (Malawi) ecological health was fractionally improved. In all cases the overall impacts of wetland cultivation were small or moderate and the overall health of the wetlands has remained in category B in the two cases in Zambia and category C in the two cases in Malawi. This suggests that adoption of dambo cultivation when undertaken along with the guidance generated by the SAB project appears to have promoted a sustainable route for livelihood development which does not have highly negative environmental impacts and can be continued. However, some key considerations were identified as possible threats to the long-term sustainable use of the dambos in the future and these need to be given due consideration in the guidance for wetland-using communities (See below).

Of the five components of ecological health which were assessed, vegetation is the component most severely affected by cultivation across all dambos, followed by hydrology and then soil organic matter accumulation (Table ES2). The geomorphology (sediment / erosion) component was least impacted with minimal erosion noted except for the Chiotha dambo, which had a significantly greater extent of erosion than the other three wetlands, but this extent has remained unchanged from 2008 to 2019.

Table ES2: Summary of the ecological health of the four dambos, assessed on a scale of 0 (critical) to 10 (pristine) and with the ecological health category represented on a scale of A (Pristine) to F (Critical)

Components of ecological health	**Chikakala**		**Mwansabamba**		**Katema**		**Chiotha**	
	2008	**2019**	**2008**	**2019**	**2008**	**2019**	**2008**	**2019**
Hydrology	8.79	8.53	8.66	7.94	6.95	6.63	6.77	6.52
Sediment accumulation/ erosion	9.74	9.71	9.63	9.41	9.33	9.41	7.62	7.72
Soil organic matter accumulation	8.70	8.62	8.70	8.28	7.32	7.30	7.30	7.56
Nutrient cycling	9.65	9.55	9.64	9.20	8.22	8.22	7.91	8.08
Vegetation	7.33	7.07	7.38	6.77	4.72	4.30	4.54	4.52
OVERALL	**8.84**	**8.68**	**8.79**	**8.28**	**7.27**	**7.12**	**6.82**	**6.85**
Ecological health category (A - F)	B	B	B	B	C	C	C	C

In terms of the institutional aspects of this study, the main findings are that while the Village Natural Resource Management Committees (VNRMCs) are not continuing in the form they were established and with the membership and frequency of meeting as originally envisaged, there are elements of the SAB project's guidance still present in these communities. In particular, many of the people most engaged in wetland farming remember and seek to apply some of the byelaws which were developed through the SAB project. Further, while the VNRMC still exists in only one village, in two others its work has been incorporated into the Village Development Committee where it can perhaps be sustained more easily. In the other case, while there is now no VNRMC, the need for some such coordination was recognized in the village focus group meeting.

A key issue for the institutional arrangements for managing the wetlands and the catchments in a coordinated manner is the economic perspective. Here it can be noted that there is a need for wetlands to continue to generate economic benefits for the majority of the community which make households want to sustain production by coordinating land use management of the wetlands and their catchments. However, as wetland use often leads to differentiation in communities a question arises as to how community cohesion can be achieved in this situation. A further area of concern is the apparent limited recognition by farmers of the potential for negative environmental scenarios with wetland cultivation due to the fragility of these areas and the resource degradation processes which can occur.

Recommendations

This study confirmed that the key recommendations of the SAB Project made in 2008 (Table ES3), which are the cornerstones of functional landscape approach (FLA), are relevant today for maintaining the ecological health of dambos. The way in which this guidance has contributed to the ecological health scores for the diverse dambo types studied, provides further confirmation that the key SAB / FLA recommendations are likely to be applicable across a wide range of dambos in continued work by Self Help Africa with wetland-using communities and smallholder farmers using dambos in Malawi and Zambia.

Table ES3: Key Recommendation from the Striking a Balance Project (2008)

1.	Confine cultivation in the dambo to mainly during the dry season
2.	Maintain the central areas of the dambo under natural vegetation
3.	Maintain extensive areas (preferably >50%) of the dambo under natural vegetation
4.	Maintain a buffer of natural vegetation around the dambo
5.	Practice crop rotation
6.	Limit cultivation of crops with high water demand, e.g. sugar cane
7.	Use manure/compost in preference to mineral fertilizer
8.	Include soil-building crops in the cultivated areas
9.	Avoid over-drainage
10.	Prohibit eucalyptus trees in and near the dambo

However, this study found that it would be useful to take note of six additions to the specific SAB guidelines (Table ES4).

Table ES4: Additional Recommendations based on 2019 Field Assessment

a.	Avoid burning of very organic rich soils
b.	As far as possible reduce tillage of cultivated dambo plots, but recognizing the problems of applying minimum tillage in waterlogged soils
c.	"Invest" in fallow areas to promote soil recovery, but recognizing that where the extent of dambo cultivation is high then opportunities for fallows will be very limited
d.	Maintain a buffer of natural vegetation upstream of erosion features, such as headcuts
e.	Avoid the use of biocides adjacent to streams and wells, especially ones used for domestic water
f.	As far as possible use crop types and varieties with tolerance of waterlogging

A detailed review of these recommendations listed above shows that they are largely being applied at the four sites (Table 6.3) and that they seem to be generally well internalized amongst the dambo farmers involved in the 2019 discussion groups. However, they need to be transferred to new entrant dambo farmers.

Applying these recommendations in the light of the institutional situation encountered suggests that communities need to consider how best through their existing Village Development Committees guidance can be agreed and sanctions enforced based on an enhanced understanding of the natural resource scenarios probable in specific wetlands, the potential economic benefits and trade-offs between these.

Overall, it may be concluded that wetland farming – as seen in the four sites studied, has moderate impacts on the ecological health of these areas, and that this need not progress to cause serious degradation of these resources provided appropriate guidance is followed. The livelihood benefits from this farming are considerable and these resources have an important role to play both in substantially addressing food security in the face of climate change and also generating capital for enterprise diversification.

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1. Background and introduction

Over much of sub-Saharan Africa, people are directly dependent on wetlands for many elements that make up their livelihoods. With rural population growth and land and water resources becoming increasingly scarce, the pressure placed on wetland ecosystems is increasing. Thus, the need is great for reconciling the demands of local people in terms of access to ecosystem services to support wellbeing and livelihoods, while at the same time not compromising the long-term ecological health of the wetlands on which they depend (Acres et al. 1985; Rebelo et al. 2010). In response to this need, the Striking a Balance project was undertaken in selected wetlands in Malawi and Zambia in order to promote sustainable management of the full range of ecosystem services[1] which help reduce poverty, improve food security and maintain environmental functioning and biodiversity (Wood 2008). The project sought to do this through the Functional Landscape Approach (FLA) which promotes sustainable land management practices in a linked unit comprising catchments and wetlands, and with local institutions (and bylaws) developed for managing these areas together (Wood 2008).

Dambos, seasonally waterlogged wetlands, usually treeless, at or near the head of a drainage network, are widespread across Africa's tropical savannas (Whitlow 1989). The direct use of dambos by subsistence farmers has traditionally played a critical role in the livelihoods of local populations (Acres et al. 1985) and researchers have long recognized the underutilized potential that dambos have for supporting cultivation. For example, Trapnell (1953) notes that although the dambos in Wisa, Lala and Livingstone are cultivated, the opportunities for cultivation offered by the humic dambo soils are "by no means completely utilized in many areas" (Trapnell, 1953: para 346). Trapnell (1953) refers to *Fisebe* gardens which are made on peaty seepage soils for maize, beans and minor crops, suggesting that they deserve careful study and encouragement. "They are of great value as sources of food in the hunger months before the small maize harvest of the ordinary gardens and offer much scope for the increased production of vegetables, peas, potatoes and other supplementary foodstuffs." (Trapnell, 1953: para 346). Trapnell (1953: para 347) notes further that "Maize cultivation on fertile dambo margin or streamside soils of the Upper Valley class has been seen to have been developing of its own accord in Mkushi and Mpika Districts. Its apparent recent increase, in the latter district in particular, should provide a valuable addition to the diet." However, limitations and environmental risks associated with dambo cultivation are also recognized, particularly in the light of rapidly increasing human populations, and the human pressures on dambos (Acres et al. 1985; Whitlow 1989).

The Mpika district in northern Zambia and the Simlemba Traditional Authority in Kasungu district in central Malawi, the areas where this study was undertaken, are examples of where there is a strong link between dambos and rural livelihoods (Mbewe 2007; Msukwa 2007). Local livelihoods are also strongly connected to the miombo woodland which surrounds the four dambos studied. Miombo woodland has nutrient-poor soils and more than 95% of the rain falls in a single 5 – 7 month wet season (Campbell et al. 1996), with profound consequences for local livelihoods and the role that dambos play in these livelihoods. Nutrients are quickly depleted under continuous cultivation of upland fields, and therefore shifting cultivation has been traditionally practiced. However, with increasing human populations, available woodland has become increasingly limited. This has resulted in dambos, with their generally higher nutrient levels, becoming increasingly attractive for cultivation. Further adding to the attractiveness of dambos is their residual moisture and access to irrigation water through shallow wells which allow cultivation to be extended through the dry season (Kotze 2011).

The ecosystem services and livelihood benefits supplied by a dambo are underpinned by its ecological health, which needs to be maintained if sustainable use is to be achieved. Assessing the dynamics of ecological health is

[1] Ecosystem services refer to the benefits that people receive from nature, including provisioning services such as food production and livestock grazing, regulating services such as flood attenuation, and cultural services through the environments they provide for relaxation and spiritual upliftment (Millennium Ecosystem Assessment 2005; Russi et al. 2013)

essential for understanding how sustainable use can be achieved. Although useful sustainable use principles (e.g. Mharapara 1995) and guidelines for the classification of the agricultural potential of wetlands (e.g. McCartney et al. 2005) already exist, these lack specific criteria for assessment of the ecological condition of wetlands. Thus, a framework, referred to as WET-SustainableUse (Kotze 2010) was developed, based closely on the work of Macfarlane et al. (2009). WET-SustainableUse provides a set of indicators for the assessment of each of five components of wetland ecological condition, namely hydrology, geomorphology, soil organic matter accumulation, nutrient cycling and retention, and vegetation composition, which are elaborated upon in Appendix A and the Methods Section (see 2 below). The indicators, which provide the basis to characterize human pressure on wetlands and to assess the sustainability of use, can be described rapidly, and therefore the framework has relevance to countries which are poor in data and resources.

In July 2019 the WET-SustainableUse method was applied to four wetlands where the Striking a Balance project had been actively involved between 2006 and 2008 and which had been assessed with WET-SustainableUse in 2008. Those studied in 2019 were Chikakala and Mwansabamba in Mpika District of Zambia and Chiotha and Katema in Simlemba Traditional Authority (TA) of Kasungu District, Malawi. The primary purpose of this report is to describe the current ecological health of these wetlands based on the WET-SustainableUse assessment and assess how this compares with the baseline assessment at the end of the SAB project in 2008. It also seeks to identify potential drivers influencing the observed ecological health trends. This will contribute to an assessment of the long-term impacts of the Striking a Balance project. The report focusses particularly on dambo cultivation as this is the primary use made of all four of the dambos, including the turf ridging and burning practices in Chikakala and Mwansabamba (Appendix B).

Sustainability is widely recognized to encompass both an environmental and social dimension. Thus, the above investigation of ecological sustainability is complimented by an investigation of the social sustainability of the use of the four dambos, based on focus group discussions at each of the four dambos and drawing on existing investigations such as that of Dixon and Carrie (2015) and Mbewe and Sampa (2018). Finally, based on the results of both the environmental and social sustainability assessments as well as reflecting on recommendations made by Kotze et al. (2008) and Kotze (2009), recommendations are provided in terms of reconciling some of the tensions between conservation and agro-development and how management initiatives can better contribute to the long-term sustainability of dambo use generally.

2. Methods

2.1 The ecological health assessment

The assessment of current ecological health/condition is based on field assessments conducted in July 2019. (This was after an above average rainfall season in Mpika, and a good rainfall season in Simlemba, which often suffers from low rainfall.) This is compared against the baseline assessments for the Simlemba dambos in Malawi (Kotze et al., 2008) and the Mpika ones in Zambia (Sampa 2008; Nyirenda 2008, Kotze, 2009). WET-SustainableUse (Kotze 2010) was the primary method used to carry out the assessment of wetland ecological health on both occasions. WET-SustainableUse (Kotze 2010) is a modular approach for assessing the present ecological condition of wetlands based on WET-Health (Macfarlane et al. 2009). It attempts to account for some of the key interacting processes that take place within a wetland and synthesize this information by evaluating inter-related components of ecological condition. WET-SustainableUse assists in identifying the likely contribution of specific uses to five discrete components of ecological health (Table 2.1).

Table 2.1: Key components considered in assessing the extent to which human use alters the ecological condition of a wetland (from Kotze 2009)

Key components of ecological condition	Rationale
Hydrology (water distribution and retention). This can be altered through (i) changes in water inputs as a result of human activities in the catchment upstream of the wetland or (ii) modifications within the wetland (notably those resulting from the excavation of artificial drainage channels) that alter the water distribution and retention patterns within the wetland. Both these types of alterations are evaluated and combined into a measure of the hydrological condition of the wetland.	Hydrology is the primary determinant of wetland functioning. The hydrological conditions in a wetland affect many abiotic factors, including soil anaerobiosis (waterlogging), availability of nutrients and other solutes, and sediment fluxes (Mitsch and Gosselink, 1986). These factors, in turn, strongly affect the fauna and flora that develop in a wetland.
Geomorphology (sediment trapping/ erosion). This is defined as the distribution and retention patterns of sediment within the wetland, including both mineral and organic sediments. This component focuses on evaluating changes in erosional and depositional patterns within the wetland as a result of human activities.	Wetlands are generally net accumulators of sediment (Ellery et al., 2008), which affects the landform of the wetland, which, in turn, has a feedback effect on hydrology. Sediment retention is also important for maintaining the wetland's on-site agricultural productivity as well as being potentially important for downstream water users by enhancing nutrient retention.
Soil Organic Matter (SOM) accumulation/depletion. SOM accumulates in the upper soil layers, and in wetlands is typically more abundant than in non-wetland areas as a result of waterlogging slowing the rate of organic matter decomposition. This component assesses, based on indicators, the extent to which human activities disrupt SOM accumulation.	SOM makes a significant contribution to wetland functioning and productivity, e.g. water holding capacity and cation exchange capacity (CEC) of the soil, and soil structure and resistance to erosion (Mills and Fey, 2003; Millar and Gardiner, 1998; Sahrawat, 2004).
The retention and internal cycling/leakage of nutrients. It is recognized that this is very closely linked with the retention of sediment, as well as being affected directly by the presence and growth of vegetation, another feature affected by human activities (e.g. crop production).	Wetlands are generally effective in retaining and cycling nutrients, which is important for maintaining the wetland's on-site productivity in terms of growth of natural vegetation and crops as well as being potentially important for downstream water users by enhancing nutrient retention (Mitsch and Gosselink, 1986)
The natural composition of the wetland vegetation. The natural composition of the vegetation of a wetland is generally most directly and dramatically altered by the clearing of vegetation for cultivation.	The particular composition of wetland vegetation is of significance in itself for biodiversity and provides habitat for a range of fauna. Particular plant species may also have direct economic importance (e.g. for use in craft production).

For each of the five components, the impacts of human activities on ecological condition were scored based on readily observed indicators/factors (e.g. artificial drainage channel depth and orientation) which are outlined in Appendix A. This scoring requires both a quantitative perspective and qualitative assessment skills on the part of the assessor. In order to promote consistency of assessment, D Kotze, who is experienced in the application of the method, carried out all of the baseline and follow-up assessments.

The spatial *extent* of the impact of individual activities was assessed and then the *intensity* of impact of each activity in the affected area was assessed based on a scale of 0 (no impact) to 10 (critical impact) (Table 2.2). The extent and intensity were then combined to determine an overall *magnitude* of impact also on a scale of 0 to 10, as follows: **Magnitude = Extent / 100 x Intensity**. For example: If a given activity was affecting 50% of the dambo and its intensity was 6 then the magnitude of the impact is 50/100 x 6 = 3. Ecological health, scored on a scale of 0 (critical) to 10 (pristine) is **inversely** related to the impact score and is determined by subtracting the sum of the impact magnitude scores from 10. If the activity in the above example was the only activity impacting on the dambo then the ecological health of the dambo would be 10-3=7, which according to Table 2.2 would fall into a C health category.

Table 2.2: Guideline for assessing the intensity of impact and ecological health of wetlands (modified from Macfarlane et al., 2009)

Impact intensity category	Description	Impact score range	Health score range	Health category
None/ negligible	No discernible modification or the modification is such that it has no impact on wetland ecological health.	0-0.9	9.1-10	A
Small	Although identifiable, the impact of this modification on wetland ecological health is small.	1-1.9	8.1-9	B
Moderate	The impact of this modification on wetland ecological health is clearly identifiable, but limited.	2-3.9	6.1-8	C
Large	The modification has a clearly detrimental impact on wetland ecological health. Approximately 50% of wetland health has been lost.	4-5.9	4.1-6	D
Serious	The modification has a clearly adverse effect on wetland ecological integrity. Well in excess of 50% of the wetland ecological health has been lost.	6-7.9	2.1-4	E
Critical	The modification is present in such a way that the ecosystem processes of this component of wetland ecological health are totally / almost totally destroyed.	8-10	0-2	F

Although the five components given in Table 2.1 are assessed separately, it is acknowledged that they are closely interlinked. Hydrology has the most influence on the other factors and is the least affected by the other factors, and can therefore be considered as the primary driving process. Conversely, nutrient cycling is the most affected by the other factors, and has the least influence on the other factors. The main influence of nutrient cycling is through plant growth and the organic matter accumulation that results from this growth, i.e., its influence on the other factors is indirect through organic matter accumulation.

When assessing the impact of catchment activities on the quantity and timing of water inputs to the dambo (directly relevant to the hydrology component) a visual estimate was made using GoogleEarth images of the approximate extent of different land-cover types in the upstream catchment of each of the dambos. These estimates were verified based on the field surveys/ ground-truthing carried out in 2008 and 2019. Within the wetland, the extent of cultivation was mapped from GoogleEarth images where available, and verified during the field assessments.

WET-SustainableUse does not prescribe, in rigid terms, what is considered sustainable or not (e.g. the overall health score of a dambo should be maintained above 6 or in health categories A to C) but instead recommends Thresholds of Potential Concern (TPCs) for catchment management and livelihood support (Kotze 2010) which were used to guide the final overall sustainability assessment, and are described in Appendix D.

2.2. The institutional assessment

2.1.1 Context

During the SAB project, the need to develop ways to encourage measures to ensure sustainable wetland use in the long term was discussed with the communities in all sites. A number of key points of guidance were identified relating to both wetland and catchment management, recognising the need for a Functional Landscape Approach (FLA). Communities – with help from project and government staff as facilitators, codified this guidance into byelaws which were approved at the village level by the village headman and then by the area Chief. To enforce these, the concept of the Village Natural Resource Management Committee (VNRMC) was in accordance with the Forest Act in Malawi, with this special committee established in each village to monitor the implementation of these byelaws relating to wetland and catchment management. The aims of the byelaws and VNRMCs were to encourage the use of specific management interventions which will maintain ecosystem services, to manage demand for wetland cultivation plots and resolve any conflicts caused by resource use competition. As an agreed approach to wetland management, these initiatives sought to build community engagement and coherence.

These VNRMCs were originally seen to be a separate committee, meeting in their own right and reporting on issues to the village headman or to the Village Development Committee, chaired by the Headman. Key members of the VNRMCs were to be the Lead Farmers, who acted as sub-community level advisors and "policed" specific areas of wetland, and sometimes adjoining catchments. All wetland farmers were meant to be members of these committees and they were supposed to meet every month to review the situation or more frequently if there were issues to discuss and cases of malpractice to be reviewed and, if necessary, passed to the Headman or area Chief for enforcement action (Sampa et al. 2008).

The byelaws which were to be enforced varied from site to site but were similar in each country. In Zambia they included the following:

· *Land in the wetlands should not be drained and cultivated within 30m of the edge of the dambo, and especially the head of the dambo.*
· *Drainage and cultivation is prohibited within the dambo in the first 10m from the centre stream, or if the dambo has a steep slope, 20m from the centre of the stream. (The rationale for this is the maintenance of natural vegetation to control erosion and maintain water.)*
· *No one should drain, plough or cut trees around water sources.*
· *Deforestation and cultivation in the catchments should be avoided within 50m of the dambo edge.*
· *Use of forest resources in the catchment is only permissible on one day per month.*
· *Degraded forest areas should be rehabilitated by controlling cutting and burning.*
· *No late burning should occur in the dambos or its upland fringes; burning should be only in June to reduce damage to the vegetation.*
· *No one should wash upstream of water collection points or near wells or water sources.*
· *People should use the correct types of traps or nets when catching fish, to reduce over-fishing.*
· *Goats should be put in an enclosure until 14:00hrs so that they don't wander too far and destroy dambo crops.*

These byelaws recognised in particular the important role of the surrounding catchment in order to maintain the seepage water supply to the wetlands.

In Malawi the byelaws were similar but with a focus more on the need for water retention given the relatively dry conditions in Simlemba. As a result, they covered:

· Designating a five metre buffer zone from the centre of the wetland (stream channel), in which no cultivation is allowed.
· Ensuring livestock are always supervised in the wetland.
· Designating specific areas within the wetland for livestock grazing.
· Prohibiting the removal of indigenous trees from the wetland.
· Advising planting of crops in basins to use water efficiently (Malawila).
· Allowing only people from the village of Chiotha and affiliated villages access to Mandela wetland.
· Prohibiting the planting of Eucalyptus trees in the wetland.
· Limiting the area of sugar cane when water is short for much of the year.
· Maintaining a non-cultivation zone of 5-10m width with natural vegetation around the wetland.
· Protecting afforested areas and zones of natural vegetation from fires, including the use of firebreaks.

2.1.2 Methods

The field review in 2019 involved two one-day visits to each dambo and its community. The first day was spent holding discussions with farmers during a full day transect walk in each site. The consultants and Self Help Africa staff were accompanied by between 2 and 4 knowledgeable local farmers with considerable experience in wetland farming. The following day there were village meetings of between 14 and 30 people, with both men and women present, and in all meetings, women were well represented. Youth were also represented, and especially well at Chikakala. In each village meeting key environmental sustainability issues identified from the previous day's walk were raised and these were used as "starting points" for discussion, prompting local farmers to share their perspectives around these and additional sustainability issues.

Part of the discussions explored the challenges of organising the management of wetland cultivation and related issues. The VNRMC was not specifically introduced as a topic, but people were asked to identify what guided their individual and community use of the wetlands and how this guidance was applied and issues addressed. Usually this led to recognition by some farmers of a number of the SAB developed byelaws which were still recognised, if not completely followed. With time the question of coordination was reached and communities themselves introduced the VNRMC.

3. An overview of the four dambo sites and their cultivation

Six dambos, which had been assessed in 2008, were considered for re-assessment in 2019. However, the time available for the assessment in 2019 allowed for the assessment of only four of these. The four dambos (Figure 3. 1) were selected in order to represent a range of biophysical features, levels of use and catchment contexts (Table 3.1). In Zambia, Chikakala dambo (31°15'16.13"E, 11°24'13.30"S) and Mwamsambamba dambo (31° 29' 58.74" E, 11° 52' 29.60" S) are located near Mpika town in the upper Congo River drainage basin in the catchment of the Chambeshi River, which feeds the Bangweulu Lake (Figure 3.1). In Malawi, Katema dambo (12°43.368'S; 33°35.940'E) and Chiotha dambo (12° 46.697' South; 33 ° 40.390' East) are located north of Kasungu town in the drainage basin of the Dwangwa River (Figure 3.1), which flows into Lake Malawi, an aquatic system of regional and global importance (Thieme *et al.* 2005). Although the mean annual precipitation is higher at Chikakala and Mwamsambamba than at Katema and Chiotha (~1100 mm compared with ~800 mm) all sites have an extended dry season from May to September / November.

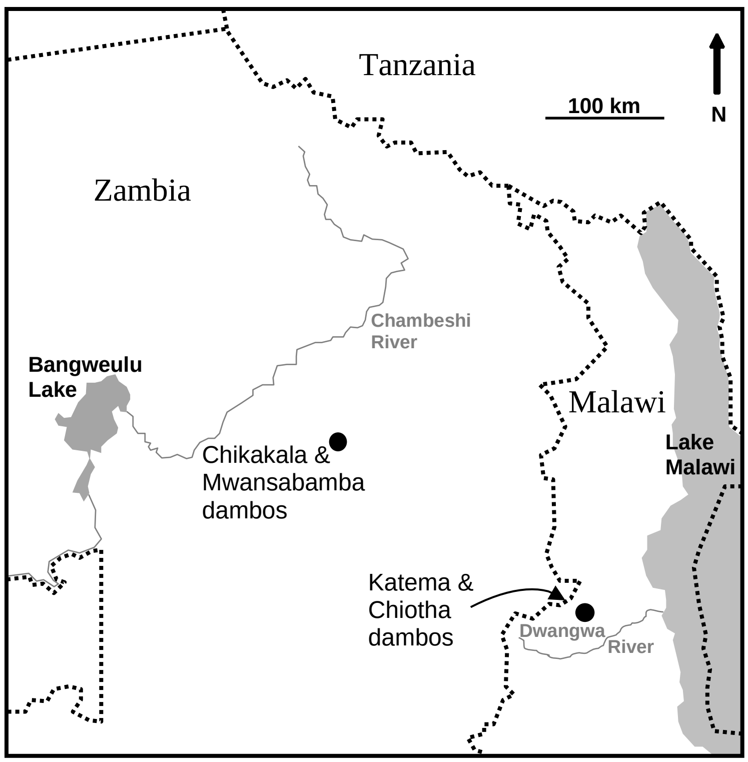

Figure 3.1: Location of the four dambos selected for the study

The relationship between the dambo and its catchment, and the consequences of this in terms of energy in water flows through the dambo, varies amongst the four dambos (Table 3.1; Figure 3.2). The Katema and Chikakala dambos are located at the head of their valleys and occupy a large proportion of their respective upstream catchments – 13 and 14% respectively. Given that the upstream catchments of both are very gently sloped (~3%) and with sandy soils having a high infiltration capacity, there is naturally very little surface runoff from the upstream catchment into the dambo. Therefore, the primary sources of water maintaining these two dambos are direct precipitation onto the dambo and sub-surface flows into the dambo as hillslope seepage.

Table 3.1: Key biophysical features of the four dambos

Dambo name	Dambo size (ha)	Size of the dambo's catchment (ha)	Dambo area as a % of its catchment	HGM (Hydrogeomorphic) setting of the dambo
Katema	33 ha	279 ha	13%	Lateral seepage grading gradually into a valley bottom (predominantly unchanneled) located in the headwater
Chikakala	254 ha	1817 ha	14%	As above, but valley bottom predominantly channeled
Mwansabamba	369 ha 1292 ha[1]	9130 ha	4% 14%	As above, but valley bottom located somewhat downstream of the headwaters
Chiotha	17 ha	808 ha	2%	Valley bottom, channeled in the uppermost and lowermost portions but predominantly unchanneled

[1]The 369 ha of assessed dambo combined with an additional 923 ha of dambo lying immediately upstream

The Mwansabamba dambo is located somewhat lower in the valley than the Katema and Chikakala dambos, and is supplied by a much larger catchment (Table 3.1). This means that relative to the size of the dambo, there is a larger upstream area potentially able to deliver water to the dambo. The soils in the catchment are predominantly sandy, which promotes infiltration and the sub-surface supply of water to the dambo, and extensive evidence can be seen of lateral seepage into the wetland. However, it is also supplied by an inflowing stream fed by the dambo's upstream catchment. The Chiotha dambo is also located further down the valley, and occupies by far the smallest proportion of its upstream catchment compared to the other sites (Table 3.1). In contrast to Mwansabamba, it is not part of a larger wetland, and upstream wetland is lacking. The soils in the Chiotha catchment are relatively sandy, but appear to generally have higher clay content than the other three wetlands. There is much less evidence of seepage in the hillslopes feeding the Chiotha dambo than in the other three dambos, and the predominant inflows to the dambo are assumed to be from the upstream catchment and infiltration into the dambo sediments when flooded. In addition, the Chiotha dambo probably has the greatest frequency of surface water inputs during major storm events in the wet season and higher energy surface flows passing through the dambo.

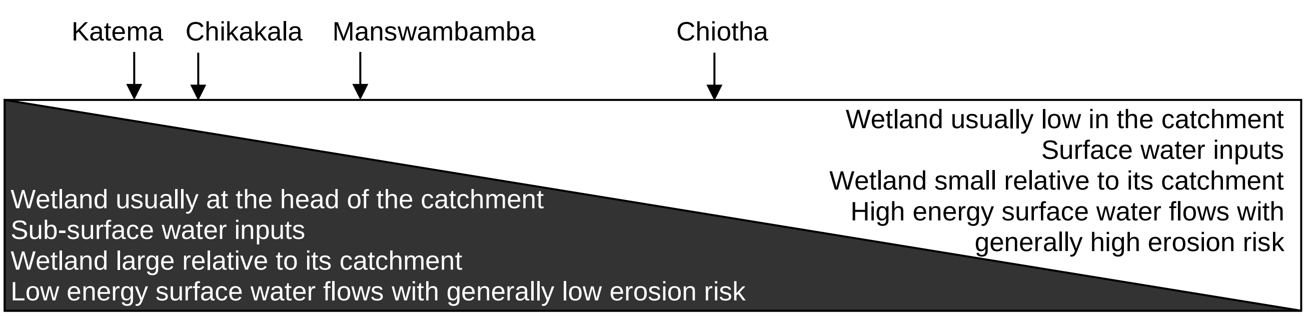

Figure 3.2: Dambo-catchment relationships characterizing the dambos in the study (modified from Kotze et al. 2008).

In all four dambos the margins are dominated by grasses, notably *Hyparrhenia* spp., while the wetter body of the wetland is dominated by sedges, including *Rhyncospora* spp., *Fuirena* spp. and *Eleocharis* spp., together with other hydric graminoids such as *Eriocaulon* and *Xyris* species.

Traditionally, the predominant agriculture practiced in the uplands around the Mpika wetlands of Chikakala and Mwamsabamba dambo was *chitemene* cultivation, where the branches and foliage of trees are collected from an area of several hectares (the "outfield"), and gathered in the "infield", an area about 0.4 ha in size, and burnt. When the infield is exhausted after a few years of cultivation, it is abandoned and traditionally left fallow for 20 to 30 years (Strømgaard, 1984a and b). *Chitemene* cultivation allows for nutrients from across a wide area to be collected and concentrated in the infield through the medium of the ash (Appendix C). In Malawi in the Katema and Chiotha area similar shifting cultivation is likely to have been carried out in the past, but now, like in most of Malawi, the demand for land is so high that fallow periods are much shorter, and most of the cultivation is now effectively permanent.

All four dambos have probably been used since pre-colonial times, but the extent of use increased noticeably in the last two decades. At Chikakala and Mwansabamba in Zambia this was stimulated by the 1990/1991 drought, together with fertilizer shortages, which caused upland harvests to fail (Sampa, 2008), while in Katema and Chiotha this was stimulated by a series of droughts from 2000 (Wood 2005). The residual moisture in all dambos supports food production in the dry season and early wet season. For subsistence farmers relying on upland cultivation, the early to mid-wet season is generally the most intense "hunger period" because most/all of the food from the previous wet season has been consumed (particularly during a drought) and the harvest is not yet ready from the current rain-fed crops (Sampa, 2008; Kotze et al., 2008). Crops grown in the Chikakala and Mwansabamba dambos in Zambia include early maturing varieties of pumpkin, squash and maize, as well as other crops such as tomatoes, onions, cabbage and beans (Sampa, 2008). The main crops grown in the Katema and Chiotha dambos in Malawi are maize, sugar cane, rape, mustard, green beans, tomatoes, Irish potatoes, and bananas. Crops are used for direct household consumption as well as for sale (Mbewe, 2007; Msukwa, 2007; Sampa, 2008; Kotze et al., 2008; McElwee and Wood, 2017).

The traditional land preparation method in Chikakala and Mwansabamba dambos involved digging up the surface soil together with plant roots in thick "slices" of turf. After being left to dry, the turf is burnt, and then cultivation takes place in the ash-rich soils (Sampa, 2008). However, burning of the thick-cut turf often proved incomplete, leading to variable yields. Thus, during the 1990s a refined method was developed. This involved cutting thin turfs, drying them on the ground (grass side down), gathering the turfs into well ventilated ridges, burning these ridges and re-ridging after burning (which covers the ash with soil, thereby preventing the ash from being blown away) (Sampa, 2008). "Overall this improves nutrient availability and moisture retention. …. this has led to a method which can sustain three to four harvests in succession over two years without chemical fertilizers and without major water application, if a moist site in a dambo is selected." (Sampa, 2008, p. 3).

Soil analyses in Chikakala and Mwansabamba confirm that available phosphorus is significantly higher in the cultivated ridges than in the uncultivated areas (26.7 ±3.5 ppm [n=3] compared with 10.0 ±9.6 ppm [n=3]), whereas nitrogen appears lower (0.10 ±0.02 % [n=3] compared with 0.37 ±0.46 % [n=3]) (Kotze 2009). The turf burning appears to concentrate phosphorus in several ways. Firstly, phosphorus which is bound in the combusted organic matter is not lost through volatilization, as occurs with much of the nitrogen, and instead remains in the ash. Secondly, much of the SOM and available nutrients are naturally concentrated in the topsoil, which is gathered together in the ridges, further concentrating available nutrients. In addition, the direct heating of the soil and increased pH that results from the ash causes some of the unavailable soil phosphorus to be converted into a form available to plants (Giardina et al. 2000).

The turf ridging and burning cultivation method at Chikakala and Mwansabamba provides an effective means of accessing available nutrients and residual moisture for dry season crop production, and the method appears to be "well-tuned" to the particular biophysical constraints and opportunities present in these dambos. Nevertheless, the effectiveness of the method in providing nutrients in a relatively nutrient-poor system has important implications for replenishing nutrient reserves, as will be explored further in the results of the sustainability assessment.

At Katema and Chiotha, the burning of turf is not practiced, but wetland plots are subject to a high level of tillage. Although some burning of weed and crop residues is practiced, the extent to which residues are returned to the plot either as compost or unprocessed residues buried in trenches within the dambo is high. In addition, the pronounced ridges and furrows common at Chikakala and Mwansabamba are rare in Katema and Chiotha, where slightly raised beds are much more common, together with depression beds in the drier areas of the dambo to facilitated watering.

The studies of dambo cultivation during the SAB project and since that time have shown that both women and men hold such gardens, in some cases in equal numbers. Access to dambo land is a traditional right under chief's land tenure arrangements with farmers of upland areas having rights to adjoining dambo areas. If that land is not suitable for cultivation, farmers can obtain wetland plots by applying to the village headman or to people with wetland plots they do not use. Wetland farming is undertaken by people of all ages, although in Chikakala there is a predominance of young men who undertake this rather than look for piece work during the rains as a way to feed their families (Wood 2008, 2017).

4. Results

4.1 Results of the ecological health assessment

4.1.1 Land-cover changes in each dambo and its catchment

The first step in establishing the ecological health of the dambos is to estimate the extent of different land-cover types in each dambo and its catchment (Table 4.1 and 4.2). The main land-cover assessment shows that the extent of natural vegetation in both the dambo and its catchment is noticeably higher in Chikakala and Mwansabamba than in Katema and Chiotha, while in terms of trends in all four dambos there was generally a slight decline in the natural vegetation and increase in cultivated area from 2008 to 2019 (Table 4.1 and 4.2). This increase was most apparent with respect to permanently cultivated areas in the dambos' catchments (Table 4.2). However, within Katema and Chiotha dambos there was a decrease in the extent of currently cultivated area (from 29% to 26% in Katema and from 23% to 22% in Chiota) (Table 4.1). The buffer index shown at the end of Table 4.2 reveals that from 2008 to 2019 there is generally a slight decline in the degree to which the dambos are surrounded by a buffer of woodland (i.e. a slight shrinkage in the spatial extent of the buffer), but in the case of Chiotha the buffer was already greatly diminished in 2008 and little changed in 2019. The implications of the land-cover figures reported in Table 4.1 and 4.2 for ecological health of the dambos are specifically addressed in Sections 4.1.2 to 4.1.6 and Appendix E.

Table 4.1: Approximate extent of different land-cover types in the four dambos (as a percentage of the dambo area)

Land-use type	Chikakala		Mwansabamba		Katema		Chiotha	
	2008	2019	2008	2019	2008	2019	2008	2019
Currently cultivated	2.0%	3.0%	2.0%	6.0%	29.0%	26.0%	23.0%	22.0%
Recently abandoned	3.0%	4.0%	2.0%	5.0%	11.0%	16.0%	12.0%	11.0%
Old abandoned	8.0%	11.0%	7.5%	12.0%	13.0%	20.0%	14.0%	18.0%
Natural/ near-natural	87.0%	82.0%	88.0%	76.0%	45.0%	36.0%	42.0%	40.0%
Roads			0.5%	0.5%				
Road prep.				0.5%				
Erosion gullies					0.1%[1]	0.1%[1]	9.0%	9.0%
Dam					2.0%	2.0%		

[1]Very localized minor erosion associated with the spillway of the dam

Table 4.2: Approximate extent of different land-cover types in the upstream and adjacent catchments of the four dambos (as a percentage of the upstream catchment area)

Landcover	Chikakala		Mwansabamba		Katema		Chiotha	
	2008	2019	2008	2019	2008	2019	2008	2019
"Permanent" cultivation areas[1]	6.0%	10.0%	8.0%	14.0%	66.0%	68.0%	53.0%	59.0%
Chitemene cultivated areas[1]	53.0%	52.0%	59.0%	56.0%	0.0%	0.0%	9.0%	10.0%
Homesteads, roads, tracks and paths & other hardened bare areas	1.0%	1.5%	2.0%	3.0%	8.0%	9.0%	8.0%	9.0%
Eucalypts bananas and other introduced trees	1.0%	1.5%	1.0%	2.0%	2.0%	3.0%	2.0%	3.0%
Natural/ near-natural woodland	39.0%	35.0%	30.0%	25.0%	24.0%	20.0%	28.0%	19.0%
Buffer index, ranging from * (no buffer) to ***** (complete and extensive buffer)	****	***	****	***	****	***	**	**

[1]Chitemene areas (includes infields, outfields and recovering areas, see Appendix C) generally appear as light-coloured circular-shaped areas in the Google Earth image in an otherwise dark green woodland matrix. Lighter areas that are rectangular in shape, usually appearing brown in the Google Earth image, are assumed to generally be more permanently cultivated, and are referred to as "Permanent" cultivation areas.

4.1.2 The hydrology component of dambo health

The ecological health of the dambo in terms of hydrology, taking into account both the impacts from land-uses in the dambo and in the dambo's catchment, is presented in Figure 4.1 (The detailed assessment for this and the other five components of ecological health, showing the intensity of impact associated with the various land-covers present in the wetland is given in Appendix E). Chikakala and Mwansabamba dambos in Zambia, which still have relatively high extents of natural vegetation in the dambo and its catchment (Table 1 and 2), have higher hydrology health scores than Katema and Chiotha in Malawi (Figure 4.1). Comparing health in 2008 to 2019, there is a slight decline in all four of the dambos, but somewhat more pronounced in Mwansabamba (Figure 4.1), which has experienced the greatest percentage increase in cultivation of the dambo, as can be seen in Table 4.1.

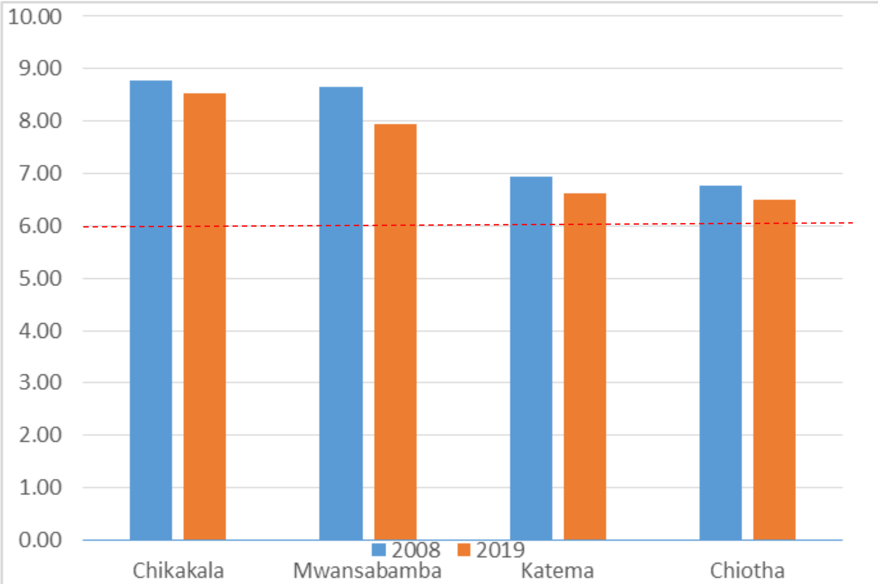

Figure 4.1: The hydrological component of the health of four dambos assessed in 2008 and 2019, with health represented on a scale of 0 (critical) to 10 (pristine) and the Threshold of Potential Concern for Supporting Livelihoods (explained in Section 4.1.7 and Appendix D) shown as a dashed red line.

The extent of homesteads, roads, tracks and paths and other hardened bare soil areas in particular result in increased peak discharges from a dambo's catchment. Clearing miombo woodland for cultivation generally results in an increase in the amount of water delivered to a dambo from its catchment, particularly surface flows (e.g. Du Toit, 1985; Mumeka, 1986; Whitlow, 1989) which may, in turn, contribute to increased erosion (Whitlow, 1989). Trees are consumers of water, generally more so than herbaceous plants (Dye et al., 2008) owing to deeper roots and greater leaf area. However, in both 2008 and 2019, evidence of greatly increased surface runoff (e.g. as a result of hardened surfaces in the catchment) is lacking at all four dambos. Further, there is very little evidence of recent sediment deposition in the dambos, which would generally be indicative of increased surface flows leading to increased levels of erosion. However, it would appear that some of the sub-surface hillslope flows into the dambo are now flowing more shallowly than was the case historically, perhaps as a result of hardpans in some of the cultivated areas, and therefore reaching the dambo somewhat more rapidly. Thus, all of the dambos were scored as experiencing small impacts from land-use activities in their catchments, but these were moderated by a reasonably intact buffer around all of the dambos except for Chiotha (Table 4.2). In the other sites, although some "shrinkage" of the buffer was noted between 2008 and 2019, these buffers were still largely maintained in 2019. In Chiotha, maintenance of minor roads through a public works programme in order to better control runoff was noted in 2019, which was an improvement in the situation in 2008 in terms of catchment impacts.

In both 2008 and 2019, the cultivation in Chikakala and Mwansabamba dambos took place predominantly using the ridges and furrows described by Sampa (2008), which are designed to control waterlogging (which limits the growth of all of the cultivated crops) while at the same time providing adequate supply of water for crops (Sampa, 2008). This is achieved by locating the plots within areas in the dambo which remain fed by seepage waters through most of the dry season, but avoiding the excessively wet central areas of the dambo and the drier portions of the dambo. The ridging system concentrates naturally-diffuse flows within the furrows, which are mainly orientated diagonally down the slope rather than along the contour. In addition, on the ridges the land surface is raised relative to the water table by about 10 to 20 cm. Overall therefore, the level of wetness of the ridged areas is lowered, but this is not a severe alteration given the fairly shallow nature of the ridges and furrows. In 2008, the Chikakala and Mwansabamba the ridges appear to have been similar in terms of height and orientation. In 2019, while the same ridges were used, some slight shifts had occurred, with implications in terms of hydrological impact. In Chikakala, in response to an above-average preceding wet season there had been a slight shift in location of cultivation more towards the drier margins away from the wetter lower slopes, resulting in a slightly lowered hydrology impact intensity score seen in Appendix E. In Mwansabamba this shift has been to a lesser extent than in Chikakala, with farmers tending more to adjust to the wetter conditions by increasing the height of the ridges, orientating the furrows with the direction of water flow (Plate 4.1) and, in some cases, constructing additional drainage ditches to speed up the removal of excess water[2]. This has increased the impact intensity on the hydrology, as reflected in the scores in Appendix E, Table E1.

Plate 4.1: A cultivated area of Mwansabamba dambo with high ridges orientated directly down the slope

[2] Appendix F provides several additional photographs of different land-use activities and issues in the four dambs

In Katema, the plots are not ridged and furrowed, although there are drainage furrows around some of the cultivated plots, while raised beds are used in the early dry season when the dambo has a high water table. Comparing the 2008 situation with 2019, the slightly reduced extent of current cultivation is offset by a slightly increased intensity of impact due to some higher ridges. In Chiotha, which is inherently the least wet of the three dambos, most cultivation takes place without any ridges and/or furrows. Thus, the intensity of hydrological impact is lower in the Katema plots than in the Chikakala and Mwansabamba plots, and even lower still in the Chiotha plots (Appendix E, Table E1). However, given that the extent of current cultivation is much greater in Katema and Chiotha than Chikakala and Mwansabamba (Table 4.1), the magnitude of impact is greater, but is nevertheless still not serious (Appendix E, Table E1).

In Chikakala and Mwansabamba dambos, once the plots are abandoned, any ridges and/or furrows present are generally left intact, although one plot was noted in Chikakala where the ridges had been flattened for a final crop before the fallow. Although the intact ridges will gradually become flatter and sediment is likely to accumulate in the furrows, the draining effect will persist long after the cultivation has been abandoned, which is reflected in the score assigned to old abandoned plots in Appendix E, Table E1. In the Chiotha dambo, there is little drainage effect in the first place which is able to persist.

4.1.3 The geomorphology component of dambo health

The ecological health of the wetland in terms of geomorphology, as represented by erosion/ sediment deposition, is presented in Figure 4.2 (see Appendix E, Table E2 for a more detailed breakdown of the assessment). In both the 2008 and the 2019 assessments, geomorphology was consistently the least impacted of the five components of ecological health across all dambos except Chiotha (i.e. comparing Figure 4.2 with Figure 4.1, 4.3, 4.4 and 4.5). Chikaklala was minimally impacted and lacking in any erosion features, while in Mwansabamba and Katema, these were very localized. However, Chiotha had noticeably more extensive erosion (Table 4.2) and the geomorphology component of wetland health was correspondingly lower (Figure 4.2).

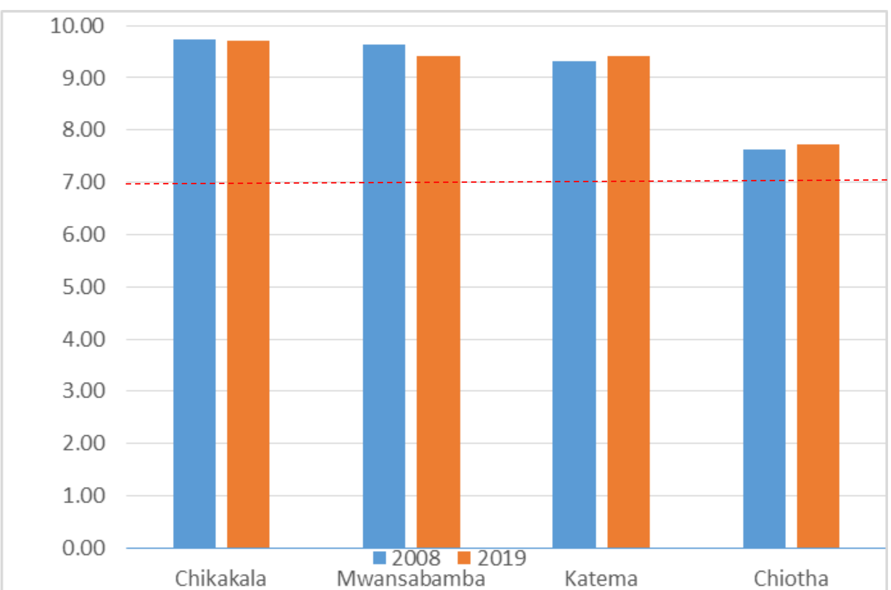

Figure 4.2: The geomorphological component for the health of four dambos assessed in 2008 and 2019, with health represented on a scale of 0 (critical) to 10 (pristine) and the Threshold of Potential Concern for Supporting Livelihoods (explained in Section 4.1.7) shown as a dashed red line.

Comparing the geomorphology component score for each dambo in 2008 and 2019 (Figure 4.2) it can be seen that there was a slight decline in scores for Chikakala and Mwansabamba, owing primarily to the increased extent of cultivation in these dambos, but in Katema and Chiotha there was a slight improvement, linked primarily to the slight decline in current cultivation and no increase in the extent of erosion gullies.

Several activities take place in the cultivated plots in the four dambos which contribute to an increased vulnerability to erosion. These include the following:

- A high level of soil tillage - disrupts soil structure and destroys plant roots which contribute to the strength of the soil.
- Combustion of the soil (in the case of Chikakala and Mwansabamba) - makes the soils more friable, particularly in the case of high organic soils, which has a similar impact to the above.
- Diminished SOM (Soil Organic Matter) levels due to cultivation – less SOM reduces the physical strength of soils, especially sandy to loamy soils.
- Concentration of surface water flow - facilitates soil erosion.
- Diminished soil cover - reduces protection of the soil against rain-splash erosion and water flow erosion (to a lesser degree).

However, several factors appear to act very strongly to limit the actual erosion that has taken place in the four dambos, including the following:

- Cultivation takes place mainly outside those portions of the dambo that appear to be most susceptible to erosion, i.e. the lowest-lying areas of the dambo which carry most of the longitudinal water flows, as recommended by Wood and Thawe (2013).
- The time when the soils are most vulnerable (i.e. when recently tilled) generally coincides with the dry season, when the threat of erosion is lowest, but where a crop is grown into the wet season then removal of the crop may expose the soil to water erosion.
- The inherent erosion hazard of the dambos and their upstream catchments is low given the gentle slope of both.

In general, very little direct evidence of erosion was observed in Mwansabamba, Chikakala and Katema dambos. Thus, the intensity of impact in terms of geomorphology, was assigned a relatively low score in these three dambos, but slightly higher in Mwansabamba and Chikakala than Katema primarily owing to the combustion of soil and the slightly higher erosion potential of Mwansabamba (Appendix E, Table E2). The limiting factors listed above are less pronounced in Chiotha than the other three dambos, particularly the erosion potential of the wetland, which is relatively high, especially due to gradients and the size of the catchment.

Comparing the 2008 and 2019 situation for each individual dambo, it can be seen that the intensity scores have largely remained low and largely unchanged in the cultivated areas (Appendix E, Table E2). A slight improvement in Chiotha is associated with a reduced proportional area under annual crops compared with sugarcane, which has a much lower frequency of tillage and provides better long-term cover to the soil.

Chikakala and Katema were lacking in any direct signs of erosion in the cultivated areas, and in Mwansabamba only very limited sheet erosion was noted in a few cultivated areas in the seepage slopes resulting in erosion by lateral inflows. However, in Mwansabamba, initial preparation carried out in 2016 for a major uncompleted road through the wetland has resulted in the localized concentration of lateral flows into the wetland, which in turn has caused rill and minor gully erosion, further concentrating flow down this feature (Plate 4.2).

Plate 4.2: A Minor erosion feature precipitated by an uncompleted road in Mwansabamba dambo

Chiotha had the greatest extent of erosion, which can likely be attributed to its inherently higher susceptibility to erosion, as identified in Figure 3.2, and a much higher catchment-to-wetland area ratio than the other three wetlands. Increased surface runoff (e.g. from roads in the catchment) and the limited natural buffer around the wetland may be further contributing factors. Erosion in Chiotha is present as a major headcut and gulley near the outflow of the dambo, as well as erosion eating longitudinally from excavated wells. Some of these small erosion features, could potentially develop into an erosion gully. However, the likelihood of these propagating some distance up the length of the dambo is less than the main headcut in the dambo.

Comparing the 2008 situation with 2019 in Chiotha, it was noted that the extent of erosion (8% of the dambo) had remained the same and the major erosion headcut near the outflow of the wetland had not progressed any further into the wetland from its location in 2008. Nevertheless, it remains a key threat to the wetland, particularly as the entire area immediately upstream of the headcut is being actively cultivated, and the protection that is provided to the soil in this regularly-tilled area is much less than would be provided by a perennial cover of strongly-rooted indigenous plants.

4.1.4 The soil organic matter component of dambo health

Soil Organic Matter (SOM) makes a significant contribution to wetland functioning and productivity (e.g. by enhancing cation exchange capacity and soil water holding capacity), and can be profoundly affected by different land-use practices (Miller and Gardiner 1998; Mills and Fey 2003; Saharawat 2004). The ecological health of the wetland in terms of SOM accumulation, is presented in Figure 4.3 (see Appendix E, Table E3 for a more detailed breakdown of the assessment).

Several factors are likely to contribute to diminished SOM levels in the cultivated plots (Table 4.3). The returning of crop residues to the plots, which is widely practiced in all of the dambos (Plate 4.3) contributes positively to SOM, but this in itself is unlikely to counter all the negative factors (Table 4.3).

Table 4.3: Factors contributing to likely diminished Soil Organic Matter (SOM) levels in the cultivated plots

Factors	Rationale
Tillage of the soil, which is high in all four dambos. It occurs for preparing the beds and ridges, and for planting and weeding.	Tillage increases the oxygen levels in the soil, which increases the rate of SOM decomposition. Another key mechanism by which the rate of decomposition of organic matter is reduced is through the organic matter being physically protected within soil aggregates, which are broken by tillage (Six *et al.*, 2002).
Reduced cover of the soil, which occurs mainly when the beds are being prepared and in the first few weeks following preparation of the ridges before the crops have developed good aerial cover	The greater the exposure of the soil, the greater the extent to which the soil is subject to temperature fluctuations, which in turn contribute to increased levels of SOM depletion (Six *et al.*, 2002).
Combustion of the soil (Chikaklala and Mwansabamba)	If the soil material is well combusted then the amount of SOM potentially lost is very high. In additiona, roots and other plant material which is combusted reduces the amount of organic matter potentially available for incorporation into the SOM pool.
Reduced level of wetness (most pronounced in Mwansabamba and least pronounced in Chiotha), exposing the soil to higher oxygen levels, and therefore more rapid decomposition rates.	Prolonged soil saturation results in the development of anaerobic soil conditions, impeding SOM decomposition (Tiner and Veneman, 1988). Therefore, the greater the level of artificial drainage, the greater the potential loss of SOM previously accumulated under the wetter conditions.
Removal of plant material from the croplands.	The amount of organic matter that would otherwise be returned to the soil is reduced.

Plate 4.3: A portion of a cultivated plot in the Chikakala dambo, with “weed” and crop residues from previous crop gathered in the furrows in preparation for the ridges to be “split” and hoed on-top of the residues as the new ridges are created.

Considering the factors given above, the severity of SOM depletion in the currently cultivated plots is assigned the highest score in Mwansababamba, followed by Chikakala and Katema (Appendix E, Table E3) owing mainly to the greatest reduction in wetness being at Mwansababamba, a high incidence of soil combustion at Mwansababamba and Chikakala and the limited burning of soil/plant residues at Katema. The impact in old abandoned plots is scored lower than in the currently cultivated areas (Appendix E, Table E7) given the absence of tillage, higher cover of the soil and cessation of soil burning. However, considering the fact that the recovery of SOM, even in wetlands, is generally slow (Six et al., 2002; Walters et al., 2006) it is assumed not to have fully recovered.

Comparing the 2008 and 2019 situation for each individual dambo (Figure 4.3), it can be seen that the intensity scores associated with cultivation have increased slightly in Mwansababamba, owing primarily to the slight increase in level of artificial drainage, while in the other three they have declined slightly. In the case of Chiotha this is associated with a reduced proportional area under annual crops compared with sugarcane, which has a much lower frequency of tillage, while in Chikakala it is as a result of a slightly decreased level of artificial drainage.

Frequent burning of the natural/near-natural areas, is assumed to contribute to a slight impact in SOM, because it appears that these fires are surface fires rather than ground fires, and the contribution of roots to soil organic matter would not be negatively affected. Owing to a reduced frequency of fire between 2008 and 2019 at Chiotha, a very slight reduction in impact is taken to have occurred.

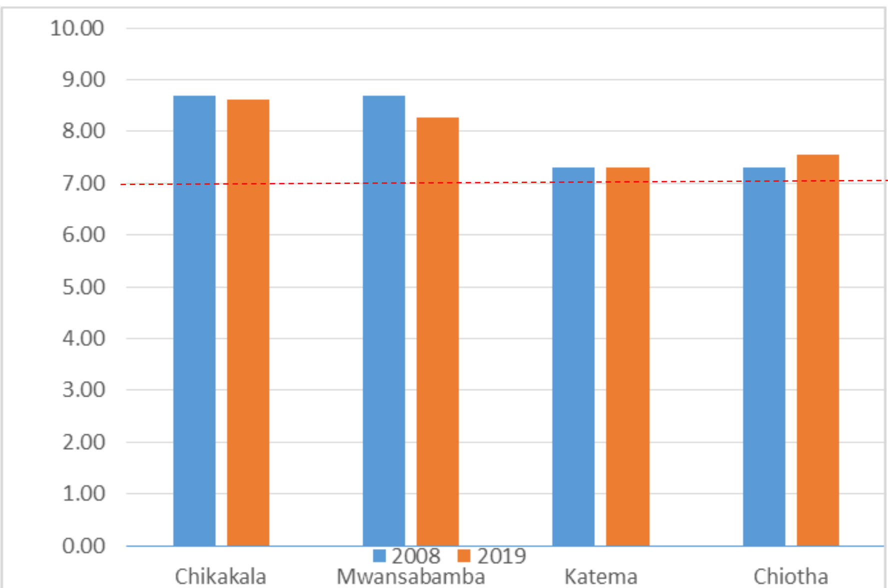

Figure 4.3: The soil organic matter accumulation component for the health of four dambos assessed in 2008 and 2019, with health represented on a scale of 0 (critical) to 10 (pristine) and the Threshold of Potential Concern for Supporting Livelihoods (explained in Section 4.1.7) shown as a dashed red line.

4.1.5 The nutrient cycling component of dambo health

Impacts on nutrient cycling in the currently cultivated plots are assigned intensity scores in Appendix E, Table E4 given the following key factors:

- Nutrient cycling is compromised by a decline in SOM (most severe in Mwansababamba), and consequent decline in cation exchange capacity (CEC), which affects the amount of nutrients potentially held in the soil (Miller and Gardiner 1998).

- The vegetation growth in cultivated plots is interrupted following the harvesting of one crop and while the next crop is still becoming established, thereby interrupting the uptake of mobile nutrients by plants and thus exposing these nutrients to increased risk of leaching (Randall and Goss, 2001). In all four dambos, crops are predominantly annuals and the interruption of plant growth is moderate to high, but less so in Chiotha where there is more extensive sugarcane, which has growth much less interrupted than in annual crops.

- Artificial drainage (most severe in Mwansabamba and least severe in Chiotha) contributes to increased leaching of nutrients (Randall and Goss 2001).

Comparing 2008 with 2019 for each dambo, impact is slightly lower for Chikakala and slightly higher for Mwansabamba (Figure 4.4), owing primarily to slight changes in SOM and the level of artificial drainage for 2008 compared with 2019. In Chiotha, the impact is slightly lower owing to less interruption of plant growth associated with a shift in cultivation to sugar cane vs. annual crops. Katema remains very similar owing to similar cultivation practices and similar cultivation extent.

Perennial vegetation rapidly establishes on abandoned plots, which contributes to the retention of nutrients, and probably also to the gradual recovery of nutrient levels. Based upon this consideration, and that erosion in the abandoned plots is very limited, impacts on nutrient cycling in the long abandoned plots are assigned a low impact intensity score (Appendix E, Table E4).

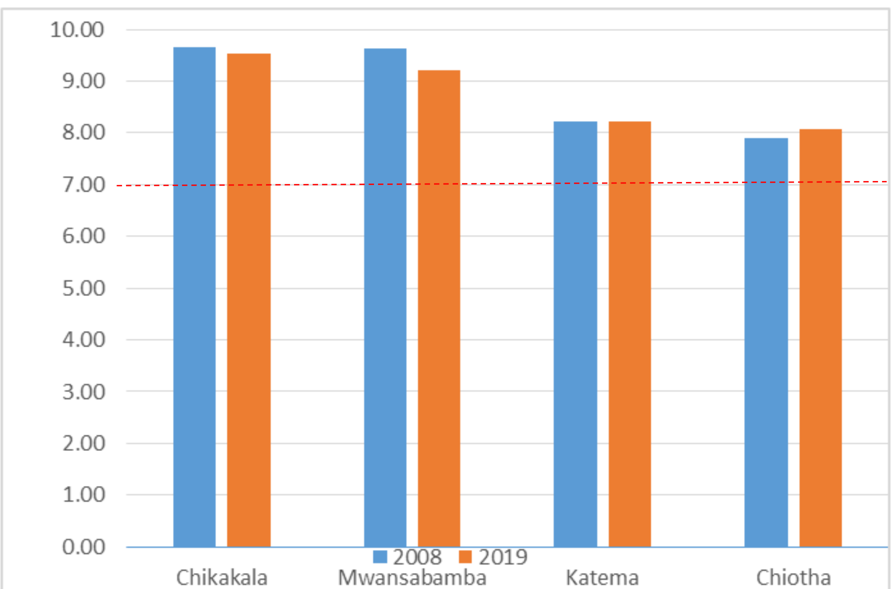

Figure 4.4: The nutrient cycling component for the health of four dambos assessed in 2008 and 2019, with health represented on a scale of 0 (critical) to 10 (pristine) and the Threshold of Potential Concern for Supporting Livelihoods (explained in Section 4.1.7) shown as a dashed red line.

4.1.6 The vegetation composition component of dambo health

Vegetation structure has an important direct influence on hydrological flows, particularly tall, dense robust vegetation which helps slow down the flow of water and protect the soils against erosion (considered in the geomorphology component of ecological health). Further, as discussed in the previous section, vegetation plays a central role in nutrient cycling and retention. The plant species composition of the vegetation, as assessed in Figure 4.5, also has an important influence over the condition of a wetland. Across all four dambos, in currently cultivated areas the natural vegetation has been completely removed, while in the recently abandoned areas recovery of vegetation species composition is still very limited. Therefore, together they are assigned close to the maximum impact intensity. In long-abandoned areas a much greater recovery of the natural vegetation was observed, varying from partial, where ruderal/pioneer species are generally still abundant, to fuller recovery where several of the original species have returned but still not fully attaining the composition of natural/uncultivated areas (Appendix E, Table E5).

In both the 2008 and the 2019 assessments, vegetation was consistently the most impacted of the five components of ecological health across all of the dambos (i.e. comparing Figure 4.5 with Figure 4.1 to 4.4). Comparing the vegetation component score for each dambo in 2008 and 2019 (Figure 4.5) it can be seen that there was a general decline in scores for all dambos, but in Chiotha it was extremely slight, more pronounced in Mwansabamba and intermediate in Chikakala and Katema. From Appendix E, Table E5 it can be seen that the changes seen in Figure 4.5 are primarily as a result of shifts in the extent of different land-cover types (notably a decline in natural vegetation and an increase in the areas of cleared and fallowed land) but the intensity scores within the respective land-uses largely remained unchanged. In addition, as noted by Kotze (2011) the vegetation in Chiotha dambo appears to recover its natural composition far more readily than Katema, and probably also the other two dambos. This may be owing to the inherently higher soil nutrient levels of the Chiotha dambo, which is naturally dominated by a few competitive species such as *Echinochloa pyramidalis* compared with the nutrient-poor and naturally more species-rich situation in the other three dambos.

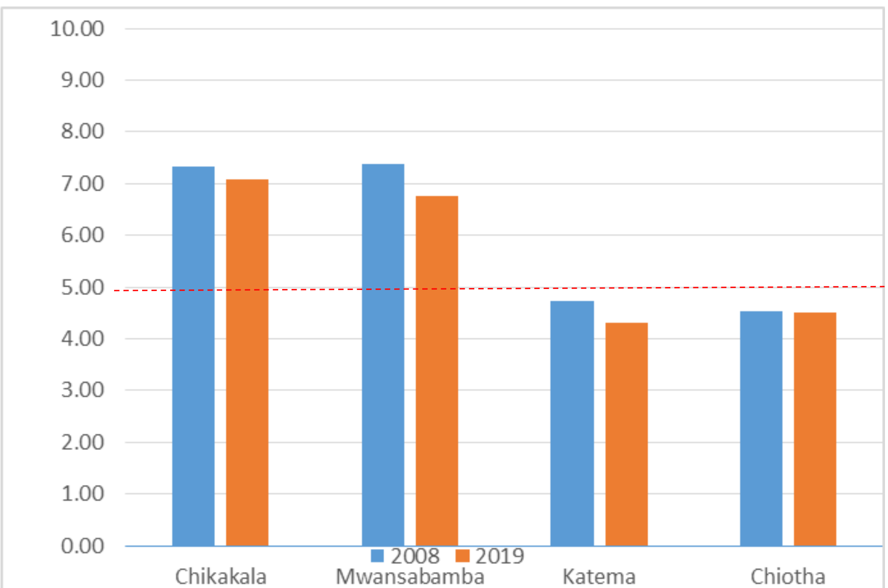

Figure 4.5: The vegetation component for the health of four dambos assessed in 2008 and 2019, with health represented on a scale of 0 (critical) to 10 (pristine) and the Threshold of Potential Concern for Supporting Livelihoods (explained in Section 4.1.7) shown as a dashed red line.

Both Katema and Chiota have fallen below the generic threshold of concern for vegetation given in Section 4.1.7, owing primarily to a fairly limited extent of remaining natural vegetation. However, there seems to be a greater basis for concern in the Katema dambo given the higher rate of decline in extent of natural area compared with Chiota, as elaborated on further in Box 1.

Box 1: The ecological motivation for maintaining extensive areas of natural vegetation in a dambo

In the functional landscape approach described by Wood and Thawe (2013) it is recommended that areas of natural vegetation be protected in the dambo, in particular to help prevent soil erosion, and that at least 50% of the dambo should be left uncultivated. In addition to soil conservation benefits, conserving indigenous vegetation is likely to contribute more broadly to ecosystem function and resilience with respect to both climatic extremes and recovery from on-site anthropogenic disturbance. In Chikakala dambo, J Sampa (2019, Pers comm., Mpika, Zambia) indicated that the native species such as *Eriocaulon* sp. which are characteristic of the seepage zone have specific value in restoring fertility during the fallow period.

Although specific studies on this contribution in dambos is lacking, a long-term study showed that conservation of grassland plant biodiversity contributed to primary productivity being more resilient to, and recovering more fully from, a major drought (Tilman and Downing 1994). It can therefore be assumed that the smaller the extent of areas of natural vegetation remaining in the dambo, the smaller will be the area sustaining a diverse and viable pool of native species specifically adapted to the different ecological zones represented in the dambo. Where the extent of natural vegetation becomes very limited then this "pool" of native species is likely to become depleted, particularly where vegetation is slow in recovering, as appears to be the case for at least the Katema dambo. From the results it can be seen that Katema has the lowest extent of natural vegetation out of the four wetlands, having dropped from 45% in 2008 to 36% in 2019. Seen together with the 20% for old abandoned lands (which appear to have largely recovered their original perennial cover) this amounts to 56% which is performing a soil conservation function. However, the native species pool of the old abandoned lands remains much depleted from the original natural vegetation, with implications for broad ecosystem function and resilience. If the current trend continues then in the next 10 years the extent of natural vegetation may drop below 30%.

Other impacts on the vegetation composition include livestock grazing and invasive alien plants. Although it was beyond the scope of the study to assess the specific ecological effects of livestock grazing, it was noted that levels of livestock use of the Katema and Chiota dambos are moderate and the Chikakala and Manswabamba are low, and obvious negative impacts on ecological health were not apparent in 2008 and 2019. Despite the Chiota dambo having what appears to be the most palatable grazing of the four dambos, the VRNMC have controlled grazing well, and it is confined to only a few specified months in the year. However, in the Lubaleshi dambo, an additional dambo 5 km south west of Chikakala dambo, grazing is continuous, cattle grazing intensities have recently increased and high levels of localized trampling were visible in 2019.

As noted in the 2008 survey, the extent of invasive alien plants in 2019 was very low in three of the dambos and moderately low in the fourth dambo, Chiota, where portions of the streamline in the downstream end of the dambo were infested with Mexican sunflower (*Tithonia diversifolia*). Although the extent of this plant is currently limited and it does not appear to have increased greatly since 2008, it could readily increase in the future. Also, although still at a very low abundance, *Lantana camara* also poses a threat to the natural vegetation in the dambo generally, together with guava and eucalyptus trees in the dambo. *Pistia stratoites* (Water lettuce), was noted in some of the wells in 2008 but not in 2019. As noted in 2008, species such as *Ageratum conyzoides* and *Bidens pilosa* are also alien plants that readily colonize disturbed areas such as old cultivated lands. However, they are annuals or short-lived perennials, and unless the area continues to be disturbed, they tend to give way to other plant species. Therefore, they are not regarded as problem plants such as *Tithonia diversifolia* and *Lantana camara* which persists and out-compete the native plant species. It should be added, however, that although representing a threat to the ecological health of the dambo, *Tithonia diversifolia* can be used as a mulch/green manure with high nutrient levels and the potential to increase crop yields, as demonstrated for maize by Ademiluyi and Omotoso (2007).

4.1.7 Overall dambo health summarized and sustainability of use assessed

Figure 4.6 presents a summary of the overall ecological health of each dambo, derived by integrating the scores for the five different components of ecological health. From this summary it can be seen that for Chikakala and Katema there was only a slight decline in ecological health from 2008 to 2019, in Mwansabamba it was somewhat more, and in Chiotha ecological health was fractionally improved.

Of the five components reported in Sections 4.1.2 to 4.1.6, vegetation is the component most severely affected across all dambos, followed by hydrology and then SOM accumulation (Table 4.4). The geomorphology component was least impacted (Table 4.4), with minimal erosion noted except for in the Chiotha dambo.

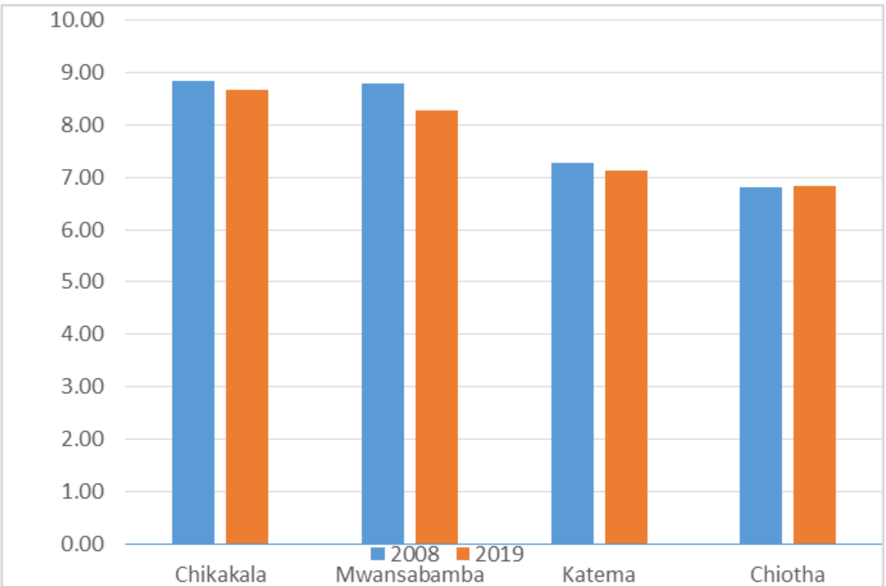

Figure 4.6: Overall ecological health of the four dambos assessed in 2008 and 2019, with health represented on a scale of 0 (critical) to 10 (pristine).

Table 4.4: Summary of the ecological health of the four dambos, assessed on a scale of 0 (critical) to 10 (pristine) and with the ecological health category represented on a scale of F (critical) to A (pristine)

Components of ecological health	Chikakala		Mwansa-bamba		Katema		Chiotha		Thresholds of Potential Concern	
	2008	2019	2008	2019	2008	2019	2008	2019	C	L
Hydrology	8.79	8.53	8.66	7.94	6.95	6.63	6.77	6.52	<8	<6
Sediment accumulation/ erosion	9.74	9.71	9.63	9.41	9.33	9.41	7.62	7.72	<8	<7
Soil organic matter accumulation	8.70	8.62	8.70	8.28	7.32	7.30	7.30	7.56	<8	<7
Nutrient cycling	9.65	9.55	9.64	9.20	8.22	8.22	7.91	8.08	<9	<7
Vegetation	7.33	7.07	7.38	6.77	4.72	4.30	4.54	4.52	<5	<5
OVERALL	8.84	8.68	8.79	8.28	7.27	7.12	6.82	6.85		
Ecological health category	B	B	B	B	C	C	C	C		

Threshold C=with the primary objective being management of catchment water quality
Threshold L= with the primary objective being management for sustaining local livelihoods

By comparing the ecological health scores to the thresholds of potential concern in Table 4.4, it can be seen that they are largely above the thresholds of concern. Therefore, from this perspective utilization of the dambos is deemed to be largely sustainable. However, there are some concerns, particularly with respect to the vegetation component, which has fallen below the threshold of potential concern for two of the dambos, primarily owing to the high extent of cultivation in these two dambos. For the remainder of the ecological health components, the score is above the threshold for livelihood support but falls below that for managing catchment water quality. The onerous threshold for catchment water quality is arguably justified given that two of these wetlands are in the catchment of Lake Malawi, for which water quality impacts have been detected (Thieme et al. 2005).

4.1.8 A summary of the intensity of impacts from cultivation

Cultivation is the most important use of the four dambos both in terms of contribution to livelihoods and in terms of impacts on ecological condition. Thus, it was considered useful to present a summary of the intensity of impacts associated with the currently cultivated plots (Table 4.5).

Table 4.5: A summary of the intensity of impact of dambo cultivation, within the cultivated areas, on the different components of ecosystem health for the four dambos

Components of ecosystem health	Chikakala		Mwansabamba		Katema		Chiotha	
	2008	2019	2008	2019	2008	2019	2009	2019
Hydrology	5.0	4.5	5.0	6.0	3.0	3.2	1.5	1.7
Erosion/ sedimentation	1.0	1.0	2.0	2.3	1.0	1.0	4.0	3.7
Soil organic matter	6.0	5.5	6.0	6.5	5.0	5.0	4.3	4.0
Nutrient cycling	5.0	4.5	5.0	6.0	5.0	5.0	4.0	3.5

The intensity of impact of cultivation at Katema has remained largely the same for all components of ecosystem health, largely as a result of similar cultivation practices in 2008 compared with 2019. A similar trend was found at Chiotha, except that the intensity of the hydrology component was slightly higher and the soil organic matter and nutrient cycling components slightly lower in 2019 (Table 4.5) with these changes largely attributed to an increase in cultivation of sugar cane relative to annual horticultural crops. The intensity of impact at Chikakala has decreased slightly over time while at Mwansabamba with the higher cultivation beds it has increased (Table 4.5) owing partly to somewhat different approaches employed by farmers in dealing with the high level of wetness of the respective dambos following an above-average rainy season, as described in Section 4.2. In all four dambos, soil organic matter accumulation remains the component most impacted upon by cultivation.

4.2 Results of the institutional assessment

A summary of the findings from the four sites concerning the Village Natural Resource Management Committees (VNRMCs) and the byelaws is presented in the following table (4.6).

Table 4.6: Village Natural Resource Management Committees, Byelaws and Institutional Issues

	Chikakala	Mwansabamba	Katema	Chiota
VNRMC	Yes in VDC	No	Yes but weak	Yes in VDC
Members	?	-	?	10
Frequency of Meeting	1 x / month	-	Rarely	2 x / month
Byelaws Recognised	Buffer, Stream, Livestock, Compost	Buffer, Livestock	Buffer, Stream, S&W Conservation	Buffer, Stream, Livestock, Eucalyptus, Burning, Soil & Water Conservation
Issues	Strong community, four wetlands only one with land shortage / pressure	Multiple villages, recognise need to meet to manage as pressures grow, external land purchases	Limited enforcement as weak headman, Newly arrived families	Key byelaws re central wells not recalled, strong headman, other village have interests

Of the four wetland sites visited, communities in three recognized VNRMCs, but in the other dambo community this institution was said to no longer exist and people could not remember when it has last met. Of the three sites where VNRMCs were recognised, in two cases wetland and catchment management issues are covered as part of the Village Development Committee's (VDC) agenda, while in the other case the VNRMC meets only irregularly, reportedly due to an inactive village headman. The two cases with regular meetings each have specific features - a very active headman in one case and a solar-powered grinding mill in the other which requires careful attention and regular meetings by the VDC. In these two cases, representatives of the VNRMC have been integrated into the VDC so that natural resource management matters can be treated in the normal agenda. Apparently, this merging of committees is not uncommon as the agendas of other specialist activities – such as health, which had also set up separate committees, are now covered in the regular VDC meetings, the proliferation of committee meetings having created a burden for the communities.

The lack of an active and separate VNRMC was in general not a concern to the community members who attended the village focus group meetings. In several cases it was suggested that there was no need for the VNRMC to meet as the communities faced no problems with respect to their dambos and there were no conflicts to resolve or specific guidance required. Indeed, it was even suggested that the development of these committees by the SAB project was premature as the SAB advice was easy to follow and in line with local understanding about wetland dynamics. This seemed appropriate due to the slight reduction in the wetland farming area in the two Malawian sites and the small percentage of the wetlands cultivated in Zambia (3% and 6%). (Of relevance here are the findings of the 2018 study in northern Zambia of the spread of wetland farming which showed that VNRMCs were not set up by communities adopting these methods outside the SAB Project, despite advice about the need to manage wetland and catchment land use in ways which sustained the wetland farming) (Mbewe and Sampa, 2018).

In contrast, in the one site without a VNRMC the need for such a grouping was recognized by some members in the focus group meeting. They felt that the rapid expansion in the area cultivated (from 2% to 6% of the dambo in 11 years) and the increasing interest in wetland cultivation from villagers and people from nearby Mpika town was leading to some conflicts. There was also some concern that the recent expansion of cultivation on a seepage zone with a considerable gradient and with downslope oriented beds, would encourage erosion especially as there are no areas of natural vegetation to stabilise the land. The need for action by the VNRMC was also noted in the village where the headman was inactive. There farmers recognised the need to control the expansion of cultivation into the centre of the wetland and the use of intensive drainage, and to prevent potentially damaging behavior rather than responding to it after the event.

In all the discussions, questions were raised about the extent to which farmers can envisage the wetland degradation scenarios which may occur and which require preventative action. In general, there was found to be very different levels of awareness of the need to invest time and sometimes resources, or forego income, in order to prevent negative developments. Hence it was encouraging that in the sites without active VNRMCs the group discussions raised questions about the need for active coordination and management in their wetlands. However, it should be noted that these responses were from people involved in wetland farming or interested in this, and so they were concerned about the need for practices which can ensure sustainable future use of these areas.

A common element of the discussions about wetland and catchment management during the transect walks and the focus group meetings was the recollection by the communities of the byelaws developed during the SAB project, and reference to the way they are still generally applied. Of these the one remembered in all sites was the need to maintain a buffer zone of natural vegetation around the wetland to halt flows of water and sediment. However, while that was recalled in all sites, between 2008 and 2019 there was a slight shrinkage of the extent of natural vegetation buffer for the dambos generally, as reported in Table 4.2, and if this shrinkage continues in the future the health of the dambos are likely to be threatened. Not cultivating in the centre of the wetland was recalled in three of the four sites, while controlling livestock grazing to protect wetland gardens and avoid compaction of soil was remembered in both Zambian sites. Improved water infiltration in the catchments through soil and water conservation, a key element of the FLA, was mentioned in both Malawian sites reflecting the greater deforestation and degradation of the catchments in that densely settled country.

The design principles proposed by Ostrom (1990) for community institutions to manage common pool natural resources were reviewed as part of this study along with consideration of these earlier conclusions by Dixon and Carrie (2015) from a study of the Simlemba sites in 2012. In terms of issues raised by the communities three were seen as most important for the sustainable management of these wetlands, namely, the origins of the wetland users, the behavior of new entrants and the active operation of the management institution, the VNRMC, with special reference to coherence and leadership.

On the first point, three communities were aware that there are people from neighbouring areas who make use of the wetland and woodland in the catchment and that this is sometimes difficult to control. This links to Ostrom's advice that commons should have clear defined boundaries – both in terms of space but also rights of access, and this is likely to be an area requiring attention where the use of wetlands increases rapidly, Mwansabamba being the most urgent case. Related to this issue of defined boundaries, is the need to spread knowledge of issues affecting sustainable wetland use and key byelaws. This was reported to have occurred in both Malawian sites where villages upstream or on the other side of a dambo have been engaged by wetland farmers not wanting their livelihood undermined. In Zambia this was not reported but the population density is much lower and the distance between wetland using communities much greater. This issue of wider coordination is important for coordination of landscape management – as recommended in the FLA, with catchments and wetlands having linked biophysical processes. Here there is a need, for instance, to engage those households who only undertake upland rainfed farming and so are not interested to maintain buffer zones around wetlands or undertake other upland measures, such as conservation agriculture or soil and water conservation, which may have beneficial impacts in the wetlands – in the form of seepage water.

The question of guiding new users was discussed given the need to also make them familiar with the byelaws developed during the SAB project. In this case it was felt that the VNRMC and lead farmers are important to ensure that the guidance previously developed is taken on board. However, where new entrants are from the next generation of existing wetland-using families, there was said to be less concern as the older generation provide guidance to the younger ones.

With respect to the active operation of the VNRMCs, it is clear that having strong and informed leadership is important, as seen in Chiotha and Chikakala. However, there is also a need for the community to have some coherence and a common sense of purpose with respect to the wetlands and their management to achieve sustainable use. This can come from engagement in the design and development of the VNRMC and its byelaws, a point which Dixon and Carrie (2015) felt was missing in the SAB work in Malawi. However, there also need to be clear benefits from the wetland farming which households come to value and which in turn encourage them to engage in the VNRMC work and adhere to the byelaws (McElwee and Wood 2017).

VNRMCs do not operate in a vacuum, and an important question is the extent to which other organizations have contributed to either strengthening or weakening application of the FLA approach at the four dambos. There was very limited time to explicitly explore this issue in July 2019, although in the various focus group meetings there were no discussions about other NGOs interacting with the FLA villages. However, in Zambia, the animateur who had introduced the controlled turf burning method- Jonas Sampa, had been employed by a Finnish government funded project to introduce the same wetland farming methods in parts of the neighbouring Luapula province in 2008-09. Government and other NGOs have also been involved in encouraging different types of wetland farming in other parts of northern Zambia since 2010 and a recent survey of the spread of the FLA and wetland farming reports these activities (Mbewe and Sampa, 2018). This report noted, for example, that the Department of Agriculture staff in three northern provinces are aware of the SAB methods (being promoted within the overall FLA approach) but it is only the use of seepage zones which they recommend and not the turf burning. Interestingly, the July 2019 survey showed that in certain circumstances (where soil organic matter levels are very high) there is justification on environmental sustainability grounds for the DOA staff's reluctance to apply turf burning. Use of treadle pumps has been an approach followed by other NGOs. Also of note in this report is the fact that communities have not spontaneously set up VNRMCs where wetland cultivation has been adopted, and resources management matters are covered by the existing village development committees.

5. Conclusions

The key question addressed in the conclusions is whether there has been a significant change in the ecological health of each of the four dambos between 2008 and 2019. This, in turn, will inform the question of the long-term impacts of the Striking a Balance project, i.e. has the ecological health of the dambos at the end of the project been largely sustained after more than 10 years of use, primarily for cultivation? In addressing this question, an attempt is made to place any detected change in ecological conditions in the context of key external pressures affecting the wetland and to assess the community capacity to cope with it.

In all four dambos the change in ecological health between 2008 and 2019 has generally been small, and the ecological health category remained unchanged at B or C (i.e. small to moderately impacted) (Table 4.4). In the case of Katema and Chiotha, both still in category C, this is owing primarily to the fact that both the extent and intensity of impact associated with cultivation in the dambo has remained very similar and with a small reduction in the percentage of the wetland cultivated. In addition, other impacts (e.g. from roads through the wetland and clearing of woodland in the wetland's catchment) were also similar in 2008 and 2019. Although the intensity of impact has increased only slightly in Mwansabamba, the extent of cultivation has increased noticeably, experiencing a three-fold increase from 2008 to 2019. While this constitutes a major change, owing to the fact that the baseline extent in 2008 was very low (only 2%), this does not constitute a major impact on wetland ecological health. Nevertheless, although its ecological health category remained at B, the ecological health score declined noticeably more than the other three dambos, and if the current rate of decline continues, over the next 10 years it will drop to a C category, i.e. to that of Katema and Chiotha. The other dambo, Chikakala, had a very slow rate of decline in its ecological health and remained well inside category B. If its current rate of decline is sustained, Chikakala will only reach a C category after several decades.

In terms of the institutional aspects of this study, the main conclusions are that while the VNRMCs are not continuing in the form they were established, with the membership and frequency of meeting as originally envisaged, there are elements of the SAB project guidance still present in these communities. In particular, many of the people most engaged in wetland farming remember and seek to apply some of the byelaws which were developed through the SAB project. Additionally, the VNRMC still exists in one village while in two of the others its work has been incorporated into the Village Development Committee where it can perhaps be sustained more easily. In the one case where there was no VNRMC the need for some such coordination was recognized in the village focus group meeting. A key issue for the institutional arrangements for managing the wetlands and the catchments in a coordinated manner is economics. Here there are two concerns, can wetlands continue to generate economic benefits for the majority of the community which make households want to coordinate efforts to ensure the sustainable management of wetlands and their catchments, and how can community cohesion be achieved when some households benefit more from wetland use than others and socio-economic diversification occurs?

Linked to all of these issues is the recognition from the field discussions that farmers do not fully understand the potential for negative scenarios in terms of resource degradation in their wetlands, or maybe they do not wish to accept these exist.

Given these observed trends in ecological health taking place between 2008 and 2019, together with any specific vulnerabilities of dambos (e.g. the major erosion headcut in Chiotha) and the institutional situation, some speculation is offered in terms of the future projected trajectory of change of the four dambos (Table 5.1).

Table 5.1: Summary of the projected trajectory of change in ecological health of the four dambos over the coming 10 years

Dambo	Current health status, Anticipated trajectory of change, Predicted health status in ten years	Key influencing factors
Chikakala	B slight decline B	A cohesive community and VNRMC issues covered in the VDC thereby managing dambo use. But the local population is projected to increase and the demand for dambo crops is likely to grow. This community is also strongly linked to the Mpika market which will increase pressures on the wetland which is quite intensively used.
Mwansa-bamba	B significant decline C	Users of the dambo are not from a single cohesive community, but from different villages and some even from Mpika town. No VNRM committee is in place, and there are many new entrant dambo farmers, which all make managing dambo use very challenging. In addition, access to markets for dambo crops is good and interest in market oriented production is increasing.
Katema	C slight decline C	Users of the dambo are from two different villages. An inactive VNRM committee and weak headman present challenges for control over dambo use. Although the initial market demand for dambo vegetables is currently lower than 10 years ago, this may change in drier years.
Chiotha	C slight to significant decline? C or D?	A cohesive community and existing VNRMC are enabling control of dambo use, but if the main erosion headcut is not protected then a significant decline in ecological health is possible with major storm event/s. With protection of the headcut using an upstream buffer of natural vegetation and good stormwater management in the catchment, only a slight decline in ecological health is likely but not guaranteed. Spread of invasive alien plants is a possible additional threat. Market opportunities for vegetables have not expanded as expected, so less expansion of wetland farming is anticipated.

Thus, it is concluded overall that the ecological health of the four dambos at the end of the project has largely been sustained after more than 10 years of wetland cultivation since the completion of the project. However, in at least two of the dambos these outcomes are threatened by weak institutional controls over use and growing land-use pressures and demand for dambo resources. Lessons from this assessment and recommendation on how to address the challenges are presented in Section 6.

6. Lessons learnt and recommendations

In this final section, key lessons are identified and recommendations provided which can be applied in Self Help Africa's continued work with wetland-using communities and smallholder farmers in Malawi and Zambia. The lessons learnt and recommendations are drawn from:

- The assessments of both the ecological and institutional sustainability in the text above,
- Discussions with local farmers and SHA staff, and
- Recommendations provided by Kotze et al. (2008) and Kotze (2009) which were reviewed to determine the use made of this guidance and their current relevance.

The key recommendations of the SAB Project made in 2008 (see Table 6.1 and the first 10 recommendations listed in Table 6.3) are the cornerstones of functional landscape approach (FLA) and appear to provide a sound basis for maintaining the ecological health of a dambo, as reflected in the ecological health scores for the four dambos presented in Table 4.4. Given that these recommendations were found to be relevant to the four diverse dambo types studied, this provides confirmation that the key SAB / FLA recommendations are likely to be widely applicable in continued work with wetland-using communities and smallholder farmers using dambos in Malawi and Zambia.

Table 6.1: Key Recommendation from the Striking a Balance Project (2008)

1. Confine cultivation in the dambo to mainly during the dry season
2. Maintain the central areas of the dambo under natural vegetation
3. Maintain extensive areas (preferably >50%) of the dambo under natural vegetation
4. Maintain a buffer of natural vegetation around the dambo
5. Practice crop rotation
6. Limit cultivation of crops with high water demand, e.g. sugar cane
7. Use manure/compost in preference to mineral fertilizer
8. Include soil-building crops in the cultivated areas
9. Avoid over-drainage
10. Prohibit eucalyptus trees in and near the dambo

However, when applying the FLA approach more widely, it would be useful to take note of the following additions to the specific guidelines (Table 6.2 and the last six recommendations listed in Table 6.3) which have been derived from the 2019 study.

Table 6.2: Additional Recommendations based on 2019 Field Assessment

1. Avoid burning of very organic rich soils (Plate 6.1)
2. As far as possible reduce tillage of cultivated dambo plots, but recognizing the problems of applying minimum tillage in waterlogged soils
3. “Invest” in fallow areas to promote soil recovery, but recognizing that where the extent of dambo cultivation is high then opportunities for fallows will be very limited
4. Maintain a buffer of natural vegetation upstream of and surrounding any erosion features, such as headcuts
5. Avoid the use of biocides adjacent to streams and wells, especially ones used for domestic water
6. As far as possible use crop types and varieties with tolerance of waterlogging

Plate 6.1: A cultivated seepage area in the Mwansabamba dambo with organic-rich soils which have burnt, increasing their vulnerability to erosion and leaching of nutrients.

In addition, the following four overall lessons can be drawn from these recommendations

- *The considerable importance of managing SOM.* While SOM management is certainly not an aspect that has been ignored in the FLA, the first three additions in Table 6.2 suggest that even greater explicit attention needs to be given to this critical aspect of dambo management for long-term sustainable use.

- *Refinement of guidelines to prevent over-drainage*. While the FLA discourages over-drainage, it would be useful to provide explicit guidance to accommodate the wetter conditions of the dambo in years of above-average rainfall (as was the case in 2019), and keep the wettest dambo areas as a "reserve" for use in dry years, rather than trying to drain them in a wet year.

- *Broaden the explicit motivation for maintaining natural vegetation beyond the primary focus of erosion control alone* (see Box 1 in Section 4.1.6). This will also help maintain ecosystem functioning and resilience, including the regeneration of natural vegetation in abandoned fallowed plots.

- *A greater exploration is required of crop types and varieties/genotypes which are tolerant of water-logging.* Adoption of such crops would minimize the artificial drainage of dambos, and ultimately improve the resilience of the dambo-cropping system. Although farmers attempted to grow rice at some of the dambos, rice production was discontinued largely as a result of high crop loss to birds. Presently farmers at the four sites have limited access to crops which are tolerant of water-logging. However, this may be something that Self Help Africa could assist farmers exploring in the future, perhaps by drawing on the extensive research and development being undertaken in countries such as India and Bangladesh to better equip farmers for climate extremes. For example, pigeon pea (*Cajanus cajan*) has several different genotypes, which range greatly in terms of their tolerance to waterlogging, with some being susceptible and others with a high tolerance as a result of adaptations such as the formation of aerenchymatous cells (Hingane et al. 2015).

Table 6.3 (see below) reviews in more detail the 16 original and additional recommendations listed above. From columns 3 to 6, it can be seen that most of these key recommendations are largely being applied at the four sites. As reported in Section 4.2, these key recommendations seem to be generally well internalized amongst the dambo farmers involved in the 2019 discussion groups but have generally not been so readily transferred to new entrant farmers.

Table 6.3: Key recommendations and the extent to which each recommendation appears to being followed at Chikakala (Ck), Mwansabamba (M), Katema (k) and Chiotha (Co) dambos

Recommendations	Rationale and additional notes	Ck	M	K	Co
Key recommendations of FLA					
Confine cultivation in the dambo to mainly during the dry season	In the context of cultivation being annual crops, avoiding land preparation in the wet season reduces the risk of erosion	✔	✔	✔	✔
Maintain the central areas of the dambo under natural vegetation.	These areas tend to be subject to the greatest flows and therefore the greatest risks of erosion	✔	✔	✓	✓
Maintain extensive areas (preferably >50%) of the dambo under natural vegetation.	The primary motivation is to present erosion. Further contributions to increased resilience are described in Box 1.	✔	✔	⚑	⚑
Maintain a buffer of natural vegetation around the dambo	This helps control runoff from the catchment	✓	✓	✓	⚑
Crop rotation	Reduces disease risk and assists in maintaining fertility	✓	✓	✓	✓
Limit cultivation of crops with high water demand, notably sugar cane	Reduces the risk of drying out the dambo	✔	✓	✔	⚑
Use of manure/compost in preference to mineral fertilizer	Reduces the contribution to soil acidity. Also contributes SOM.	✔	✔	✓	✔
Include soil-building crops in the cultivated areas	This improves soil health and reduces the need for external fertilizer inputs.	✓	✓	✔	✓
Avoid over-drainage	Over-drainage contributes significantly to increased SOM depletion and increased risks of erosion and nutrient leaching	✔	⚑	✓	✔
Prohibit eucalyptus trees in and near the dambo	To reduce the risk of drying out the dambo	✔	✔	✔	✔
Additional recommendations					
Avoid burning of very organic rich soils	Burning of organic-rich soils has potentially serve effects on the soil health in terms of soil strength and the capacity to hold nutrients.	✔	⚑	✔	✔
As far as possible reduce tillage of cultivated dambo plots.[1]	Tillage is a key factor contributing to the depletion of SOM.	⚑	⚑	⚑	⚑
"Invest" in fallow areas to promote soil recovery.[2]	Include measures to facilitated re-wetting (e.g. flattening of ridges) and consider planting soil building perennials such as *Sesbania sesban* or a waterlogging tolerant cowpea genome if available.	✓	⚑	⚑	⚑
Maintain a buffer upstream of natural vegetation upstream of erosion headcut.	To minimize the risk of headcut advance through the dambo, the area immediately upstream of the dambo should remain under permanent vigorous vegetation cover.	-	-	-	🚩
Avoid the use of biocides adjacent to streams and wells, especially used for domestic water.	Application of biocides adjacent to aquatic systems poses risks to aquatic fauna as well as to human health.	✓	✓	✓	✓
As far as possible use crop types and varieties with tolerance of waterlogging	The currently cultivated crops and varieties appear to all have a low tolerance to waterlogging, therefore often involving artificial drainage to allow for their cultivation in the dambos, in turn impacting on SOM and nutrient retention.	⚑	⚑	⚑	⚑

Note: see following page for legend and table footnotes [1] and [2]

Recommendations are largely being followed

Recommendations are being followed to some extent

Recommendations are being followed to a limited extent

Recommendations are not being followed

[1]In attempting to reduce tillage, it is acknowledged that applying minimum tillage in waterlogged soils is generally inappropriate and leads to reduced yields (P Wagstaff, Pers comm. 2019. Self Help Africa, Dublin, Ireland). Therefore, opportunities for reducing the level of tillage are likely to be greatest in the direr portions of the dambo and in dry years when water tables are low and waterlogging much more limited (than in wetter portions/years) and when the need is greatest for water conservation, which reduced tillage helps to promote. Further opportunities for reduced tillage would be through sourcing perennial crops which are tolerant of waterlogging and acceptable to local farmers.

[2]In promoting fallows, it is recognized that in the Malawi dambos, where individual farmers have limited available land and the extent of dambo cultivation is high, opportunities for fallowing are very limited, and a more viable option is to promote crop rotations. However, at the Zambian sites the spatial extent of cultivation is still low enough to allow for some fallowing of lands, which is taking place but which could potentially be improved with a little more "investment" in the fallow.

In applying these recommendations and the additional four points, attention is directed to institutional issues and the question of how best can these matters be owned and addressed by the wetland farming communities and individuals. No single model can be proposed and local adaptation will be necessary, but the following questions may be helpful.

a) Is a separate VNRMC needed or are the issues related to coordinating wetland and catchment management best dealt with in the Village Development Committee, with one or two persons having specific responsibility for these issues?

b) How can specific FLA extension advice be disseminated across all farmers when there is no government extension staff or they have limited time? Are volunteer Lead Farmers required?

c) What is the importance of positive economic returns from wetland farming for encouraging farmers to consider the value of having some byelaws, or other guidance, and enforcing such?

d) Can a visioning process be developed which will help communities understand better the risks to wetland sustainability and explain their fragility? (For example, with erosion gulley advance, which often takes place episodically such as in a one-in-20 year storm)

e) How can visioning of positive as well as negative scenarios across a village landscape be achieved to engage the whole community and build a common interest and coherence?

f) When a wetland and its catchment include land from several villages, and when upstream and downstream links exist, how can a sense of mutual understanding and responsibility be achieved across the landscape?

g) How can local knowledge and self-learning be supported so that wetland farming groups develop flexibility in terms of byelaws and guidance about wetland farming methods as experience develops – e.g. adjusting methods of wetland farming to suit years with different amounts of rainfall and reducing environmental impacts?

h) A long-term perspective of wetland use should be encouraged in wetland using communities and extension staff, with consideration of the potential for households to move beyond the view of wetland farming as a business to generate income to one which sees such farming more as a source of capital for enterprise diversification as seen in the 2016 Mpika study (McElwee and Wood 2017). Pressure on wetlands is already reducing in Malawi, probably due at least in part to excess production of vegetable for markets, and so intensive wetland use may only be a feature of a specific stage in the development process for some rural areas[3].

Overall, with respect to the ecological health of dambos it may be concluded that wetland farming – as seen in the four sites studied – has small to moderate impacts when first begun, and can be limited after that, and need not progress to cause serious degradation provided appropriate guidance is followed. The livelihood benefits from this farming are considerable and there is a need to understand the trade-offs which are being made. Key elements in sustaining wetland agricultural use include:

- Ensuring that local farmers and government and NGO staff (including that of SHA) have the capacity to monitor these areas and build a clear shared understanding of the potential positive and negative effects of different scenarios for wetland management.

- Fostering an enabling learning environment whereby local farmers currently practicing the FLA may pass on this approach to new entrant farmers and succeeding generations, and are also able to respond and adapt to emerging issues and opportunities.

- Strengthen local institutional arrangements and develop the governance capacity required to maintain the health of these wealth creating resources, but not necessarily through establishing new institutions.

In terms of building the capacity of staff to monitor the ecological sustainability of dambo use, it is recognized that applying the ecological health assessment used in this study requires a reasonably high level of training and experience. Therefore, as a simplified means of assessment, it is suggested that Table 6.3 be used as a check-sheet to highlight, at a glance, some key cultivation practices that are likely to be contributing, either positively or negatively, to achieving environmental sustainability. Farmers could then be encouraged to continue with the positive practices, and for the negative practices to seek appropriate alternatives. The check-sheet in Appendix A, Table A5 may also be of assistance with capacity building.

In closing, it is important to acknowledge that the scope of this project only allowed for the assessment of four dambos, all of which were sites where the FLA has been promoted. For further investigations it is recommended that "control dambos" where the FLA has not been directly applied (but which are otherwise comparable to the four dambos) also be included. In addition, the use of remote sensing with high-resolution, multi-spectral images is recommended to measure spatial metrics such as intactness of the dambo buffer and extent of cultivation in the dambo. Furthermore, it is recommended that the selected time-periods of assessment include both drought years and normal to above-average rainfall years. It is anticipated that such research would provide valuable insights into the multiple factors affecting dambo cultivation and the ecological health of the dambos. Such research would, for example, contribute to understanding the relative importance of: (a) evolving market demand, and (b) fluctuating climate in explaining the reduced pressure on the Malawi dambos for vegetable production observed in July 2019 (which followed a wet season with above-average rainfall).

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[3] However, it should be noted that in several African countries including Zambia, medium-size farms are accounting for a growing proportion of total farmland, and such farms are often financed by non-farm income and reflecting an increased interest in land by urban professionals and influential rural people (Jayne et al. (2016). Thus, although not appearing to be a current trend at the four dambos, a future possibility is that commercially successful farmers expand their production within dambos.

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Appendix A: A summary of key factors considered when assessing the intensity of impact of cultivation on the different components of ecological health (modified from Kotze 2010)

WET-Sustainable-Use provides a description of specific factors to consider when scoring the intensity of impact of cultivation on the five components of ecological health, namely hydrology erosion/sedimentation, Soil Organic Matter (SOM) accumulation, nutrient cycling, and vegetation composition. As a guide to assessing the intensity of impact within cultivated areas, Tables A1 to A4 list these factors (and underlying rationale) for the first four of these components. For the fifth component, vegetation composition, impact impacts are almost always high given that native wetland plant species, except for some generalist, weedy species, are able to persist in any abundance in cultivated plots.

Table A1: Key factors contributing to the intensity of impact of artificial drainage on the hydrological health of a wetland

Factors	Rationale
Features of the wetland	
Slope of the wetland	The steeper the slope, the more vulnerable the wetland is to artificial drainage
Texture of mineral soil, if present*	The coarser the texture of the soil, the more easily draining it is and the more vulnerable the wetland is to artificial drainage.
Degree of humification of organic soil, if present*	The lower the degree of humification, the coarser the particles and more easily draining it is, and the more vulnerable the wetland is to artificial drainage
Natural level of wetness in the cultivated area	The higher the natural level of wetness the more vulnerable the wetland is to artificial drainage
Features of the artificial drains	
Depth of the drains/gullies**	The deeper the drains, the greater is their draining effect
Density of drains (metres of drain per hectare of wetland)	The denser the drains, the greater is their draining effect
Location of drains/gullies in relation to flows into and through the wetland.	The more effectively the drains intercept flow entering the wetland, the greater is their draining effect
Obstructions in the drains/ gullies	The less the extent of obstructions in the drains, the greater is their draining effect

Table A2: Key factors contributing to the intensity of erosion within cultivated plots in a wetland

Factors	Rationale
Vulnerability of the site to erosion (given slope & discharge)	The greater the vulnerability, the greater is the likely erosion under cultivation. The vulnerability of the overall HGM unit is determined based on the steepness of the longitudinal slope of the wetland and its size, which is the same approach used in the geomorphology component of Macfarlane et al. (2008).
Location in relation to storm-flow paths	A cultivated area located in the path of regular storm-flows will be subject to much more erosive conditions than an area located outside of this path.
Location in relation to an existing erosional feature	If cultivated land is located immediately adjacent to an existing erosion feature (notably the head-cut of an erosion gully) then the disturbance associated with the cultivation could potentially increase the likelihood of the erosional feature expanding into the area where cultivation is taking place. This risk is particularly high if it is located upstream of the feature.
Frequency of tillage	The greater the frequency of tillage, the greater will be the risk of erosion, given that each time the soil is tilled, its structure is disrupted and plant roots contributing to the strength of the soil are destroyed. Whether a crop is annual or perennial, or a root or aerial crop, affects the scoring of frequency of tillage. As highlighted in Section 5, annual crops required more frequent tillage than perennial or biennial crops, and root crops require tillage at both planting and harvesting (i.e. the highest frequency of tillage).
Extent of tillage in the cultivated area	The greater the horizontal extent of tillage, the greater will be the risk of erosion, particularly if the erosion hazard of the site is high, given that tillage disrupts soil structure and destroys plant roots which would otherwise contribute to the strength of the soil.
Depth of tillage	The greater the depth to which tillage takes place, the greater the volume of soil rendered more susceptible to erosion
Impact associated with traffic of implements	The impact associated with traffic of implements (e.g. from animal hooves or wheels) during the tillage process add further to the disturbance associated with tillage.
Timing of tillage in relation to timing of flooding	Soils are most susceptible to erosion immediately following tillage and then become progressively less susceptible as vegetation establishes itself and becomes more developed. If tillage takes place during the main flooding season, the chances are much higher that a major flood will occur soon after tillage than if tillage occurs outside of the main flood season.
Reduction in SOM (Soil Organic Matter)	Soil organic matter enhances the physical strength of soils, especially sandy to loamy soils, by promoting aggregate stability. This in turn increases the resistance of the soil to erosion (Miller and Gardiner 1998). Clay soils are, however, less positively affected by SOM.
Level of soil cover (with vegetation and/or mulch)	Soil may be covered by living and/or dead organic material. The positive effect that soil cover has on controlling erosion has been well demonstrated. The cover protects the soil against rain-splash erosion as well as providing some measure of protection against erosion from the flow of water over the soil surface.
Level of reduction of surface roughness	Surface roughness has a significant influence on the velocity of water flow across the surface of the ground. The greater the surface roughness, the greater the frictional resistance to the movement of water and the greater will be the level to which flow velocity is reduced
Concentration & direction of water flow (includes the orientation of drains / furrows)	For a given volume of water flowing through the wetland, the more concentrated the flow, the lower the wetted perimeter, the higher the velocity, and therefore the greater the capacity to erode.

Table A3: Key factors contributing to the intensity of impact on Soil Organic Matter (SOM) accumulation within cultivated plots in a wetland

Factors	**Rationale**
Reduction in plant inputs (plant growth)	The primary input to the SOM pool is from in situ plant growth, including roots and above-ground material (Mills and Fey 2003). It stands to reason, therefore, that the greater the reduction of in situ plant growth (e.g. as a result of desiccation of the wetland) the greater will be the decline in inputs.
Decreased level of wetness (see Table A1)	Prolonged soil saturation or flooding results in the development of anaerobic soil conditions. This, in turn, promotes the accumulation of SOM by impeding its decomposition. Thus for a given wetland, the more that the level of wetness is decreased the greater will be the potential depletion of SOM previously accumulated under the wetter conditions.
Level of erosion (see Table A2)	The greater the level of erosion, the greater will be the physical loss of SOM, given that much of it is concentrated in the upper levels of the soil (Mills and Fey 2003).
Frequency of tillage	The greater the frequency of tillage, the greater will be the reduction in SOM through microbial decomposition.
Depth of tillage	The greater the depth of tillage, the greater will be the volume of soil subject to disturbance, which in turn will lead to reduced SOM levels, through the same mechanisms described for frequency of disturbance.
Level of soil cover	The greater the exposure of the soil, the greater the extent to which the soil is subject to temperature fluctuations, which in turn contributes to increased levels of SOM depletion (Six et al. 2002).
Removal of whole plants or plant parts, e.g. through burning	Removal of whole plants or plant parts may be through export with the harvested crop, removal by grazing livestock or by burning.
Level of physical removal of organic sediment (e.g. through peat mining or ground fires)	The greater the physical removal of organic sediment (e.g. through peat mining or ground fires) the greater will be the depletion of the SOM store.

Table A4: Key factors contributing to the intensity of impact on nutrient cycling within cultivated plots in a wetland

Factors	**Rationale**
Level of artificial drainage (see Table A1)	Artificial drainage of a wetland affects how water is distributed across the wetland (channelled flow vs. diffuse flow) as well as its retention in the wetland. Artificial drainage tends to reduce the retention time in a wetland and promote the leaching of nutrients.
Level of erosion (see Table A2)	The greater the level of erosion, the greater will be the loss of nutrients adsorbed to the mineral particles lost through erosion, which applies particularly to P and other elements bound to the mineral particles in the soil.
Level of SOM depletion (see Table A3)	The greater the depletion of organic matter (e.g. through drying out of the area), the greater will be the loss of the pool of nutrients contained within the organic matter.
Texture of the soil	Generally, the coarser the texture of the soil, the greater will be the relative contribution of the SOM to the CEC of the soil, and therefore the more severely it will be affected by a decline in SOM.
Synchronization of nutrient availability and plant uptake	The greater the level of interruption of actively growing vegetation (between harvesting/ senescence of one crop and the full establishment of the next crop), the lower will be the capacity of the plants to take up mobile nutrients and prevent them from being leached (Randall and Goss 2001).
Export of nutrients in harvested or burnt plant material	The harvesting of a crop results in the removal of some nutrients, although the quantity of nutrients removed varies greatly amongst different crops
Addition of nutrients	The greater the rate of fertilizer application, the more difficult it is for the system to recycle most of the incoming nutrients, and the greater will be the extent of leakage.
Extent of soil building crops	The most important soil building crops are those that fix gaseous nitrogen (N2). Tropical grain legumes in particular may fix large quantities of N2, and some of these, such as cow pea and pigeon pea, return a large proportion of this to the soil. Deep rooted crops (e.g. pigeon peas) may also contribute to the building of soil by taking up some nutrients from the deeper layers, and when plant litter falls to the ground this may become incorporated into the topsoil.
Diversity of crop types &/or varieties	A system with several crop types and/or varieties is likely to be more resilient than a system with only a single crop (Altieri 1987a and 1987b; Richards 1995). This, in turn is likely to enhance the capacity of the system for retaining nutrients. A multiple crop system is generally more resilient to extreme events (e.g. in particularly wet periods, those crops better adapted to waterlogging will do better, whilst in particularly dry periods those crops better adapted to droughts will do better).

It is recognized applying the Ecological health assessment encompassed in Table A1 to A4 and described in full in Kotze (2010) requires a reasonably high level of experience in undertaking such rapid ecological assessments. Therefore, for fieldworkers lacking such experience, a checksheet is presented in Table A5 which highlights, at a glance, those cultivation practices that are likely to be contributing positively to achieving sustainability (and farmers can be encouraged to continue with these practices), as well as those likely to be contributing negatively (and here, work could be done with farmers to explore alternative practices that would have less impact).

Table A5: Checksheet for indicating how different cultivation practices in the dambo may generally impact upon the environmental condition of the dambo and its long term sustainable use

Cultivation practices	**Likely intensity of impact**		**Rationale**
	Low	**High**	
Crop type	Perennial / Aerial crop	Annual / Root crop	Annual crops and root crops require a greater level of soil disturbance than perennial crops and aerial crops.
	Low to moderate water use (e.g. beans)	High water use (e.g. sugar cane)	The higher the transpiration rate, the greater the loss of water from the wetland.
	Inherently high cover	Inherently low cover	The lower the cover, the lower the protection provided against erosion.
	Soil building properties high	Limited soil building properties	The higher the soil building properties, e.g. from nitrogen fixing plants, the greater the contribution to plant production and soil health.
	Multiple crop types	Single crop type	A multiple crop system is generally more resilient to extreme events (e.g. particularly wet or dry periods).
Timing of planting	Outside the main flood season	Within the main flood season	Planting in the main flood season is most likely to result in crop damage and soil erosion.
Weed management	Weeds suppressed with mulch or cover /alley crops	Tillage	Tillage is much less favourable for controlling erosion and overall soil health than mulch or cover/alley crops.
Artificial drainage	Low level of drainage (e.g. few/shallow drains &/or ridges very low)	High level of drainage (e.g. many/deep drains &/or ridges high)	The higher the level of drainage, the greater will be the impact on the natural retention of water in the wetland.
Tillage	Limited extent / Low intensity (e.g. minimum tillage)	Extensive area tilled / High intensity (e.g. mechanized deep plowing)	Tillage reduces soil strength and soil organic matter content, leading to greater levels of erosion and loss of nutrients and moisture holding capacity of the soil.
Utilization of crop/weed residues	Incorporated or mulched (most preferred) in the plot	Cleared and discarded and/or burnt	Crop residues returned to the wetland soil (e.g. through mulching) contribute to SOM, which promotes nutrient retention.
Bands/border of natural vegetation	Present and running at right angles to the direction of water flow (high surface roughness most preferred)	Absent	Bands of natural vegetation promote the binding of soil, and if the surface roughness of the vegetation is high, the flow velocity of water is reduced.

Cultivation practices	Likely intensity of impact		Rationale
	Low	**High**	
Vulnerability to erosion of the cultivated area	Cultivation is in an area that has a low risk of erosion	Cultivation is in an area that has a high risk of erosion (e.g. immediately upstream of an erosion head-cut)	Cultivation exposes an area to erosion, and therefore if cultivation takes place where there is a high risk of erosion then the likelihood is high that this will contribute to erosion.
Natural level of wetness of the cultivated area	Cultivation is in an area with a naturally low level of wetness	Cultivation is in an area that has a naturally high level of wetness	The higher the level of wetness, the greater the likely need for artificial drainage, given that most crops have a low tolerance to waterlogging.
Overall extent of remaining natural vegetation in the wetland	Cultivation is confined to a relatively small proportion of the wetland and natural vegetation occupies >50%	Cultivation covers a relatively large proportion of the wetland and vegetation occupies <50%	The lower the proportion of the wetland covered by natural vegetation, the greater the impact

Appendix B: The turf burning and ridging method (modified from Kotze 2009)

The traditional land preparation in the Mpika dambos involved digging up the surface soil together with plant roots in pieces, or turfs, with quite thick "slices" taken. After being left to dry, the turfs are burnt, and then cultivation takes place in the ash-rich soils (Sampa, 2008). However, burning of the thick-cut turf proved very variable, with light and incomplete burning where the turfs were not fully dried at the time of the burn. This led to low amounts of ash from the burning, which in turn led to poor yields. However, areas which received a good burn due to the thorough drying of the turf had more ash and gave better yields (Sampa, 2008). Building on the existing traditional dambo cultivation methods at Mpika, Jonas Sampa worked with local farmers in the early to mid 1990s to develop a more refined method, referred to in this document as the turf burning and ridging method.

"This (the turf burning and ridging method) involves cutting thin turfs, drying them first on the ground (grass side down), gathering the turfs into well ventilated ridges, burning these ridges and re-ridging after burning (which covers the ash with soil, thereby preventing the ash from being blown away). Overall this improves nutrient availability and moisture retention. …. this has led to a method which can sustain three to four crop harvests in succession over two years without chemical fertilizers and without major water application, if a moist site in a *dambo* is selected." (Sampa, 2008, pg 3). Sampa (2008) describes in detail the sequence of steps involved in the turf burning and ridging method, including:

- Land preparation (including cutting of the turfs, turning the turf over to expose the roots and leaving the turfs to dry fully),

- Ridge making, whereby the turfs are heaped into a ridge approximately 0.5 m wide aligned slightly across and slightly down the slope, so as to control drainage but not to cause erosion.

- Burning of the ridged turfs on a hot sunny day and burying of the ash in the ridges through the addition of soil from next to the ridge while the ridge is still hot. This heats up the added soil and prevents the ash from being blown away.

- Planting within planting stations about 10 cm deep in the centre of the ridge.

- Watering, which is only required in those dambo areas that are inherently less wet, and even here it is only required at intervals of two to four weeks.

Dambo cropping using the turf burning and ridging method is predominantly in the dry season and early wet season, but may begin in March before the end of the rains for the first crop. The second crop is generally around July and the third crop in October, which will be picked up by the early season rains for full ripening (Sampa, 2008). As highlighted by Sampa (2008) in Table 2.1, different crops are grown at different times, although there is a high level of overlap between the crops. For example, cabbage production is restricted to the dry winter season, while maize production occurs both in the dry season and extends well into the wet season.

The turf ridging and burning method has similarities with the *ecobuage* (soil cooking) method described by Husson et al. (2001). Both techniques use burning to make nutrients available, and the burnt material is buried. However, a key difference between the two is that in the turf burning and ridging method, burning takes place before burial, but in the *ecobuage* method, the organic matter is first buried and then is burnt underground by means of a "wick". In addition, the former is built up into a ridge while the latter is buried in a trench. The *ecobuage* method is reported to provide rapid improvement in crop yields on degraded soil (Husson et al., 2001). However, like the turf burning and ridging method, it is dependent on organic material as an important source of nutrients.

Turf burning and ridging has many positive short terms effects for crop production, which according to Sampa (2008) include the following.

- An increase in the availability of nutrients.
- An increase in the pH of the highly acidic soil.
- An increase in friability of the heavy clay soils (which makes them more easily tilled and better aerated).
- Control of weeds by destroying their seeds and roots
- Assistance in controlling plant diseases and pests such as nematodes

Sampa (2008) highlights further that the ridging itself is carefully designed to help control the following two factors affecting plant growth.

- Waterlogging (i.e. the depletion of soil oxygen as a result of prolonged saturation of the soil) which severely limits the growth of most crops unless they have specific hydric plant adaptations to deal with such conditions
- An adequate supply of water to support plant growth. This is achieved by locating the turf burning and ridging plots within areas in the dambo that remain fed by seepage waters through most of the wet season, but avoiding the excessively wet central areas of the dambo and the drier margins. Areas with suitable hydrology are fairly limited in extent in the dambo and are indicated by the short sedge, *Bulbostylis buchanani*. Areas dominated by *Eleocharis* sp. sedges would generally be too wet and those areas dominated by *Hyparrhenia* spp. would be too dry fro applying turf burning and ridging. (Sampa, 2008; Wood A, 2009, *Pers comm.* Centre for Wetlands, Environment & Livelihoods, University of Huddersfield, United Kingdom).

Given that crops are grown on ridges, their rooting zone is raised above the water table, but the capillary fringe above the water table supplies the ridge with moisture. Sampa (2008) suggests further that the ash assists in drawing up residual moisture from beneath the ridge. The orientation of the ridges in the general direction of the slope (although not directly downslope) contributes further to reducing the level of wetness of the cropped area. Thus, the system is finely tuned to reducing the level of wetness to an extent that provides just enough water for crop growth but limits waterlogging within the ridges, where the crops are growing.

Appendix C: Chitemene cultivation (modified from Kotze 2009)

Chitemene (meaning to cut) is a particular type of slash-and-burn agriculture practiced in the wetter miombo woodland along the Zaire-Zambezi watershed, which has been in existence for several centuaries (Chidumayo, 1996; Frost, 1996). Within an area, usually several hectares in size and circular in shape, referred to as the outfield, the branches and foliage of the trees are cut off, rather than chopping the trees down at ground level, which allows for more rapid regeneration during the following fallow period (Frost, 1996). The branches and foliage that have been cut are gathered in a central part of the cut area (the infield), usually about 0.4 ha in size, allowed to dry out then burnt just before the first rains. The first crop, often finger millet [*Elusine coracana*], is sown in the ash-covered ground of the infield. Other commonly grown crops include groundnut, millet, beans and cassava (which is often intercropped with the finger millet and harvested toward the end of the cultivated period). When the field is exhausted after a few years, it is abandoned and traditionally left fallow for 20 to 30 years (Strømgaard P, 1984a and b; Frost, 1996; Mathews, 2005).

The ash provides a very important source of nutrients. For example, at a site near to Mpika (approximately 100 km north) Strømgaard (1984b) found that the potential fertilizing effect concentrated in the ash on the infield was equivalent to 1310 kg ha^{-1} N, 411 kg ha^{-1} P, and 606 kg ha^{-1} K. Araki (1992, as cited by Chidumayo, 1996) showed that there is a positive correlation between the amount of ash in the infield and the yield of finger millet.

The area in which foliage and branches (and the nutrients that they contain) are harvested, is five to ten times larger than the area in which the foliage and branches are gathered and burnt and in which the cultivation takes place in the ash-covered ground. Therefore, *chitemene* provides a very effective strategy for dealing with the inherently nutrient-poor soils by "collecting" nutrients from across a wide area and concentrating the nutrients, through the medium of the ash, in the smaller area that is cultivated. Furthermore, the long periods of fallow provide for the recovery of the exhausted soil fertility. However, under increasing human population pressure, and reduced availability of unoccupied land, it is becoming increasingly difficult in some locations to sustain the required length of fallow (Strømgaard P, 1984a and b; Frost, 1996).

Appendix D: Guidelines for assessing sustainability of use based on Thresholds of Potential Concern

WET-SustainableUse does not prescribe, in rigid terms, what is considered sustainable or not (e.g. "to be sustainable, the environmental condition must not be reduced by more than 30%"). It is up to the users to decide what constitutes sustainability. Nevertheless, WET-SustainableUse recommends placing the assessment of sustainability within a strategic adaptive management context. An important element of adaptive management is setting TPCs (Thresholds of Potential Concern) that define the threshold along a continuum of change (Rogers and Bestbier 1997; Rogers and Biggs 1999). When the threshold has been exceeded, or is close to being exceeded, then this highlights the need for specific management intervention and/or further investigation.

As a starting point, TPCs are suggested for three general management objectives (Table D1). As can be seen from Table D1, the thresholds vary according to the health element considered and the primary management objectives. For example, in the case of retention and internal cycling of nutrients, a more stringent threshold is set (>1 compared with >3) if the primary objective is catchment management for water quality than if the primary objective is livelihood support. In the case of vegetation composition, a stringent threshold is set for biodiversity conservation but a much more lenient threshold is set for catchment management for water quality (>2 compared with >6). The rationale for the different thresholds is given in Table C1.

Table D1: Thresholds of Potential Concern (TPCs) for the five key elements considered by WET-SustainableUse and for three different management objectives

Key elements considered by WET-Sustainable-Use that determine wetland environmental condition	**Threshold impact value for different primary management objectives (The continuum of impact values ranges from 0 [no impact] to 10 [critical impact])**			
	Biodiversity conservation	Catchment water quality management	Livelihood support	**Rationale for the choice of threshold values**
Hydrology *(the distribution and retention of water in the wetland)*	>1	>2	>4	Hydrology is the most important determinant of wetland structure and function, and therefore the level of disruption to the hydrology should generally be minimal in order to maintain wetland biodiversity. The capacity of a wetland to enhance water quality is also dependent on a low level of disruption to the hydrology. An important way in which wetlands generally support livelihoods is through wetland cultivation, which, by its nature, generally disrupts hydrology. If livelihood support is the primary objective then the threshold is set at a moderate level of disruption, unless there is direct dependency on the wetland for water supply, in which case a much more stringent threshold may be required.
The retention (or erosion) of ***sediment*** *in the wetland*	>2	>2	>3	Impacts on sediment retention should be kept low in order to maintain wetland biodiversity, and the capacity of a wetland to enhance water quality is also dependent on low impacts to sediment retention. Cultivation of wetlands will generally lead to some erosion impacts, but these should not exceed a moderately low level, otherwise sustained production is likely to be under threat.
The accumulation of ***SOM*** *in the wetland*	>2	>2	>3	Impacts on the accumulation of SOM should be kept low in order to maintain wetland biodiversity and the capacity of a wetland to enhance water quality. Cultivation of wetlands will generally lead to some impacts on SOM, but these should not exceed a moderately low level, otherwise sustained production is likely to be under threat.
The retention and internal cycling of ***nutrients***	>2	>1	>3	Impacts on nutrient retention should be kept low in order to maintain wetland biodiversity. This factor is the most critical in terms of the capacity of the wetland to maintain a high water quality, so impacts should be minimal. Cultivation of wetlands will generally lead to some nutrient retention impacts, but these should not exceed a moderately low level, otherwise sustained production is likely to be under threat.
Natural ***vegetation*** *composition in the wetland*	>2	>6	>5	In order to maintain wetland biodiversity, impacts on the natural vegetation should be kept low, given that vegetation is an important part of biodiversity and provides habitat for many other taxa. Provided that plant production is maintained, the retention and internal cycling of nutrients may be little diminished (or may even be enhanced) by a change in vegetation composition. Livelihood support generally does not require that vegetation is minimally impacted. However if there is direct dependency on resources which are only present when the vegetation is minimally impacted, then a much more stringent threshold may be required.

Appendix E: The Ecological health tables for the four dambos

Table E1: Within-dambo impacts on the hydrology component of ecological health of the four selected wetlands based on the Intensity (I), Extent (E) and Magnitude of impact for the respective land-use types occurring within each dambo

	Chikakala						**Mwansabamba**						**Katema**						**Chiota**					
Land-use type	**2008**			**2019**			**2008**			**2019**			**2008**			**2019**			**2008**			**2019**		
	I	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**
Currently cultivated	5	2%	0.10	4.5	3%	0.14	5	2%	0.10	6	6%	0.36	3	29%	0.87	3.2	26%	0.83	1.5	23%	0.35	1.7	22%	0.37
Recently abandoned	3	3%	0.09	2.5	4%	0.10	3	2%	0.06	3.5	5%	0.18	2	11%	0.22	2	16%	0.32	1	12%	0.12	1	11%	0.11
Old abandoned	2	8%	0.16	2	11%	0.22	2	8%	0.15	2.5	12%	0.30	1	13%	0.13	1	20%	0.20	0.5	14%	0.07	0.5	18%	0.09
Natural/ near-natural	0	87%	0.00	0	82%	0.00	0	88%	0.00	0	76%	0.00	0	45%	0.00	0	36%	0.00	0	42%	0.00	0	40%	0.00
Roads			0.00			0.00	10	0.5%	0.05	10	0.5%	0.05			0.00			0.00			0.00			0.00
Road prep.			0.00			0.00			0.00	7	0.5%	0.04			0.00			0.00			0.00			0.00
Erosion gullies			0.00			0.00			0.00			0.00			0.00			0.00	8	9%	0.72	8	9%	0.72
Dam			0.00			0.00			0.00			0.00	9	2%	0.18	9	2%	0.18			0.00			0.00
Overall impact			**0.35**			**0.46**			**0.36**			**0.92**			**1.40**			**1.53**			**1.26**			**1.29**

Table E2: Within-dambo impacts on the sedimentation/erosion component of ecological health of the four selected wetlands based on the Intensity (I), Extent (E) and Magnitude of impact for the respective land-use types occurring within each dambo

	Chikakala						Mwansabamba						Katema						Chiota					
Land-use type	**2008**			**2019**			**2008**			**2019**			**2008**			**2019**			**2008**			**2019**		
	I	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**
Currently cultivated	1	2%	0.02	1	3%	0.03	2	2%	0.04	2.3	6%	0.14	1	29%	0.29	1	26%	0.26	4	23%	0.92	3.7	22%	0.81
Recently abandoned	1	3%	0.03	1	4%	0.04	1.5	2%	0.03	2	5%	0.10	1	11%	0.11	1	16%	0.16	2.5	12%	0.30	2.5	11%	0.28
Old abandoned	0.5	8%	0.04	0.5	11%	0.06	1	8%	0.08	1	12%	0.12	0.5	13%	0.07	0.5	20%	0.10	1	14%	0.14	1	18%	0.18
Natural/ near-natural	0.2	87%	0.17	0.2	82%	0.16	0.2	88%	0.18	0.2	77%	0.15	0.2	45%	0.09	0.2	36%	0.07	0.5	42%	0.21	0.5	40%	0.20
Roads		0%	0.00		0%	0.00	10	1%	0.05	6	0.5%	0.03		0%	0.00		0%	0.00		0%	0.00		0%	0.00
Road prep.		0%	0.00		0%	0.00	7	0%	0.00	7	0.5%	0.04		0%	0.00		0%	0.00		0%	0.00		0%	0.00
Erosion gullies		0%	0.00		0%	0.00		0%	0.00			0.00		0%	0.00		0%	0.00	9	9%	0.81	9	9%	0.81
Dam		0%	0.00		0%	0.00		0%	0.00			0.00	6	2%	0.12		2%	0.00		0%	0.00		0%	0.00
			0.26			**0.29**			**0.37**			**0.58**			**0.68**			**0.59**			**2.38**			**2.28**

Table E3: Within-dambo impacts on the soil organic matter accumulation component of ecological health of the four selected wetlands based on the Intensity (I), Extent (E) and Magnitude of impact for the respective land-use types occurring within each dambo

	Chikakala						Mwansabamba						Katema						Chiota					
Land-use type	**2008**			**2019**			**2008**			**2019**			**2008**			**2019**			**2008**			**2019**		
	I	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**
Currently cultivated	6	2%	0.12	5.5	3%	0.17	6	2%	0.12	6.5	6%	0.39	5	29%	1.45	5	26%	1.30	4.3	23%	0.99	4	22%	0.88
Recently abandoned	5	3%	0.15	4.5	4%	0.18	5	2%	0.10	5.5	5%	0.28	4	11%	0.44	4	16%	0.64	3	12%	0.36	3	11%	0.33
Old abandoned	2	8%	0.16	2	11%	0.22	2	8%	0.15	2.5	12%	0.30	2	13%	0.26	2	20%	0.40	1.5	14%	0.21	1.3	18%	0.23
Natural/ near-natural	1	87%	0.87	1	82%	0.82	1	88%	0.88	1	76%	0.76	1	45%	0.45	1	36%	0.36	1	42%	0.42	0.7	40%	0.28
Roads		0%	0.00		0%	0.00	10	1%	0.05		1%	0.00		0%	0.00		0%	0.00		0%	0.00		0%	0.00
Road prep.		0%	0.00		0%	0.00	7	0%	0.00		1%	0.00		0%	0.00		0%	0.00		0%	0.00		0%	0.00
Erosion gullies		0%	0.00		0%	0.00		0%	0.00		0%	0.00	4	0%	0.00		0%	0.00	8	9%	0.72	8	9%	0.72
Dam		0%	0.00		0%	0.00		0%	0.00		0%	0.00	4	2%	0.08		2%	0.00		0%	0.00		0%	0.00
Overall			**1.30**			**1.39**			**1.30**			**1.73**			**2.68**			**2.70**			**2.70**			**2.44**

Table E4: Within-dambo impacts on the nutrient cycling component of ecological health of the four selected wetlands based on the Intensity (I), Extent (E) and Magnitude of impact for the respective land-use types occurring within each dambo

	Chikakala						**Mwansabamba**						**Katema**						**Chiota**					
Land-use type	**2008**			**2019**			**2008**			**2019**			**2008**			**2019**			**2008**			**2019**		
	I	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**
Currently cultivated	5	2%	0.10	4.5	3%	0.14	5	2%	0.10	6	6%	0.36	5	29%	1.45	5	26%	1.30	4	23%	0.92	3.5	22%	0.77
Recently abandoned	3	3%	0.09	2.5	4%	0.10	3	2%	0.06	4	5%	0.20	3	11%	0.33	3	16%	0.48	2	12%	0.24	1.5	11%	0.17
Old abandoned	2	8%	0.16	2	11%	0.22	2	8%	0.15	2	12%	0.24	0	13%	0.00	0	20%	0.00	1.5	14%	0.21	1.5	18%	0.27
Natural/ near-natural	0	87%	0.00	0	82%	0.00	0	88%	0.00	0	76%	0.00	0	45%	0.00	0	36%	0.00	0	42%	0.00	0	40%	0.00
Roads		0%	0.00		0%	0.00	10	1%	0.05		1%	0.00		0%	0.00		0%	0.00		0%	0.00		0%	0.00
Road prep.		0%	0.00		0%	0.00	7	0%	0.00		1%	0.00		0%	0.00		0%	0.00		0%	0.00		0%	0.00
Erosion gullies		0%	0.00		0%	0.00		0%	0.00		0%	0.00		0%	0.00		0%	0.00	8	9%	0.72	8	9%	0.72
Dams		0%	0.00		0%	0.00		0%	0.00		0%	0.00		2%	0.00		2%	0.00		0%	0.00		0%	0.00
			0.35			**0.46**			**0.36**			**0.80**			**1.78**			**1.78**			**2.09**			**1.93**

Table E5: Within-dambo impacts on the vegetation composition component of ecological health of the four selected wetlands based on the Intensity (I), Extent (E) and Magnitude of impact for the respective land-use types occurring within each dambo

	Chikakala						**Mwansabamba**						**Katema**						**Chiota**					
Land-use type	**2008**			**2019**			**2008**			**2019**			**2008**			**2019**			**2008**			**2019**		
	I	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**	**I**	**E**	**M**
Currently cultivated	9	2%	0.18	9	3%	0.27	9	2%	0.18	9	6%	0.54	9	29%	2.61	9	26%	2.34	9	23%	2.07	9	22%	1.98
Recently abandoned	9	3%	0.27	9	4%	0.36	9	2%	0.18	9	5%	0.45	9	11%	0.99	9	16%	1.44	9	12%	1.08	9	11%	0.99
Old abandoned	6	8%	0.48	6	11%	0.66	6	8%	0.45	6	12%	0.72	6	13%	0.78	6	20%	1.20	6	14%	0.84	6	18%	1.08
Natural/ near-natural	2	87%	1.74	2	82%	1.64	2	88%	1.76	2	76%	1.52	2	45%	0.90	2	36%	0.72	2	42%	0.84	2	40%	0.80
Roads		0%	0.00		0%	0.00	10	1%	0.05		1%	0.00		0%	0.00		0%	0.00		0%	0.00		0%	0.00
Road prep.		0%	0.00		0%	0.00	7	0%	0.00		1%	0.00		0%	0.00		0%	0.00		0%	0.00		0%	0.00
Erosion gullies		0%	0.00		0%	0.00		0%	0.00		0%	0.00		0%	0.00		0%	0.00	7	9%	0.63	7	9%	0.63
Dams		0%	0.00		0%	0.00		0%	0.00		0%	0.00		2%	0.00		2%	0.00		0%	0.00		0%	0.00
			2.67			**2.93**			**2.62**			**3.23**			**5.28**			**5.70**			**5.46**			**5.48**