SUSTAINABILITY INDICATORS IN COMMUNAL WETLANDS AND THEIR CATCHMENTS

Lessons from Craigieburn wetland, Mpumalanga

Report to the
Water Research Commission

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The publication of this report emanates from a project entitled: *Review of cases of community (local)-based governance of freshwater resources in southern Africa to inform potential governance arrangements of communal wetlands*. (WRC Project No. K5/1709)

Executive summary

This constitutes the final report of the project: **Sustainability Indicators in Communal Wetlands and their Catchments** (K5/1709). The aim of the work was as follows.

> *To develop and test a coherent and practicable set of indicators for an integrated approach to the sustainable use and management of communal wetlands and their catchments, with a strong focus on rehabilitation*.

This work emerged from the growing acknowledgement of the importance of wetlands in the livelihoods of people, in particular of the rural poor in communal lands in South Africa (the former Bantustans). However, many of these wetlands, used as common-property resources, are degraded. Indeed, the Association for Water & Rural Development (AWARD) has been involved in a range of action-research and developmental projects in the Craigieburn wetlands of the Sand River Catchment because of the biophysical and social impacts of degradation. Central questions that have emerged are *'what indicators can be used to assess the situation, to track change and to evaluate impacts*?' and further "*how can these be developed in a way that is meaningful both for managers but also for the users themselves?*"

Although a number of methods exist to assess wetland condition using indicators, many are either not holistic (integrative), or are not readily usable by the wetland users themselves. This project focused on the practical application by practitioners including the wetland users, custodians of wetlands within the community and wider. Indicators are *qualified or quantified parameters of system performance which can be used for a number of purposes at different points within a project cycle by a range of users*. In this project the focus is on indicators of sustainable use, management and governance of wetlands in communal areas where they are used mainly for subsistence purposes.

A number of key concepts are reviewed or developed as an introduction to the work. A fundamental concept is that integrated management typically deals with interlinked, dynamic and hence complex systems. Complexity and systems thinking critiques conventional management approaches for their failure to recognise variability and linkages as essential properties of many complex systems. Indicators are thus needed that describe the performance of the individual systems and their contribution to the performance of wider systems. Since outcomes are not entirely predictable they have to be managed through a process of strategic adaptive management that embraces <u>learning-by-doing</u>. Indicators need to support this premise.

Another central concept – that of 'wise-use' – is discussed and defined. We suggest that it is too narrowly interpreted, thus omitting a large part of what constitutes the so-called 'wise use of wetlands' (e.g. governance). We provide the following definition

> *The wise use of wetlands is an integrated strategy for the sustainable and equitable use of wetlands through good governance and land- and water-use practices that promote healthy wetlands so as to continue to provide services, products and benefits that are enjoyed by and that sustain human livelihoods (including those of future generations), as well as biological diversity.*

Other concepts are reviewed including complexity and learning, wetland health and sustainable livelihoods. These all contribute to an integrative model that guided the project (see Figure 1.3).

This model shows the links between societal values, plural governance systems, land and water use, wetland integrity and livelihoods.

Chapter 2 provides an in-depth review of sustainability indicators, their categorisation and uses, as well as specific indicators of different components of the model. This includes governance, wetland health, soil health, water and sediment balance and plant production. Indicators may be diagnostic, process, performance or outcome indicators depending on the objective at hand. The frameworks that govern indicator development may be either *top-down* (rooted in scientific reductionism, explicit quantitative indicators), *bottom-up* (community-based, draws on social sciences and emphasises the importance of local context) or a blend of the two. Various frameworks are discussed.

Governance indicators are very varied and are predicated on context. Important concepts include legal pluralism, institutions and organisation, power, legitimacy, adaptive collaborative management and issues of rights, responsibilities, and authority. Indicators for the assessment of wetland health tend to be based on top-down approaches and require expertise. A number of these, including that of Ramsar and two locally-derived approaches (Wethealth and Wet-Sustainableuse), are discussed. A synopsis of approaches to monitoring sediment and water status is presented and the differentiation between direct (e.g. depth of stream channel against a stage gauge) and indirect (proxy) indicator types noted. Types of indicators suitable to participatory approaches are discussed. Indicators of soil health and the relationship of this with crop types reveal important baseline parameters, notably that croplands on granitic sandy soils in the communal areas that have not had applications of manure or inorganic fertilizers now show nutrient deficiencies.

Chapter 3 introduces Craigieburn village and wetlands of the Sand River Catchment. Craigieburn is located in the north-eastern region of the country, where wetlands comprise 10-15% of the catchment area. It is a small, headwater wetland that receives its water from runoff and groundwater in the rainy season, and groundwater in the dry season. Craigieburn typifies the bio-physical and socio-economic attributes of conditions found in communal lands of the lowveld of South Africa. As former Bantustan areas, the apartheid legacy means that local livelihoods are increasingly vulnerable. People have turned to wetlands for an important livelihood support through the provision of natural resources (cropping, grazing, reeds, water and other services). However landuse pressures around and within the wetlands have lead to increased erosion, desiccation of the landscape, decreasing fertility and decreased production. The baseline research (Phase I) established the relationship between these factors.

Some 60 and 70% of Craigieburn residents – mainly women from single-headed households between the ages of 35 to 70 – use wetlands. About 25% of households secure food through what they grow, and over half (60%) have limited income. Some 60% of households accessed their land by opening up fields without permission, 63% in the last decade, pointing to the erosion of community-based governance. Craigieburn wetlands offer a safety-net, particularly for the poor, contributing about 40% of the food grown. The goods and services are estimated at a total net direct benefits of R110 000 p.a. However, within-wetland practices, weakening governance and varying levels of awareness regarding sustainable landuse practices are compromising the wetland and livelihood integrity and catchment water security.

Phase II includes various initiatives to address these problems in an integrated way including in-depth hydrological analysis, a Farmer Support Programme, support for improved governance and this indicators project.

To develop indicators, the project adopted a hierarchical approach centred on developing a collaborative understanding of context, principles, a vision, objectives and then indicators. In summary the iterative process involves:

- describing the context (using the suggested framework described below)
- identifying and agreeing on key strengths and problems
- agreeing on principles
- developing a collective vision
- developing objectives, and drawing up plans
- developing and testing indicators (using the framework below)
- exploring possible scenarios
- implementation of plans
- cycles of monitoring, reflection, learning and action.

The objective of *wise and effective governance of natural resources* is central to the development of indicators discussed in Chapter 4. ***Wise*** governance understands and balances the immediate needs and rights of people, sustainable use of natural resources, and the rights of future generations to a healthy environment. ***Effective*** governance responds to issues through action and feedback. It seeks to work cooperatively across levels.

Generally governance tends to be dealt with naively. However it is essential to conceptualise governance with suitable complexity so as to arrive at a requisite simplicity, thus facilitating the development of appropriate and meaningful indicators. Given the complexity, a hierarchical, participatory approach together with principles and frameworks with which to do this are recommended. Definitions of governance vary widely, and depend upon the context. Governance is often conflated with management (an aspect thereof) and associated only with government (only one of the actors involved). *Legal pluralism,* characteristic of natural resource governance systems, recognises that a resource is normally subject to many institutions from statutory laws to local/ customary 'rules of the game'. Thus it involves community structures, traditional authorities, civil society and government. Governance of natural resources involves the power, processes, rights and responsibilities that are associated with making and enforcing the rules that guide society in relation to natural capital.

The following collaboratively-developed principles guided the governance work:

- People's claims and rights to access and to benefit from natural resources, and the basis of these, need to be known and defended.
- Sustainable use should be understood and defended.
- Prompt response to feedback signals (of problems that need addressing) at a number of levels of governance.
- Authority must be accessible, exercised and co-operative across levels and plural systems.

Given the complexities that practitioners and researchers face in describing 'the governance system', a framework for understanding governance was developed based on these principles. The framework was tested and refined. The objective of the framework is to as a guide for the assessment of governance, to inform facilitation, and for the development of indicators with key stakeholders. It is also a heuristic with practical application (see Figure 4.1), based on the approach that 'everyone has a body' and thus can easily recall four elements of governance:

1) the lifted left hand is a universal symbol of power (and ***authority)*** which confers
2) ***rights*** (shown with the right hand);
3) with rights come ***responsibility*** and thus the left leg balances, or grounds, the rights; and
4) with rights (of use) come ***benefits and costs*** which need to be considered (right leg).

The vision of ***equity and sustainability*** lies at the heart of governance.

Aspects of the process of indicator development and testing remain to be done, but the plan of action offers a guide for other work seeking to develop indicators. Currently governance over land and natural resources in South Africa is in a state of flux due to policy transformation, contestations over power and the slow rate of reform. An informed and judicious approach is thus required noting that there are no 'blue print' indicators. Rather the process of understanding the context collectively and arriving at agreed vision and principles is more likely to lead to locally-understood indicators that build adaptive capacity.

Chapter 5 addresses support for sustainable practices – and hence indicators – that can be used by farmers at the scale of their agricultural plots, as well as for the wetland and micro-catchment. This is because threats to wetland integrity originate outside of the plot. This can only be addressed if villages form part of governance structures that extent beyond the village scale. Although micro-catchment scale assessments are beyond the scope of this report, the principles outlined in Chapter 5 are considered sufficiently robust to apply to upland areas as well.

The objective for the component on sustainable wetland use was to track change in wetland health – and specifically the direction of change – as a result of changing land-use practices, both as an appraisal process and to support farmers in a process of self-assessment. Farmers consistently use plant production to assess the health of the wetland. Although we initially focused on plant production as a proxy for wetland health, there are a number of constraints which are discussed.

The approach to developing indicators followed that described above: the development of a farmer-based vision coupled with core principles and a framework, and associated indicators. A systems diagram to illustrate linkages provided a starting point (Figure 3.3). An iterative process of development, testing and refinement through a blend of local knowledge and specialist inputs was used. Each indicator was supported by an underlying rationale which was discussed with farmers and, where possible, upper and lower ranges were assigned to each indicator. The core principles which formed the basis of all work, included:

- management of ***water*** so as to maintain soil moisture (and SOM) and soil stability;
- control of ***soil movement*** and erosion so as to retain soil moisture, SOM and nutrients;
- management of ***soil health*** so as to sustain plant growth and biological activity; and
- maintenance of ***indigenous plants*** (both functional and biodiversity aspects) which are essential to maintaining the key characteristic of wetlands.
- The selection and management of ***appropriate crops*** (focus on agro-ecology).

From a preliminary set of 18 indicators (Table 5.2), eight core indicators were selected for testing and refinement. These, listed below, offer a potential set of principle-based indicators for future use. The motivations and ranges are discussed in Table 5.3. In general these indicators can be applied at any time of the year and in any of the three eco-zones.

Water management:

1. Bed / furrow orientation (Zone A and B) or Effective contouring (Zone C)
2. Furrows blocked

Erosion and the control of soil movement

3. Furrow elevation
4. Height of beds
5. Extent of soil denudation

Soil health

6. Presence and extent of organic matter
7. Extent of mulching

Conservation of wetland plants

8. Presence and extent of wetland plats.

An interest in agro-ecology will require an additional assessment of practices associated with crops. The use of 'weeds' as indicators of degradation and soil fertility are also discussed.

Given the detailed and complex information, a framework for soil and water conservation, based on the aforementioned five principles was developed (Figure 5.2). The framework – known as the "hand of change" – was used as a heuristic to organise key concepts, principles and indicators, thereby supporting learning-for-change. Each finger represents the five key principles. Wetland health is now understood by farmers according to this framework.

In support of reflexive practitionership, the indicators were then used as the basis for self-assessment by farmers but using a modified approach to accommodate lower literacy levels. Preliminary tests suggest that farmers appreciated and supported such an approach.

Beyond the plot, a wetland-scale assessment is important for two reasons: (a) it creates a sense for farmers that they and their plot-level practices exist within and are linked to a wider system, and (b) a number of threats to wetland integrity come from beyond the scale of plot. Thus a framework for this is also provided (Table 5.4). To this, a sixth principle was added:

- The protection of ***sensitive areas*** within or around the wetland.

The chapter reaches a number of conclusions, in particular the importance of a collaborative, locally-derived process. It stresses the importance of understanding baseline conditions to derive appropriate indicators and hence sustainable practices. Soil fertility is illustrative. Results indicated that soils at Craigieburn are acidic and deficient in nutrients. Without such information farmers inevitably set goals that are not achievable (e.g. yields that are not tenable). Some suggested indicators, together with their thresholds and rationale are given in Table 5.5

Also this work attempted to develop the concept of indicators within the context of complexity and variability by incorporating ranges of values within which a variable can 'bounce around' without being deemed unsustainable. This exercise was constrained by a lack of data and demonstrated how poorly understood, or at least quantified, many relationships are.

Lastly we must not lose sight of the fact that wetland health – and ultimately the sustained inputs into peoples' livelihoods – is predicated on a wide range of factors that constitute 'wise use'. The implication of describing and tracking the health of the wetland as a whole is that ultimately the micro-catchment condition and use must also be understood, tracked and addressed.

Chapter 6 places indicator development within the broader context of strategic adaptive management. We suggest that development of indicators for a formative evaluation process (an evaluation by the users themselves), forms part of an adaptive planning process where the indicators provide the link in the process of learning-by doing – an approach important in complex systems where outcomes are not always predictable.

The attempt to develop indicators based on a holistic approach draws on a wide range of disciplines. In recognising complexity, variability and dynamism of complex systems with multiple drivers and inter-linkages that vary across scales, one also recognises that there may be multiple ways to arrive at an objective. Consequently the development and use of indicators forms part of an adaptive planning process that supports learning-by-doing and that is sufficiently structured so that each indicator can be 'tracked back' to higher-order objectives which themselves are based on an understanding of context and underlying principles. Whilst the indicators are context-specific and cannot simply be transposed to another system, the higher-order principles are sufficiently robust to apply beyond the borders of a single wetland.

Although we have focused on governance, wetland health and sustainable practices, other initiatives may want to adopt additional areas of focus as appropriate. This may include micro-catchment health or livelihood assessments. In any of these cases the process set-out above is recommended. An integrative model that indicates the group's understanding of inter-linkages constitutes an important starting point.

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Chapter 1

Key concepts for understanding indicators in the context of 'wise wetland use'

1.1. Introduction and Purpose

This constitutes the final report of the project: **Sustainability Indicators in Communal Wetlands and their Catchments** (K5/1709). This chapter introduces the project, its objectives and provides an overview of the key concepts guiding the work.

South Africa's Integrated Water Resources Management policies are grounded in an ecosystem approach, requiring the integration of numerous components of the system. Wetlands are important components of catchments, providing catchment water security and other ecosystem services. In communal areas in particular they represent the challenging intersection between sustainable management and the livelihood needs of people making use of the wetlands (Pollard et al., 2007). Certainly, the last few years has witnessed a growing acknowledgement of the importance of wetlands in the livelihoods of people, and in particular of the rural poor (see for example, Pollard et al., 2006). It is also recognised that many of these wetlands, used as common-property resources within communal lands, are degraded. In response, Working for Wetlands (www.wetlands.sanbi.org) has invested substantial efforts in the physical rehabilitation of these wetlands. However, longterm biophysical integrity is determined by a wider range of factors than simply the physical rehabilitation of erosional headcuts. Land-use practices, both in the wetland and beyond, the livelihoods strategies of the users, governance arrangements and wider socio-economic factors all play a role (Pollard et al., 2005; Pollard et al., 2008a).

Against this background, the Association for Water & Rural Development (AWARD) has been involved in range of action-research and developmental projects in the Craigieburn wetland of the Sand River Catchment. Aimed at an integrative approach to addressing the aforementioned issues, areas of focus have included a three-year capacity development programme for wetland users and practitioners such as extension staff, funded by The Green Trust (WWF-SA). A central question that emerged from this work was *'what indicators can be used to assess the situation, to track change and to evaluate impacts*?' A further question was "*how can these be developed in a way that is meaningful both for managers but also for the users themselves?*" The work reported herein builds upon and integrates the wealth of experience AWARD has gained from its work on wetlands. An important conceptual consideration is that integrated management typically has to deal with complex systems. Indicators are thus needed that describe the performance of the individual systems and their contribution to the performance of other wider systems (Bossell, 2001; and see Pollard et al., 2008b).

Indicators are qualified or quantified parameters of system performance which can be used for a number of purposes at different points within a project cycle by a range of users. In this project the focus is on indicators of sustainable use, management and governance of wetlands in communal areas where they are used mainly for subsistence purposes. A preliminary review of indicators being used in relation to wetlands interventions suggested that these different purposes are sometimes conflated in less than useful ways, neither recognising linkages in the system nor being grounded in the realities of wetlands use and management in communal areas. (see for example, e.g. Brouwer, 2007). Thus, not only must these ideas be appropriately unpacked and understood but indicator development must be tested for their practical application. Furthermore, the *process* of indicator development is as important as the indicators themselves. Understanding this recognises the utilitarian nature of indicators so that that they are developed with a purpose in mind and are not regarded as a given – or immutable – over time.

Against this background, the overall aim of the work was as follows.

> *To develop and test a coherent and practicable set of indicators for an integrated approach to the sustainable use and management of communal wetlands and their catchments, with a strong focus on rehabilitation*.

It is important to emphasize that a number of methods already exist to assess wetland condition or management but these are either not holistic (integrative), or they readily usable by the wetland users themselves. This project was designed with a focus on practical use by practitioners including the wetland users, custodians of wetlands within the community and wider (e.g. extension staff) and staff such as those from developmental or interest-based projects.

To this end, the first step of the project placed considerable effort and emphasis on developing and understanding the underlying concepts that framed the development of indicators including clarity on the term 'wise use'. This in turn spoke to issues of systems thinking, complexity and social learning as framing concepts and more specifically, the associated concepts of governance, wetland health and livelihoods. These are dealt with below. This was accompanied by a literature review which also provided a sound conceptual basis for the definition and selection of potential indicators and is dealt with in Chapter 2. Chapter 3 frames the work within the context of Craigieburn, the study site for the work, providing an overview of the major features and work to date. Both Chapters 4 and 5 focus on indicators for governance and land-use practices respectively, describing the overall approach and methodology for each of these components and results of their development and testing. Finally Chapter 6 provides a synthesis and an overarching framework to assist in the development and selection of indicators.

1.2. Important Framing Concepts

1.2.1. Wise use as a framing concept

A fundamental departure point for this work was to explicitly address the meaning of the term "wise use" of wetlands. This is because it – or the counterpart of good practice – is becoming increasingly prolific in both the literature and in project plans pertaining to wetland rehabilitation, conservation and livelihood security. In our view this term is far too narrowly interpreted and this omits a large part of what constitutes the so-called 'wise use of wetlands'. It is a useful term in that it is short and 'catchy' – unlike more cumbersome phrases such as 'good management', or poorly understood phrases such as 'good governance'. However, since it is the most frequently used term it requires adequate definition. It is normally interpreted rather narrowly to refer only to the practices of use (e.g. harvesting, crop production) and not the wider *milieu* that frames such practices. Although this may appear to be semantics, the implications are far reaching since the interpretation – and hence expected outcomes – <u>may chart an outcome that is flawed</u>. Often the thinking runs along the following lines: unsustainable use (i.e. normally referring only to poor (land-use or harvesting) practices is a problem, and if these practices are improved (i.e. we have 'wise use'), then the problem of wetland degradation will be ameliorated. However, the actual practices of harvesting or cropping do not explain – alone – all the drivers of wetland degradation and loss. Thus excellent land use practices may prevail in the wetland but still wetland degradation continues. This begs the question 'why?" and prompts a deeper consideration of additional drivers that are often ignored (Pollard et al., 2008a; Pollard et al., 2008b). An examination of the linkages, such as those shown in Figure 1.3, demonstrates the point.

Indeed if one examines the mission of Ramsar (1971) and the definition adopted in 1987, and modified by in 2005 (Ramsar, 2007) this wider view is readily apparent. Some 35 years ago, the Convention on Wetlands (Ramsar, 1971) noted that its mission is "the conservation and wise use of all wetlands **through** local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world". In 2007 (Ramsar, 2007), the 'wise use of wetlands' was defined as "the maintenance of their ecological character, achieved through the implementation of **ecosystem approaches**, within the context of sustainable development". Also importantly, the Strategic Plans adopted at COP-6 (2000) and COP-8 (2002) equate "wise use" with "**sustainable use**", promoting practices that will continue to provide invaluable services, products and benefits enjoyed by, and sustaining, human populations (including future generations), as well as for the conservation of biological diversity. All of the phrases that are emphasized above point to a wider interpretation of wise use than simply that of the land-use practices themselves. In particular it is valuable to explore the thinking that underlies ecosystem approaches, as mentioned in the Ramsar definition since this is the basis for understanding a wider definition of "wise use".

Essentially, ecosystems approaches arose as a critique of the reductionist approaches of traditional management and policy frameworks within the natural resources disciplines. In particular, many of these frameworks treated people as separate to, instead of an integral part of ecosystems. In most cases, the focus was on the isolated problem at hand with little cognisance of the wider context and its role and was, more often than not, product driven. For example, a product-driven approach has meant that freshwater systems, forests and agricultural land have been conventionally managed to achieve growth in outputs. This narrow focus has come under scrutiny and a number of assessments, including both the PAGE assessment[1] (World Resources Institute, 2000) and the Millennium Ecosystem Assessment (2005), which concluded that these increased outputs had been at the expense of other goods and services such as water quality and quantity and carbon storage. In particular, the management of freshwater systems for human utility has generally followed unsustainable routes (Boon et al., 2000; Harris, 2007), amongst many). Likewise, many supply-driven approaches to water shortages (even those that embrace the principles of democracy and participation) have been unsuccessful because the underlying cause of the problem is related to a far wider range of social and natural resource issues such as unsustainable water and land-use practices upstream in the catchment. These, in turn, are often related to wider political and socio-economic factors (Pollard and Du Toit, 2009).

In response to these constraints, calls were made for more holistic approaches to planning for sustainability. Indeed, this thinking has rapidly gained credence and support, especially as the basis for discussions in Rio for Agenda 21 (Prof. I. McIntyre, University college Cork, pers. comm., 2009) and has been adopted by many institutions (e.g. IUCN, see Pirot et al., 2000; WRI et al., 2000) and in a number of planning frameworks (e.g. the Millennium Ecosystem Assessment, 2005) and policy statements. The Convention on Biological Diversity (CBD, 1993) has endorsed the ecosystems approach (see Box 1 for definition).

[1] The PAGE (Pilot Analysis of Global Ecosystems) was a global study undertaken to assess the condition of, and changes in the Earths major ecosystems: agro-ecosystems, coastal, forest, freshwater and grassland ecosystems.

BOX 1.1
An **ecosystem approach (CBD 1993)** is a *strategy* for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way

This approach recognises that humans are an integral part of most ecosystems. The foundation is to achieve a **balance** between peoples' needs and longterm sustainability. However as the above definition suggests it is about more than that. An ecosystem approach essentially represents systems thinking which recognises that a system is made up of complex and **interconnected parts**. A system approach relates to the properties of the system as a whole and hence calls for different types of decision-making and management action (Everard and Powell, 2002). This evokes new methodological practices that essentially aim to temper human activities against the principles of sustainability and equity. Thus ecosystem-based management (and we would suggest, governance- see Chapter 4) attempts to strike a balance between benefiting from natural resources while maintaining and ecosystem's ability to provide these at a sustainable level, now and in the future (Pirot et al., 2000).

Thus for our purposes we have defined the "wise use of wetlands" as follows (Box 2):

BOX 1.2
'Wise use" of wetlands as defined in this project
The wise use of wetlands is a integrated *strategy* for the sustainable and equitable use of wetlands through good governance and land and water use practices that promote healthy wetlands so as to continue to provide services, products and benefits that are enjoyed by and that sustain human livelihoods (including those of future generations), as well biological diversity

This definition requires that we unpack some important framing concepts, namely integrated strategies within complex, dynamic environments, the issue of good governance, sustainable land and water use practices, wetland health and livelihoods. Also worth mentioning are a series of principles that help to frame wise wetland use. A principles-based approach is important because no two areas are exactly the same and hence blueprints for wise use are not appropriate. Some of these principles – although still in draft form – and developed through a collaborative effort[2] focus on complexity and inter-linkages, local livelihood support, good governance and participation.

1.2.2. Wetlands as part of complex, dynamic systems

Ecosystem approaches are part of a wider body of systems thinking that arose as a critique of the traditional, reductionist approaches to natural resources management and use. The essence of the concern was that despite enormous effort focussed on research and the management of natural system, sustainability remains – for the most part – an elusive goal. We have largely failed to chart a sustainable

[2] Workshop held in 2007 between AWARD, Mondi Wetlands Project (WWF), Working for Wetlands, the University of KwaZulu-Natal and Wessa

future (see for example Levin, 1999; Gunderson and Holling, 2002; Holling, 2001; Folke et al., 2002; Folke, 2003; Allison and Hobbs, 2006; Walker et al., 2004; Anderies et al., 2006). The underlying causes for this failure were distilled to a number of factors. One critique emphasised that such approaches had failed to see ecological systems as part of a broader socio-economic and political context and hence had not recognised the importance of key drivers that were not ecological in nature. The term linked socio-ecological systems (see for example (Berkes and Folke, 1998) was coined to try to develop a stronger focus on linked systems and *interconnectedness* became a key consideration. Furthermore, many systems had been managed as if they were stable systems in a state of equilibrium, leading to the development of single-value offtake or harvest rates (maximum sustainable yield), irrespective of variations in the socio-economic, political and natural context. Rather, it was pointed out, ***socio-ecological systems*** are complex, dynamic systems. In accepting this, one has to accept a number of characteristics of complex systems (see also (Burns and Weaver, 2008). Although difficult to distil their essence (see Box 3), the overarching characteristics are that the systems are not entirely predictable (although they show pattern) and therefore have to be managed through a process of strategic adaptive management, that fundamentally embraces learning by doing. Thus sustainability can rather be regarded as an envelope within which the system 'bounces around' so to speak. This is fundamental to the development of indicators because in recognising that systems are dynamic, the challenge is to develop indicators that take account of the dynamism.

BOX 1.3
Complexity in a nutshell (from Pollard et al., 2009)

Complex system can be contrasted with simple or **complicated systems** which are predictable in that their relationships are always the same (e.g. a car engine). A complex system can be distinguished from a simple one, albeit complicated, by a number of attributes including non-linearity, uncertainty, emergence, multiple scales and cross-scale effects, self-organisation and feedback loops. A complex system shows feedbacks (reinforcing or balancing) in its cause and effect relationships, which, usually because of operation at different scales, cause emergence (i.e. the feedbacks generate surprising new properties not predictable from the original bits and pieces making up the system).

Ironically, complex systems often have only a few predominant drivers – it is the way these interact (and in particular the feedbacks) which produce the complexity. The drivers invariably vary in strength over space and time, producing different combinations of outcomes. At a certain range (called a *threshold*) in the values of these different drivers, systems can fundamentally change their nature, say from grassland to savanna, or from family to sibling kinship networks. In practice this usually takes place as a series of linked thresholds and system states, called a *regime*, and a regime shift follows (see *inter alia* (Scheffer et al., 2001), (Carpenter, 2003), (Folke et al., 2004). An example of a regime shift is the change in the nature of rivers in the lowveld from bedrock-influenced. higher-flow, and with lower human utilisation to alluvium-dominated, lower flow, and with higher levels of human abstraction. A series of interlinked thresholds is crossed in each of these factors, leading to a different overall state. Essentially in a new state the rules-of-the-game – or underlying processes – change.

Complex patterns stand in contrast to *complicated* patterns which, in a technical sense, have very many parts but these parts are connected in a way which produces a deterministic (always the same, entirely predictable) outcome. Examples of complicated systems are aircraft or electronic circuit boards. These fundamental concepts are reviewed by Walker and Salt (2006) and a series of thresholds and regime shifts are listed on the Resilience Alliance website http://resallaince.org.

As part of the recognition of complexity and systems dynamics, Holling (1986) introduced a key concept – that of resilience – which has been further developed by the Resilience Network. They suggest that this concept lies at the very heart of sustainability in that a resilient socio-ecological system can buffer disturbance and adapt to change without flipping states (a fundamental shift in the underlying characteristics of a system). Importantly, ecological, social and economic sustainability is synonymous with resilience[3] (Berkes et al., 2003).

A recent WRC-project has explored the potential for such thinking as an overarching framework for understanding interrelationships between main drivers (be they social, economic or biophysical) in the Sand River Catchment (Pollard et al., 2008a). Much of the history and development of systems thinking, complexity theory and resilience analysis is contained in that report, to which readers are referred for greater detail. The approach highlighted key drivers of change at both a catchment scale and at the scale of wetlands. It appears that despite policy changes, many of the drivers and their reinforcing pathways of degradation and livelihood insecurity are still in place. This raises the profile of two important components of the overall model shown in Figure 1.3, that of wetland health and livelihood security which are explored later in this chapter. First however, let us examine what role learning plays in resilience and sustainability and more specifically how indicators are important in informing management actions aimed at 'wise use'.

1.2.3. Complexity and learning

In complex systems, learning becomes critical because – as indicated earlier – complex systems may be unpredictable and lead to unexpected surprises. But what is the role of learning within complex systems? More specifically, does learning have a role to play in moving systems towards more resilient, stable and sustainable states?

Complexity theory proposes that socio-ecological systems derive their essential properties, and in fact their existence, from their relationships (Capra, 2007). The character of these relationships is influenced by interactions around events, communication and **learning**. The resilience, and hence sustainability of a system, is not an individual property, but a property of an entire network of entities. One would assume that a vulnerable (unsustainable) system would have weak networks where feedback plays little or no role in organizing or regulating the system. This means that learning (from mistakes for example) cannot – or does not – occur. On the other hand, a system that is able to experience events, reflect on them and so learn is assumed to be responsive and capable of adapting to changes that are inherently part of complex systems.

Assessing the modes and modalities of learning within socio-ecological systems potentially provides a way of understanding just how adaptive and resilient the system is or can be. In a sense, such an exploration would look at the 'internal intelligence' or capability of social system to learn and respond to contextual events and changes. If we accept that learning has a vital role to play in ensuring that feedback loops have an impact on self-regulation and self-organization then it becomes a critical process in the support for, or hindrance to, establishing resilient, sustainable systems. In this regard, learning is taken to be a social process where engagement, communication and dialogue provide the basis for reflecting on and

[3] This does not imply that all resilient systems are favourable. Indeed many longstanding but nefarious political regimes are resilient (over a certain timescale) but are ultimately unsustainable

responding to feedback in a way that is open to change and that encourages creative and innovative responses to an ever evolving context.

As the context evolves so there is a need to update information and knowledge so that responses are appropriate and relevant. This is where indicators have an important role to play in that they are a source of information which has the potential to direct responses in ways that benefit the system. However, the use of indicators for monitoring and tracking does *not* necessarily mean that learning is occurring and that actions are leading to more sustainable configurations. The critical issue is that indicators need to be integrated into a holistic and comprehensive plan to deal with data and information that they generate. Feedback loops are therefore critical regardless of the source of level of complexity of the indicator. In this study we propose that simply articulated indicator systems have as much potential to effect change and influence 'wise use' as do highly technical ones.

1.2.4. Wetland health

Wetland health lies at the core of this work since the maintenance of a healthy wetland (through good governance and sustainable land-use practices, for example) allows the flow of ecosystem goods and services that sustain peoples' livelihoods and other living resources (see Figure 1.1). However, what does *wetland health* mean? This merits some discussion because despite the widespread use of the term in the environmental field, no single definition exists. This probably reflects the fact that wetland health (or ecosystem health) is a metaphor that arose in response to the notion of degradation. Since it draws on a medical connotation, it is easily embraced (but not necessarily well understood) by the public at large. Thus one can fairly quickly get general buy-in to discussions that something has 'gone wrong'. But part of the problem in defining wetland health is that it is neither a single attribute nor value; such as for example (and by extension of the metaphor) – human temperature. As body temperature that rises above 37^{o} C, suggests cause for concern and tracking the trend (increase or decrease) is essential in deciding that the person is in poor health and ultimately in danger. Nonetheless as we saw earlier – and in keeping with thinking regarding complex systems – although the term is used to describe some degree of deviation from a natural or functioning wetland, some degree of variation is to be expected, and is not necessarily indicative of an "unhealthy wetland".

Definitions available in the literature reflect the objective of the project in question. For example, Macfarlane et al. (2007) defined wetland health as "a measure of the similarity of a wetland to the natural reference condition". This definition reflects the objectives of their work which is to provide an approach to assessing change in wetlands; it answers the questions "how much change has there been?" For other purposes however, and as pointed out above, although a system may deviate from natural, it may still be regarded as healthy in that production and resilience is maintained. For example, a small net loss of sediment or water at a certain time scale (e.g. months) may not limit or significantly impact on production and may be replenished over a longer time scale (cycles of wet and dry years). Thus scale is also an important dimension.

In the case of this project, two key questions guided the development of indicators and hence wetland health:

- What is the condition of the wetland in terms of a sustainable supply of goods and services?
- Are current practices ameliorating or compromising this flow of ecosystem services?

Thus Pollard et al. (2008b) used the following definition: "*Wetland health refers to the ability of the wetlands to sustain production (plants, crops, fish,) through maintaining the water and sediment balance.*

A component of this includes continued water security at a micro-catchment level[4]". Drawing on resilience theory, a healthy wetland *represents a resilient socio-ecological system that can buffer disturbance and adapt to change without flipping states*.

Much of the work on wetland health, or condition, focuses on observing the wetland's structure and function. Examples of wetland structure (its parts) include: water quality, soil condition, geology, hydrology, topography, morphology, carrying capacity, species composition, food web support, and nutrient content. Examples of function (what it is doing), include: surface and ground water storage, recharge and supply, floodwater and sediment retention, nutrient cycling, biomass production, reduction of erosion, and purification of water.

There is no one characterisation that describes a healthy wetland because of the huge diversity of wetland types and the diversity of objectives. Some suggest that the most reasonable way of describing wetland health is to compare the wetland of interest with other less altered similar sites (see http://www.umt.edu/watershedclinic). This helps answer the question, "what is the potential of this site?" Another method of describing degradation is to measure attributes over time. If the wetland's structure and function no longer measure up to its potential, it is said to be unhealthy but of course this points to the challenge: what is the potential and how to measure this? Moreover, what degree of change from the potential or attributes is acceptable?

The proximal determinants of wetland structure and function are water and sediment, i.e. hydrology and geomorphology (and hence water quality). These shape the habitat which in turn determines the biological response of vegetation and biota (Figure 1.1). Research or monitoring initiatives (using indicators) that are designed to track wetland health focus on any or some of these components.

[4] The micro-catchment refers to the wetlands catchment i.e. all of the area of the wetland (upstream and lateral to) that supplies water to the wetland through surface and sub-surface flows.

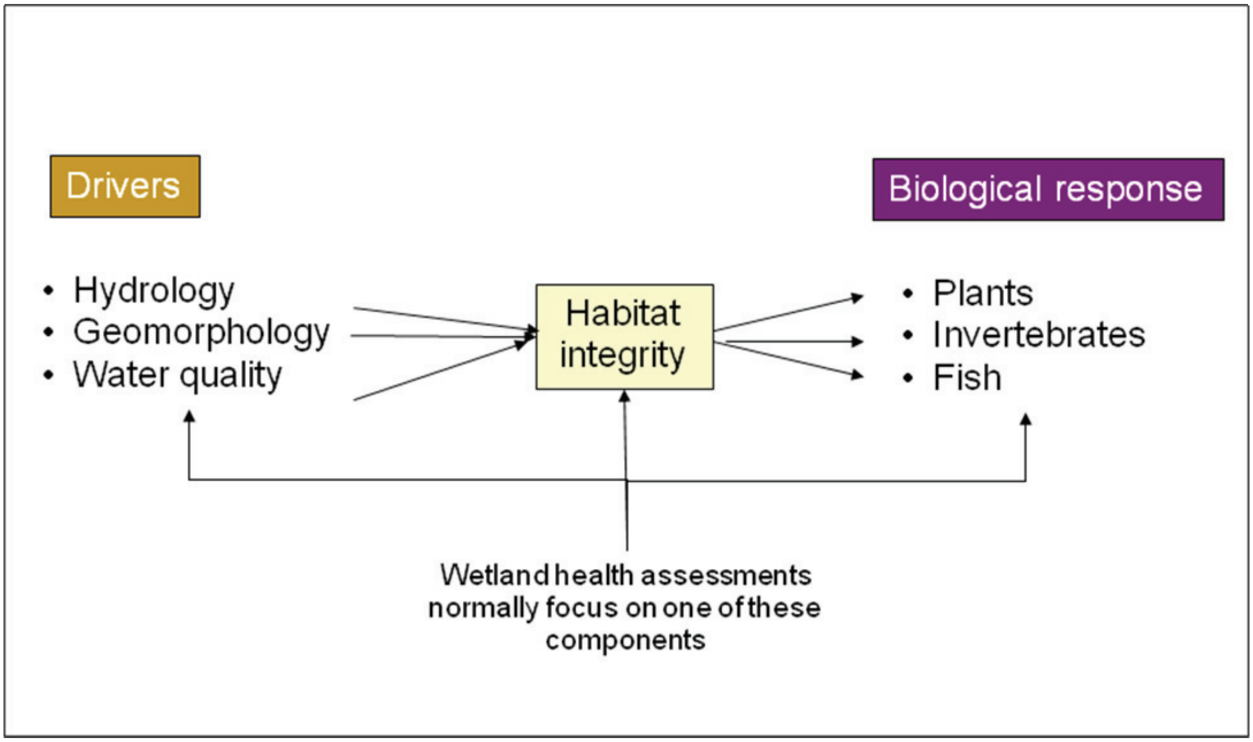

FIGURE 1.1: The drivers/ primary determinants of wetlands and the biological responses indicating that wetland health assessment may focus on any of these components.

Most importantly, we must remember the following.

1. Wetlands are dynamic systems so that each of the characteristics shown in Figure 1.2 will vary naturally. For example, the hydrology (or water inputs and outputs) vary over and between years. Thus a decrease in water inputs at a point in time does not necessarily mean a loss of wetland health.
2. Wetlands can be used and lose some of their 'naturalness' without being losing resilience or necessarily being deemed unhealthy; the challenge is to determine what change is unacceptable;
3. The social element of *who* determines the level of acceptability is of critical importance where wise use is concerned. Indicators for healthy wetlands and wise use need to be integral to the social system that derives benefit from the wetland. Indicators that are of no value to users are largely meaningless in the quest to develop sustainable practices.

Given this context, and the focus of wetlands in communal lands and the contribution to livelihood security, we are ultimately interested in healthy wetlands because of their potential to deliver ecosystem goods and services. These can be measured but this can be difficult particularly given the context of this project. For example, the measurement of plant production (as an indicator of wetland health) would require a number of years and consideration of confounding factors – such as climate – for example. Some suggest that in many cases it is better to examine wetland attributes and assume that if the wetland is healthy it can deliver goods and services (Whigham, 2003).

1.2.5. Livelihood security: natural resources as one of the five capitals

A discussion of a complex socio-ecological system would be incomplete without adequate attention to the human and social aspects. Although the development of indicators for livelihood security is beyond the scope of this project, recognition of the contribution of healthy wetlands (i.e. natural capital) to livelihood security needs to be understood. In this regard we have drawn on the widely-used livelihoods framework.

The livelihoods framework recognizes five essential capitals: human, natural, financial, social, and physical (Chambers and Conway, 1992; Scoones, 1998; Carney et al., 1999; Farrington et al., 1999; Bebbington, 1999; Campbell et al., 2002). Again, whilst a detailed analysis of livelihoods approaches is beyond the scope of this report, it is important to note that the emergence of livelihoods approaches has led to new understandings for the discourse on poverty, and the ability of people to move out of poverty. Notably, it recognises that peoples' ability to survive is not simply reliant on financial resources but is predicated on a range of assets. Much of the thinking emerged from work by Chambers and Conway (1992) who defined livelihoods thus:

> *A livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living: a livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation: and which contributes net benefits to other livelihoods at the local and global levels in the long and short term.'*

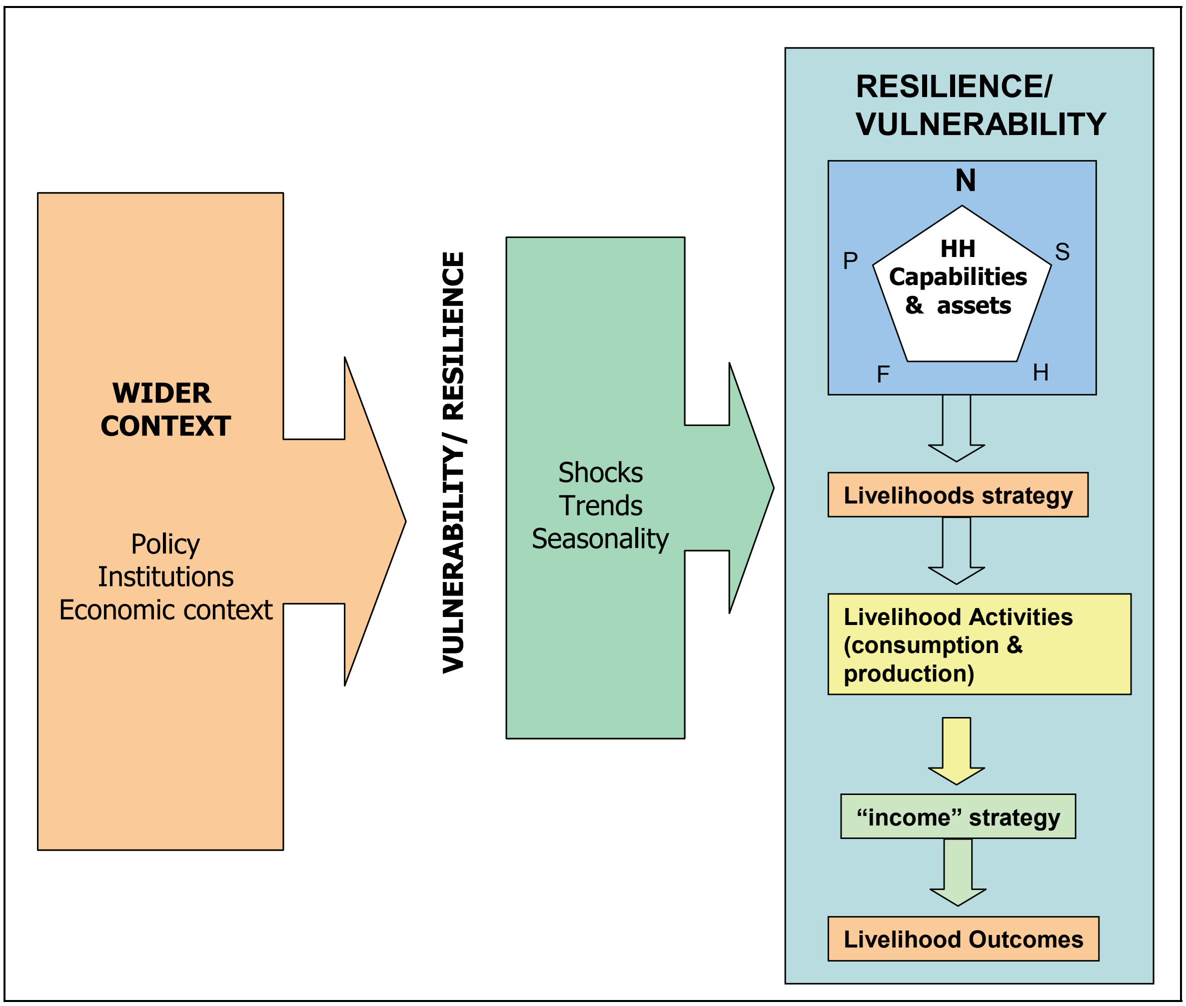

FIGURE 1.2: The livelihoods model that frames work reported in this study (Pollard et al., 2007; adapted from (DFID; Drinkwater and Rusinow, 1999). The five capitals used by households (HH) include natural (N); social (S); human (H); financial (F) and physical (P).

Central to the livelihoods approach is to understand the capabilities and assets (or lack therefore) that are available to people and in particular to the poor. This includes:

1. Human capabilities (such as education, skills, health, psychological orientation);
2. Assets – access to tangible and intangible assets (this includes human, material[5], social, natural and economic capital);
3. Activities – these capabilities and assets define the sorts of activities that make up the livelihoods of the poor and, through strengthening them, form the basis for many actions to reduce poverty.

The interaction between these attributes defines what livelihood strategy a household may pursue. Based on work by Chambers and Conway (1992), a number of fairly similar livelihoods models exist, such as those of DFID and CARE. The differences have been addressed by Carney et al. (1999). The model used in this report, shown in Figure 1.3, is one adapted from these aforementioned models. This indicates that natural resources are one of the five capitals upon which people rely directly and hence contribute to peoples' livelihoods. The tenet of this study is that the rehabilitation of wetlands (the natural capital) will lead to improved financial and social security.

1.3. Overall Integrative Model for Communal Wetlands

The preceding discussions highlight a number of key concepts that informed the initiation and development of the project. Central to this was the development of an overall framework to support the process. Thus conceptually our starting point was to develop an overarching systems diagram that linked the micro-catchment, its wetland and the livelihoods of its residents, based on research from Craigieburn.

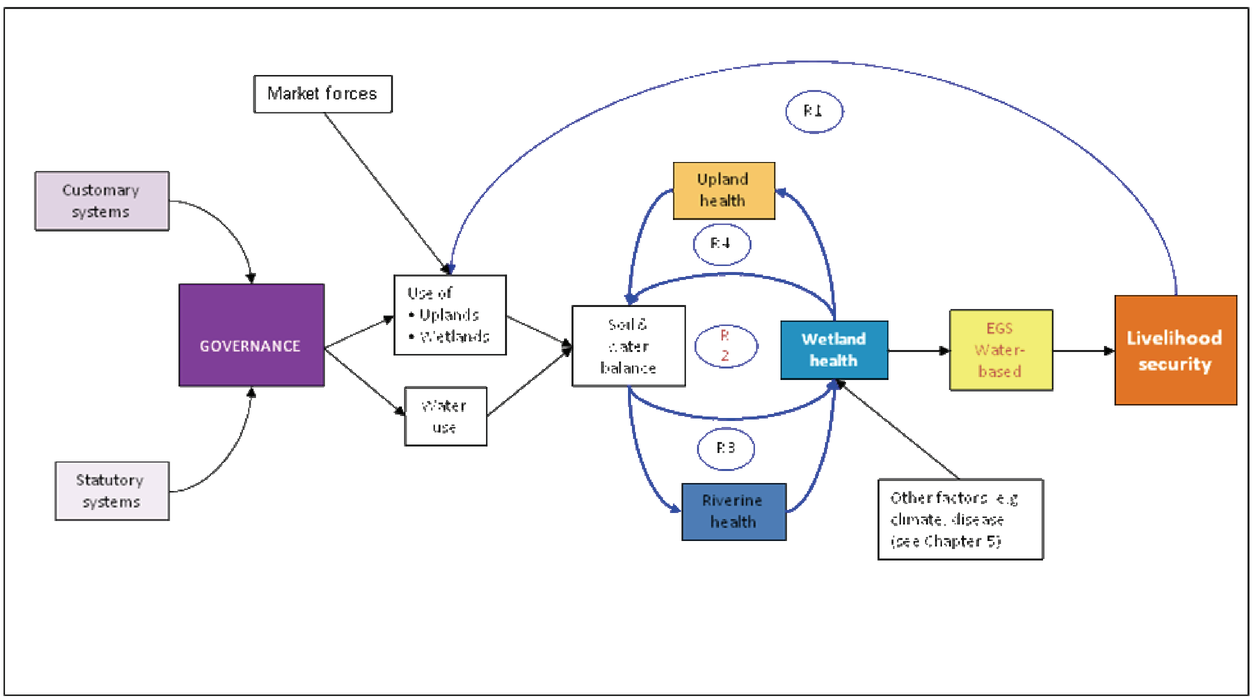

FIGURE 1.3: Overall conceptual model for communal wetlands (based on findings from Craigieburn) showing the links between the governance, land and water use, wetland health and livelihood security, showing key drivers, parameters, inter-linkages and feedback loop loops. The model highlights the links between ecosystem integrity (wetland health in this case) and livelihood security. Note that although livelihood security is the focus of rehabilitation, additional ecosystem goods and services (EGS) are derived from wetland integrity including water security and biodiversity. R = reinforcing loop (see text for details).

[5] Access to land, other natural resources, financial capital and credit, tools and inputs into productive activities and others

The model, summarised in Figure 1.3, indicates the linkages between the governance, land and water use, wetland health and livelihood security and indicates key drivers, parameters, linkages and feedback loops. Governance is derived both from customary and statutory systems and directly influences land use (extent and practices) in both uplands and wetlands (see Pollard and Cousins, 2008), and to a lesser degree water use (referring to water for domestic purposes such as drinking, washing and stock watering). These in turn influence sediment and water dynamics (inflows) which, amongst other factors, characterise wetland health. The health of the wetland determines its ability to deliver key ecosystem goods and services (such as water, crops and reeds) which contribute to livelihood security (through sale or household use). Livelihood security (or vulnerability) directly drives land use – a key feedback loop in the system (R1). Other feedback loops include those between wetland health and soil and water balance (for example a degraded wetland no longer attenuates sediment; R2), wetland and riverine health (R3), and upland and wetland health (R4) (see Pollard et al., 2008a), for further discussion). Wetland health is predicated on water and sediment balance which may change as a consequence of changes on the hillslope and/or within the wetlands. Plant and crop production contribute to food and household products which are mainly used for household consumption. These represent the natural and financial capital inputs to peoples' livelihoods. From this conceptualization it is clear that ecosystem health is directly linked to peoples' well-being.

We propose a holistic and integrated orientation to the development of indicators for sustainable wetland management. In this regard, and following the format of the model (Figure 1.3), there is a focus on indicators of sustainable wetland use, sustainable upland/ hillslope use, wise and effective governance and some exploration of indicators of wetland health and soil and water balance. We also show that the social process of indicator development is essential in that processes that exclude the actual users are problematic, often including the user as part of the problem rather than as the transformative agent in the progress towards sustainability.

Chapter 2
Literature review

2.1. Conceptualising Sustainability Indicators

2.1.1. Introduction

Much of the integrative work being done in wetlands in southern Africa is concerned with the issue of sustainability[6] and, as pressures on natural resources mount, the issue of sustainable development lies at the core of this interest. The concept, as described in *Our Common Future* (WCED, 1987) describes sustainable development as "…development that meets the needs of the present without compromising the ability of future generations to meet their needs". Not only are we challenged to think about how this can be realised (Burns and Weaver, 2008), but questions also arise as to how progress towards such a goal can be tracked, and how we can learn as we do the monitoring? Part of the response inevitably involves the call for suitable indicators but as the literature demonstrates, the development of suitable and appropriate indicators is extremely difficult and as King et al. (2000) point out, the literature on indicators is extensive.

Added to this is the 'uncertainty' that is brought to bear by recognizing that wetlands are complex, socio-ecological systems in themselves (see Chapter 1) and layers of complexity are added when one recognizes that wetlands are part of catchments, themselves complex systems (comprising nested, interlinked sub-systems). Contemporary thinking regarding natural resources management- including that of wetlands – stresses the need for an integrated approach, and sometimes also recognizes the need to deal with complexity (see Pollard and Du Toit, 2007). As pointed out in Chapter 1, a key feature of complex systems is that the outcomes are not always completely predictable and hence there is a degree of uncertainty. This is because multiple variables interact with and influence other variables[7] – and the degree of influence varies – such that complex systems do not behave in a linear, predictable fashion. Moreover, because systems are linked, changes in one 'sub-system' will cause changes in other sub-systems.

Numerous definitions of indicators are apparent. It is generally accepted that used alone or in combination, indicators provide the means to assess the progress towards one or more objectives. Indicators may take many forms and measure a variety of issues for diverse management and decision-making purposes. As mentioned in Chapter 1, an indicator is defined as a parameter or value that reflects the condition of an environmental or social component usually with a significance that extends beyond the measurement or value itself (Shear et al., 2005). In complex systems indicators are often used as representations of the most significant parameters of an observer-defined system when the focal object of the study is too complex to be measured directly, or of its features are not accessible with the available methodologies (Muller, 2005). Also when linked systems are being considered, indicators are needed that describe the performance of the individual system, and its contribution to the performance of other systems where single value outcomes are not the key focus (Bossell, 2001; and see Pollard et al.,

[6] There is no consensus on the precise operational definition, meaning, and boundaries of "sustainability". Pretty et al. (2003, p.218) state that "systems high in sustainability are making the best use of nature's goods and services whilst not damaging these assets".

[7] For example, wetland production can be influenced by a range of practices (crop types, mulching, furrows, manure etc) and each of these can vary in their strength of influence on an annual basis. Production is thus predictable only within a certain range (x – y kg/ha) and then if other factors change (land tenure for example) production may become even less predictable.

2008a). More recently, as appreciation for the importance of variability grows, the issue of thresholds or ranges associated with indicators has emerged. This is further dealt with in Section 2.1.4.

There are certain acknowledged – if somewhat ambitious – requirements for indicators. They should be easily measurable, rapidly aggregated, and sensitive to spatio-temporal change, cost effective, reliable and robust, scientifically credible, policy relevant, make use of available data, and they should depict the investigated relationships in an understandable manner (Muller, 2005; Reed and Dougill, 2003).

Sustainability indicators provide a primary method to monitor the progress towards sustainable development through practical means. Reed and Dougill (2003) suggest that sustainability indicators are key tools for community-based monitoring as they can easily capture complex information about human-environmental interactions. Reed et al. (2005, p.1) define sustainability indicators as "the collection of specific characteristics of society that address social, economic and environmental quality". Sustainability indicators are more than just a measuring process of sustainability; they can enhance the overall understanding of environmental and social problems, they can facilitate community capacity building, and help guide policy and land-use management projects (Reed et al., 2005).

The identification, selection, classification, interpretation, and participatory use of sustainability indicators have become an integral part of international and national policy in recent years. There are, however many practical difficulties and conflicting frameworks (Reed et al., 2005). In practice it has proven difficult to identify indicators of sustainability *per se*, thus the focus has shifted towards identifying activities that contribute to unsustainable states and (un)healthy ecosystems. Brooks et al. (2007) states that the current set of ecological and socio-economic indicators available for assessing and predicting environmental integrity, health, and sustainability is not complete. Much of the work has been heavily criticised for being developed in isolation and delinked from action. This is partly a problem of scale since the majority of existing indicators are based on a top-down definition of sustainability that is fed by national-level data. This may miss critical sustainable development issues at the local level and may fail to measure what is important to local communities (Reed et al., 2005).

Nonetheless in developing locally-appropriate indicators, it is important to understand their classification as well as the numerous frameworks that have emerged against which indicators have been developed. These are briefly reviewed below.

2.1.2. Sustainability-indicator classifications: diagnostic, process, and outcome indicators

Sustainability indicators are widely used to assess the current state of a system and to monitor changes in the system over time (Sayer et al., 2006). Indicators are used in a variety of contexts and consequently the list of sustainability indicators cited in the literature is extensive (refer to Table 2.1 for a glossary of indicators types). The classification of sustainability indicators into three main groups; diagnostic, process and outcome indicators is a theoretical exercise that can contribute to their analysis and improvement. The classification process is a critical part of indicator development and depends on several influences, such as the operating scale, target sector, regional and cultural influences, and the intended use of the indicator set (Bell and Morse, 2001).

Diagnostic indicators (status or condition indicators) convey information about the current condition of a system by observing the state of some system element(s) (Wardrop et al., 2007; Hershner et al., 2007). They are parameters or processes that can either provide insight into the causes of ecosystem deterioration or measure the success of ecosystem restoration and protection programs (Cairns et al., 1993). Examples include measurable chemical, physical (flow regimes), or biological parameters, improved recruitment classes of targeted species, biotic diversity, productivity, or keystone species. The support for biological diagnostic indicators is that organisms have an intricate relationship with their environment, which reflects current and cumulative ecosystem condition (Reiss and Brown, 2007).Diagnostic indicators require an appropriate reference standard, such as the allowed concentration of a toxic substance in a river system, to indicate whether the system concerned is in good or bad condition (Wardrop et al., 2007).

Diagnostic indicators provide an opportunity for the root causes of an environmental condition to be identified within a larger more complex system (Duda, 2002). They may, therefore serve to evaluate the achievement of specific management objectives as well as to communicate an environmental condition to a broad audience. This means that diagnostic indicators can inform adaptive management and affect overall management goals (Hershner et al., 2007). Diagnostic indicators are arguably the most useful for ecosystem restoration programs but are the most challenging to develop. Boulton (1999) states that this is mostly a scale related issue. Certain indicators may respond to ecosystem stressors at different spatial and temporal scales and thus no single indicator can unequivocally reveal ecosystem health (see also Section 1.24). The appropriate choice of indicator needs to be matched effectively to the objectives of the monitoring and evaluation projects concerned.

Evaluation and monitoring efforts can usually be divided into those that measure process and those that measure outcomes. Traditionally, **process indicators** have been a measure of progress in project activities involving inputs and outputs of goods, physical structures, and services. Process indicators have also been able to demonstrate actual, on-the-ground institutional and political progress in the implementation of program activities. They are a particular value used to measure the products of activities such as policies, the laws passed, permits issued or denied, and the money spent (Duda, 2002). Process indicators thus are able to track domestic and national institutional, policy, legislative, and regulatory reforms necessary to bring about planning and reform. A focus on process indicators thus aims to elucidate and understand *how* the dynamics of a program, organization, or institution operate. Capacity development and stakeholder participation have also been recognized as important to achieving sustainable project outcomes and are commonly considered by process indicators (Duda, 2002). Ecological process indicators, on the other hand, are representations of ecological processes occurring at certain spatial and temporal scales (Bar and Loffler, 2007). The capacity of rangelands to produce commodities, for example, are dependent on a number of self-sustaining ecological processes such as soil genesis, nutrient cycling, energy flow, and the structure and functional dynamics of plant and animal communities (Joyce and Heitschmidt, 2003).

Outcome indicators document the changes in socio-economic or physical conditions brought about by the activities of a program. Segnestam (2002) asserts that they measure the immediate short-term results of project implementation, although why medium term results are not included is unclear (examples include the acres of land protected, number of public access sites established, an improvement in water quality, or measures of organizational learning or progress). Bowen and Riley (2003) state that a focus on outcomes rather than solely on process indicators intends to shift the central focus of a program towards accountability-driven results. Numerical indicators of outcomes, such as a percentage increase in a parameter, are important to provide concrete evidence of overall patterns of change. The wetlands project however, has placed an important focus on qualitative outcomes as these are able to effectively demonstrate the sharing of knowledge in a community and between practitioner and community, which in turn aids adaptive learning processes. Creating an indicator framework that includes both process and outcome indicators can help trace management efforts more directly to environmental and social conditions.

Ramsar (2007) details the use and development **performance indicators**. These are used for monitoring progress in achieving a certain set of objectives and are thus considered as part of the outcome indicators group. In general, performance indicators are characteristics, qualities or properties of a wetland that represent the general ecological, socio-economic and cultural features. Performance indicators for a species would include, for example the total size of population, the total number of breeding adults, the population size at a specified point in an annual cycle, and the spatial distribution of the population (Ramsar, 2007).

TABLE 2.1: Additional categories of sustainability indicators cited in the literature

Indicator	Description	Key Reference
Performance Indicators but this is dealt with above so not additional	These define the performance standard that, when reached, represents achievement of an objective. Examples include the availability of a policy to the public, the principles of the policy, and level of the community involvement	Schoeman and Magongo (2004)
Early warning indicators or alarm indicators[8]	These represent indicators that need to be constantly monitored in order to give timely warning about adverse changes threatening to exceed set thresholds (similar concept to TPCs). For example, electric conductivity of water. The value of using early warning indicators when monitoring wetlands has been emphasised by Van Dam et al. (1999). Ramsar (2007 p.57) define early warning indicators as "the measurable biological, physical or chemical responses to a particular stress, preceding the occurrence of potentially significant adverse effects on the system of interest". The underlying concept of early warning indicators is that effects can be detected, which are in fact, precursors to, or indicate the onset of, actual environmental impacts.	Van Dam et al. (1999); Segnestam (2002); Ramsar (2007).
Stress Reduction Indicator	These document on-the-ground action that has occurred. Such actions include, for example, an enforcement action on an industrial pollution discharge that resulted in less pollution loading, an investment that helped a municipal sewage treatment plant reduce nitrogen loading, or larger-sized mesh net regulations being enforced for a fishery.	Duda (2002)
Representative Indicator	The variable that provides reliable information that is characteristic of a whole complex situation. For example, the relative abundance of lichen could serve as a representative indicator of air pollution.	Bossel (2001)

[8] Defined as "*a measurable biological, physical or chemical response to a particular stress, preceding the occurrence of potentially significant adverse effects on the system of interest*" (Van Dam et al., 1999).

2.1.3. Frameworks for sustainability indicators

Indicators are not developed in a vacuum but are generally informed by an overarching framework which embraces the underlying philosophical and conceptual approaches and outcomes as well as practical considerations. The literature on sustainability indicators is now so prolific (Table 2.2) that King et al. (2000) refer to it as "an industry on its own". This literature falls into two broad methodological paradigms or frameworks; top-down and bottom up. These frameworks are briefly reviewed below but it must be noted that their specific reference to indicators per se varies widely from broad reference to requirements for indicators to detailed indicator development and specifications. It should also be noted that the terms top-down and bottom-up are not value-laden since the appropriateness of each approach depends on the objectives of the work in question.

This section of the literature review analyses the top-down and bottom-up frameworks – relevant to our objectives – for developing and applying sustainability indicators at the local scale. The strengths and weakness of each framework (summarised in Table 2.2) are presented and coupled with a recently developed framework by Reed et al. (2005). They refer to an integrated approach which combines elements of both the top-down and bottom-up approaches (termed "elements of both" in Table 2.2). We rather reserve this term to describe the integration of socio-economic and biophysical systems. Top-down and bottom-up frameworks may therefore be integrated in their approach to the combination of social and physical systems. Bowen and Riley (2003) state that without an integrated indicator-based system it is unlikely that critical linkages can be established in complex ecological and human-environmental systems.

The **top-down paradigm** is rooted in scientific reductionism and advocates the use of explicit quantitative indicators (Reed et al., 2005). This approach is expert-led, often refers to long-term analysis such as climate change, and is common in the fields of research such as landscape ecology, conservation biology, and soil science. This approach often fails to engage local communities. Reed et al. (2005) advocate that sustainability indicators need to be linked to action that provides immediate and clear local benefits to enable the participation of local communities. These authors point out that indicators need to be relevant to local people and the methods used to collect, interpret and display data must be easily and effectively used by non-specialists so that local communities can be active participants in the process.

The **bottom-up paradigm**, on the other hand, is community-based having an understanding of the local context and perceptions of the environment and society. It draws on the social sciences and emphasises the importance of the local context to setting goals and establishing priorities. Community participation is central to this process in order to gain relevant and meaningful perspectives on local issues, which enhances the communities and researchers capacity for learning and understanding (Reed et al., 2005). In this spirit, the wetlands project has placed a strong emphasis on developing community-based indicators. Importantly in this case, 'community' refers to both the wetland users and the practitioners (e.g. extension staff; AWARD) that have been working there. From the practitioner perspective, the need to track change over the length of the Farmer Support Project has been recognised and, at the same time, farmers have needed a plan for a vision and to assess change against this vision. Indicators can fulfil all these functions if chosen well (Reed et al., 2005).

Reed et al. (2005) attempt to move the debate on sustainability indicators from the theoretical to the practical – from simply measuring sustainability to facilitating sustainable practices. They point out that despite the development of numerous indices and classification frameworks there have been few attempts to develop indicators that can feed practically into sustainable land-use management. To do this, research must focus at scales relevant to land users before considering scaling up to national and international levels. Local-scale sustainability assessments tend to be more accurate and relevant to local circumstances and priorities, which are rarely homogenous within or between nations. **Sustainability indicators based on local data** provide a practical method to monitor progress towards sustainable development. However, since there are many conflicting frameworks proposed to develop indicators, it is unclear how best to collect these data. The frameworks proposed in this paper (see Chapters 4 and 5) provide a method for developing sustainability indicators that can be used easily by land users to provide guidance on sustainable land management.

TABLE 2.2: Summary of the variety of sustainability indicator frameworks reported in the literature (adapted from Reed et al., 2005; note that the term integrated approaches is different to that used by Reed et al., 2005).

Top-Down	Description	Key References
Orientation Theory **Integrated approach**	Develops indicators to represent system "orientators" (existence, effectiveness, freedom of action, security, adaptability, coexistence and psychological needs) to assess system viability and performance	Bossel (2001)
Panarchy Theory & Adaptive Management **Integrated approach**	Scale: Systems Based on a model that assesses how ecosystems respond to disturbance the Panarchy framework suggests that key indicators fall into one of three categories: wealth, connectivity, diversity. Wealthy, connected and simple systems are most vulnerable to disturbances	Gunderson and Holling (2002)
Pressure-State-Response (PSR), Driver-State-Response (DSR) and Driver-Pressure-State-Impact-Response (DPSIR)	Identifies environmental indicators based on human pressures on the environment, the environmental states this leads to and societal responses to change for a series of environmental themes. Later versions replaced pressure with driving forces (which can be both positive and negative, unlike pressures which are negative) (Driver-State-Response) and included environmental impacts (Pressure-State-Impact-Response). This approach has been criticised for not embracing variability in the assessment of "state".	OECD (1993)
Framework for Evaluating Sustainable Land Management	A systematic procedure for developing indicators and thresholds of sustainability to maintain environmental, economic and social opportunities with present and future generations while maintaining and enhancing the quality of the land.	Dumanski et al. (1991)
Well-being Assessment	Uses four indices to measure human and ecosystem wellbeing: a human well-being index, an ecosystem well-being index, a combined ecosystem and human well-being index, and a fourth index quantifying the impact of improvements in human well-being on ecosystem health.	Prescott-Allen (2001)
Thematic Indicator Development **Integrated approach**	Identifies indicators in each of the following sectors or themes: environmental, economic, social and institutional, often subdividing these into policy issues	UNCSD (2001)
Eight level classification of ecosystem health indicators	The ecosystem health indicators that are currently being applied to a range of different problems in different contexts and ecosystems can be are classified on eight levels from the most reductionistic to the most holistic indicators.	Jorgensen et al. (2005)

USEPA Wetland Assessment Levels	Three categories of wetland assessment methods have been recognized by the United States Environmental Protection Agency: Level 1 – Landscape-scale Assessment; Level 2 – Rapid Field Methods; and Level 3 – Intensive Biological and Physio-chemical Measures.	Reiss and Brown (2007)
WET-Health	A framework developed to assess the health of South African wetlands, to identify and evaluate impacts, to improve wetland management, and to monitor management and rehabilitation effectiveness.	Macfarlane et al. (2007)
Bottom-up	**Description**	**Key References**
Soft Systems Analysis	Builds on systems thinking and experiential learning to develop indicators as part of a participatory learning process to enhance sustainability with stakeholders.	Checkland (1981)
Sustainable Livelihoods Analysis **Integrated approach**	Develops indicators of <u>livelihood sustainability</u> that can monitor changes in natural, physical, human, social and financial capital.	Scoones (1998)
Classification Hierarchy Framework	Identifies indicators by incrementally increasing the resolution of the system component being assessed, e.g. element = soil; property = productivity; descriptor = soil fertility; indicator = % organic matter	Bellows (1995)
The Natural Step	Develops indicators to represent four conditions for a sustainable society to identify sustainability problems, visions and strategies	TNS (2004)
Elements of both	***Description***	***Key References***
Framework for participatory indicator development	This approach offers a more holistic process for measuring the process towards sustainable development as it integrates the thinking from the top-down and bottom-up paradigm. Indicators developed by communities are combined and compared with sustainability indicators (developed in comparable environments) from the literature creating an indicator framework that is <u>relevant to the local user</u>.	Reed et al. (2005)*;* Reed and Dougill (2003)
WET-Sustainable Use	Developed to assist in assessing the ecological sustainability of wetland use, focusing on the grazing of wetlands by livestock, cultivation of wetlands and harvesting of wetlands for crafts. This approach requires the perspectives of the land users on how they see their land-use activities affecting the wetland condition.	Kotze (2009)

Top-down indicators

In the past the top-down frameworks characterized by quantitative, technocratic and prescriptive approaches have tended to dominate the monitoring of sustainability (Sayer et al., 2006). The most commonly used of these are the Framework for the Evaluation of Sustainable Land Management (Smyth and Dumanski, 1993) and the Pressure State Response framework (OECD, 1991). These frameworks are more systematic than earlier *ad hoc* approaches but have still been criticized for not being able to capture multiple causality and the numerous interactions within systems (Sayer et al., 2006). In addition, the majority of existing sustainability indicators have been identified, selected, evaluated and applied by researchers at the national or international scales and often carry little meaning for the local land users (Reed and Dougill, 2003).

The orientor approach (Bossel, 2001) is a systems-based approach for deriving comprehensive indicators and is based on new developments in ecological and general systems theory. Reed et al. (2005 p.4) states that the **Orientation Theory "**helps researchers develop a conceptual understanding of relevant systems by identifying a hierarchy of systems, sub-systems and supra-systems and describing the relationship between 'affected' and 'affecting' systems". Bossel (2001) advocates that an assessment of performance of systems such as integrated natural resources management must take into account their complex nature. Performance indicators of such complex systems must reflect the viability of a component, its contributions to other components and to the total system. A system that satisfies most of its orientors (existence, effectiveness, freedom of action, adaptability, security, coexistence and psychological needs; see Box 2.1 for definitions) is more robust and has better performance. This set of environmental orientors was applied by Peng et al. (2007) to evaluate the social sustainability of the "Grain for Green" project in Zhangye, Northwest China (see Box 2.1 for examples of the indicators used).

Reed et al. (2005) state that orientor approach for deriving comprehensive indicator sets provides one of the most holistic frameworks for developing sustainability indicators demonstrating that the focus has moved from ad hoc approaches to more systematic-based procedures with clear goals. It ensures that indicators cover all important aspects of system viability, performance, and sustainability, and recognizes that a system cannot be assessed in isolation from the systems upon which it depends and which in turn depend upon it. Bossel's approach is part of a wider convergence toward integrating participatory and reductionist approaches to measure progress toward sustainable development.

Bossel (2001) introduces the concept of "essential indicators" and notes that defining an appropriate set of indicators for sustainable development is a difficult task. Too few indicators mean that crucially important developments may escape attention, whilst a large number results in costly and time-consuming data acquisition and data analysis. It is therefore essential to define a set of representative indicators that provide a comprehensive description, or as many as are essential, but no more. He poses the question 'But what are the "essential" indicators?" This served as a precaution for the project (see Chapter 5).

BOX 2.1
Examples of the indicators used in the social sustainability assessment of the "Grain For Green" project in Zhangye, China (Peng et al., 2007).

Basic orientors	*Definition*	*Indicative measures*
Existence	Is the system compatible with and able to exist in its environment?	Food stocks
Effectiveness	Is it effective and efficient in its processes and operations?	Probability of participating in the GFG project
Freedom of action	Does it have the freedom and ability to respond to environmental variety?	Financial liquidity
Security	Is it secure, safe, and stable despite a variable and unpredictable environment?	Times under strain vs. relaxed
Adaptability	Can it adapt to new challenges from its changing environment?	
Coexistence	Is it compatible with interacting systems?	Wish to provide better schooling to children
Psychological needs	Is it compatible with the psychological needs relevant to this system?	Woman's proportion of the family income
		Sense of accomplishment

The orientation theory echoes Gunderson and Holling's (2002) **Panarchy Theory** of adaptive cycles. Hierarchies and adaptive cycles comprise the basis of ecosystems and social-ecological systems across both spatial and temporal scales. Together they form a panarchy. The term panarchy was devised to describe evolving hierarchical systems with multiple interrelated elements and it has been applied in a variety of contexts to account for the socio-economic impacts of ecological disturbances (Reed et al., 2005). Panarchy refers to the structure in which natural and combined human-environmental systems are interlinked in continual adaptive cycles of growth, accumulation, restructuring, and renewal. Two features thus distinguish a panarchic representation from traditional hierarchical ones. The first is the importance of adaptive cycle and the second is the multiple connections between phases at one level and phases at another level (Holling, 2001). Panarchy Theory uses three broad categories of indicators, namely wealth, connectivity, and diversity to identify where complex systems exist on an adaptive cycle. For example, Fraser (2003) used this approach to identify social and ecological indicators that help explain why Irish society in 1845 was so vulnerable to the outbreak of a relatively common potato blight. There has, however been limited application of this approach to social systems (Reed et al., 2005).

The **Pressure State Response** (PSR) model was developed by the Organisation for Economic Co-operation and Development (OECD) for analyzing the interactions between humans and the environment at the national, regional and international level (Bowen and Riley, 2003). This framework states that human activities exert "pressures" on the environment, which can induce changes in the "state" of the environment. Society then "responds" through policies or programs intended to mitigate the effects of the changes in the environment.

Indicators are a key tool used to identify and support PSR relationships. As a result a major part of the OECD's work is devoted to developing a Core Set of environmental indicators (OECD, 2001), which is a commonly agreed upon set of indicators for OECD countries, published regularly. It provides a first step in tracking environmental progress, the factors involved in it, and is a major tool for measuring environmental performance (see Box 2.2 for an example). This Core set of indicators is never complete as it evolves over time as new knowledge is gained.

BOX 2.2
An example of the OECD Core Set of Environmental Indicators

ISSUE: FOREST RESOURCES

Pressures	• Intensity of forest resource use (actual harvest/productive capacity)
State	• Area and volume distribution of forests (by biome) (e.g. volume distribution by major tree species group within each biome, share of disturbed/deteriorated forests in total forest area)
Responses	• Forest area management and protection (e.g. % of protected forest area in total forest area; % of harvest area successfully regenerated or afforested)

There are several important points that the OECD work highlights when using indicators. Firstly, a good data set is required to set appropriate performance targets and develop effective indicators. Secondly, different people living in different places have different values, and indicators must take cognisance of these. Lastly, indicators can play an important part in the way in which human influences on the environment operate and it is important to consider that by changing the indicators the system may also change.

It is claimed that the PSR framework provides a means of selecting and organising data/indicators in a way useful for decision-makers and the public. By highlighting the relationships between the environment and economic dimensions of sustainable development, it assists policy-makers to design policies that address problems at the appropriate level. They are in the process of extending the PSR framework to cover the environmental/social interface of sustainable development in order to better track the course towards a sustainable future.

The conceptual limitations of the PSR framework are, however, significant. The framework is narrow in scope as it describes a simplified system (Bowen and Riley, 2003). It suggests a linear relationship in the human-environment interaction and does not consider system complexity and natural variability. In addition, the PSR framework is lacking a reflective view of how degraded environments affect livelihoods, that is, the pressure arrow between the "state" box and the "pressure" box could go in both ways (Segnestam, 2002). The PSR model typically identifies stakeholders only so as to understand the source of human pressures on the environment, for example people living in watersheds (Reed et al., 2005).

The PSR model has been further expanded in three different directions: the first variation replaces the pressure indicator category with a category of driving force indicators (creating a Driver-State-Response framework), the second variation adds a category of impact indicators, transforming it into a Pressure-State-Impact-Response (PSIR) framework, and, finally, the last version includes all five indicator categories creating a DPSIR framework. Driving force indicators are able to encompass social, economic, and institutional aspects. The impact indicators are able to capture changes in physically measurable characteristics of the environment, and are able to focus on existing policies and management practices used (Segnestam, 2002).

In South Africa, both the PSR and DPSIR frameworks have been used extensively by the National Environmental Indicators Programme in the development of state-of-the-environment reports. Here the set of environmental indicators were divided into eight themes designed to address the priority national environmental issues facing South Africa; atmosphere and climate, inland water, biodiversity and natural heritage, land use, environmental management, marine, coastal and estuarine, human well-being, and waste management.

Dumanski and Smyth (1991) **Framework for Evaluating Sustainable Land Management** (FESLM) is a structured, logical pathway of making decisions on whether a system is sustainable in a defined situation over a period of time. The logical pathway approach was selected because it allows for some decision-making without having to wait for final research results to be available. The authors point out that a detailed sustainability analysis is costly and unrealistic, thus applying the full range of FESLM procedures is not always justified at a local level. Although the approach does not anticipate decisions regarding appropriate sustainable practice to be based on a very local scale (individual fields for example) it hopes to inform and guide 'improved' methods in agriculture. The approach focuses on the stability of systems and the need to use sustainability evaluation to maintain stability in agriculture. The process of evaluation seeks to identify points of instability through "thresholds" that can guide action. A "master (reference) version" of a fully developed FESLM is being developed to include details of an evaluation procedure, a comprehensive checklist (databank) that record environmental influences adversely affecting stable[9] land management that include:

- Environmental indicators that reflect influences
- Actions that can be taken to minimise instability in each instance
- Criteria (factors, formulae, models) that relate to environmental change
- Measurable threshold value that determine at what level each influence is a threat to sustainability

The Master Framework is supposed to be independent of scale (i.e. a worldwide scope of applicability is intended). They draw considerably on expert inputs in the evaluation of sustainability and they accommodate inputs form 'elsewhere' with the result that the approach can be seen as adaptive and evolving within particular context. The framework includes a comprehensive checklist of factors, criteria, indicators and thresholds that may be relevant to the monitoring of sustainability across all spatial and temporal scales. This checklist approach resonates with 'five-fingers" method developed by this project (see Chapter 5).Ultimately, the aim is to simplify the approach and make it more adaptable and accessible. The use of computers in processing indicators is alluded to.

The second framework embraced by the FESLM is the Action (or local) Framework which draws on the principles, procedures and structures advocated by the Master Framework. This framework outlines a procedure for evaluating the sustainability of a specific kind of land-use, in a specific location, over a specific period of time. In terms of value, the relationship between sustainability evaluation and the development of Action Frameworks resonates with the Action Project approach of the project based on the appraisal of wetland fields.

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[9] Dumanski and Smyth (1991) refer to aspects of the ecosystem, such as topographic form or geology, that do not change rapidly over time as stable whereas those aspects that change frequently and rapidly, such as the incidence of pests or disease are termed unstable.

Using the framework for evaluating sustainable land management, Lefroy et al. (2000) conducted detailed socio-economic and biophysical surveys of 53 farms in Indonesia, Thailand and Vietnam. The surveys aimed to characterize the land management systems, outline their constraints and potentials, and identify indicators and thresholds of sustainability in line with the five pillars of sustainability in the FESLM: productivity, security, protection, viability, and acceptability (see Box 2.3 for examples of indicators used). These indicators are highly specific and highly simplified, however they make a useful first step towards the development of a more generic system for evaluating Sustainable Land Management at a specific locality.

BOX 2.3
Sustainable land management indicators developed by Lefroy et al. (2000)

Productivity indicators	• mean yield over seven years • plant growth • soil colour • leaf colour
Protection indicators	• topsoil eroded • cropping intensity and extent of protection • cropping pattern
Viability indicators	• net farm income • off-farm income • difference between market and farm price • availability of farm labour • land holding size • availability of farm credit • percentage of farm produce sold in market
Acceptability indicators	• tenurial status • access to extension services • access to primary schools • access to health centre • access to agricultural inputs • subsidy for conservation practices • training in conservation practices • village road links to major roads
Security indicators	• average annual rainfall • residue management • drought frequency income from livestock

Within the **Well-being Assessment** framework, sustainability is based on human well-being and ecosystem well-being. It uses different indexes for human well-being and ecosystem well-being to aggregate impacts (see Box 2.4). Human well-being is defined as the condition in which all members of society are able to determine and meet their needs and have a large range of choices to meet their potential. Ecosystem well-being is defined as the condition in which the ecosystem maintains its diversity and quality and thus its capacity to support people and the rest of life and its potential to adapt to change and provide a wide range of choices and opportunities for the future (Prescott-Allen, 2001). The power of the wellbeing assessment approach lies in its capacity to identify and process a complex mix of human and ecosystem elements. Over the past decade, there has been a growing scientific interest in well-being assessments across a spectrum of scales and sectors (Eckersley, 2008). It is, however, important to note that well-being assessments are fairly contested. Eckersley (2008) argues that while well-being assessments have helped to broaden the focus of social measurement to include an assessment of the impacts of various socio-economic factors on wellbeing, they present an overly positive view of modern western societies and they overestimate the positive effects and underestimate the negative.

BOX 2.4
Dimensions of the human and ecosystem well being indices (Prescott-Allen, 2001)

Human well-being	**Ecosystem well-being**
1. Health and Population	1. Land (Diversity and Quality)
2. Household and National Wealth	2. Water (Inland and Sea)
3. Knowledge and Culture	3. Air (Local Air Quality, Global Atmosphere)
4. Community (Freedom, Governance, Peace and Order)	4. Species & Genes (Wild & Domesticated Diversity)
5. Equity (Household and Gender)	5. Resource Use (Energy, Materials & Resource Sectors)

The **Thematic Indicator** framework is not covered theoretically in the literature though numerous examples from national and international policy documents are given (see Box 2.5 for an example from the European Environment Agency).

BOX 2.5
Examples of the topics and focus of indicators in the European Environmental Agency (http://eea.eu.int)

Theme	**Indicator**
Energy	• Emissions from electricity generation
Transport	• Clean technology and fuels
Agriculture	• Organic farming
Climate Change	• Mean temperature

Jorgensen et al. (2005) present an **eight level classification system** for the identification of ecosystem health indicators that are currently being applied to a range of different problems in different contexts and ecosystems. These indicators are arranged from the most reductionistic to the most holistic indicators. Level 1 covers the presence or absence of a certain species. Level 2 utilizes the ratio between classes of organisms, for example the Nyggard algae index. Level 3 is based on the concentration of specific chemical compounds, such as the total phosphorus concentration which is an indicator of the level of eutrophication of a water body. Level 4 uses the concentration of entire trophic levels as indicators of ecosystem health. Here phytoplankton can be used as an indicator of eutrophication. Process rates, such as primary production or mortality, are used as indicators in Level 5 indicator sets. Level 6 covers the composite indicators, such as biomass or respiration, included in E.P Odum's attributes and various indices. Level 7 utilises holistic indicators such as biodiversity, resistance, resilience, connectivity of the habitats, and the transfer of energy. Lastly, Level 8 indicators are thermodynamic variables which are termed super-holistic indicators. (e.g. energy, entropy production, power and mass). It is important to note that indicators in level 1 and 2, for instance, would give the same indication as indicators from level 6 and 7.

Three **categories of wetland assessment** methods have been recognized by the US Environmental Protection Agency, which can be applied to asses the ecological condition of wetlands. The criteria for these three different procedures are determined based on the intensity and scale of the wetland assessment as well as the management objectives. These are described as:

- Level 1 – Landscape-scale Assessment; utilizes GIS and remote sensing to describe the condition of a wetland
- Level 2 – Rapid Field Methods; e.g. Wetland Rapid Assessment Procedure (WRAP), incorporating relatively simple and efficient procedures (see Box 2.6 for WRAP scoring criteria).
- Level 3 – Intensive Biological and Physio-chemical Measures (Reiss and Brown, 2007); objective is to establish an integrated understanding of the current wetland ecosystem condition rather than simply the cause and effect relationship.

Cairns et al. (1993) state, however, that this approach has missed important steps that are required before indicators are accepted or used. They advocate a mix of approaches to be applied at different scales. This is as indicators are dependent on system purpose and context and therefore need to be in conjunction with the end users of the indicator as part of an ongoing learning process.

BOX 2.6
Summary of scoring criteria for the Wetland rapid Assessment Procedure, Level 2 Assessment (Reiss and Brown, 2007)

Score	Wildlife utilization	Wetland shrub canopy	Wetland ground cover	Adjacent upland/wetland buffer	Field indicators of wetland hydrology
0.0	None	None	None	No adjacent buffer	Hydrologic regime severely altered
1.0	Minimal	Minimal	Minimal	Buffer averages 30 ft with desirable plant species	Hydrologic regime inadequate to maintain viable wetland system
2.0	Moderate	Moderate	Moderate	Buffer averages 30-300 ft with predominantly desirable plant species	Hydrologic regime adequate to maintain viable wetland system
3.0	Strong	Strong	Strong	Buffer is greater than 300ft with predominantly desirable plant species	Hydrologic regime adequate to maintain viable wetland system

A local example is that of WET-Health (Macfarlane et al., 2007), which is an approach developed to assess the health of South African wetlands. It provides guidelines for scoring the health of a wetland in relation to its natural state, with three modules: hydrology, geomorphology and vegetation (Figure 2.1). It helps to identify the wetlands trajectory of change and to diagnose the causes of degradation. It focuses on wetland process rather detailed biotic responses. Expert knowledge is incorporated in "rules of thumb" to assist in the evaluation of the health of the wetland. This knowledge is developed into a scoring system to inform non-expert land-users. The general monitoring approach can be tailored for another country or different ecosystem provided that indicators of the key components of ecosystem health are identified to guide the evaluation process.

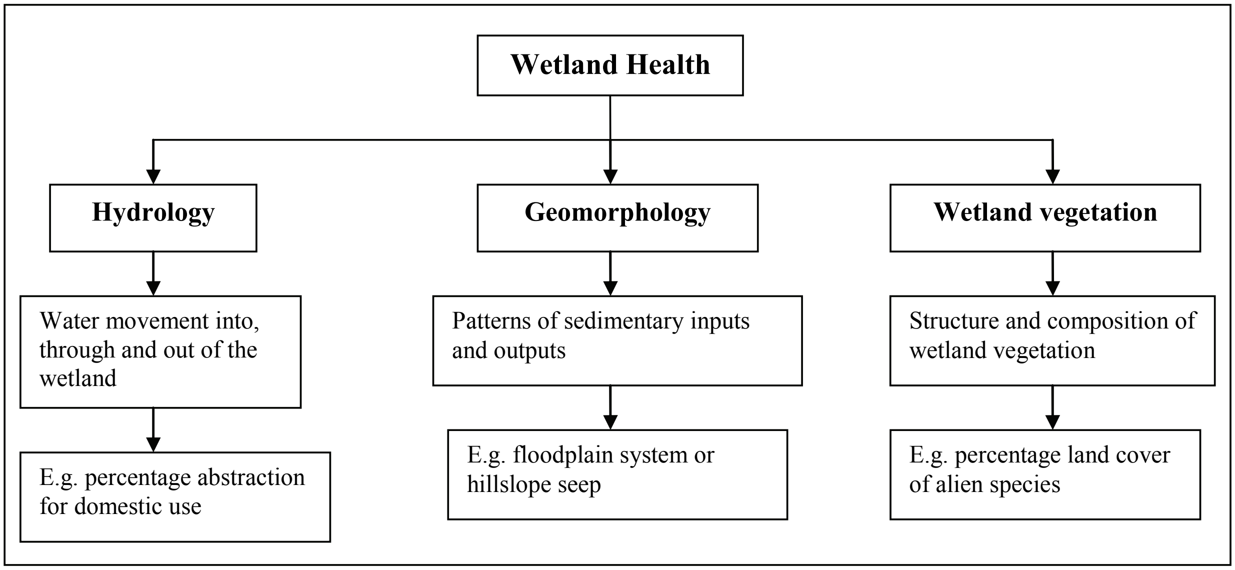


FIGURE 2.1: WET-Health framework with examples of indicators used in the three different assessment categories; hydrology, geomorphology, wetland vegetation (after Macfarlane et al., 2007)

Bottom-up indicators

In recent years, more qualitative and participatory approaches have been advocated and many authors are calling for a greater integration of indicators from a range of disciplines. Consequently, it is now widely agreed that local communities need to participate in all stages of project planning and implementation, including the selection, collection and monitoring of indicators. The bottom-up paradigm uses a variety of participatory tools to define and describe the system that is being assessed. Reed et al., (2005) state that participation should be viewed as a persons' fundamental right to be involved in processes that affect their lives and well-being.

One of the most widely used methods is the **Soft Systems Analysis**, which begins by expressing the problem situation with stakeholders through a participatory process. This approach attempts to understand the scale, scope and nature of problems in the context of the community's organizational structure and the processes and transformations that occur within it. The methodology moves from finding out about the situation to taking action within it, and does so not by relying on expert experience (Checkland, 1984). The recent work on soft systems methodology offers a new view the systems approach as it develops a systemic process of enquiry whose aim is learning rather than optimization. The methods used in Soft Systems Analysis have considerable overlap with participatory tools, such as transect walks, oral histories and participatory mapping, used to describe livelihood systems. This approach has been used to provide a longer-term view of how environmental changes affect the vulnerability context of a community (Reed et al., 2005).

The IDS **sustainable rural livelihoods framework** (Scoones, 1992) is accepted as a useful approach to guide research into the multiple dimensions of rural livelihoods. Scoones (1992) used the universal definition of sustainable livelihoods (Chambers and Conway, 1992) to delineate livelihood and sustainability elements, from which indicators were developed. The sustainable rural livelihoods framework demonstrates how in different contexts sustainable livelihoods are achieved through access to a range of livelihood resources (natural, economic, human and social capital) which are combined in the pursuit of different livelihood strategies (agricultural intensification or extensification, livelihood diversification or migration). Scoones (1998) suggests that in order to analyse the sustainability of livelihoods one must answer the following key questions:

- Given a particular context, what combination of livelihoods resources result in what combination of livelihood strategies, with what outcome?; and
- What are the institutional processes that influence strategy utilisation to achieve outcomes?

Sustainable Livelihoods analysis is a conceptual tool that can help researchers to interact with the community members to identify problems, strengths and opportunities around which goals and strategies can be developed. Using this approach, community members identify and describe the financial, natural, human, physical, institutional and social capital assets they have access to, and discuss how these assets have been used to overcome past problems (Reed et al., 2005). Reed and Dougill (2003) state, however, that the use of the sustainable livelihoods approach to assess environmental sustainability in a clear, quantifiable manner can be questioned. This framework will be discussed further under the livelihoods component of the literature review.

This approach was used by Fraser (2002) when developing the goals of a community-based urban greening programme in Bangkok, Thailand. Here communities were encouraged to elect a working group that then mapped the assets present in the community; buildings, trees, utilities and canals. This map formed the basis of a series of urban green plans that the communities executed with help from local municipalities (Reed et al., 2005). Box 2.7 outlines the progress indicators that were developed during this project.

BOX 2.7
Summary of process indicators developed by Fraser (2002) and the methods used to measure these indicators

Indicator	Measurement
• Establish green plan	Area planted and number of species present
• Community capacity building	Number of people participating
• Poverty reduction	Income generated by community gardens
• Linking the communities with government	Resources provided by Non-Governmental Organizations
• Status of women	Number of women participating in events
• Develop model for other communities to follow	Creation and distribution of educational material describing urban greening in a step-by-step fashion

The TNS Framework is a methodology for successful organizational planning, developed by **The Natural Step**. It is founded on the premise that anthropogenic activities are unequivocally affecting the earth's system at the global scale and that action is urgently required to mitigate the long-term effects. By incorporating a perspective of a sustainable future the TNS framework enables organisations to create optimal strategies for dealing with present-day environmental change by facilitating an integration of business development with sustainability. The TNS focus is on organizational planning and operation. Key aspects that apply here are on an orientation that recognizes the importance of complexity, systems thinking, the role of society, the attention to large/higher scale issues of context (sustainable society). Attention is paid to basic needs in society and how these affect the prospects of sustainable society. The Authors maintain that "the TNS Framework has helped many organizations around the world proactively embrace sustainability as a strategic opportunity rather than an unknown liability" (The Natural Step 2000, 1).

The TNS framework is based upon a method of looking at the current situation from a future perspective, termed backcasting. This results in investments and activities that not only move the organization toward sustainability, but also maximize short-term profitability and long-term flexibility. The crucial flaw of this approach is that whatever is considered a priority at present comes to define the future.

To enable a sustainable future scenario to be outlined in detail a set of basic principles that must apply in any sustainable society are outlined by The Natural Step. These principles termed 'four system conditions' focus on the causes of environmental and social problems rather than the effects of them. The four system conditions that the TNS has developed for a sustainable society (only last two are of immediate applicability to our project) are as follows:

- concentrations of substances extracted from the Earth's crust,
- concentrations of substances produced by society,
- degradation by physical means, and
- in that society people are not subject to conditions that systematically undermine their capacity to meet their needs.

The Natural Step Framework Guidebook (2000) provides a series of sustainability objectives. In terms of process, and using a different orientation they arrive at a 'more holisitc' systems approach to the assessment, monitoring and evaluation of sustainability. The value lies in the deliberation around the social issues associated with establishing sustainable societies. It is useful as a heuristic to compare and elaborate on what we are saying about sustainable societies/communities. Also, there is reference to complexity and the need to consider the collective. It will be useful for deliberation around reflexivity, vision, recursivity, self-organization in complex learning environments.

In 2007, Brouwer undertook a survey for an M.Sc. thesis that focuses on the social dimension of sustainable development for wetlands. He aimed to present a set of **social sustainability indicators** (Table 2.3) to enable, in combination with economic and environmental indicators, the assessment of the development of wetland rehabilitation projects in South Africa. Accordingly, the main research question of this study is subsequently formulated as: *What do stakeholders consider to be appropriate social sustainability indicators for assessing the development of wetland rehabilitation projects in South Africa?*

The stated aim was to streamline wetland rehabilitation programs and to make the process more cost effective. He also attempted to expand the traditional state of the wetland analysis to include stakeholder participation. Indicators are presented in the form of a checklist with a specific section on stakeholder participation is presented. These were gleaned through a series of interviews but were never tested. The indicators highlight particular areas but they were more about evaluating a rehabilitation process and less about learning and action. Given their course nature, it is doubtful that the indicators will contribute to communal efforts to work towards more sustainable livelihoods. The section of participation is not particularly valuable as the indicators do not consider the VALUE of the engagement and hence are somewhat crude in their approach. For example, 'numbers of people trained by a project' says little about how effective or sustainable this was.

Elements of both top-down and bottom-up approaches

By integrating approaches from the top-down and bottom-up paradigms (from a participatory paradigm to a combination of the qualitative and the quantitative methods), Reed et al. (2005) state that the progress towards sustainable development can be holistically measured. This approach emphasizes the importance of participatory approaches setting the context for sustainability assessment at local scales, but stresses the role of expert-led methods in indicator evaluation and dissemination (technical knowledge). Local involvement can also ensure that indicators are dynamic, evolving over time as goals are met or as circumstances change (Reed et al., 2001).

Important reflections on indicator development and use have been made by Reed et al. (2005). Firstly, there is a danger that indicators developed primarily through bottom-up participatory techniques alone may not have the capacity to accurately or reliably monitor sustainability as certain beliefs or values that may lead to unsustainable practices can become popularized. Secondly, communities are unlikely to invest in collecting data on sustainability indicators unless monitoring provides immediate and clear benefits that they can see and feel. Thirdly, by empirically testing indicators developed through participatory research, it is possible to retain community ownership of indicators, whilst improving accuracy, reliability and sensitivity. It may also be possible to develop quantitative thresholds through reductionist research that can improve the usefulness of sustainability indicators. This is particularly relevant under conditions of rapid environmental change where local knowledge may not be able to guide community adaptability.

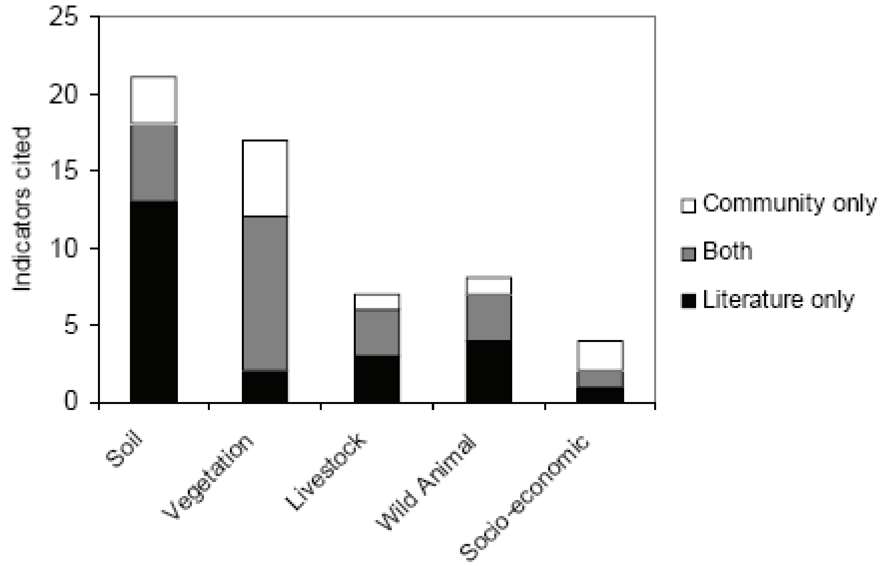
Research findings from around the world (Fraser, 2003), have demonstrated how integrated approaches can be used to develop indicators that are both scientifically rigorous and objective while remaining easy to collect and interpret for communities (Reed et al., 2005). Of particular value here, are monitoring exercises that are linked more explicitly to grass-roots action to improve the sustainability of land use. These approaches are characterized by ongoing learning process for both the communities and researchers. When it comes to conceptualising an approach and a suite of indicators, it is likely that in a participatory framework, the value of certain indicators for each purpose may vary considerably amongst the groups involved, such that parallel (qualitative and quantitative) indicators may be required. This was noted by Sayer et al. (2006) involved in various landscape conservation initiatives in Africa. Here local communities and the scientific/NGO sector differed in their values of effects on natural capital (e.g. deforestation, soil erosion), and consequently indicator sets varied. This was attributed to the fact that communities generally valued a natural asset when it directly affected them, for instance on their small holdings (landscape unit), whilst the scientific/NGO role-players valued landscape capital more broadly. As a result the authors while strongly advocating the participatory approach emphasised the need to combine participatory inputs with expert judgement, through which indicators would be assessed in the field to determine their robustness.

Reed and Dougill (2003) tested this integrated approach was tested in the Kalahari, Botswana where unsustainable land use practices are leading to bush encroachment, which is perceived as a major livelihood constraint by local communities. Results demonstrate that participatory approaches are capable of eliciting a broad range of indicators encompassing both socio-economic and biophysical parameters. There was considerable overlap between scientific and local knowledge (illustrated in Figure 2.2). The majority of community based indicators (see Figure 2.2 for examples) have an empirical basis. Communities were thus able to provide more meaningful interpretations of existing indicators, with non-technical means of measuring complex variables (Reed and Dougill, 2003). Participatory indicator development, therefore, has the potential to generate reliable, accurate indicators that can be used easily, cheaply and rapidly by land uses. Reed and Dougill (2003) state that, a trade-off between participation and scientific rigour is by no means inevitable. There are, however, a number of drawbacks to the approach advocated here, in particular comparability of results across agro-ecological zones and between countries.

In the case of the Okoba et al. (2007), who worked with highland farmers in Kenya, a suite of visual erosion indicators were presented to the farmers through transect walks, who through consensus chose the appropriate indicator sets and weighting in order to monitor the frequency and severity of erosion problems in their vicinity. These indicators included: gullies; broken soil and water conservation measures; stoniness; red soil colour; rock exposure; rills; root exposure; sedimentation; sheetwash; splash pedestals; and loose soil. These weighted indicator values where then incorporated into a map which illustrated to farmers the a priori nature of their practices for downstream farmers. Meanwhile a financial tool was also incorporated into this monitoring technique which allowed farmers to become aware of the economic implications of their own actions as well as the potential benefits of employing soil and water conservation techniques in their own land management.

A similar but more technical approach was taken by Everson et al. (2007), in which again a mapping approach was used as the initial construct for setting up a land monitoring group. However, the approach for the monitoring took the form of simplified scientific monitoring techniques, in which the monitoring group were trained to implement, maintain the equipment and then analyse the resulting data, in order to assess the success or failure of attempting to rehabilitate degraded grasslands in a small catchment of the Maloti-Drakensberg mountains in South Africa. This approach although not scientifically rigorous did allow for the quantification of the rehabilitation response and a less subjective analysis than that of the former study.

Although there are clear benefits to both bottom-up and top-down approaches to sustainability monitoring, integration of these approaches will produce more accurate and relevant results. The balance between top-down and bottom-up, however, will reside at a location influenced by many factors, including who funds the project, the availability of resources, the time scale for outputs to be achieved, the desires, wishes and commitment of those involved.



Sustainability indicator	Local alternative
Soil	
Increased organic matter	Soil becomes dirtier
Vegetation	
Increase in specific palatable species	Increased abundance of medicinal and edible plants
Livestock	
Increased availability of livestock products	Particularly milk
Wild Animal	
Increased species richness and abundance of small mammals	Increased abundance of burrowing mammals
Socio-economic	Increased herd size and calving rate
Increased livestock production	

FIGURE 2.2: Graph of sustainability indicators in five categories (soil, vegetation, livestock, wild animal, and socio-economic) cited by the Kalahari communities, peer-reviewed literature and both. The table provides some examples of the indicators in each of the categories shown in the graph (after Reed and Dougill, 2003)

Both **Wet-Health** (Macfarlane et al., 2007 **and WET-SustainableUse** (Kotze, 2009) are locally-developed integrated frameworks and assessment approaches. These are discussed in more detail in the section dealing specifically with wetland integrity (Section 2.3).

2.1.4. Strategic adaptive management (SAM) and thresholds of potential concern (TPCs)

The purpose of this section is to build on the work of Reed et al. (2005) by presenting an adaptive learning process that integrates both bottom-up and top-down approaches.

A useful framework currently used by SANParks is that of Strategic Adaptive Management (SAM) where park stewardship is based on learning-by-doing. Adaptive management integrates research, planning, management and monitoring in repeated cycles of learning that seek to improve on, and achieve, objectives (Pollard and Du Toit, 2007). It is built on the assumption that socio-ecological systems are complex and that a complete understanding thereof is never completely attainable. This represents a fundamental shift from the previous 'command and control' management paradigm which was strongly interventionist. This viewed the National Parks as a stable, linear system where natural variability was attempted to be reduced. Accompanied with this was a shift away from a 'top down' approach to a more inclusive management structure where the involvement of key stakeholders is key at all levels.

Recent recognition of the lowveld savanna, including the Kruger National Park, as a complex adaptive system necessitated a new approach to management that explicitly recognizes heterogeneity and variability as key characteristics. In response to questions regarding how to structure a management system around these characteristics SAM was adopted and developed in South Africa in 1996. A key aim was to move environmental management away from stable system thinking and from one that was reactive, conflict-driven to one that was census-driven and learning-orientated (Biggs and Rogers, 2003; Pollard and Du Toit, 2007). The Kruger National Park has adopted SAM based on a clear statement of vision and mission developed through extensive stakeholder involvement. Flowing from this is a hierarchy of objectives, which, through increasing levels of detail, is ultimately linked to clear, auditable endpoints called Thresholds of Potential Concern (TPC). These TPCs are upper and lower limits of acceptable change in selected environmental or biodiversity indicators. The specified upper and lower ranges are essentially set as hypotheses of spatial and temporal limits of acceptable ecosystem change that are mutable as new learning is brought to bear. The TPCs are thus based on the best available understanding and can be subsequently refined as knowledge of the system improves. TPCs are meant to provide an early warning that some ecological specification is in danger of being exceeded through a "red flag" concept (Pollard and Du Toit, 2007). Linked to the TPCs are clear lines of roles and responsibility.

In order for a TPC to be set, an existing understanding of the dynamics of the system is required to determine the agents of change, appropriate indicators of change in these agents, and the limits of acceptable change in the indicators. For example, in rivers of the Kruger National Park reduced flows, reduced floods and increased sediment inputs are a major concern. This is thought to be causing a reduction in the availability of bedrock habitat for woody plants due to the increased sediment storage (Pollard and Du Toit, 2007). Scientific research allows the natural limits of change in selected indicators to be identified and measured; based on the best current understanding of the natural dynamics of the river (Figure 2.3).

Rationale: Increased sediment storage causes alluviation, loss of habitat diversity from bedrock influence and reduction in diversity of woody species regeneration niches.		
Indicators	**Measurement**	**TPC**
Population structure of woody species which regenerate on the bedrock template	**Size class frequency distribution every 3 yrs and events >1:25 yrs in selected representative reaches/channel types**	**E.G. *Breonadia salicina:* loss of negative J population structure in pool rapid reaches/channel types**

FIGURE 2.3: An example of a TPC for flow and sediment as agents of change in riparian systems

A monitoring programme is required as part of SAM framework in order to measure the indicators of change as well as a reporting feedback system to evaluate the effectiveness of management options and appropriateness of the TPCs set (Pollard and Du Toit, 2007). The development of TPCs through a hierarchical process offers a useful approach for developing indicators for this project. This involves working from:

- a goal/vision, to
- a management objective, to
- components of concern/ focus, to
- a description of a desired state for that component, to
- indicators for that component, to
- a rationale for that component, to
- a TPC.

Overall lessons are embodied in a number of fundamental principles (Breen et al., 2000; Biggs and Rogers, 2003), which are summarized below (modified from Pollard and Du Toit, 2007).

BOX 2.8
The use of TPCs

- Management should be directed towards **achieving a desired state**, together with a vision and mission, objectives and sub-objectives.
- Measurable endpoints or TPCs are the practical output of the desired state. They define a **desired 'envelope'**.
- In semi-arid savannas this desired state is **not a stable state.** It is their variability which confers resilience.
- Thus it is necessary to **monitor** conditions and to revisit management objectives.
- The **collaborative role in developing TPCs** cannot be underestimated in terms of developing commitment and buy-in.
- **TPCs are hypotheses** that can be tested and revised.
- **Knowledge management** is a challenge that needs to be addressed. The SAM approach is likely to generate a wealth of **field data that needs to be recorded, captured and made accessible**.
- This also raises the need for **shared learning**.
- The question of "**how many TPCs**?" is an important one given the nature of constraints that might be experienced at the implementation level.
- The **risk of a 'false alarm'** is an important consideration.
- The SAM system within which management endeavours to stay is seen as divergent from traditional target setting associated with management planning by conservation agencies.

2.2. Indicators of Wise and Effective Governance

2.2.1. Definitions of governance

Both the literature and AWARD's experience show that definitions of terms and concepts are important in order to grasp what that governance is, and what it is concerned with. However, the readings on governance often avoid giving a definition of governance, and where the term is defined it tends to be dense and abstract. Moreover, the definitions of governance depend upon the context in which it is being used: e.g. nation states, financial markets, transboundary resources, property, or social relations. The literature on governance indicators focuses largely at the level of the nation state (Besancon, 2003; Landman and Häusermann, 2003; www.wikipedia.org). In this context the term used is "good governance", and often "democracy and good governance". This has World Bank origins, and refers to national governments and their economic performance – which is in turn linked to concepts like: transparency, accountability, equity, sustainability, economic and social development, democratization and human rights. Ultimately this literature did not prove useful when working on governance of natural resources, and other literature such as that on livelihoods and co-management proved more fruitful.

Pollard and Cousins (2008), looking specifically at community-based governance of water resources and wetlands in Southern Africa, highlighted the dearth of documentation in this regard. They also noted that the terms management and governance are sometimes used interchangeably, and that governance is also sometimes confused with government. Governance is also often thought of as the same as government – and indeed governments are engaged with governance – but they are only one of the institutions and actors involved. Governance is often taken to mean management, but we regard management as only one aspect of governance. Given the misunderstandings and the fact that these terms are often conflated in less than useful ways, they provided the following definitions:

- Governance is a socio-political process to manage affairs; it thus describes the relationships between people and the rules and norms that are set up to guide these interactions. It may include collaboration.
- Management refers to the implementation of actions aimed at achieving a particular agenda. Management is not the same as governance although the same body could be involved.
- Government is a body that has the power to make, and the authority to enforce rules and laws within various groups (civil, religious, academic).

Staying with definitions, Peters (2000) describes governance as including management functions and going beyond them. She notes that governance is not located at one particular level, but will often reside at a number of interacting levels, and that it includes idea of power and of authority which management, with its focus on practical functioning, does not. In contrast, Neba (2009) asserts that forest management is complex "in due part to its governance aspects", which he then describes as "the way actors organize access to resources and benefits and ensure positive outcomes in a cooperative and iterative manner". Stoker (2002) offers a sociological view to understand the changing processes of governing in the context of decentralization. This framework recognises the interdependence of public, private and voluntary sectors in developing countries. He describes governance as the interaction of multiple (self-governing) actors, and processes, and as it being about exercising power to manage affairs, or creating conditions for ordered rule and collective action.

Ultimately, the literature revealed no single suitable definition of governance pertaining to natural resources and thus this was undertaken as part of the project (see Chapter 4).

2.2.2. Key concepts related to indicators for wise and effective governance

Despite the lack of literature on indicators for wise governance of natural resources, we drew on work regarding indicators of co-management, institutions and social capital, all of which are aspects of wise and effective governance. Also, work on indicators in other fields proved useful – specifically on water and on forest management, and on indicators of tenure security in land.

The Sustainable Livelihoods Framework (SLF) emphasises the study of ***institutions and organisations*** as important structures and processes that can create restrictions and opportunities to sustainable livelihoods (Scoones, 1998). This takes us into the question of how "institutions" are defined. Pollard and Cousins (2007), drawing on various definitions, proposed a description of institutions as: *The sets of rules actually used by people to organize repetitive activities (e.g. marriage). They are socially constructed. They can include both statutory and local instruments (the law, courts) and organisations (catchment councils; chieftaincies). Institutions regulate the way an individual, or a group, interacts with another or a resource*. This takes the reader into the arena governance is concerned with, and points to the depth, breadth and complexity of these aspects. A key issue that emerges from the literature is that ***power dynamics*** are intrinsic to governance (e.g. Scoones, 1998). Peters (2000) points out that power and authority in institutions of governance are not secured and static, but rather are contested – a dynamic political dimension that is important to recognise. In addition to this ***values or beliefs*** add another dimension influencing the meaning that people bring to principles, rules or the basis for claims and negotiation/ These are dependent upon their social, cultural and class position.

Pollard and Cousins (2007) suggests that the term ***legitimacy***, which is tightly linked to governance, places power at centre stage, recognizing that it can be based in both control of material resources, and in the ability to shape legitimacy through social norms and interactions. Indeed, rarely is a resource subjected to one institution, and ***legal pluralism*** is then an almost ubiquitous characteristic of natural resource governance systems. Lying at the heart of legal pluralism is the important recognition that common property regimes are fundamentally different to those built on western notions of private property ownership, bringing us back to Peters (2000) emphasis on the importance of meaning.

Peters argues for the importance of conceptualising governance with appropriate ***complexity*** – pointing out that conceptualisation affects how issues are seen, and are acted upon. In a similar vein, Bebbington (1999) places emphasis on social capital and on its complexity and importance in livelihoods. Peters (2000) stresses the importance of not confusing stated norms or principles (what people say they <u>ought to do</u>), with statements about practice (what people say they <u>do</u>), with actual practice and behaviour (what people are <u>seen to do</u>). This was found to be important in understanding land management in Craigieburn (Cousins et al., 2007). Von Bendan Beckman (cited in Cousins et al., 2007) asserts that it is not that there is a gap between these layers of a property system that is important; rather it is their mutual interdependence, without prioritising one layer over the other, that should be analysed. Pollard et al. (2008b) support the relevance of thinking of layers and levels, highlighting the value of working at the local scale (e.g. livelihoods, ecosystem functioning, services and governance) and beyond (multiple statutory policies related to natural resources governance). Moreover they point out that understanding the re-enforcing loops in the system is the main way to determine the direction of a trajectory. They also argue that complexity calls for ***adaptive management*** (see Chapter 1). Diaw (2009) suggests that complexity theory offers explanations of resilience and change in systems, and points to the similarities of system dynamics of both social and ecological systems. However he also argues that the human capacity of consciousness and the ability to "look forward" give social systems the possibilities to make wise and socially progressive adaptive choices, to be flexible and to make institutional realignments while retaining core attributes of a social order. This underlies the essence of adaptive management.

A further key issue is that of ***rights*** (as part of social capital) – and the processes of assertion and decision-making around these – which comprise the critical content of what governance deals with. Murphree (1991 cited in Pollard et al., 2007) identifies the importance of sanctioned user-rights to natural resources (the right to decide, to determine the extent and mode of use and to benefit from exploitation). Bebbington (1999) asserts that social capital is more difficult to understand and define than other assets, but also that it is critical to impacting on sustainable livelihoods. He then describes the key processes that social capital enables people, in relation to other assets, to (a) claim and access, (b) defend, (c) transform and, (d) challenge the basis of asset distribution and transformation. Thus people can access and defend resources, and transform them into income, and access institutions and organisations in the spheres of state, civil society and the market. Drawing from various authors Pollard and Cousins (2007) set out the following categories of rights (as a guide for developing indicators):

1. Use rights of access and withdrawal;
2. Decision-making rights to regulate and control (water) use and users, including the rights to exclude others, manage the resource, or alienate it by transferring it to others, and to appropriate.
3. Usufruct rights or the right to earn an income from a resource.

2.2.3. Frameworks for deriving indicators

The following literature provides useful insights both on the possible content of indicators, as well as on conceptual and practical methodologies for developing indicators. Much of what is within the concepts of the "institutional" and "social capital" aspects of the SLF (Scoones, 1998; Bebbington, 1999) can be brought into governance indicators (although not all issues of social capital are covered by governance).

Narayan-Parker (1989) sets out a framework of indicators for evaluating community management specifically to elucidate community participation and women's involvement in water projects. The hierarchical framework set out the goal (*achieving sustainable and effective utilisation of systems through methods that are replicable*), and thereafter three broad indicators were identified to weigh achievements towards this goal (*effective utilisation, sustainability, replicability*). Each is fully described and from that categories of indicators are developed. They go on to develop tools and processes for capturing the data working on the basis of this framework.

Cousins and Hornby (2002) describe a framework for assessing common property institutions and their performance. A set of indicators of tenure security (the focus of their work) were then derived from the content of this framework. According to their framework, tenure (land and natural resource) arrangements comprise a set of connected elements and processes:

- Rights and duties to property, and benefits flowing from property
- Procedures, rules and systems for managing these property rights and duties
- Authority in relation to these rights, duties and procedures
- Social and institutional practices governing rights, duties, processes and procedures
- Also fairness, and constitutional principles of non-discrimination, can only be ensured if people subject to authority can appeal decisions that affect them i.e. if they have effective recourse.

Other writers focus on the process of developing indicators, and offer approaches and reflections on this. Reed and Dougill (2003) note that eliciting sustainability indicators can be problematic. Their approach was to focus on rangelands and on land degradation, asking pastoralists to identify signs of detrimental change in the condition of their rangeland. Sustainability indicators were then developed as the antithesis to degradation indicators. Tiani et al. (2009) describe the concepts and processes of developing criteria and indicators (C&I) to evaluate the sustainable management of co-management of forests. They emphasise the need to simplify criteria and indicators for use at local level and also by stakeholders at the meso-level. The hierarchical methodology involved visioning with people, developing objectives, and then criteria and indicators. They note that some indicators can be considered to be principles because they express norms or higher objectives. These can be valuable to aid decision-making, social communication and claims negotiation, but can also used by the majority to legitimate domination.

Plummer and Armitage (2007) note that adaptive co-management is a relatively new concept with little evaluative experience as yet. Their framework (drawing on the SLF) describes both outcome and process-oriented parameters for evaluation (see Section 2.1). Their outcome parameters focus on both enhanced livelihoods and ecological sustainability, for which they list first-order parameters of concern, both tangible (e.g. resource management plans) and intangible (e.g. creative ideas for solving problems). Second-order parameters are sought outside the project boundaries, at other scales (e.g. new cooperative activities beyond the specific project issue), whilst third-order parameters are evident at a subsequent time (e.g. new institutions codified and/or enshrined in law).

The framework Neba (2009) reports on is referred to as a tool for adaptive collaborative management and local governance. It is a hierarchical model of the determinants of forest governance performance, which reflect various stakeholders' visions. Here too the SLF provides the scaffolding, with lengthy lists of indicators under four of the five capitals (social, human, financial and physical). These are suggested as a set of issues of concern for management (i.e. local governance) that need attention in collaborative planning, and which can be used as a reference when seeking to build agreements in multi-stakeholder contexts and as the basis for impact evaluation.

2.2.4. The content of indicators for governance

Whilst frameworks are described, the literature does not provide sets of 'ready-made' indicators of governance. However noting the key content the authors identified above, the following provide some content suggestions for indicators for governance.

Cousin et al. (2007) worked on developing principles from which people can derive practice. Local people found it easier to talk about governance when they spoke of governance as being to do with *rights, responsibilities, authority and benefits* (see Chapter 4). Access is the most basic right (see earlier), and can be inherently inequitable. For example, access to different kinds of resources can be gendered and can change over time.

The indicators of tenure security were re-framed by Cousin et al. (2007) as aspects (or meta-level indicators) of a viable, effective and wise governance system for natural resources. These include (i) clarity[10] on who holds rights, where, when, how and on what basis; (ii) clarity on where authority resides;

[10] By clarity what is meant is that most people know, not that these issues are legally clear or necessarily formally documented and static

(iii) known and used processes for application, transfer, adjudication, evidence and land use regulation; (iv) accessible, known places to go for recourse, and people use these; (v) processes do not discriminate unfairly (women, "common" people) and finally (vi) there are no major contradictions between law and practice.

Important issues and processes for land management around which indicators can also be developed include:

- allocation and exclusion;
- evidence and recording;
- adjudication;
- land use regulation (making, monitoring, enforcing principles & rules);
- distribution of benefits, and
- an authority that is known, legitimate, accessible, exercised, and that is not competing or mutually undermining.

Plummer and Armitage (2007) offer lists of characteristic of adaptive co-management and "process parameters" for evaluation which are essentially indicators. The characteristics are (a) collaboration – comprising pluralism and linkages, communication and negotiation, and transactive decision-making, and (b) social learning. They give examples of parameters on each:

- Pluralism and linkages: multiple stakeholders; diversity of interests represented; multiple perspectives on problem domain; connections across scales
- Communication: shared understanding develops; dialogue builds appreciation; perspectives modified
- Transactive decision-making: diverse inputs present; multiple types of information accepted
- Social learning: shared action undertaken; modifications made from reflection; response to errors (single loop learning), responses to values and policies (double-loop learning), active questioning of norms (triple loop learning).

2.2.5. Conclusion

The literature emphasises the complexity and the layered nature of governance. Governance in the context of this report deals with the rights to access natural resources and the dynamics of power and authority that surround this, posing challenges in the development of indicators. It is notable that the work on adaptive, collaborative management is an important aspect of wise and effective governance for natural resources – both with common roots in complexity thinking. There is a strong argument that detailed indicator development on governance must be done with stakeholders for this activity is itself part of the process of engaging in governance so as to achieve objectives of sustainability and equity. In naming a goal clearly, values should be made explicit, for these inform what is then measured. However to inform research and intervention practitioners/ researchers need to have developed their own clarity on governance and what wise governance entails, as the starting point for both analysis and for action.

Working from complexity to a requisite simplicity (Holling, 2001) is what indicator development demands. The various frameworks all offer either processes or actual indicators. The emphasis on local meaning is also a warning on developing a long comprehensive list of indicators against which data are collected. An appropriate mix is needed – of a considered framework, with concepts that have appropriate levels of complexity and simplicity for use with participants.

2.3. Indicator Frameworks for Assessing Wetland-Health and Sustainable Practices

An overview of the concept of wetland health was given in Chapter 1, where it was noted that 'wetland health' (or ecosystem health) is a metaphor drawn from the medical field that emerged to describe degradation or a loss of integrity. The important point is that it is not a single state (i.e. 'healthy' or 'unhealthy'), but rather is a deviation from the expected state which, at some point (and this can vary according to the objectives and assessment) is deemed unacceptable according to various criteria. Appreciably deriving indicators for an assessment of wetland health in this somewhat varied context is challenging but necessary. Brooks et al. (2007) point out that given limited resources for such assessments, a suite of ecological and socio-economic indicators, if properly selected, evaluated and synthesized, could help document trends, prioritize issues and target management activities.

Wardrop et al. (2007) maintain that if indicators of ecosystem health are to be integrated into environmental decision-making, a comprehensive framework for indicator selection and use is necessary. Any indicator or framework that can rapidly classify wetlands into discrete classes, such as optimal, sub-optimal, or marginal categories can prove to be a powerful assessment tool (Brooks et al., 2007). This remains a challenge however as data and information are required from large number of indicators (Ling and Jacobs, 2003). It is not possible to find one indicator or even a few indicators that can be used generally to assess the health of a wetland. In the work reported herein, for example, farmers use plant production – of both crops and indigenous vegetation – as a proxy for wetland health which, if true, reduces the number of indicators that need to be monitored. Given the definition of wetland health[11] in Chapter 1, the assumption is that if plant production is maintained then the wetland can be regarded as healthy; that is, it continues to deliver this key provisioning service and the underlying supporting services are in place. Primary production however is affected by numerous factors including crop diseases, climate, hydrology, nutrients (fertilizer), light, disturbances (grazing), and competition from plants other than those of interest. The exclusion of these factors from an assessment of primary production could misclassify the wetland concerned as either healthy or unhealthy (Kotze, 2009). An additional issue is that some aspects of wetland health may change but are not reflected in the production of the wetland. The loss of a certain keystone species, for example, may be hidden by an increase in the growth of other species. Overall, as pointed out by Jorgensen et al. (2005), there are general indicators that are used in almost every case to assess wetland health but they are never sufficient to present a complete diagnosis. Indeed, Wells (2005) states that the measures of ecosystem health are still in their infancy.

2.3.1. Wetland assessments and indicators of wetland health

Ramsar (2007 p. 9) define wetland assessment as the "identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities". There are various conceptual frameworks for assessing ecosystem health and environmental quality (Wells, 2005). Section 2.1.3 provides a review of various assessment methods. With respect to wetlands specifically, Ramsar (2007) outlines a number of other assessment methods that can be used to determine wetland health. These include environmental impact assessments, strategic environmental assessment, risk assessment, vulnerability assessment, change (status and trends) assessment, species-specific assessment, indicator assessment, resource (ecosystem benefits/services) assessment,

[11] Wetland health was defined as the *ability of the wetland to sustain production through maintaining the water and sediment balance*.

assessment of values of wetland benefits/services, and environmental water requirement (environmental flows) assessment.

Wetland assessments can be undertaken at various scales depending on the objectives of the project. Typically, rapid assessment methods, including rapid biological assessment and remote sensing, are applied at broad scales whereas assessments at specific sites may require more detailed quantitative methods (Ramsar, 2007). The purpose of rapid assessments of wetlands is to firstly collect baseline biodiversity data for a given area, secondly to gather information on the status of target species (threatened or endangered species) and the condition of the wetland ecosystem, thirdly to gather information on the effects of human disturbance on a given area or species, and lastly to determine the potential for sustainable use of biological resources in a particular wetland ecosystem. Staying with the issues of scale, Ling and Jacobs (2003) report a promising method of wetland assessment that will help environmental managers quickly take stock of wetlands across an entire watershed. They contend that tools for this kind of rapid watershed-scale assessment, which rely on a few easily measurable key factors, have been previously unavailable. They use a hydrogeomorphic approach where the ecological conditions were inferred from observable indicators, such as the plant species present. They caution that, while the models cannot predict the precise conditions at a given site they can provide enough information to identify potentially degraded areas and help guide management priorities in a watershed.

Other assessment methods include that of Ramsar (2007) where indicators are developed to assess the temporal patterns in the status and trends of ecosystems, habitats and species, the pressures and threats they face, and the responses made to address these. Such indicators are not designed to provide a complete and comprehensive assessment of all aspects of wetland ecosystems and their dynamics: rather they are intended to give a series of related pictures of these patterns to guide further design and decision-making. The Wetland Assessment Techniques Manual for Australian Wetlands outlines seven groups of key indicators of wetland health (connectivity, bank condition, hydrological change, habitat potential, wetland vegetation, acid sulphate soils and human disturbance) and bases the assessment on simple desk-top techniques. The volunteers of the Wetland Health Evaluation Program monitor two primary indictors of wetland health (macro-invertebrates and plants) given differential species tolerances to human disturbance and water. These are then used to measure the wetland health through a scoring system termed the Index of Biological Integrity (IBI).

Both *Wet-Health* (Macfarlane et al., 2007) and *WET-SustainableUse* (Kotze, 2009) are locally-developed integrated frameworks and assessment approaches which respectively aim to assess the ecological integrity and sustainability of wetland use in South Africa. The latter focuses on grazing of wetlands by livestock, cultivation of wetlands and harvesting of wetland plants for crafts. It assists in determining the effect of use on the ecological character of a wetland based on an assessment of the extent to which key inter-related elements of a wetland have been altered, which are based on those elements assessed in WET-Health. WET-Sustainable Use asks to what extent the use of the wetland has altered: (1) the distribution and retention of water (2) the retention and accumulation of sediment, (3) the retention and cycling of nutrients and (4) the natural composition of the vegetation in the wetland. A recent assessment framework has been designed for staff at the level of middle management based on results from three southern African countries (Finlayson and Pollard, 2009).

WET-SustainableUse assists the user in answering the above questions by providing a set of indicators and a structured way of scoring these indicators and deriving an overall score. Two levels of indicators are used to assess the ecological state: Level 1 is less detailed and rests upon several generalizations regarding each of the land-uses considered. Level 2 is more detailed, and its approach and structure is derived from WET-Health (Macfarlane et al., 2007). The rationale behind the selection of each of the metrics is also provided, together with the rationale for combining the scores of the different metrics into a single score. Kotze (2009) makes the point that if a system such as a wetland is being used in a natural or near-natural state, the assessment of sustainable use primarily involves assessing the sustained yield of the particular resource(s) being used (e.g. reeds harvested for thatching). However, where use involves transformation of the system (i.e. altering its ecological character), assessment is more complex, so as to determine how far a system can be modified before the ecological character is said to be no longer being maintained.

2.4. Indicators of Water and Sediment Status

As noted water and sediment are the primary determinants of wetlands and their characteristics. Nonetheless, many of the assessment methods (and hence indicators) are costly, requiring large amounts of data, equipment and expertise. In this section we examine the literature for suitable indicators and assessment methods for use by community members of the soil and water status of wetlands and their contributing catchments.

A review of relevant approaches to monitoring sediment and water status in terms of sustainable land management and rehabilitation is presented in Herweg et al. (1999). They differentiate between direct (e.g. depth of stream channel against a stage gauge) and indirect (proxy) indicator types, from which inferences to state changes of a variable are made (e.g. vegetation cover is used to infer the level of evapotranspiration occurring in a landscape). However despite the need to develop proxy indicators in the absence of direct alternatives, the use of such must be cautionary as the output may have a variety of underlying causes (see for example, Okoba and Sterk (2006b). Composite indicators which are able to describe the behaviour of multiple variables over time or space may also be used within a landscape management framework. For instance an erosion gully may be seen as a conveyer of both water and sediment.

The types of indicators suitable to participatory approaches vary from qualitative assessments through to more detailed and rigorous quantitative assessments which – at a participatory level -could be applied in a semi-quantitative manner (ranked values based on subjective judgement). This approach was applied successfully by Okoba and Sterk (2006a; 2006b) in working with farmers in Kenya, where qualitative erosion indicators were developed in a participatory manner from visual cues of erosion processes within the catchments studied. In parallel, the authors developed a quantitative index, based in scientific understanding of the erosion processes, which when applied to the qualitative indicators facilitated a determination of where remedial action in terms of soil and water conservation measures could be prioritised.

As with any study of landscape ecology the issue of scale is always pertinent. Thus when developing an indicator monitoring system, one must always be aware of the scale that one is monitoring and the limitations for extrapolating the results to larger scales for which an overall picture is ultimately desired. This was clearly demonstrated by Cammeraat (2004) who conducted trials on hydrological and erosion response units in a nested catchment study in a semi-arid catchment of southern Spain. Here the scales ranged from point measurements, open unbounded plot measurements, micro-catchments, sub-catchments and first order catchment. He found that runoff generation in both bounded and unbounded plots was highly variable and depended in the vegetation structures. In addition, these runoff generating areas had different thresholds of response at all scales and the stochastic nature of rainfall and rainfall intensity was crucial for runoff and erosion response. Also, sediment yields were variable across land use types. This study highlighted the need to account for spatial and temporal heterogeneity in the landscape.

2.4.1. Hydrology as a driver of wetland health

Hydrology is the most important driver that shapes a wetland (and hence wetland health), the particular plant species that are found in the wetland and the primary production of these plants (Mitsch and Gosselink, 2000; Wassen et al., 2002). The availability of water is a key factor limiting plant growth, and therefore the direct presence of water promotes plant production. However, the prolonged presence of water also potentially inhibits plant growth, principally through the very low, free-oxygen conditions that develop in saturated soil, commonly referred to as waterlogging[12]. Only those plants with special adaptations (e.g. aerenchymous tissue) are able to tolerate prolonged waterlogged conditions. Hydrology also affects plant production indirectly through the effect that it has on other processes, including sediment retention/ erosion, nutrient cycling and soil organic matter accumulation, which are covered in the following sections. It is important to highlight that not all wetlands remain permanently wet. Wetlands range from areas which remain permanently flooded or saturated throughout the year to areas which are flooded or saturated at, or close to, the soil surface for only a few weeks in the year, but still long enough to develop waterlogged conditions. Thus, areas at the permanently wet-end of the wetland continuum are generally never soil-moisture limited (even in the dry season) but remain soil-oxygen limited for all or most of the year. In contrast, temporarily wet areas are soil-oxygen limited for only short periods in the wet season, but may be subject to prolonged periods of moisture limitation, particularly in the dry season, and especially in the context of arid to semi-arid climates. Seasonally wet areas are intermediate between temporarily and permanently wet.

Formal methods of hydrology involve an assessment of the water balance over time. A *water budget* considers the inflows and outflows to a system with the difference between the two amounting to the storage state of the system. The catchment discharge, actual evapotranspiration, change in soil moisture storage and the change in groundwater storage all need to be monitored when dealing explicitly with water in a landscape unit, especially when aiming to understand what the natural variations in each of these over time. A water balance requires determining the inputs and outputs of water from a storage unit, then quantifying the volumes (bulk) of surface water and its quality (volume of carried sediments). Monitoring of these requires expertise and equipment beyond the bounds of most participatory, community-based methods. Thus most methods involve indirect or proxy indicators such as changes in soil-moisture, changes in vegetation composition and evidence of soil and water movement (but note cautionary comments on the issue of scale, above).

Wetland plant species (and crops planted in wetlands) vary according to the level to which they are adapted to drought periods (Pagter et al., 2005; Touchet et al., 2008). Many wetland plants are vulnerable to drought as they have high amounts of aerenchyma that improve oxygen availability in flooded soils but also enhance transpiration in dry conditions (Lenssen et al., 2004). However, even some plants typically adapted to the most prolonged saturation conditions may also have mechanisms for dealing with droughts, e.g. *Phragmites australis* is able to shed some of its leaves under drought conditions in order to reduce water loss by the plant (Pagter et al., 2005). Wetland plant species also

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[12] The water in a saturated soil profile acts to exclude O_2 from the profile because O_2 has a diffusion rate 10 000 times slower in water than in air.

vary according to the level to which they are adapted to waterlogging, with some such as *Phragmites australis* being well adapted to prolonged and intense waterlogging, while others are much less well adapted. Maize, a staple crop in communal areas, has a relatively low tolerance to waterlogging, while madumbes (*Colocasia esculenta*) has a much higher tolerance, but even so is not adapted to permanent waterlogging.

It is well known that different types of vegetation have different water use rates in their active transpiration processes and this has received considerable attention in recent years in light of streamflow reduction activities (Jarmain et al., 2004). Also, above threshold levels groundwater abstraction can impact the productivity of certain plant species, especially of phreatophytes which utilise water from the water table (phreatic surface) rather than moisture held within the soil store. Therefore degradation or sustainable use may lead to changes in the vegetation types of a catchment. For instance the rehabilitation of a degraded, desiccated wetland occupied by facultative less hydric tolerant species may lead to the re-establishment of obligate wetland species with a different water demand on the system. These all offer potential for the selection of indicator species.

2.4.2. Sediment balance

Within drainage basins there are two sources of sediment; slopes and channels, and these are activated by raindrop impact, sheet runoff, concentrated slope runoff (channels), mass movements and stream runoff (Loughran and Campbell, 1995). Despite fairly extensive tests under controlled conditions (e.g. Van Dijk et al., 2003) there are limited field tests at the micro-scale particularly in the context of working with subsistence farmers.

Soil detachment occurs in two phases, by rainfall impact and the shear stress of flowing water. These two factors are influenced by rainfall intensity; soil texture; position on a slope and its gradient and cover by vegetation and organic litter. Soil detachment by rainsplash has been measured in the field in a participatory context has been successfully used by Everson et al. (2007), which yielded quantitative data. The runoff component of sheetwash/ interill erosion can be measured in a variety of ways by (a) determining the volume of sediment (bulk and suspended) in a unit volume of water discharged from a unit area of land surface or (b) by describing channelisation (see Chapter 5).

2.4.3. Frameworks for developing soil and water indicators

Many case studies in the literature point to the value of mapping exercises and transect walks, especially in participatory approach, as a tool to familiarise stakeholders with degradation problems in their landscape and furthermore to develop basic conceptual models of process interaction in their catchments (see Pollard et al., 2007). This approach allows the stakeholders to get a sense of whether their landscapes are 'leaky' or 'conserving' systems. Particularly noteworthy are those projects presented by Okoba et al. (2007) and Everson et al. (2007; see earlier discussions).

Brokensha et al. (1980 cited in Herweg et al., 1999) used indigenous knowledge systems to develop an indicator scoring system for soil and land classification based on vegetation, for assessing the landscape in Burkina Faso. This qualitative system could be used by both local communities and extension staff, whereby soils are given a nomenclature based on impressions of soil and terrain properties and land-use. Furthermore, the vegetation system identified dominant plant species by apportioning cover classes to various land-use areas. The appearance of certain bio-indicators then signalled that a rehabilitative intervention was required. This methodology is similarly advocated by Campbell et al. (2001) to derive a conceptual framework and bounding of the landscape system in question.

Additionally there is a body of literature that describes various scoring systems for assessing soil quality and fertility, although these have been derived mainly for trained agriculture personnel. However Ditzler and Tugel (2002) describe a dual scoring-card system which serves both the trained personnel by collating quantitative values of soil quality scores (requiring several hours field work), examining various biological (soil respiration, earthworm activity), physical (infiltration, water content, bulk density etc) and chemical (pH, electrical conductivity etc) aspects of the soil. This is complemented by a qualitative tool that rates various visual aspects of soil conditions. In testing the two systems they found the qualitative approach agreed favourably with the more detailed quantitative method. They endorse developing a qualitative system together with local land-users.

In terms of the biophysical landscape, Tongway and Hindley (2004) present some conceptual underpinnings for the assessment of landscapes which, although largely centred around biogeochemical processes, serve to highlight those hydrological and geomorphic processes that affect the soil and water status of catchments. A component of the Landscape Function Analysis (LFA) framework of Tongway and Hindley (2004) allows for a detailed, rapid and low-cost assessment of soil surface conditions, designed for land-use managers. This component, called the 'soil surface assessment indicators', could be adapted to local conditions and would allow a semi-quantitative assessment of the landscape over time, especially of the micro-catchment of the wetland in question. The soil surface assessment indicators include; rainsplash protection, perennial vegetation cover, litter, cryptogram (algae) cover, crust brokenness, soil erosion type and severity (visual assessment of rills and sheet erosion etc), deposited materials, soil surface roughness, surface nature (resistance to disturbance), soil stability (slake test), soil texture (bolus test). The scoring of these factors is then used in a combined calculation to derive a soil surface condition score, which could be monitored over time.

A relatively new approach along similar lines has now been put forward to assess the landscape function through remote sensing techniques, in which spatial organisation of vegetation and interpatch areas are delineated from aerial photographs, which at present are being related to geohydrological processes (Imeson and Prinsen, 2004). This represents a potential methodology that could be employed to determine at least qualitatively, the direction and intensity of soil water processes operating at a landscape scale.

Other factors to consider in a local context that may contribute at the macro-scale to soil and water budgeting of landscapes are grazing intensity and burning (as well as developmental activities such as mining), and these could be picked up in a scoring system similar to that outlined in soil surface assessment method.

2.5. Cropping and Soil Health

One of the major concerns persistently raised by farmers relates to declining soil fertility. As stated, many wetlands are used throughout southern Africa for subsistence purposes, and particularly for crop production (see FAO, 2002; Pollard and Cousins, 2007; Finlayson and Pollard, 2009). The constraints placed upon the cropping systems by the environment (see for example, Kotze, 2009) in terms of crop yields and in turn, the impacts of cropping on soil fertility must be closely examined. Linked to this are questions regarding suitable indicators for establishing the links between cropping and soil fertility. This is particularly important since it was one of the main concerns raised by the Craigieburn farmers (see figure 5.1).

Shifting cultivation with long-duration fallow periods has in the past, sustained the low but relatively stable production of food crops in Southern Africa. However, with increasing pressure for land, cultivation has become more sedentary and periods of fallow, if still practiced, are now of shorter duration. This intensification of agriculture has not been matched by sufficient inputs of nutrients (e.g. biological nitrogen fixation, application of animal manure and inorganic fertilizers) to match the output of nutrients through harvested products and other losses (erosion). The result has been widespread mining of soil nutrients and depletion of soil fertility in smallholder agriculture in Africa (Buresh and Giller, 1998; Adey, 2007). Soil fertility decline is considered to be a major constraint to sustainable small-holder farming in sub-Saharan Africa (Smaling and Braun, 1996; Vanlauwe and Giller, 2006; Adey, 2007) with the deficiency of soil nitrogen and phosphorus the key biophysical constraint to food production (Sanchez et al., 1997; Adey, 2007).

Wetlands are well known for the abundant natural resources that they offer but are also vulnerable to human impacts on the integrity of the system (Dugan, 1990). Wetlands are transitional between terrestrial and aquatic systems (Cowardin et al., 1979) and are often strongly linked with other elements in the landscape, including those located both upstream and downstream within the catchment. Thus, the functioning of wetlands is influenced by processes occurring locally at the wetland and by processes operating at broader scales across catchments and landscapes. Similarly, wetlands supply ecosystem services locally as well as to distant beneficiaries (e.g. water-users downstream benefit from the water quality enhancement provided by the wetland). Therefore, wetlands are often subject to conflicting land-use demands (e.g. they are recognized as having high biodiversity value, while at the same time providing potentially fertile lands for cultivation, particularly for farmers lacking resources for irrigation and fertilizers).

Craigieburn is also located on granites and has similar climatic and edaphic features to Zimbabwe, for which considerable literature exists. This includes substantive research dealing with issues faced specifically by smallholder farmers (e.g. Giller et al., 1998; Grant, 1967; Grant, 1970; Grant, 1995; Mapfumo et al., 1998; Mtambanengwe, 1998; Mugwira and Murwira, 1998; Nzuma and Murwira, 1999; Nzuma et al., 1998; Van Straaten, 2000), which further adds to its relevance to Craigieburn.

The sandy, granitic sands of Zimbabwe are typically acidic, low in nitrogen, phosphorus and sulphur as well as having low Cation-Exchange-Capacity due to the low clay and organic-matter contents (Mugwira and Murwira, 1998). "Many croplands on granitic sandy soils in the communal areas that have been cropped without regular applications of manure or inorganic fertilizers now show multiple nutrient deficiencies of nitrogen, phosphorus and sulphur and sometimes magnesium and potassium, as well as micronutrients such as zinc." (Grant, 1970, as cited by Mugwira and Murwira, 1998). The wetlands typically have higher soil organic matter levels than non-wetlands (e.g. wetland: 2.1% total carbon, wetland margin: 1.5%, and adjacent non-wetland: 0.5% (Grant, 1995). Thus, given that the N stocks in particular in a soil are strongly linked to the level of soil organic matter (Buresh and Giller, 1998) one would expect the nutrient stocks in wetlands to be generally higher than that for non-wetlands. However, although the cropping potential of wetlands in these landscapes is high, these wetlands are also typically low in nitrogen, phosphorus and sulphur, as for the corresponding non-wetland areas. Many of these wetlands are also acidic (Grant, 1995), and thus they are also susceptible to nutrient deficiencies where there has been an inadequate application of nutrients. Grant (1995) recommends "To get the benefit of the dambo (wetland) moisture, fertilizers or manure must be applied".

2.5.1. Crops and replenishment of nutrients

Leguminous crops can make a significant contribution to the N fertility of the soil, through biological N fixation. Up to 60 % of the total N requirement of legume crop can be supplied through biological N fixation (Stoorvogel et al., 1993; Giller, 2001). Groundnut, pigeon pea and cowpea have N-fixing potential established at 112-152 kgN/ha; 68-200 kgN/ha and 53-85 kgN/ha respectively (McDonagh et al., 2001; Tilak and Singh, 1996). Non-leguminous crops can benefit from the inclusion of legumes in multiple cropping systems, spatially and temporally. The amount of N added to the soil by planting pigeon pea in rotation with maize is estimated to be up to 40kg/ha per year, resulting in higher yields of maize (Kumar et al., 1983; Tilak and Singh, 1996).

The microbial fixation of atmospheric N by leguminous plants into compounds available for plant uptake has a residual effect. This means that some N is made available to plants for a number of seasons, giving long-term benefits (Ledgard and Giller, 1995). The input of nitrogen into the soil profile from atmospheric deposition is unknown but likely to be low or moderately low. As the level of total N in Craigieburn-Manalana soils is relatively low, the opportunity for loss of N through denitrification, ammonia volatilization and leaching are limited. However, even though the level of N is low, the field preparation practices exacerbate this shortage because the N availability and crop demand are not well synchronized. This is because the fields are often cleared well in advance of planting, which results in the release of inorganic N through mineralization.

The loss of N through the erosional loss of organic N in the topsoil depends on the amount of organic material contained in the topsoil and its level of erosion. The amount of nitrogen entering the wetland through the application of manure is likely to be moderately low, given the following: (1) the amount of manure applied is widespread, but moderately low (2) the quality of the animals' diet is relatively low, (3) storage and handling practices are relatively poor (leading to further lowering of the N content of the manure). The amount of N entering the wetland through biological N fixation is also likely to be low, given that (1) the cultivation of N-fixing crops is limited and (2) where these crops are cultivated, the residues are seldom adequately incorporated back into the soil.

Chapter 3

An overview of the Craigieburn wetlands

3.1. The Sand River Catchment as a Case Study Area

Craigieburn wetland (also known as the Manalana wetland) is located in the north-eastern region of the Sand River Catchment (Figure 3.1). It is a small, headwater wetland that receives the bulk of its water from runoff and groundwater in the rainy season, and via groundwater input in the dry season. The Sand River Catchment is a relatively small area of 2000 km^2 and home to some 383,000 people (Pollard et al., 1998). With the exception of the wetter, western mountainous region, the catchment is semi-arid with an average rainfall of 600 mm. The Sand River rises at an altitude of some 1800 m but descends rapidly to an altitude of 500 m in the lowlands (known in South Africa as the lowveld). The abrupt change in altitude from the escarpment to the lowveld is characterised by narrow, valley-bottom wetlands where they comprise some 10-15% of the catchment area (Pollard et al., 2005). Craigieburn typifies the bio-physical and socio-economic attributes of the vast majority of the wetlands of the Sand River Catchment and indeed, of the wetlands in communal lands of the eastern lowveld of South Africa.

The area comprises principally the former Bantustans of Gazankulu and Lebowa. Over the years, livelihoods for the catchment residents became increasingly vulnerable under grand apartheid planning and today, most families rely on income from pensions or wage remittances. The effect of poverty that accompanied mass removal of people to the area is reflected in the increasing environmental degradation (Pollard et al., 1998).

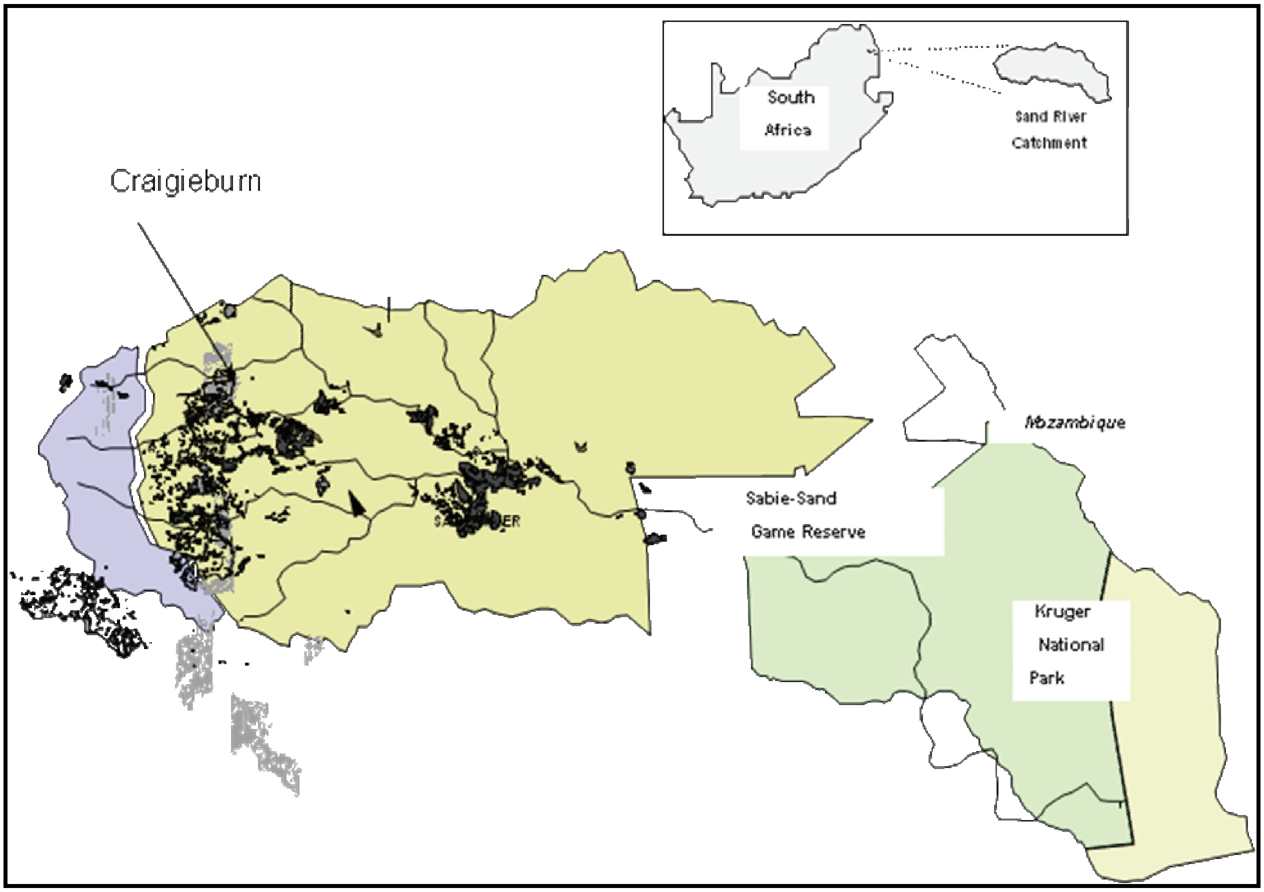


FIGURE 3.1: Map of the sand River Catchment showing the location of Craigieburn wetland

Data from the Wales rainfall gauge (Station no: 594819; 30°58'; 24°39'; 10904 – 2004 daily, patched) records an average rainfall of 1084 mm. This is however highly variable. Rainfall is strongly seasonal falling between October and March. The average mean annual summer temperatures range between 26-31°C, and rarely drop below 10°C in winter (Schulze and Maharaj, 2004).

The main land-uses (Figure 3.1) include commercial forestry in the upper catchment, rural residential areas combined with subsistence agriculture, and some limited irrigated agriculture in the central region, and conservation (mainly exclusive high-income tourism) in the eastern region.

3.2. Craigieburn Wetlands: Summary of Findings from Previous Work

The following section summarises work undertaken in Phase I, between 2003 and 2005. This indicated that the wetlands in the Sand River Catchment are widely used for subsistence purposes offering an important livelihood support through the provision of natural resources such as cropping, grazing, reeds, water and other services. With an estimated total net direct benefits of about R110,000 p.a. (Pollard et al., 2008a). However, with landuse pressures within the catchment and the wetlands themselves, there is concern over increasing degradation. This will impact on both of the integrity of the natural resources as well as on peoples' livelihoods, often the poorest.

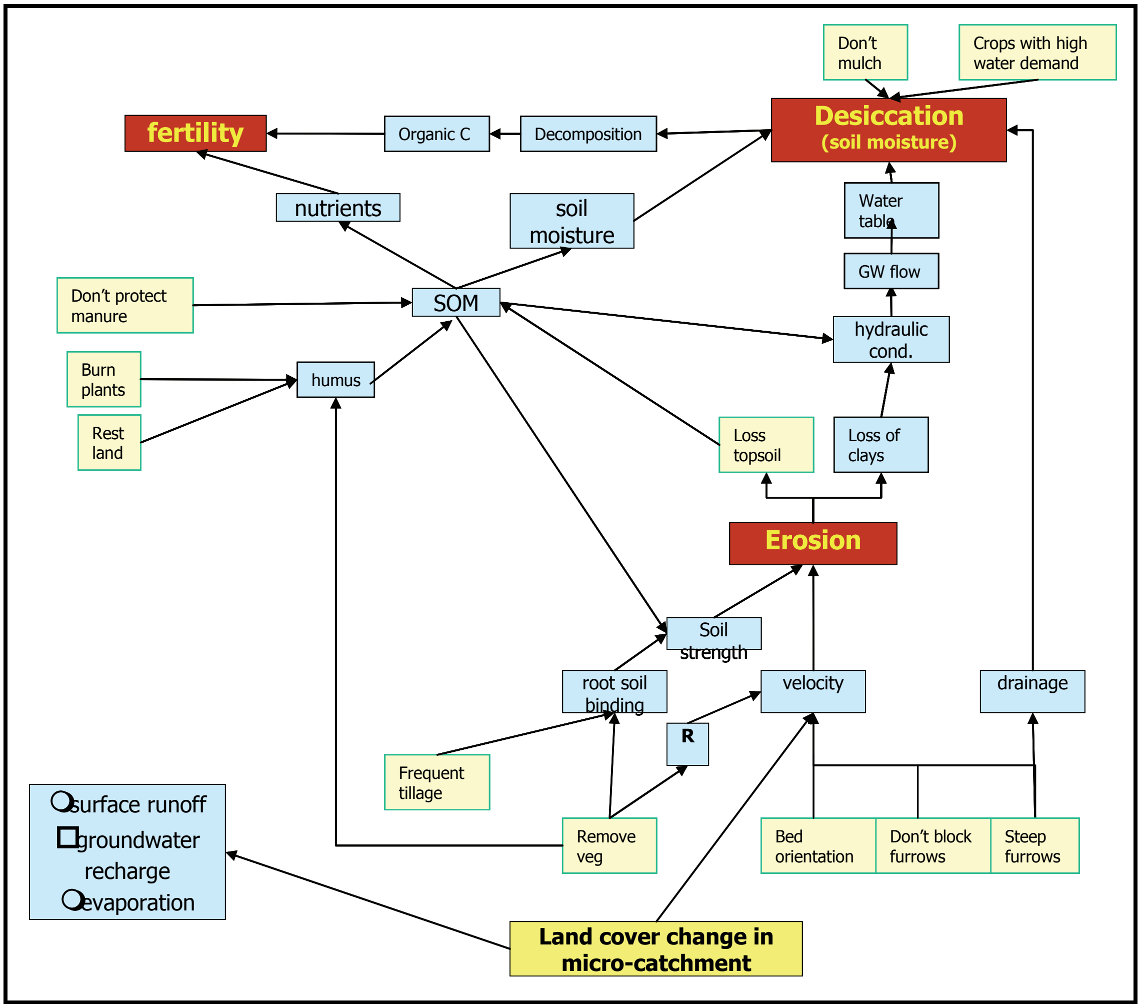


FIGURE 3.2: Systems diagram (biophysical) showing the links between mechanical disturbance (yellow boxes), erosion, desiccation and soil fertility in Craigieburn wetlands (adapted from Pollard et al., 2005)

Indeed, the wetland farmers who approached AWARD for support in addressing wetland degradation cited desiccation, erosion and reduced fertility as key concerns. The baseline research (Phase I) established the relationship between these factors and demonstrated that wetland integrity was being severely compromised by both within-wetland practices, as well as by landuse practices in the surrounding micro-catchment. In summary, an intimate relationship exists between landuse practices, infiltration – and runoff – and erosion, and between erosion and a reduction in the water table. Landscape desiccation reflects a change in these relationships as described below. A series of interlinked factors lie behind this (Figure 3.2). Some of these are related to the inherent biophysical characteristics of the area (sandy soils) whilst others reflect current landuse practices. For example, farmers are drawn to the wetlands because of moist conditions but then subsequently drain them through canals and raised beds, citing water-logging as a problem.

To understand such changes it is instructive to appreciate landcover/ landuse changes that have occurred. The effects of moving people into the area are highly visible between 1965 and 1974 when the residential areas increased dramatically (1000% increase in nine years) and veld areas decreased (Figure 3.3). The micro-catchment area of the wetlands under consideration is approximately 140 ha. Within this, wetlands are estimated to have decreased by 50% (as suggested by the vegetation/ soil data comparison) from 23 ha to about 13 ha.

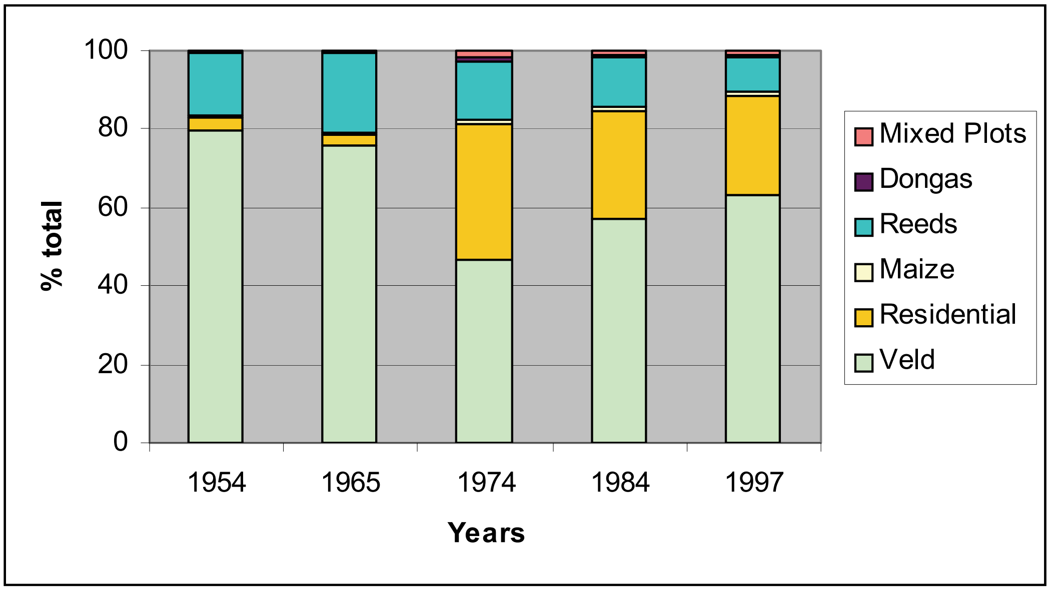


FIGURE 3.3: Changes in land cover / use between 1954 and 1997 (from Pollard et al., 2005).

3.2.1. Major threats to Craigieburn wetlands and peoples' livelihoods

Erosion is the major threat to the wetlands of Craigieburn and hence to peoples' livelihoods. Studies undertaken in 2003/2004 suggest that the desiccation of the wetlands and the surrounding landscape is intimately linked to erosion, which in turn impacts on production. Erosion is caused by a number of factors. First, at a geological scale, the wetlands occur in an area a naturally eroding landscape (see Pollard et al., 2005) and secondly, clearing of the hillslopes that surround the wetlands has provided diffuse sediment source into the wetlands. In Craigieburn the main impact, which is acute, is on the slope as the wetlands accumulate sediment. This aggregated sediment is very difficult to remove and the only way is through incision – the effect of which are profound (see later). Finally certain farmer practices within the wetlands – elaborated below – act to increase water velocity and hence erosion.

It is important for the purposes of this report to differentiate the 'types' of erosion.

- Sheet or rill erosion (Figure 3.4a) is evident of the hillslopes and on the surface of the wetland plots (the latter being 'within-wetland erosion').
- A more visible and acute type of erosion is that referred to as 'headcut erosion' which describes erosional features that advance upstream through a wetland, effectively causing a major loss of wetland extent (Figure 3.4b).

At a macro-scale, Craigieburn wetlands occur in "over-steepened" sections where the water table is held in place by a plug of fine material at the toe of the wetland. This landscape setting means that Craigieburn wetland is highly vulnerable to erosion as landscape processes seek to reduce the wetland slope. The gulley erosion and loss of fines at the toe of the wetlands raises the hydraulic conductivity and hence groundwater flow within the soil, so that there is a gradual drawdown of the water table**.** The concomitant desiccation of the landscape creates conditions which are unfavourable for the production of organic carbon, and hence fertility declines. Indeed, a comparison of the historical hydrological characteristics (indicated by soil characteristics) and the contemporary vegetation distribution suggested that there had been widespread desiccation of the landscape, and a 50% reduction in wetland areas, probably over the last two decades.

Compounding this are the hillslope activities, demonstrating the link between wetlands and the surrounding micro-catchment. On the hillslopes the lack of adequate vegetational cover, or soil and water conservation practices, as well as poorly-conserved fields all result in increase runoff and higher water velocities that, combined with the soil properties and an extensive path and track network that concentrates runoff, all contributes to the observed erosion (sheet deposits, rills and gullies). Consequent decreased infiltration and an augmentation of peak discharges in turn expose the wetland to greater risks from erosion. The impacts are (a) desiccation of the wetland; (b) increased levels of sediment loss from the hillslopes and deposition within the wetlands, further steepening the wetlands and increasing their vulnerability to erosion; and (c) increased levels of organic matter and nutrient losses from the system.

FIGURE 3.4: (a) Example of erosion evident within wetland plots, and (b) Example of headcut erosion

3.2.2. Overview of hydrological characteristics

Hydrological simulations for a number of sub-catchments in the upper reaches indicate that wetlands contribute to hydrological functioning of the micro-catchment through the attenuation of peak discharges and increased baseflows. These results suggest that wetland degradation impacts through a reduction of base flows.

To examine these linkages further work was undertaken as part of a Ph.D. The basis for the work lies in recognising that hydrology is the most important driver that shapes a wetland, the particular plant species that are found in the wetland and the primary production of these plants (Mitsch and Gosselink, 2000; Wassen et al., 2002).

The current understanding of the hydrology of Craigieburn (Riddell, in prep.) is summarised below.
Rainfall partitioning is influenced by the geology of the hillslopes in the following way.

i. The dominant granite slopes have shallow coarse soils that transmit water rapidly as lateral sub-surface and surface (runoff) to the valley bottom (wetland). These are not recharge slopes. These slopes also yield greatest sediments to the valley bottom.
ii. The patchy doleritic slopes have deep fine soils that transmit water slowly with very little lateral subsurface and surface water. Most water is retained in soil and freely drains into the underlying soil matrix and these are true groundwater recharge slopes. These slopes yield very little sediment to the valley bottom, but probably contribute valuable fine clays to the wetland over geological timescales.
iii. Both granitic and doleritic hillslopes have recharge areas at the toe of slope (i.e. the Kroonstads) with deep clay-rich G-horizons. These are very important parts of the catchment as they buffer the flows from upslope absorbing water slowly during the wet season and relinquishing it slowly as the catchment dries up. The assumption is that these soils are good for baseflow maintenance. Once saturated these soils facilitate rapid water delivery into the wetland during large rainfall events as perched water (lateral contributions from upslope) passes over these soils into the wetland.

Two main regions are apparent in terms of wetland hydrology. Firstly, in the seasonal (headward) areas, where capillary and leaching processes in soil matrix have facilitated the layering of fine clays from coarse sandy material, in essence creating a series of aquicludes. These aquicludes enable the existence of perched water tables (these can exist as multiples at same location). Over time this facilitates deeper recharge to underlying wetland substrate, but also causes lateral movement of water along longitudinal profile of wetland in a series of overlying (effectively) confined aquifers. Notably, with gully erosion these processes are lost and recharge potential of the wetland is significantly reduced. Secondly, in the perennial areas a shallow coarse matrix overlying deep clay rich substrate is apparent. The shallow coarse soils transmit water relatively rapidly, whilst the deep clay rich profiles absorb and retain water well into the dry season. These deep clay soils also form clay plugs. Additionally, clay plugs are present and are likely formed by clay illuviation from surrounding hillslopes at areas where the catchment becomes constricted perpendicular to its longitudinal orientation.

3.2.3. Wetlands, land use and livelihoods

It is estimated that between 60 and 70% of Craigieburn residents use wetlands to sustain their livelihoods. The overriding profile of wetland users is that of women between 35 and 70 years of age –

mainly from single-headed households. In general, livelihoods are very vulnerable. A quarter of all households has minimal income and secures food through what they grow. Indeed, only 14% of users are regarded as well-off, whereas over half (60%) of users have limited income. Some 60% of households accessed their land by opening up fields without any permission or negotiation, pointing to the erosion of community-based governance. Equally striking is that 63% have accessed their fields in the last 10 years, citing hunger as the key driver. Craigieburn wetlands offer an important safety-net, particularly for the poor, and are estimated to contribute 40% of the food grown. However, within-wetland practices, the lack of governance and varying levels of awareness regarding wetlands are compromising the integrity of the wetlands and in turn, the livelihoods and catchment water security.

Within the wetlands, a number of landuse practices exacerbate erosion and hence desiccation, either directly but reducing soil structure or by increasing water velocity. The associated reduction in fertility, also compounded by practices that directly reduced organic matter, result in reduced agricultural production. This has implications for peoples' livelihoods.

The study concluded that agricultural utilization of the wetlands should be based on the realization that wetlands derive their potential from high moisture and organic matter content of the soil. However wetlands tend to be highly sensitive and fragile. The following factors were identified as important for rehabilitation and management.

- The micro-catchment area has to allow rainwater to infiltrate, to slowly release this water subterraneously into the wetland and to have erosion from surface runoff reduced to the barest minimum.
- The wetland should have capacity to receive both catchment and incident water without being eroded, hold excess water and release it slowly into streams.
- The wetland must have capacity to accumulate organic matter.
- The wetland needs to be able to receive and accommodate soil and solute eroded from the micro-catchment area, and prevent the scouring and gullying, reducing siltation in the stream.
- The critical balance between inputs and outputs – water, nutrients and soil – has to be maintained.

Importantly, since the impacts on wetlands arise from interplay of within wetland activities <u>with</u> micro-catchment practices, both of these issues need to be addressed with full involvement of Craigieburn residents.

3.2.4. Use of the wetlands and farmer practices

As stated, Craigieburn wetlands are used mainly for subsistence agriculture. Farmers grow a variety of crops depending which zone of the wetland is used (see later) but by far the most commonly grown crop is *Colocasia esculenta* (marope). Together with farmers, three zones are recognised in the wetlands (see Chapter 5): Zones A, B and C (Zone A being the wettest and C, the driest).

The initial research in these wetlands (Pollard et al., 2005) revealed a range of farmer practices that had both negative and positive effects on wetland integrity. These are summarised in Table 3.1, which provides an analysis of how prevalent the practice is, and each practice is briefly reviewed below. No fertilizers are applied in Craigieburn and hence this is not discussed.

TABLE 3.1: Summary of landuse practices and key characteristics of the wetland agro-ecosystem of Craigieburn based on baseline survey

Feature	Detail
Eco-zones (see Figure 7) (n=42)	Many fields (38%) had all three zones. Just under a quarter (21%) had only B and C. Some fields have only zone C and they probably need a different approach
Bed orientation & furrow direction (n = 39)	Nearly 50 % of all fields have furrows that exclusively act to channel the runoff at higher speed (i.e. parallel to incident runoff). A further 20% of fields also do so although they have a mix
Drainage (n= 38)	In almost all cases (90%) people are undertaking some form of drainage of the fields. Some 40% of this is extreme.
Fertility (n = 40)	Fertility is an issue in all but 7% of the fields. In 32% of cases it is very bad.
Weed quantity (n = 42)	Many fields have a moderate to bad weed problem. However, need to be cautious about what is considered to be a "weed".
Erosion (n= 39)	Nearly three-quarters of all fields (71%) have an erosion problem. Clearly this needs to be a focus of the work.
Cover (n = 42)	Only 20% of the fields visited had adequate cover. In 80% of the cases soil exposure was an issue.

- **Water resources management**
  - Bed orientation

Generally, plots comprise a number of raised beds, which range from about 30 cm in height in the less wet areas to over 70 cm in the permanently wet areas. By and large, the orientation of these beds and the inter-bed furrows is parallel to the direction of surface runoff. These beds serve the dual purpose of: (1) reducing excessive waterlogging and (2) allowing floods to pass between the beds without washing away the crops and soil. The orientation of plots results in too much water draining too fast, while in some cases the beds retain water in the plots. The preparation of ridge-furrow systems includes the removal of vegetation, poor orientation of raised beds and the steep gradient of many drainage furrows, removal of furrow vegetation, leading to over drainage. Although marope (*Colocasia esculenta*) is cultivated in areas that are semi-permanently inundated, furrows are still excavated.

In some cases, these effects are mitigated by blocking furrows – either manually or by planting reeds. Another aspect of bed 'design' is that of staggering the beds in the landscape such that water velocity is reduced, thereby reducing erosion. Some 71% of all fields assessed in 2005 showed signs of erosion.

  - Furrows blocked

The preparation of ridge-furrow systems including furrow management was described in under bed orientation. Not only is indigenous vegetation removed but no crops are planted in furrows to reduce water velocity and hence prevent erosion. Agricultural conservation tillage approaches seek to reduce both of these by ensuring a low furrow gradient (1% and less) and vegetated furrows. Given the above practices, these areas are therefore generally of no direct productive value to the farmer.

- **Soil health**
  - Mulching/ cover

In terms of soil cover, fields in Craigieburn are poorly protected (although there was a marked improvement in 2008). In over 80% of the cases, soil exposure was considered to be a major issue. Cover can be provided in one of 2 ways (a) through leafy plants, often achieved by intercropping and (b) through the use of mulch.

- <u>Manure application</u>

There are two ways in which N is released: either through decomposition of organic matter or through the application of manure. Farmers apply manure in about November after fields have been prepared. However, although highly prized, manure is in short supply and is not always available to all farmers in the quantities they desire. Generally it is stored, unprotected, on the side of the field until application when it is sprinkled on the soil surface and sometimes dug in. In Craigieburn the current impacts of manure application are thought to be low although farmers perceive the importance of manure to fertility as high.

- <u>Frequency of tillage</u>

Tillage frequency is known to have a major impact on soil structure. Farmers start preparation of their field by clearing, burning and tillage in about September. Shallow tillage also takes place about three times a year. This involves forming mounds around the madumbis. Tillage impacts on soil temperature and increased oxygen resulting in oxidation (mineralisation) which impacts on SOM.

- <u>Burning</u>

Burning by farmers is undertaken to 'clear' an area in preparation for planting and also to reduce the risk of snakes and rats. Burning does not refer to a ground fire but rather the annual removal of vegetation, stacking it on a bed and then burning. This results in a substantial release of P, but also to the loss of N. For farmers burning releases P and could be regarded as a benefit (albeit short-term).

- **Erosion and control of soil movement**
  - <u>Extent of denudation of soil</u>

Much of the plot is cleared and denuded of vegetation. Soil is thus left exposed and for a considerable period between preparation and planting during the hot summer period. In November 2003, with most plots had below the 30% cover considered to be the general minimum acceptable for cultivation (Fowler, 1999).

- **Resting of land**

This refers to taking the field out of production for a year or more. Resting is very uncommon in Craigieburn as farmers – under substantial pressure to produce food from limited resources- do not feel they have such an option. Indeed taking a field out of production occurs only by default when a farmer finds other work or with the death of the farmer or helper.

- **Crop production**

The main crop grown in Craigieburn wetlands is *Coloscasia esculenta*, also known locally as madumbe (Tsonga) or marope (Sotho). The variety of crops (Table 3.2) that is grown in wetlands is higher than that in drylands. This differentiation is also seen between zones in the wetlands (see Chapter 5). From observed crop types on each of the farmers' fields, some 14, 9 ad 5 crop types occurred in zones A, B, and C respectively. A number of points pertain to rehabilitation in this regard.

- Madumbis, maize and pumpkins are the most ubiquitous crops with madumbis being more common in the wetter zones and maize in the drier zones. Madumbis have a relatively high protein content.
- The variety of crops, and in particular the diversity of vegetables offer important sources of nutrition over longer periods of the year than would be available from dryland plots.

The estimated yield is 25 kg m^{-2}. In highly productive fields, the estimated yield is **30 tons per ha**, which is commensurate with estimates from elsewhere (e.g. Kotze et al., 2002). As mentioned above, fertility is a major issue for nearly all farmers. In a third of all fields visited, crops showed signs of major fertility problems. Field observations indicate signs of N deficiency (yellow-ish leaves, leaves narrower / a bit smaller than normal size are) and P deficiency (yellow-ish or purple-ish (colour depends on species) stripes along leaves).

TABLE 3.2: Occurrence of crop varieties in plots of different wetland zones (Information comes from an assessment at the end of the wet season and so may be under-representative of full crop variety (source Pollard and Du Toit, internal report)

CROP	A n =27	B n = 18	C n = 13
Root crop			
Madumbe	19	12	3
sweet potatoes		1	
Masetla		1	3
Vegetables			
Spinach	2		
Pumpkins	5	5	2
Tomatoes	1	3	
Maize	6	10	10
Cabbage	1	1	
Beans		2	1
Onions	2		
Nkaka	1		
Nuts	1		
Goundnuts	1		
bambara nuts	2	1	
Fruit			
Sugarcane	7		
Bananas	2		
watermelon	1		

Phase II, which flowed from this research was designed to support improved practices in order to rehabilitate the wetlands and therefore impact positively on peoples' livelihoods. This consists of a number of action-research components.

1) The first of these is support for improved wetland-use practices through the Farmers Support Programme (the indicators work reported herein).
2) Research to understand the learning processes associated with the development of wetland practices. This is being done through participatory methods and discourse analysis.
3) Action research in support of the wise and effective governance of the wetlands
4) A detailed hydrological analysis is nearing completion.

A concurrent piece of work involved dynamic modelling to assess which practices were most important (Pollard et al., 2008b). These results, although not conclusive, indicated the following:

- The most significant impact on erosion and water stress appears to be through mulching, and crop/vegetational cover, and to a lesser extent through the application of manure.
- Unsurprisingly, erosion increases markedly when the clearing of land is syncrohnised with rainfall events (such as in November).
- What is less clear are the impacts of changed bed management but this is thought to reflect limits to the model

- Improvements in fertility and production are seen with the application of manure (4 kg/m^2), resting and mulching. However, the initial application of higher levels initially (4 kg/m^2) than those that are currently reported in Craigieburn appears to be quite important.
- Unsurprisingly, taking the field out of production for the 4-year period has a strong mitigatory effect.

3.3. Soil Health and Soil Fertility

In order to make reasonable assessment of potential indicators some baseline research was needed regarding the inherent fertility of Craigieburn wetland and upland soils. Doing this is a relatively simple and cost-effective process and not beyond the means of most projects (Adey and Kotze, 2009). In summary, results indicated that soils at Craigieburn are generally, acidic, deficient in phosphorus, potassium, nitrate and zinc and have little organic carbon. This is important baseline information against without which farmers inevitably set goals that are not achievable. For example, high soil acidity will affect plant yields not matter how sustainable the landuse practices are. The following key points summarise the major characteristics that guided the development of indicators both for the macro-context as well as for the plot-level indicators.

Acidity

- The greatest factor affecting crop yield is the acidity of the soils at Craigieburn. Some of the Acid Saturation values are very high (45%; See Table 3.3);
- The application of plant nutrients to the soil is unlikely to improve crop performance unless the acidity of the soil is addressed first. Lime[13] is the most cost-efficient method of neutralising excessive soil acidity

Macro-nutrients

- The deficiency of phosphorus (P) and nitrogen (N) is the second greatest factor (after acidity) affecting crop yield.
- The levels of P, N and potassium (K) in most of the Craigieburn soils, are too low to provide a continuous and adequate supply for crop requirements according to the norms recommended by Manson (1996).
- P and K levels are higher in the homestead plots, most likely due to a higher nutrient input
- The soil P in most of the samples from Craigieburn falls well-below the threshold value for vegetables of **27mg/L**, implying that P is limiting for adequate crop growth.
- To apply sufficient P for adequate crop production, on average, an excess of 40t/ha of high-quality animal manure will have to be applied to the plots.
- The application of animal manure will more-readily address the deficiency of K in the soil, as the proportion of K[14] in animal manure is higher than that for P.

Micro-nutrients

- The soils generally have low levels of zinc.
- Manganese levels are well-above the threshold
- Levels of copper are moderately low

SOM/ SOC

- The mean = 1.5%
- Levels of organic carbon are relatively similar across the zones and land uses.
- It was also unexpected that the organic carbon levels in the wetland soils were lower than those in the upland zone.

[13] Should be applied to the land a few months before planting and be incorporated to depth of at least 20 cm.
[14] However, K is more mobile within the soil profile than P, and is more-readily lost through leaching and run-off

Clays

- The mean clay content is 44%

TABLE 3.3: Permissible acid saturation values for a variety of different crops compared with the mean value measured in Craigieburn-Manalana. Lime would be needed if acidity exceeds these values

Crop Type	**PAS %**
Cabbage	1
Onion	5
Pumpkin	5
Sorghum	10
Sweet potato	10
Maize	20
Mean of all soil samples	**17**

3.4. Major Governance Characteristics

Legal pluralism is in natural resources governance (see Chapter 2 for definition) is widely evident, so that both customary and statutory systems shape the governance of land tenure rights and administration. Importantly both of these are closely tied to natural resources management (Pollard and Cousins, 2008), and they do not operate independently or in parallel, but with some interaction.

The wetlands of Craigieburn are found on different sorts of property including both fields and commonage and on which different "rules" apply. Families and individuals have strong claims to fields whilst all community members have access to and claims on communal or "unassigned' lands. In Craigieburn, fields within or partly within the wetlands have a particular value for the prolonged growth of certain crops. Women are the main users and thereby have strong claims to these fields; they can open new fields themselves, and this is often done with others – usually family members. They can also negotiate taking over unused fields form other families. Fields appear to have lesser status than residential sites, and they are not subject to levies or approvals by Traditional Authorities (TA) or the state. Although wetlands are officially prohibited for cultivation, this is not enforced. The commonage does not have clear and agreed boundaries since these vary depending on the resource in question and moreover, there are different views in the community about who has claims to the resources. Although there are recognised rules for access to and times for reed harvesting, these have been increasingly flouted in the past decade are not enforced in Craigieburn. There is an ambivalent attitude to this lack of enforcement, with a strong expression that people "do not listen", that such rules cannot be enforced because of poor peoples' need, and that authority cannot be exerted because of "freedom" (meaning political freedom post 1994).

3.4.1. Rights and authority

A useful way to understand the property and governance systems is by analyzing the rights and authority with regard to different "sticks in the bundle" of property (see Cousins and Pollard in prep).

Households and families have a lot of authority with regard to their residential plots, and also fields. While these may be weak legally, functionally people feel they have strong and autonomous rights – more subject to family authority than external actors. The TA plays the role largely of providing an administrative affirmation of their decisions. However the TA can be called to resolve disputes that the family or neighbours cannot resolve.

While the TA claims, and is recognized as having, responsibility and authority for a range of roles regarding land and resources management, as well as dispute resolution, this is no longer exercised. The loss of governmental support after 1994, together with challenges to legitimacy during the resistance years of the 1980s, and ineffective individuals, means that governance of natural resources by TAs is weak. Problems regarding fields or the commons are left for households and individuals to deal with, or live with. Likewise, while roles for government departments and the magistrate are described – both formally and informally – it is also clear that these are no longer played in any significant way. Remnants from apartheid era years, this is an expression of the long drawn-out transition in land administration of communal areas, leading to inconsistent, often illogical and sometimes illegal practices. New roles of oversight, planning, monitoring and support that are derived from revised environmental laws are largely not understood, or there is no capacity or institutional will to implement in the communal areas.

3.4.2. Governance of natural resources management

Table 3.4 focuses specifically on natural resources management, unpacking the rights and responsibilities, together with where authority for these lies. This takes plural systems into account and so includes both formal statutory and local custom. As cautioned by Peters (2000), it is important to distinguish between what ought to happen (*de jure*), and what actually happens (*de facto*), and this is indicated in regard to natural resources in Craigieburn.

TABLE 3.4: Summary of role-players involved in natural resource governance in the Craigieburn (from Cousins & Pollard in prep). T.A. = Traditional Authority; CDF = community development forum; NGO = Non-governmental organization. Blue = do play this role Orange = should but currently do not play this role.

Governance	Community membership	Traditional Authority	CDF	NGO/ civil society	STATE (department depends on resource)
Rights					
To use resources (for self)					
To participate in setting rules & sanctions					
To participate in decisions regarding major changes					
To self-organise	starting				
Responsibilities					
To abide by rules					
To monitor state of resource and use					
To report on above					
To act on transgressions					
To mediate disputes					
To act as recourse when rights infringed					
Authority					
To approve landuse change with conditions					
To allocate usufruct					
To set rules and sanctions					
To monitor resources, and transgressions					
To enforce rules					

It is notable which rights are or are not taken up. For example, community members are able to access resources, but not decision-making despite provision being made in statutory and customary systems. When it comes to responsibilities, only the NGOs are carrying out their rather limited role at present. Statutory bodies provide no monitoring role, and no recourse to investigate or check abuses. Although lack of capacity is cited as the reason, there is no expression of political will. Authority is only expressed in a limited way with regards to administration. The local government councillor and local structure that is the link to the councillor – the community development forum – are seen to be extensions of the ruling political party, and so carry political more than functionary power. These bodies express no concern for or interest in or understanding of natural resources, and their sustainable use and livelihood role, but focus solely on their potential or actual commercial exploitation.

Wetland farmers experience numerous difficulties that they cannot solve themselves and that go beyond an individual field, lying in the realm of collective action, together with authority for conflict resolution or exertion of power. It took some years of work with farmers before they have started to take up these issues more actively with authority and as a group, and this is still in an early stage. A number of problems, which are experienced as crises, have become opportunities to work on governance issues of rights, responsibilities and authority and at multiple levels.

Chapter 4

Deriving principles and a framework for indicators of wise and effective governance

4.1. Introduction: Overall Approach and Methodology

In this chapter we describe a participatory approach to understanding governance in order to develop appropriate indicators of *the wise and effective governance of natural resources*. Importantly, as noted in Chapter 2, the literature emphasises the complex and the layered nature of governance. Governance in the context of the work reported herein deals with the rights and responsibilities over natural resources, which includes issues of power dynamics and authority, as well as the values and beliefs that surround this. Also notable is that adaptive, collaborative management is an important aspect of wise and effective governance for natural resources, both with common roots in complexity thinking. There is a strong argument for grounding the development of indicators in robust conceptual underpinnings such that practitioners and researchers need to have developed their own clarity on governance and what wise governance entails as the starting point for both analysis and action. Co-development of this understanding together with stakeholders is itself a key part of the process of engaging in governance so as to achieve objectives of sustainability and equity. In this spirit, the wetlands project has placed a strong emphasis on developing community-based indicators supported by a strong conceptual underpinning. Importantly in this case, 'community' refers to both the wetland users and the practitioners (AWARD) that have been working there. Working in a nuanced and complex *milieu* – from complexity to a requisite simplicity (Holling, 2001) – is challenging but is what indicator development demands. The emphasis on local meaning is also a warning against developing a long comprehensive list of indicators against which data are collected. Rather, an appropriate mix is needed based on a considered framework, with concepts that have appropriate levels of complexity and simplicity for use with participants.

The overall approach, hierarchical in nature, consisted of developing a vision together with principles and objectives and, where appropriate, also deriving indicators. In the case of governance this last step was not completed given the considerable delays in the land tenure reform process (by government). This process should have provided the scaffolding, against which the derivation of principles would have been developed. However, it is behind schedule and at the time of writing it appeared that key legislation may be revised. However, considerable effort was invested in understanding, together with the community, the nature of governance and in developing heuristic tools which, we believe, will greatly facilitate the development of indicators once the reform process is ready. This chapter presents an overview of the process of developing a vision, principles and heuristic tools.

4.2. Understanding Governance

The overall objective – or vision – for the governance component of the wetlands project is *to support wise and effective governance of the wetlands and natural resources*[15] *of Craigieburn, and to share these*

[15] The focus of governance was expanded beyond wetlands alone because wetland governance is undertaken within the broader realm of land and natural resources governance in and around Craigieburn (i.e. wetlands are part of a wider system and are managed as such).

findings more widely. The development and testing of indicators was thus undertaken with this objective in mind and with specific emphasis on the concepts of *wise, effective governance of natural resources in communal lands*. Thus the overall approach was to 'unpack' these central concepts, their underlying principles and from these findings to develop a framework that could be used, together with key principles and questions, as a heuristic to support work of this nature. Indicators can then be derived through a participatory process with the community using the framework to guide the process.

Governance was discussed in detail in Section 2.2, and the characteristics of governance of natural resources in Craigieburn – as well as the wider factors operative beyond the physical boundaries of the village – were described in Chapter 3. Nonetheless it is useful to summarise and reflect on the key characteristics and the findings as a backdrop to this chapter's work.

As pointed out in Chapter 2, definitions of governance vary widely, and depend upon the context in which it is being used, such as in the case of nation states and sovereignty, financial markets, transboundary resources, property, or social relations. In this work the context is governance of natural resources which is not a well-understood field. Importantly the term *governance* is often conflated with other terms such as 'management' – which is only one aspect of governance, or with 'government'. Indeed governments are engaged with governance – but they are only one of the institutions and actors involved. In essence, ***governance*** is a socio-political process to manage affairs. It thus encompasses the relationships between people and the rules and norms that are set up to guide these interactions. It operates at a number of nested as well as independent levels. *Management* on the other hand, refers to the implementation of actions aimed at achieving a particular agenda. Management is not the same as governance although the same body could be involved. Another term that is rather narrowly interpreted is that of institutions, often thought to refer only to organisations. However, in the literature on property regimes *institutions* are defined more widely to include not only organisations (e.g. catchment councils; chieftaincies) but also the associated statutory and local instruments (i.e. the rules, the law and the courts). In essence then, institutions regulate the way an individual, or a group, interacts with another, or a resource and includes sets of rules actually used by people to organize repetitive activities (e.g. marriage). The governance of natural resources – the socio-political process – involves the power, processes, rights and responsibilities that are associated with making and enforcing the rules that guide society in relation to natural capital. The vision of *wise and effective governance* encompasses one of enhanced livelihoods and also ecological sustainability. *Wise* governance will understand and seek to balance the immediate needs and rights of people, sustainable use of natural resources, and the rights of future generations to a healthy environment. *Effective* governance will responds to issues through a feedback process involving action to solve problems. It thus seeks to work cooperatively across levels.

The extensive range of institutions that govern natural resources – from international law to local rules – are rarely uniquely present. Importantly for communal wetlands and natural resources in general, this situation of overlapping 'laws' is referred to as ***legal pluralism*** and is an almost ubiquitous characteristic of natural resource governance systems in many countries including southern Africa (Pollard and Cousins, 2007). Legal pluralism recognises that only rarely is a resource subject to one institution. For example, in theory natural resources may be governed by the formal laws of the land, but in practice their day-to-day use and management is subject to local 'rules of the game' and is more often a blend of customary and statutory systems (see Chapter 3). Thus, governance of natural resources involves community structures, traditional authorities, civil society and government.

It is apparent therefore that in many cases governance tends to be dealt with somewhat naively but it must be stressed that it is important to conceptualise governance with appropriate complexity in order to arrive at a requisite simplicity (see Holling, 2001[16]). Complexity calls for adaptive management (see Chapter 1), which is characterised by learning, flexibility, feedbacks, and in which collaboration and social learning are important. Working in a developmental or action-research process, developing indicators for 'wise governance for sustainability' needs to be carried out with the relevant people as part of a process of supporting wise use. This will inevitably be a negotiating activity requiring some facilitation. Since governance is complex, it is tempting to attempt to deal with all the important aspects, generating many indicators. However, as we have pointed out, indicator development demands working from complexity to a requisite simplicity. It is wise to select just a few key indicators, for unwieldy lists work against stakeholders making meaning and learning.

All of the above characteristics are evident in Craigieburn (see Chapter 3). Governance is both complex dynamic and is differentiated between residential plots, fields, communal land (the commons). Legal pluralism is widely evident with people drawing on both statutory and 'customary' institutions, although more often this is a blend of the two. Over the past decade governance has weakened considerably and people generally recognise the need for more effective governance, especially with respect to regulation. More recently issues have emerged regarding usufruct rights, with outside entrepreneurial interests (sand mining companies) resulting in inequitable benefit-sharing. An added layer of complexity and uncertainty is evident with land tenure reform which will bring changes to authority, rights and responsibilities of land and hence the governance of natural resources. Support for wise and effective governance must be developed within the context of this changing political environment so as not to work at cross-purposes to statutory law, ultimately rendering people more vulnerable than before. Nonetheless moving forward with this vision has been hindered by the slow rate of implementation and, more recently, suggestions that certain legal instruments are to be revised yet again. Given this it can be appreciated that the development of indicators is a challenging and dynamic process.

4.3. A Framework for Developing Indicators

As stressed in Chapter 1, the development and application of governance indicators should be seen as part of a process of seeking to improve governance and importantly, needs to include those who are willing from amongst users and actors from the nested layers of authorities, from both customary and statutory systems. In summary the process, which is not necessarily linear but rather iterative, involves:

- describing the context (using the suggested framework described below)
- identifying and agreeing on key strengths and problems
- agreeing on principles
- developing a collective vision
- developing objectives, and drawing up plans
- developing and testing indicators (using the framework below)
- exploring possible scenarios
- implementation of plans
- cycles of monitoring, reflection, learning and action.

The context, strengths and problems relating to governance over land and natural resources were summarised in Chapter 3. Further detail was also provided through the development of a framework, developed principally as a tool with which to engage and deepen understanding together with the community and other actors. However, prior to discussing this, we introduce the principles that were

[16] Holling (2001) asserts that "there is requisite level of simplicity behind the complexity that, if identified, can lead to an understanding that is rigorously developed but can be communicated lucidly."

developed together with the community and that guided much of the community engagement. These principles are an important component of developing higher-order indicators.

4.3.1. Principles for wise and effective governance

Building on the original principles defined by LEAP[17] for land rights (Cousins et al., 2007), wise and effective governance concerns itself with the following principles which are interlinked:

1. People's claims and rights to access and to benefit from natural resources, and the basis of these, need to be known and defended.
2. Sustainable use should be understood and defended
3. Prompt response to feedback signals (of problems that need addressing) at a number of levels of governance.
4. Authority must be accessible, exercised and co-operative across levels and plural systems

The rationale for each principle is set out in Table 4.1, below:

TABLE 4.1: Four key principles guiding the wise and effective governance of natural resources on communal land (adopted from http://www.leap.org.za/concept/)

Principle 1 **People's claims and rights to access and to benefit, and the basis of these, need to be known and defended**
It is important to understand that on communal land peoples' rights to land and natural resource use derive from both customary and statutory law – and that these confer significantly different kinds of rights, which are at times contradictory. The equitable distribution of benefits and costs, and sustainable beneficiation, will not happen without active and effective governance, as there are competing interests, immediate needs and power differentials involved. Rights are the basis for seeking equity in society, and they reflect that some people and groups are more vulnerable than others, and need protection by those in authority. Weak and insecure rights undermine achieving equity and motives for working the land sustainably. Rights that are not understood will not be defended, and rights must be defended or they will be lost to the powerful. Rights that cannot be defended against the powerful provide no incentives and no security and rights without recourse are not real. Rights need to be known by people themselves, and known by those in authority – through the layers and levels. Authority is needed where people seek recourse, or for conflict management
Principle 2 **Sustainable use should be understood and defended**
For users and those in authority to carry out their responsibilities with regards to sustainable use they need to have a base of understanding to work from. This need not – and perhaps cannot – be complete, but will be built up through reflexive learning processes. The status of the resource needs to be understood by people who are responsible for its care (Pollard and Cousins, 2007). The resources and their use need to be monitored if the resources concerned are to be protected. When monitoring detects problems, action needs to be taken to defend the integrity of the resource. When decisions are made about resource allocation and use, the health of the resources and the sustainability of these needs to be brought to and taken account of at the decision-making table.

[17] **Leap** (Learning Approaches to Tenure Security) is a voluntary association in South Africa that brings people together to work in a learning approach, to practically explore and recommend appropriate tenure arrangements in urban and rural contexts

Principle 3 **Prompt response to feedback signals (of problems that need addressing) at a number of levels of governance.**
People rights and the status of the resources can come under threat from various quarters – social and environmental trends, seasonal events, or unexpected disasters. Depending on the nature of the threat or problem, adaptive management experience indicates that an operative feedback loop is a key attribute of effective governance (see Pollard and Du Toit, 2009). Lack of response can lead to undermining the legitimacy of authority, exacerbating the problem at hand and creating a negative cycle in people and in the natural system.
Principle 4 **Authority must be accessible, exercised, and cooperative across levels and plural systems**
In addition to existing structures (e.g. Traditional Authorities) and emerging bodies (e.g. Communal Property Associations), new policies also create structures, confer rights and assign authorities over land. Thus not only do the land and resources involved have different but overlapping boundaries, but such reforms lead to overlapping rights, responsibilities and authorities. Mechanisms for communication, collaboration and cooperation that acknowledge this dynamic are required. Land and water are governed by different polices, but wetlands are an intersection between land and water. This adds an additional layer of complexity for governance, because in the face of problems different bodies have authority over water and land resources, Again this must be accounted for. To be effective, those with responsibility for resources need to have the requisite authority to be effective. This delegation needs to be agreed between different authorities at different levels. Authority needs to be considered legitimate to be exercised. Authorities need to be accessible to common people, and to each other. Authorities should not be competitive or mutually undermining, but cooperative.

4.3.2. A framework for understanding governance and describing the context

Given the complexity of governance and the difficulties that practitioners and researchers face in describing 'the governance system' in a particular situation, a framework for understanding governance was developed. The framework was tested both in the field and with a wider stakeholder group and continuously refined over a two year period (see Cousins et al., 2009). The objective of the framework is to provide the tools to enable the assessment of governance within a particular rural context, to inform facilitation, and for the participatory setting of indicators with key stakeholders. The initial framework was developed from two key sources, namely

(a) literature (summarised in Chapter 1 and part of completed and ongoing projects on governance see Cousins et al., 2007; (Pollard and Cousins, 2008); (Cousins and Pollard, 2008)
(b) the contextual profile of governance in Craigieburn as described by our research (See Chapter 3).

In developing the framework, the aforementioned principles were used in the work at Craigieburn as a basis from which people can derive practice to improve governance. In discussing these, local people found it easier to think and talk about governance when the team spoke of rights and responsibilities, benefits and authority. These are four key aspects of governance, and a focus on these collectively enabled people to analyse and work on improving governance systems. A key question, shown in Figure 4.1, underlies each aspect (and additional prompt questions are given in the following section).

Rights	Responsibilities
Benefits	Authority

A key output of the governance project has been the refinement of this simple framework matrix, and its four elements, into an organising framework which is also a heuristic with practical application (Figure 4.1). The heuristic is based on the approach that 'everyone has a body' and thus can easily recall the four elements, as follows

5) the lifted left hand is a universal symbol of power (and ***authority)*** which confers
6) ***rights*** (shown with the right hand);
7) with rights come ***responsibility*** and thus the left leg balances, or grounds, the rights; and
8) with rights (of use) come ***benefits and costs*** which need to be considered (right leg).

In answer to the question of '*governance for what?,*' the vision of ***equity and sustainability*** lies at the heart of governance.

This heuristic can be used to describe the governance context as well as offering a basis for a discussion in deriving indicators (i.e. for planning purposes). Although key questions are indicated, further questions can be explored under each of the four aspects; the most relevant will depend on the situation at hand. It should be used in conjunction with the principles in Table 4.1. As a simple organising diagram it is equally useful for the literate as one can use the body as a reference.

FIGURE 4.1: The body as a simple organising framework for describing, understanding and discussing governance. The framework is informed by key concepts and definitions and well as foundational principles.

As noted, this tool has been tested on a number of occasions. Cousins et al. (2007) describe the framework as applied in Craigieburn village to explore tenure arrangements and what this implies for natural resource management and governance. This framework has guided the action research with a focus on (a) the land and natural resources and the rights and obligations in relation to these resources, (b) the processes and procedures through which rights and obligations are invoked and materialised; and (b) the structures and authority systems which oversee or implement procedures and processes. Two 'layers" were described: the "rules of the game" (what people say is supposed to happen), and the actual practices and social relationships. In general all participants responded very favourably to the discussion and later used the heuristic to remind themselves of the key elements of governance. It was also used as a part of discussions for World Wetlands Day in February 2009 and with the Freshwater group of WWF and Green Trust. It was also introduced to participants in November 2008 in Nairobi at a workshop for hosted by the IDRC, in which a number of practitioners and researchers explored strategic directions for improving development research in Southern and Eastern Africa for IDRCs Rural Poverty and Environment Programme[18]. Here it was used by a sub-group as a basis for discussion and to develop proposals regarding governance of natural resources. Additionally it was presented it at the Regional Meeting of the International Association for the Study of the Commons Regional Policy Forum[19] – where it stimulated a lot of discussion on the importance of 'requisite simplicity' throughout the meeting.

4.3.3. Process for exploring, setting and using indicators

As noted before, the framework can also be used in a "top-down" mode of assessment of governance, to inform research, or the design and facilitation of interventions. In the Craigieburn context the governance aspect of the work has been conceptualised as action-research, and therefore developing and using indicators is being undertaken in a participatory manner. Some of the process of indicator development and testing remains to be done (for reasons discussed earlier), so that what is now discussed is the intended plan of action.

The next step will be to work with stakeholder groups, with a focus on those that have expressed a willingness to work on governance. Such groups will be worked with separately at first (to allow for thinking and negotiation in separate processes, given the nature of power dynamics) and then brought together. The vision, principles and framework will guide the discussions with the framework providing the common heuristic thread. The process will be to go through each of the four aspects (rights, responsibilities, authority, benefits and costs), drawing on the research outcomes and interacting on these to first discuss and then seek negotiated agreement on:

- How is this aspect working, or not working?
- What tells us this?
- What then, are the three key problems (as a tenable number) in this aspect?
- What do we seek to see in this aspect?
- What would tell us that this desired state is taking place?
- Agree on the one or at most two things that i) are most significant and ii) we can see.

It is recommended that between four and eight indicators are agreed on amongst stakeholders, and taken forward into visioning and planning.

[18] "Charting New Frontiers in Rural Poverty, Environment and Natural Resources Management Research for Development in Eastern and Southern Africa Regional Consultation Workshop. Held at the Windsor Golf Hotel/ Country Club, Nairobi, Kenya 24-26 November 2008, *workshop report produced by Jürgen Hagmann, Rachel Rege*

[19] Scaling Up Conservation Practices for Natural Resource Commons in Africa 20 – 22 January 2009, Cape Town, South Africa

When utilising the indicators, visual tools are used to capture and report where on a continuum each aspect is, as a base line and for tracking movement over time. A number of authors (Reed and Dougill, 2003; Reed et al., 2005; Sayer et al., 2006) suggest tools such as polygons, AMOEBAs, webs, pentagons, wheel charts or radar diagrams. Along each "arm" qualitative categorical measures can be used (e.g. 1-5). Such an approach is an advantage for negotiation processes, as a measure is to be placed on the continuum invites expression of opinions, understanding others perspectives, and negotiation to reach agreement. Srivanasan (1990 p.p.48) suggests using the symbols of the environment to mark progress, e.g. along a path going over a mountain for self evaluation. The farmer support programme uses symbols of a traffic light – green, yellow and red – which could also be adapted for this purpose. What is important is that whatever is measured and reflected on over time is the direction of the movement – towards or away from improvement.

4.4. Concluding Remarks

As noted by Pollard and Cousins (2008), governance tends to be dealt with somewhat naively in many cases but it must be stressed that it is important to both conceptualise and understand governance with appropriate complexity so as to arrive at a requisite simplicity, and moreover, so as to develop appropriate and meaningful indicators. We suggest a hierarchical, participatory approach and offer principles and frameworks with which to do this. Like many situations in South Africa at the moment, governance over land and natural resources is in a state of flux due to policy transformation, contestations over power and the slow rate of reform. In such circumstances it is advisable to note the challenges posed by such change and to work in an informed and judicious manner. It is particularly important to note that in such circumstances there are no 'blue print' indicators. Rather it is the process of describing the context collectively and arriving at agreed vision and principles that is more likely to lead to tenable indicators that have meaning locally and build adaptive capacity.

Chapter 5

Deriving principles and a framework for indicators of sustainable wetland use

5.1. Introduction and Objectives

A major focus of the work in Craigieburn has been on supporting sustainable practices – and hence indicators – that farmers could use at the scale of their agricultural plots. Additionally, farmers and residents have been supported to think 'beyond the fence' so as to consider the wetland system – and the micro-catchment – as a whole. This is because, in many wetlands such as Craigieburn, threats to wetland integrity come from beyond the plot scale. In other words, farmers may be employing entirely sustainable practices within their plots (see Table 5.1) and yet the wetland may continue to degrade. This is principally because of (a) the practices on the surrounding hillslopes and (b) because of the role of instream headcuts in wetland health and how they are formed and propagated. Not only do these wetlands occur in naturally eroding landscapes, in which hillside erosion and instream headcuts are a fairly common feature (see Pollard et al., 2007 for more details) and thalweg levels have experienced at least three different stages (Ellery and Kotze, 2008), but also downstream practices may create a headcut that propagates upstream if not controlled. This is clearly beyond the control of the wetland users alone and can only be addressed if villages form part of governance structures that extent beyond the village scale.

Thus whilst micro-catchment scale assessments are essential, the development of indicators for such an assessment is beyond the scope of this report[20]. Nonetheless, other assessment methods are available such as those detailed in Section 2.3. It is also suggested that the principles outlined below, informed by a global understanding of ecological health and soil and water conservation practices (see Chapter 2), are considered sufficiently robust to apply to upland areas as well.

The overall objective for this component was to track change in wetland health – and specifically the direction of change – as a result of changing land-use practices. Within this, two objectives guided the development of plot-level indicators, namely:

a. to track land-use change as part of an appraisal process; and.
b. to support farmers in a process of self-assessment.

From the practitioner's perspective, the need to track change over the length of the Farmer Support Project (FSP) was recognised and, at the same time, farmers have needed to assess change against a collective vision (Du Toit et al., in prep.). Indicators can fulfill all of these functions if chosen well (Reed et al., 2005). In this chapter we describe the approach to and development of indicators for sustainable wetland-use practices. In keeping with the blend of 'top-down' and bottom-up" (see Chapter 2), this work placed considerable emphasis on developing community-based indicators[21] supported by a strong conceptual underpinning. Depending on the objectives, more formal assessments are possible using WET-SustainableUse (Kotze, 2009) and WET-Health (Macfarlane et al., 2007; see Chapter 2).

The overall framework (see Figure 1.3) was central in guiding the process for each of the components. Equally useful was the more detailed biophysical systems diagrams developed as part of Phase 1 (Figure

[20] A holistic framework is currently being developed for Craigieburn.
[21] Importantly in this case, 'community' refers to both the wetland users and the practitioners (AWARD and others) that have been working there.

3.3). This indicates the linkages between various characteristics of a healthy wetland, and in particular those identified by farmers, namely erosion, desiccation and a loss of fertility. Central to this model is plant production which farmers consistently use to assess the health of the wetland, albeit indirectly. For farmers, declining plant/ crop production indicates declining soil fertility (i.e. health) and hence wetland health. Although initial efforts focused on the use of plant production as a proxy for wetland health, it must be recognised that a number of constraints may confound a direct extrapolation and these are discussed at some length below. Ultimately the underlying assumption of this work is that wise land-use practices will result in improved wetland health although the degree of improvement cannot be quantified and is dependent on a wider range of factors (see Figure 1.3).

5.1.1. The use of wetland production as a proxy for soil and wetland health

Not only is plant production the key 'indicator' of soil (and wetland) health used by farmers themselves, but also by some researchers and therefore this particular indicator merits some discussion. Indeed, the close link between plant production and soil health is emphasized strikingly by Doube and Schmidt (1997) who contend that soil health is a plant-driven concept, and the most relevant and measurable parameter for soil health is long-term plant productivity (without environmental damage). They therefore adopt a plant-driven definition of soil health[22]. They point out that estimates of optimum long-term, net primary productivity of a soil are dependent on the particular plant species in question and argue for a species-based definition of soil health. "The search for a universal definition of healthy soil which is independent of plant species creates an array of questions of overwhelming complexity that authors are forced to retreat into platitudes, analogies and generalities. With a species-based definition, soil health can be quantified, and so the measure is useful, even if only a limited way (Doube and Schmidt, 1997: p. 269).

The attractiveness of using a single measure as a proxy for wetland health is that health has many dimensions which, if integrated into one measure, can be monitored more expediently than might otherwise be the case. However, whilst yield integrates several factors, some of which are related to soil health, others (such as climate variability) are not. Therefore as Rapport et al. (1997) point out, it is import to consider the impact of non-soil factors on yield changes before drawing conclusions regarding soil health. Two principles underscore this caution:

- Plant production is potentially affected by factors additional to the wetland health (e.g. crop diseases).
- Wetlands and the primary production that takes place in wetlands are naturally dynamic. They respond to external events that happen at varying temporal and spatial scales, such as daily or weekly storms, seasonal flood events or long-term climate cycles (operating over decades, centuries and millennia), as well as the geological and geomorphological evolution of the landscapes in which they are found.

Taking the plant-production-as-a-proxy approach, a dramatic decline in the production of crops may lead one to conclude that there had been a corresponding decline in wetland health. On closer examination this may be attributed to other factors such as crop disease, or from a succession of dry years, which is entirely part of the natural dynamics of the wetland. In both cases the conclusion would have been spurious. Consequently, wetland production as a proxy for wetland health is only useful if there is a sound understanding of the different factors that potentially affect production and that these are taken into account. Thus, using plant production as a proxy for wetland health is not as elegant as it may first

[22] "Healthy soils are those in which the capacity of plants to convert sunlight and CO_2 to structural carbohydrate (i.e. the capacity to grow) remains near the upper limits of potential productivity (set by environmental constraints) over an extended period (years) (Doube and Schmidt, 1997: page 269)."

appear. It is further open to misuse. If, for example, a dam is used to irrigate crops in a seasonal wetland, (where plant productivity naturally fluctuates considerably), the sustained production may lead to a conclusion of improved wetland health. This assessment is clearly open to question.

Additionally, production may change in a way that does not signify improved wetland health. For example, a shift from a multiple-species to a single species vegetation type may occur, either maintaining or increasing overall production levels (e.g. *typha capensis* which, with increased nutrients, outcompetes other species). This loss of species diversity may constitute a dramatic change from the reference composition, resulting in major loss of high value craft species such as *Schoenoplectus brachyceras* (higher than *T. capensis*). According to production alone, this scenario would be considered to be one of increased wetland health which would be false.

A further issue is the time lag for plant production to respond to deterioration in the other aspects of health. For example, the early stages of gully erosion may have little effect on production but may be indicative of a trajectory that will lead to a dramatic decline in future. Thus it may be more appropriate to select additional indicators that provide early-warning signs of declining wetland health thereby allowing for a timeous management response (see Section 2.1.4 on Thresholds of Potential Concern).

5.2. Overall Approach for Developing and Testing Indicators

The approach to developing indicators followed that described in Chapter 4. This involved included refining the systems diagrams (e.g. Figures 1.3 and 3.3) the development of a farmer-based vision coupled with core principles and a framework, and associated indicators. The framework was used as a heuristic to aid in the development and use of indicators. An iterative process of development, testing and refinement through a blend of local knowledge and specialist inputs was used, focusing on the plot-scale and to a lesser degree, the wetland scale. Each indicator was supported by a description of the underlying rationale which was discussed with farmers and, where possible, upper and lower ranges were assigned to each indicator.

5.2.1. At the Plot-scale

At the plot-scale a number of key steps were undertaken as follows.

1. Delineation

As a starting point it was important for farmers to characterise the wetland from their perspective (i.e. so that it has meaning for the users themselves). Farmers quickly pointed out that conditions differed according to three eco-zones in the wetland, sometimes with different practices, and through facilitated discussions, described each zone.

2. Underlying principles

Drawing on knowledge of soil and water conservation in wetlands, a participatory process was used to develop core principles underlying wise practices for wetland health and livelihoods. Although reference is made specifically to wetlands they apply equally to sustainable use of micro-catchment.

3. Indicators

Based on each of these principles, indicators were developed, tested and refined in the field through a number of iterations over a three-year period. The same indicators were developed for both objectives (see above) to facilitate continuity and integration. A preliminary set of indicators were derived in 2005 from the existing landuse practices together with the above principles. The rationale for each was examined in detail. These 18 practice-based indicators were used in a process known as detailed appraisals conducted in 2006. Once refined, a reduced set of indicators was used for subsequent rapid appraisals in 2007 and 2008 (see Du Toit et al., in prep).

The detailed appraisals involved visiting and assessing each field together with the farmers. Detailed notes were taken of practices and underlying reasons as well as the farmers' understanding of the impacts of each practice on wetland integrity and crop yields. The rapid appraisals involve an abridged version – an important consideration in cases where time and budget are a constraint. The three annual rapid appraisals, undertaken between 2006 and 2008, allowed for further refinement. The rapid appraisals focused on fewer fields (between 20 and 25) and were undertaken by a practitioner. Importantly each zone was assessed so that a total of between 60 and 75 assessments were taken.

A final step in was to assign thresholds (upper and lower ranges) for each indicator (see Section 2.1.4). This is because, as described in Chapter 1, variability is an important characteristic of ecosystem resilience and single-value management objectives have been severely critiqued for their failure to incorporate system dynamics. Recommending and setting thresholds was based principally on a review of the literature or, in some cases, from field-work in Craigieburn.

4. Requisite simplicity and the development of a heuristic

Over time it became clear that given the complexity of information (the interactions between a wide range of landuse practices, and the multiple links between cause and effect, as well as cross-scale effects), a clearer and simpler approach was needed for work with the farmers. This led to the development of a framework to help organise and structure ideas, ultimately used as a heuristic for understanding wise wetland-use practices as well as indicators thereof. Additional indicators were also developed and tested over the course of the work. It is important to note that whilst the principles are widely-applicable, the indicators apply specifically to within wetland plots (i.e. not beyond the plot fence).

5.2.2. Beyond the plot

A critical step in supporting natural-resource users to consider the system as a whole and hence the linkages between components of the system is to start by mapping the area[23]. If community involvement and buy-in are fundamental to the aims of the work, this should be done with or by them, following some basic training.

Nonetheless, at the start of the work in 2005 each farmer worked autonomously with little sense of group interaction. Although clusters of farmers were formed under the Farmers Support Programme to initiate a process of collaboration, information-sharing and trust, farmers still expressed concern at being seen to be examining areas beyond their own plot. This was regarded as akin to spying. Given that fears of witchcraft are very real, the development and testing of indicators at the wetland-scale has been constrained by such considerations and is still being refined. To date the underlying principles have been discussed with farmer clusters and at community meetings as a process of trust-building.

[23] The objective of the mapping exercise is to note the key bio-physical features such vegetated and cleared areas both within the catchment and wetland, erosional features, the location and orientation of plots within the wetlands, major topographical changes, the presences and status of headcuts within the wetlands and the extent and status of wetland vegetation.

One of the major gaps in information data on soil fertility, in that discussions with farmers regarding the inherent soil-fertility properties at Craigieburn – and hence the anticipated trajectories – were uninformed by any baseline data. Thus a soil fertility assessment was done as part of the project (see Chapter 3).

5.3. Development and Testing of Plot-Level Indicators

5.3.1. Delineating eco-zones in wetlands

Describing and understanding the eco-zones that occur in wetlands is an important step because not only do the biophysical properties differ, but so sometimes do the landuse practices. For example, whilst farmers create channels in the wetter zones this is not the case in the drier zones and hence the associated indicators would only apply to the former.

Through a participatory process, the wetland users identified three eco-zones that made sense to them (Figure 5.1). The defining characteristics of these, called A (permanently wet), B (seasonally wet) and C (wetland bank – temporarily wet) were delimited and described (Table 5.1). These zones are not dissimilar to the zoning currently applied in South Africa[24]. The process of working with farmers involved the recognition of these differences and the subsequent design of activities that are appropriate for rehabilitating each.

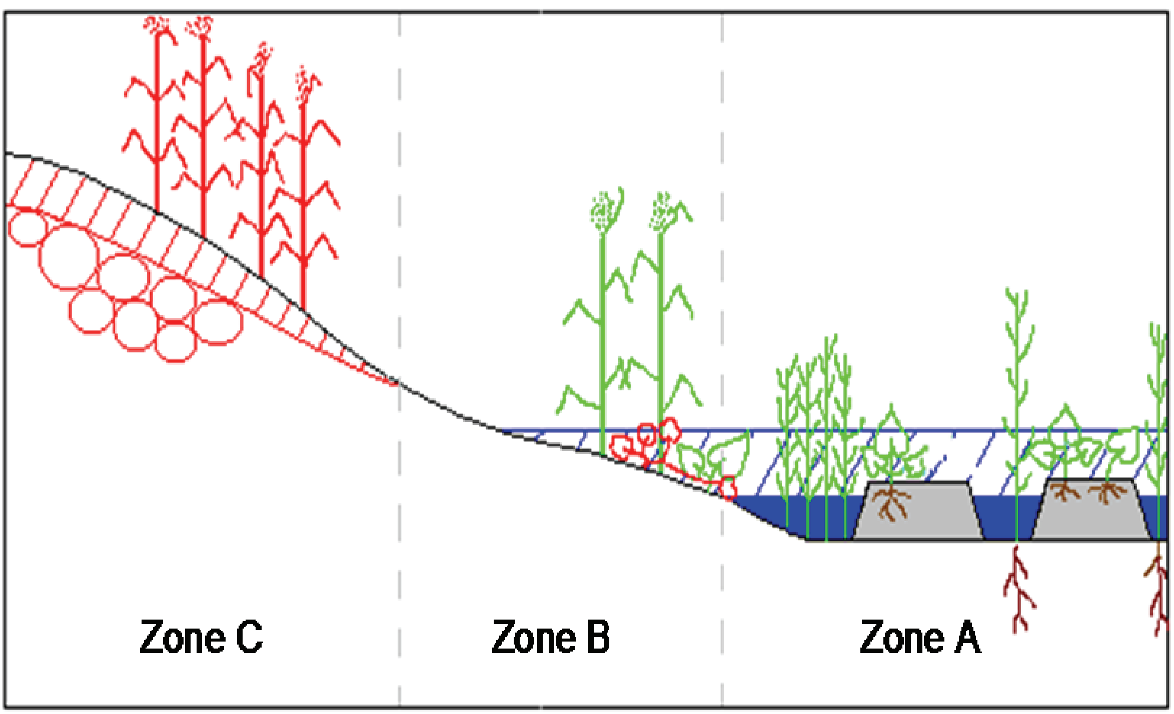


FIGURE 5.1: Three Eco-zones delineated by wetland farmers in the Craigieburn wetlands

[24] The DWAF guidelines for wetland delineation, which is currently under revision, also recognizes three zones but in their case Zone C is the permanently saturated zone whilst Zone A refers to one which is 'seldom saturated' (and Zone B is 'quite often').

TABLE 5.1: Eco-zones and defining characteristics as given by wetland farmers

Zones	Defining characteristics	Current status as described by users
A: Permanently wet	• Always water underfoot • Normally flat gradient • Presence of reeds (Leshako *Schoenoplectus corymbosus*, Lehlakanuko *P. mauritianus*) • Suitable for Maropi (*C. esculenta*) and some other crops that like water • Does not need to water	• Cane rats and snakes are problem • Gets water from the river • Leshako and Lehlaganuko present • Risk of crop flooding during heavy rains
B: Seasonally wet	• Wet soils are apparent if one digs; in rainy season it can be wet underfoot • Presence of reeds (mainly Lehlakanuko) • Suitable for Maropi and also other crops that don't need standing water	• The place between the wet zone and dry zone • Sometimes wet, sometimes dry • Water from rain and sometimes from A • Important because many different things grown • Soil forms lumps with white and red spots
C: wetland bank – temporarily wet	• Sometimes reeds but very few • Normally steeper • Sandier • Area suitable for maize	• Gets water from rain • Skekenini (*Richardia brasiliensis)* is main problem weed, and molwane (witchweed) • Kwiti (moles) are a problem • Shallow soils • Soils get tired quickly • Gogulegu (erosion)

5.3.2. Core principles and indicators

The core principles which are elaborated later and which formed the basis of all work, included:

1. the management of water so as to maintain soil moisture (and SOM) and soil stability;
2. the control of soil movement and erosion so as to retain soil moisture, SOM and nutrients;
3. the management of soil health so as to sustain plant growth and biological activity; and
4. the maintenance of indigenous plants (both functional and biodiversity aspects) which are essential to maintaining the key characteristic of wetlands.

The following principle more concerned with agro-ecology, was added, namely:

5. The selection and management of appropriate crops.

The preliminary set of 18 practice-based indicators is shown in Table 5.2, and the eight core indicators in Table 5.3. Each indicator has been formulated as a question. The core indicators were selected for testing and refinement through the rapid appraisal process and for self-assessment by farmers. These offer a potential set of principle-based indicators for future use. The motivations and ranges for each of this are detailed in Table 5.3. In general these core indicators can be applied at any time of the year and in any of the three zones unless otherwise indicated. The additional indicators shown in Table 5.2 add to the overall assessment but it must be noted that they are season-specific and thus only applicable at certain times of the year. For example, the practices of burning of field residues or the extent of tillage almost always take place at the time of field preparation (in Craigieburn this is around October but may start as early as September or extend into November).

An interest in agro-ecology will require an additional assessment of practices associated with crops. In some cases the type of crop is placed under scrutiny but any suggestion of changing crop type should be undertaken with caution and resistance to change should not be underestimated. Crop selection is a function of habit, preference and markets amongst other factors, so whilst it may appear to be sensible to practitioners to replace a crop, the fact that people do not like the crop, and hence will neither consume nor be able to sell the crop weighs heavily against change.

TABLE 5.2: The overall framework for sustainable practices within wetland plots in Craigieburn wetlands, together with the five principles and their associated indicators which are posed as questions to facilitate use. Highlighted rows indicate those that can be used throughout the year and hence constitute the core indicators, whilst others are only apply at certain times of the year. SOM = soil organic matter

Area	Principle	Indicator (as a question)	Comments
1. Water	Proper management of water is required to maintain high moisture and high SOM	1.1 Is there effective contouring?	Only Zone C
		1.2 Does bed orientation slow run off?	Only Zones A, B
		1.3 Are the furrows blocked?	Only Zones A, B
2. Erosion	Control of soil movement and erosion so as to retain soil moisture and SOM	2.1 Are the furrows steep (<1%)?	Mostly Zone A, B
		2.2 What is bed height (>40cm; 40-21cm; 20-0cm)	Mostly Zone A, B
		2.3 What is the extent of soil that is denuded?	
3. Soil health	Management of soil health is key for sustaining plant growth and biological activity. Soil health is a function of physical and chemical properties – many of which are a function of SOM	3.1 Is topsoil present (SOM)?	
		3.2 Extent of mulching?	
		3.3 Are there nitrogen fixing plants?	Seasonal (cropping season)
		3.4 How much live cover?	Seasonal
		3.5 Is there evidence of burning residues	Seasonal
		3.6 Extent of tillage	Start cropping season
4. Wetland plants	Wetlands derive their character from presence of wetland plants and a proportion of these should be maintained	4.1 Extent of wetland plants	
		4.2 Diversity of wetland plants	
5. Crops	Selection of appropriate crops and their management to support above conditions for wetland health and sustainable livelihoods	5.1 Is there evidence of intercropping?	Seasonal (cropping season)
		5.2 Are there weeds?	Seasonal (mainly fallow)
		5.3 How much high-water demand crops?	Seasonal (cropping season)
		5.4 How much water tolerant crops?	Seasonal (cropping season)

With respect to the issue of crops and wetland plants, one of the indicators of soil fertility that was selected by farmers was that of weeds. However, given that interpretations of 'weeds' exist, it is important to discuss this issue with farmers early in an initiative designed towards sustainable wetland use. This is because there are diverse – and discipline-specific – interpretations of weeds with agronomist often categorising all non-crop species as 'weeds', whilst ecologists tend to be more conservative in their designation of a plants species as a 'weed'. Initially for example, indigenous wetland reeds were simply termed weeds but later the definition was changed to refer specifically to invasive (sometimes alien) plants found on disturbed land that is often low in nutrients. From this definition a number of weed species were regularly mentioned by farmers as indicative of poor soil fertility. These included:

- Skekenini – *Richardia brasiliensis* (Brazil pusley or Mexican *richardia*),
- Mošitša – *Bidens biternata* (Blackjack), and
- Mulwane – *Striga asiatica* (Witchweed).

Less frequently mentioned was a plant called Sihlabani Sihlabani – *Hispidum* sp. (starburs).

Both *R. brasiliensis* and *B. biternata* were introduced to South Africa from South America, whereas *S.asiatica* is indigenous to South Africa. *R. brasiliensis* and *B. biternata* are identified by numerous authors to be prevalent in cultivated and disturbed areas (see Appendix A). Most maize crops, both in the wetland and in the upland plots showed a moderate to low infestation of *Striga asiatica*. *S.asiatica* is a semi-parasitic plant on maize, sorghum and sugarcane; it has bright green to yellow-green leaves and brilliant orange-red to red flowers and is known to suppress maize growth (see for example http://cenchemrawn.wordpress.com/2007/12/ *Maize gets help from its neighbours*). A number of other weed species were common in the cultivated plots, such as *Ageratum conyzoides* (Blue weed or invading ageratum), *Commelina benghalensis* (wandering Jew), and a species of the genus *Oxalis* (Sorrel). Many of these are potential indicators of areas of poor soil health. For a fuller review of the weeds see Appendix A. A survey of the most common herbaceous plants was undertaken in November 2008 (Appendix B).

5.3.3. A framework for using indicators as part of a learning process and support for farmers

In 2006 The Farmer Support Project set up a learning-action process with some 60 farmers and although numbers swelled to 120 over the next two years not all farmers remained active throughout. A core of 60 farmers formed the backbone of the project. So as to facilitate the learning process, they were divided into 5 clusters based on the geographic locality of their fields in the wetland (see Du Toit et al., in prep).

Given the detailed and complex information, a key advance was the development of a framework for soil and water conservation, based on the aforementioned five principles (Figure 5.2). The framework – known as the "hand of change" – was used as a heuristic to organise key concepts, support learning for change and for the development of indicators. Like the heuristic for governance, the approach is that 'every farmer has a hand," and can thus be used to aid recall of the principles. The main objective in the case of the Farmer Support Project was to examine land-use practices and their link to wetland health. Wetland health is now understood by farmers according to the five fingers framework. Linked to each of these five areas are key land-use practices as well as indicators.

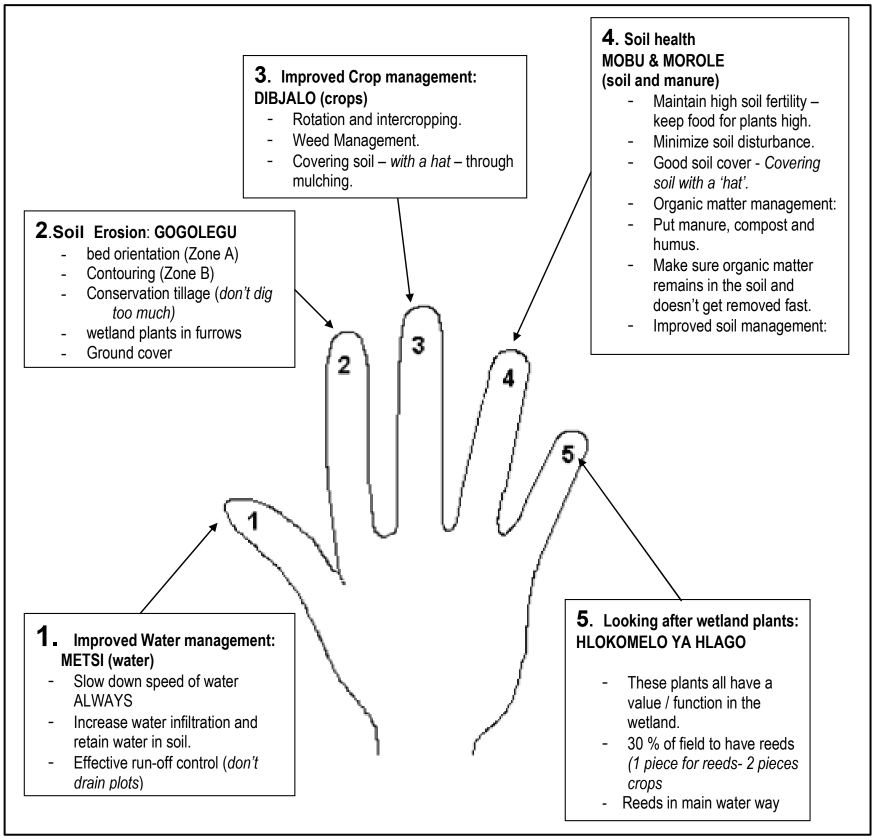


FIGURE 5.2: The Five Finger Framework show the five key areas for wetland management that are the starting point for the learning process. Each finger represents an aspect of the wetland that farmers can engage with through action projects

5.3.4. Self-assessment: Testing plot-level indicators for self-assessment by farmers

In order to support reflexive practitionership, farmers were encouraged to assess their own practices in terms of sustainability. The above indicators were then used as the basis for self-assessment by farmers but using a modified approach to accommodate lower literacy levels than that required for the appraisal process. This process was tested in December 2008 at the start of the rainy season when field preparation was already underway.

Each of the indicators from the appraisal form was simplified and translated into vernacular (Figure 5.3). The three response categories for each of the indicator questions were represented as red, orange or green (see example in Figure 5.4) – using the metaphor of a traffic light. Farmers were then assisted with rating their own practices in relation to each of the questions. The farmers responses where then translated into coloured cards for each question and discussed with the farmer in the following way:

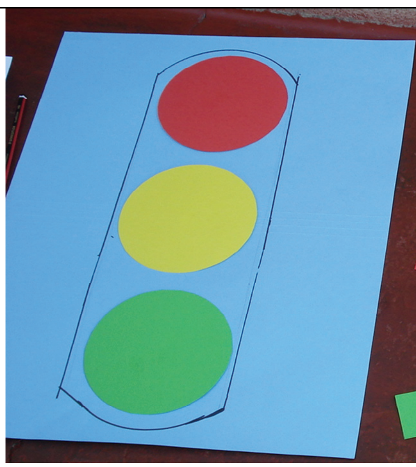
- Red card: the practice that the farmer is involved with is damaging the wetland and is unsustainable. The farmer should think of ways to change the practice over the next growing season

- Orange card: the practice is not yet damaging but there are signs that the practice can become problematic and unsustainable over the long run. The farmer needs to consider options for improving the situation or the practice
- Green card: the farmer is being responsive to the context and is engaged in sustainable practices. The farmer should continue with current practices but evaluate the situation from time to time.

In this way an individual farmer was able to get a sense of how sustainable (both generally and specially) his or her practices are.

	Wetland	Indicator		√		√		√
1	**Water** ***meetse***	1.1 Does bed orientation slow run off? **Naa go fetola seemo sa serapa go ka fokotša lebelo la Meetse?**	Little **Ga nyane**		Some **tšedingwe**		A Lot **Kudu**	

FIGURE 5.3: An example of how wetland practices, indicator questions are matched with three possible response categories – ranked as unsustainable (red), zone of concern (orange) and green (sustainable).



In an attempt to help farmers understand the concept of sustainability the analogy with a traffic light was used. Those practices that are categorised as 'green' are sustainable and the farmer is encouraged to continue with them, those that are 'red' are unsustainable and the farmer is encouraged to stop. Those that are in the orange category are in the 'zone of concern' and the farmer needs to be aware that they can lead to degradation and unsustainable use. The overall score of red and green cards gives a general picture of practice on a particular field. The scores for each field are used in a formative manner to encourage change and innovation.

FIGURE 5.4: The traffic light as an assessment tool

Data from the assessment process was used in a number of ways. The first and most important application is the formative evaluation conducted with the farmer. Once the assessment was complete, the farmer and facilitator discussed the totals of each colour category in order to get a sense of how the farmer is doing in terms of sustainable wetland management. A high total score for red cards indicates overall unsustainability while high scores for green indicate more sustainable practices. The red cards are an important point of departure for designing future activities (action projects). The data can also be pooled for clusters and for the entire wetland to give a picture of levels of sustainable use.

Figure 5.5 provides an example of the output of such an exercise, in this case the response of 45 farmers to the question dealing with mulching. Whilst 27 farmers said that they mulched their fields extensively, 16 did not, and two said they did to some extent. In such a situation the action of the facilitator is to convince the resource users with practices in the 'red' category to move their practices towards the green category. The trend over consecutive growing seasons would be an important indicator of the progress (or retrogress) towards sustainable or wise wetland use. The outcomes of the analysis were then discussed with individual farmers, clusters and the entire farmer group.

Part of the process of developing the indicators is to ensure that there is an opportunity to reflect upon and refine the questions, together with the users, based on experiences from the field. This process should ideally be repeated after every growing season so that the indicators are made more relevant and appropriate for use. Further issues are discussed in Chapter 6.

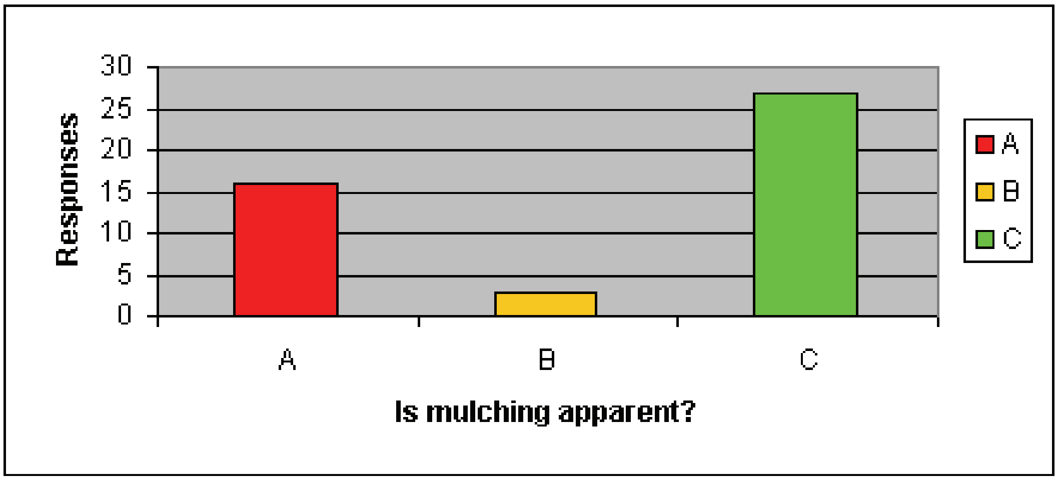


FIGURE 5.5: An example of the self-assessment responses to indicator questions dealing with mulching. A= none; B= some; C= a lot

TABLE 5.3: Core indicators

Discussion on the rationale, thresholds (if available) and recommended practices associated with each of the indicators. The current practices associated with each are discussed in Chapter 3. WRM = water resources management; SOM= soil organic matter; SOC = soil organic carbon; POM = particulate organic matter; CEC – cation exchange capacity. For several indicators, there is lack of clear and unambiguous thresholds, demonstrating how poorly understood relationships are

Indicator	Rationale	Thresholds of potential concern	Recommendation
Water resources management			
1a. What is the bed / furrow orientation? (Zones A and B)	**Orientation** of raised beds and furrows parallel to direction of water flow and **gradient** of furrows that is too steep (i.e. >1%) leads to: a. "Over-drainage" of areas b. Increased surface water velocity a) "Over-drainage" contributes to desiccation of wetland and plant stress. Loss of a saturated soil profile can lead to loss of SOM[25]. When soils dry out, decomposition proceeds more rapidly under aerobic conditions so that rate of loss of SOC increases. The SOC inputs will be reduced when plants are subjected to stressed, dry conditions such as during drought. b) Increased surface water velocity (especially stormflows) leads to increased erosion and reduced sediment trapping.	Relationship between the proportion of correctly orientated beds and soil moisture and stability has not been quantified. Nonetheless, the principle that water should not be artificially drained from wetlands (i.e. anthropogenically excavated drains) and that water velocities should be minimised are important considerations for farmers to address.	Beds re-orientated such that they hinder flow and provide a sinuous path for water to reduce water velocity (It is noted that there is a possibility that a more sinuous path leads to furrows being filled to capacity and spilling across the beds (thereby causing erosion of the beds). However, the erosion threat from straight steep channels is far greater). Bed walls should be inclined and planted.
1b. Zone C – is there effective contouring?	***As above .*** If contours are not dead level, then a slope of 0.4% for standard contours is recommended (drop of 1m for every 250m). Maximum of 1% recommended[26].	Literature suggests that any contour slope exceeding 1% (drop of 1m for every 100m) is cause for concern	Contours and/or ridges laid in field at a grade of 0.4-1 % across the slope. Maximum of 1% recommended
2. Are the furrows blocked?	Failure to block furrows and fully "re-wet" plot (especially when resting) results in: ▪ increased desiccation ▪ failure of SOM to recover ▪ erosion of the channels ***See also rationale for No 1*** Note: Effects of increased water velocity are exacerbated by straight, long channels results in erosion of channels (through increased hydraulic conductivity, lack of root binding and reduced soil strength), and increased desiccation of soils in beds. Soil erosion in channel is a function of soil strength and power of flowing water[27]. In turn, stream power is a	Relationship between furrow blocking and benefits of reduced water velocity and decreased desiccation has not been quantified[28]. In general however, principle is that high proportion of channels should be blocked. Any sign of unblocked furrows especially during the rainy season is cause for concern. Trend should be towards all furrows being blocked. It is a relatively simple intervention and brings the benefit of harvestable resources if indigenous plants (reeds) are used.	Most if not all furrows must be blocked. Indigenous plants such as reeds should not be removed as they are well-adapted to wetland conditions and can provide a harvestable resource. Furrows can be used for crop production but must be blocked by other means after harvest

[25] Mills and Fey 2004
[26] Zimbabwe Farmers Union and Agritex (undated), *A guide for farmers on good land husbandry: Soil and water management. Agritex. Zimbabwe*
[27] See e.g. Sallway et al 1994

Indicator	Rationale	Thresholds of potential concern	Recommendation
	function of shear stress and flow velocity both of which are dependent on furrow hydraulics.		
	Erosion and the control of soil movement		
3. Furrow slope < 1% steep	***Discussed under WRM indicators (see above).*** A slope > 1 % will result in furrow eroding due to water velocity ***(see No 2)***	Discussed under WRM indicators (see above). Furrow slopes approaching 1% are cause for action. Impacts make this land-use practice an important one to be adopted by all farmers.	A slope of < 1 % is recommended
4. Height of beds	In addition to rationale regarding bed orientation ***(see No. 1)***, the higher the bed height the greater the desiccating effect (note also that if furrows are not blocked they are susceptible to erosion. ***See Indicator 1 for effects of desiccation)***	Relationship between proportion of low beds and improved WRM and soil stability has not been quantified. Nonetheless, the principle that bed height should be limited below 40cm (especially in Zone B which likely to dry out more rapidly) and monitored.	Suggested reduction in bed height to <40cm (requires validation). Bed walls should be inclined and planted to reduce desiccation
5. Extent of denudation of soil	Clearing of vegetation and exposed soils lead to: 1. Reduced soil strength and root binding of the soils – more vulnerable to erosion, leading to a loss of topsoil (SOM, including humus) and desiccation. 2. Greater exposure to solar radiation = increased temperatures = a. loss of soil moisture through evapo-transpiration, temperatures and oxidation. b. increased rates of decomposition in remaining organic & humus layer c. Release of N through ammonization and volatilization. d. Mineralisation (thus loss of SOM) 3. Despite sandy soils of Zone C and uplands, there is sufficient fine material in soil for crusting on extensive bare ground, thus reducing infiltration capacity and increasing runoff [29] ***See also rationale of SOM under 6***	Relationship between proportion of covered soil and improved (a) soil moisture and (b) SOM has not been quantified in this study. Nonetheless, mulching has been shown to have the single most important impact on improved soil health (see Chapter 2). Any exposed soil is cause for action. The principle that land and beds should always be covered, especially during the fallow season, makes this land-use practice a critical one to be adopted by all farmers.	Limit removal of cover and/or mulch on all soil surfaces. All soil surfaces must be covered. Particular attention must be paid to ensuring cover during: a. fallow times b. post field preparation whilst crops are growing
	Soil health		
6. Presence and extent of topsoil (organic matter and	SOM – and SOC – are the essence of soil health, because of contribution to soil fertility, soil structure, nutrient and water holding capacity, and to survival, activity and diversity of soil animals and microbes[30]. Presence of organic layer[31] ("topsoil") confers NB properties:	SOC- threshold for most sites is 2% (equivalent of 3.4% SOM), below which most soils (especially sandy soils) become prone to destabilization and yields reduced[33]. However very variable – different soils with different clay contents reach different	There are constraints to measuring SOM (and SOC[36]). Simplest approach – examine for presence and extent of OM[37]. Wetland practitioners should become tuned to trends (i.e. moving from "none"

[28] See discussion in Pollard et al. 2007 which explores impacts of landuse practices
[29] Pollard et al. 2005
[30] See for example Pittaway 2006 amongst others
[31] a) litter layer – larger fragments/ residues of plants and animals + smaller living and non-living products of microbial activity, and b) lower layer = more resilient, non-living humus.

Indicator	Rationale	Thresholds of potential concern	Recommendation
humus)	a) Litter layer protects soil surface (reducing erosion), microbial fraction aids in binding soil particles together (improving soil structure); b) humus[32] binds with soil nutrients to increase concentration available for plant uptake (increasing CEC). Humus also increases water storage capacity (up to 20x their weight). Microbes associated with OM (especially anaerobic microbes) are responsible for toxicant and contaminant removal (e.g. phosphates and nitrates)	SOC equilibria. For soils with 38% clay[34] (like Craigieburn) – lower and upper limits are **3.5 and 4.4%** (Adey & Kotze, 2008). Irrespective of soil type it appears that if SOC content is **below 1%,** it may not be possible to obtain yields[35]	to "a lot"). Animal manures, litter and green manures (short term organic deposits), mulching (tougher material for the longer term organic pool) and co-compositing are all means to improving topsoil.
7. Extent of mulching	***See rationale under No. 5 and 6***	In numerous studies, mulching has been shown to have the greatest impact – relative to other factors – on plant production (see Chapter 2). Thus it is imperative that soil is always covered, either through live cover or mulched. No thresholds available.	Soil must always be covered, either through live cover or mulched. ***See No. 5 and 6***
	Conservation of wetland plants		
8. Presence and extent of wetland plants	Wetland plants[38] are specifically adapted to the water-logged anoxic conditions of wetlands. They perform important functions including: • Flood attenuation • Decrease water velocity and erosion • Water quality enhancement: • Wetlands can trap, precipitate, transform and remove many water-related contaminants – many of these functions undertaken by wetland plants)	Extent of wetland plants- and a minimum value – has yet to be established although a rule-of-thumb of 30% threshold has been suggested. This remains to be verified. Plots that are completely cleared are cause for concern.	Some areas must be left under natural wetland plants but as yet no value has been determined. Delineation of sensitive areas and the exclusion of anthropogenic disturbances in these areas are essential (e.g. areas prone to headcut erosion).

[33] See Krull et al. 2004

[36] Methods to estimate soil health (via POM or SOC) are not readily available for local practitioners – require laboratory tests (carry logistical and financial constraints).

[37] Elliott (1997) points out that particulate organic matter (POM) can be used as an indirect measure of soil health because of its short turnover time.

[32] As noted by Pollard et al (2008) definitions vary. In soil science, humus refers to organic, non-cellular, long-lasting component of soil. It is mostly extremely stable carbon compounds (hence organic) with no phosphorus or nitrogen that resists decomposition by microorganisms. Humus might, if conditions do not change, remain essentially as it is for centuries, or millennia. http://www.suprahumic.unina.it/). In agriculture, "humus" is often used simply to mean mature compost, or natural compost extracted from a forest or other spontaneous source for use to amend soil.

[34] Korschens et al (1998)

[35] Kay and Angers 1999

[38] In the eastern, lowlands of the country are the sedges, rushes and some of the grasses. For example, the sedge *Schoenopletus crymbosus* (Leshako) and the reed *Phragmites mauritianus* (Lehlakanoka) are characteristic of wetlands in the area and are well-known by all. *P. mauritianus* can "invade" in areas of fast flow, high O^2 conditions

5.4. The Wetland System: Indicators 'beyond the plot fence'

A wetland-scale assessment is important for two key reasons. Firstly, it creates a sense for farmers that they and their plot-level practices exist within and are linked to a wider system (the wetland and the catchment). In early work in Craigieburn this was clearly not the case as farmers only occasionally considered that their plot-level actions impacted the wetland as a whole and equally, that actions in the wetland and beyond impacted on them at the plot level. Secondly as explained earlier, the situation in Craigieburn and in many other wetlands is such that a number of threats to wetland integrity come from beyond the scale of plot, principally from the surrounding micro-catchment landuse practices. Although the focus of the Farmer Support Project was on farmer practices within their plots, a framework based on similar principles and rationale to those outlined in Section 5.4 was developed for soil, water and plant management. Depending on ones objectives, a more formal assessment is possible using one of the methods suggested in Section 2.3. In addition to plot-scale principles, a fifth principle was added, for use at the wetland-scale, namely: The protection of sensitive areas within or around the wetland.

Once the area is mapped (see earlier), the condition of the wetland can be described using the same principles outlined at the start of the chapter. These together with potential indicators are given in Table 5.3. Although this process is still underway in Craigieburn, the following approach is suggested. It is best to subdivide the area into natural clusters to facilitate the work. Nonetheless although people may describe the cluster in which they work or with which they are familiar it is essential that they visit all areas to get a sense of the wider condition, issues and threats. Many of the features outlined in Table 5.3 can be noted on a map and rated on a simple scoring system. However, measurements for gulley widening and headcut progression are necessary. Headcuts can be marked with a readily visual stake and tracked over time. Fixed point photography for each of the features is also an advantage if available.

TABLE 5.4: A preliminary framework, based on core principles, for assessing the integrity of the wetland as a whole. Some potential indicators are listed. These principles are considered sufficiently robust for use at the micro-catchment scale.

	Area	Principles/ consideration	Potential indicators
1	**Water management**	Soil moisture maintenance and stability is critical, therefore: • Vegetation should act to slow water velocity. Assess the extent and cover of vegetation (Note the location (wetland, hillslope), dimension, status (active) and source) • Plot location, position and bed orientation both in the wetland and on the hillslopes must act to slow water and increase infiltration	Extent of cleared areas Footpaths and roads act to channel water and increase velocity
2	**Soil movement and erosion**	Control of soil movement and mitigation of erosion is essential, therefore: • Assess headcuts location and status (active) – is this an advancing headcut? • Assess gulley location, dimension and status: Is this a dynamic gulley (is it active/ incising or filling)? • Assess sediment deposition, sheet erosion, rills; (Note the location (wetland, hillslope), dimension, status (active) and source) • Assess field and plot location	Movement of headcut upward or laterally in stream channel Dimensions- gulley is widening or lengthening over time Sediment deposition within gulley (filling) Undercut banks to gulley (incising) Presence/ absence of sediment, sheet erosion, rills; Extent of the above Are fields located upstream and/or close to headcuts?
3	**Soil health**	Management of soil health is key for sustaining plant growth and biological activity. Soil health is a function of physical and chemical properties – many of which are a function of SOM • Soil fertility	See Table 5.2
3	**Extent and diversity of indigenous plants**	Maintaining vegetational cover in the micro-catchment and wetland plants is essential to soil moisture, fertility and sediment control, therefore; • Assess extent of indigenous vegetation and trend if change is evident. Of the total wetland area, the proportion that has been converted to another landuse should be determined • Assess diversity of indigenous vegetation • Evidence of practices regarding burning of residues. Burning of crop residues likely to have much more severe consequences than burning of standing litter in natural vegetation, with the latter possibly having very little effect on SOM levels. • Assess noteworthy species (e.g. protected or sensitive species if applicable).	Extent of indigenous vegetation (% of total) per sub-system (e.g. wetland zones, hillslope rangeland) Changes in extent (e.g. from aerials) Diversity of indigenous vegetation (if needed) Changes in extent (may not be possible)
4	**Sensitive areas: "no-go" zones**	Identify sensitive areas, e.g.: • Acid and P limited • Headcuts	See above

5.5. Comments on Indicators of Soil Fertility

As noted at the start of the chapter, farmers have various ways of assessing soil fertility (often their major concern), using mainly crop yields as the primary indicator. However, it was also noted that baseline soil conditions need to be understood in order to derive appropriate indicators and hence sustainable landuse practices. Results indicated that soils at Craigieburn are generally, acidic, deficient in phosphorus, potassium, nitrate and zinc and have little organic carbon (see Chapter 3). This is important information without which farmers inevitably set goals that are not achievable. For example, high soil acidity will affect plant yields not matter how sustainable the landuse practices are and additionally, are likely to drive certain practices in the quest for improved yields. Thus understanding soil acidity and nutrient deficiencies based on key indicators may prove invaluable to farmers. Some suggested indicators, together with their thresholds and rationale are given in Table 5.5. These remain to be tested in the field.

Box 5.1
Litmus paper to test soil acidity

Litmus paper is an inexpensive way of measuring pH in the field. It employs strips of paper that change color based on the pH of a sample solution. The strips come in a variety of resolutions, from simple acid vs. base comparison (turning red or blue, respectively) to much finer distinctions. The colours are indicated on the package and vary for different pH ranges and manufacturers. Before using the litmus paper, a soil sample must be prepared. To do so, take a sample of the soil, crush any clumps, and close it in a jar filled with distilled water. Shake vigorously and leave for 10 minutes to let any soluble substances dissolve and solid particles settle. Next place a drop of the solution on the litmus paper and compare the colour to the reference colours given on the package.

The rationale and motivation is summarised in Table 5.1 whilst Appendix C offers a visual assessment.

TABLE 5.5: Summary of indicators and thresholds of soil fertility and their underlying rational (see also Appendix C)

Indicator	Current status	Rationale	Field indicators	Threshold
		Soil acidity		
Acid saturation	Very acidic soils (Acid Saturation is 45%). Mean PAS for Craigieburn = **17** and thus only maize will tolerate acidity of the soil.	Acid Saturation level used to determine if a particular soil is too acid for adequate growth of crop in question, and thus application of lime is necessary. Acidity of soil means that they are generally susceptible to nutrient deficiencies and this will impact on crop yields. Permissible acid saturation (PAS) is highest level of acid saturation that a particular crop will tolerate without adversely affecting crop yield (see Table 3.4). Mean PAS for Craigieburn is 17, thus of all crops grown, only maize will tolerate soil acidity, sweet potato and sorghum doing potentially much better than crops such as pumpkin, onion and cabbage. Generally lime would be needed.	Litmus paper – inexpensive way of testing pH in field (see Box 5.1). However, many farmers know which areas of land are of poor fertility; this is most often due to low nutrients and/or acidic soil. Field worker asks farmer about these areas and combines this knowledge with that of nature of parent material (e.g. sandy, granitic soils in Craigieburn) and soil type – likely to give an indication of potential acidity. Soil analysis is only sure test of acidity and corresponding nutrient levels.	PAS upper limit is **17%** (Manson and Miles, 1996). Crops will not be able to grow if this level of acidity is exceeded.
		Nutrient deficiencies		
Potassium (K) Nitrogen (N) Phosphorus (P)	Levels of K, N and P in most of Craigieburn soils low due to nature of parent material. Soil P in most samples fall below threshold value for vegetables of **27mg/L.** Soils also deficient in zinc and organic carbon.	If soil is deficient in an element, then likely that plant in that soil will also be deficient. There are visual indicators ('symptoms') in plant (e.g. colour, growth form, see **Table 5.2**). Levels of P, K and N in most Craigieburn soils are too low to provide continuous and adequate supply for crop requirements according to the norms recommended by Manson (1996). In most cases animal manure will have to be applied to the plots.	Plants often express nutrient deficiency through specific symptoms that can be observed in field (**Table 5.2**). However, interpretation of symptoms requires experience[39]. Symptoms' for deficiency of P, K and N are specific (do not overlap and relatively easy to identify in field). Can examine these from photos showing 'symptoms' as they vary between different crops and stages of plant growth (see Appendix C).	Threshold value of P and K is **27mg/L** and **120mg/L** respectively (Roberts *et al.*, 2003)
SOM	Variable but depleted in most cases	**Dealt with in Table 5.6.** No standard for "enough" SOM (Pittoway, 2002), making benchmarking difficult.	Although somewhat difficult to assess, Pittoway (2002) recommends checking for an upper litter layer and softer, underlying layer. Farmers well aware of organic humus (particularly relationship with manure) and with experience can assess relative amounts (i.e. moving from "none" to "a lot"). **See Table 5.3.**	**See Table 5.3.**

[39] Thus caution needed in providing easily applicable visual indicators of nutrient deficiencies in plants that can be used by a generalist field assessor. Importantly, local farmers, although possibly not being able to identify specific nutrient deficiencies, may be well attuned to identify general nutrient deficiencies in their crops.

5.6. Concluding Remarks

Eight core indicators were selected for testing and refinement through the rapid appraisal process and for self-assessment by farmers. These offer a potential set of principle-based indicators for future use. Given the objective of tracking change and specifically the direction of change in wetland health as a result of (improved) wetland practices, much of the focus of indicator development was at this scale. The use of principles drawn from previous work, a wider discourse, and discussions with wetlands users, provided a framework that is, we believe, sufficiently robust to be used in communal areas beyond Craigieburn. This framework, captured in a heuristic as the 'hand-of-change', supported the development of conceptual understanding and practice-based learning for farmers themselves. Meaningful indicators are much more likely to emerge from such an approach as is demonstrated in this work. Nevertheless whilst the framework can be used elsewhere the application of indicators in one place in another should be undertaken judiciously. Not only may the biophysical conditions vary but also the indicators will be far more meaningful, and likely to be used, if developed locally. For example, farmers in Craigieburn are less likely to use crop yield (see earlier discussion) as the only indicator of wetland yield now that they draw on the principles that underlie the 'hand-of-change'.

This work attempted to develop the concept of indicators within the context of complexity and variability by incorporating the concept of ranges of values within which a variable can 'bounce around' without being deemed unsustainable. We drew heavily on the concept of thresholds of potential change or TPCs (see Chapter 1). This exercise was constrained by a lack of data and demonstrated how poorly understood, or at least quantified, many relationships are. This constraint confounded much of the earlier modelling of wetland practices using Stella (Pollard et al., 2007). Thus for example the extent of mulching and the proportional benefit is largely unknown such that questions arise which are difficult to answer (i.e. to set ranges). Given that farmers are struggling to find sufficient mulch, must 100% of the plot be mulched to get the benefit, or can it be less, and how much less?

Moreover, we must not lose sight of the fact that wetland health – and ultimately the sustained inputs into peoples' livelihoods – is dependent on a much wider range of factors that constitute 'wise use'. In addition to issues of <u>governance,</u> it is important to have some understanding of the wider micro-catchment context and in particular the hydrology and soils, as well as the wetland as a whole. The results of Phase I indicated that much – if not most – of the wetland degradation is due to micro-catchment practices. Not only do adjacent hillslope practices impact on wetland health, but downstream practices can <u>migrate upstream</u> through the movement of headcuts, with huge costs as described by Pollard, Kotze and Ferrari (2008). The implication of describing and tracking the health of the wetland as a whole is that ultimately the <u>micro-catchment condition</u> and use must also be understood, tracked and addressed This is currently being initiated at Craigieburn and will be reported on at a later date. Nonetheless, many of the same principles to soil and water conservation as those provided above, apply.

Chapter 6

Synthesis and recommendations for the development and testing of indicators

6.1. Overview

It is important to bear in mind that the indicators, as conceptualised in this work, are designed largely with a highly practical objective in mind; that is for use by practitioners and wetland users themselves. This is contrast to the more formal, quantitative assessments[40] (mainly of biophysical conditions) that are described in Chapter 2 which require considerable external expertise. This does not imply that they are mutually exclusive; rather they are complimentary, each with a different emphases and objectives. Also the approach reported herein takes a holistic definition of *wise use* (see Chapter 1) and hence also addresses issues including governance that will need to be tracked in the development of a holistic approach to the wise use of wetlands in communal lands.

Given the holistic emphasis this chapter provides a synthesis of the process for the development of indicators for a formative evaluation; that is an evaluation by the users of the wetlands themselves and potentially by the wider community, including support agents such as extension staff and NGOs. Essentially this forms part of an adaptive planning process (see Chapter 1) where the indicators provide the link in the process of learning-by doing – an approach regarded as fundamental in complex systems where outcomes are not always predictable.

6.2. Approach to the Development and use of Wise Use Indicators within an Adaptive Planning Cycle

Based on the concepts of complexity and learning, strategic adaptive management – or SAM – provides an overall framework for the development of wise-use indicators. The SAM process has been well described by a number of authors and readers are referred to their work for further detail (see Chapter 1). In the context of South African protected areas, Biggs and Rogers (2003) built on the early work of Rogers and Bestbier (1997) and Breen (1993) whilst Pollard and Du Toit (2007) summarised these experiences and explored experiences with local practitioners in the Kruger National Park. Indeed the SAM process has gained considerable ground in the arena of natural resources management although actual implementation is still in the early stages. Many claim that they are 'doing SAM already' when in fact there is little evidence that learning is taken into the next cycle of planning and setting of indicators, nor are the indicators themselves regarded as hypotheses that require testing and reflection.

In essence the SAM process (Figure 6.1) starts with a 'triad' of elements focused on developing a vision based on an understanding of context, values and principles. As part of this process, the

[40] The strength of methods such as those described by Macfarlane et al. (2007) or Kotze (2009) is as a quantitative assessment of biophysical wetland metrics or wetland-use practices (mainly subsistence use) respectively, allowing for a more formal, comparative assessment by an external agent over a number of years.

vital attributes and their determinants are then explored and understood; in other words, the key characteristics of the system (often positive) and what drives them. All this information is used to determine a desired state or a statement of 'where we want to go'. This is detailed though a series of strategic and operational objectives, nested hierarchically, which are then monitored, using indicators. These indicators must capture the natural dynamics inherent in most systems and provide an 'early warning' of a particular trajectory of change.

From this brief description it is apparent that although indicators are most explicitly derived in the later stages as part of the objectives and their monitoring, their development is intimately linked to understanding the context, principles and values (i.e. the earlier steps). Hence we place particular emphasis on these initial stages as an essential component of the development of indicators.

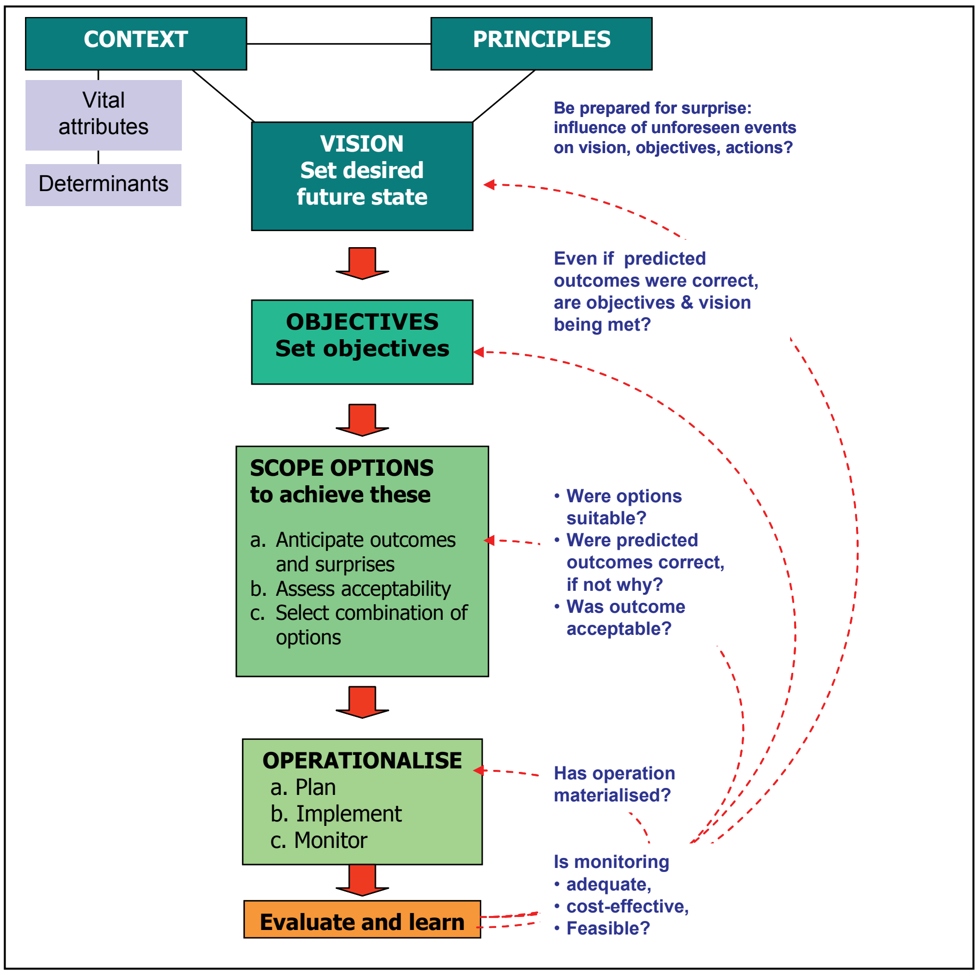


FIGURE 6.1: A Framework for SAM showing key steps (adapted from Biggs and Rogers, 2003; Pollard and Du Toit, 2007)

This framework outlines in broad terms, the overall process for the participatory development and application of indicators adopted in this work (see Chapters 4 and 5).

- a description of the <u>context</u> for the element in question (using a framework)
- identifying and agreeing on key <u>strengths and problems</u>
- agreeing on <u>principles and a framework</u>
- <u>developing and testing</u> indicators (using the framework)

- developing a collective vision
- developing objectives, and drawing up plans
- exploring possible scenarios or options for working towards the vision
- implementation of plans
- cycles of monitoring, reflection, learning and action.

Interestingly this approach, although not precisely laid out as above, is now being used in the development arena (e.g. Diaw et al., 2009). Experience shows that in reality up until the development of a vision, this is not a rigid, step-wise process but rather, as indicated in Figure 6.1, a number of steps may be undertaken in parallel through various iterations. For example, in some cases key principles may emerge from earlier work, or from initial discussion with the community and these in turn may form the basis for a framework to guide the work. In other cases principles or a framework may emerge from a more detailed description of context.

6.2.1. Understanding context

In this spirit there are a number of issues that need to be addressed as part of a preparatory phase before embarking on the development of indicators or an adaptive management process. These include clarity on issues of definition and project objectives, understanding experiences elsewhere and being explicit about how well the system is understood. Many of the steps comprise part of a macro-assessment of context. Context refers to the socio-economic, biophysical, political and institutional elements of the systems, sometimes referred to as a *socio-ecological system* (see Chapter 1). In integrative approaches such as for the development of indicators described herein, it is important to build some understanding of these aspects exists through collaborative, participatory enquiry. The underlying premise is that it is critical that wetland users, practitioners and those in authority to consider the wetland as a whole (rather than just the areas under use), and that there is some understanding regarding the condition of the wetland. This is important as a starting point for any wise use initiative for two reasons. Firstly, it creates a sense for farmers that they and their use practices exist within – and are linked to – a wider system (the wetland and the catchment). Secondly, in many cases some of the threats to wetland integrity come from beyond the plot so that whilst practices may be entirely sustainably, the wetland may continue to degrade. Many of the drivers for this lie beyond the control of the wetland users themselves and can only be addressed if villages form part of governance structures that can work across scales.

In Chapter 1 some *definitions of indicators* (e.g. process versus outcome) and their categories (top-down, bottom-up and so on) was given and it is useful to go through a participatory process of understanding the purpose of indicator development, the types of indicators needed and by whom. It can be appreciated that different processes and indicators may be needed to meet different objectives such as that of self-assessment (for example, 'how well are we managing our wetlands?' or 'how well am I doing in my plot?') versus project objectives ('how well is the intervention doing in support of changed practices?').

An exploration, definition and analysis of the key drivers and *components of the system*, the boundaries and their inter-linkages need to be explored collectively (e.g. governance, sediment and water balance, users and so on). In this regard the development of a *systems diagram* (or 'the way the world works'), such as those shown in Figure 1.3 and 3.2), proved crucial in our work (a more detailed description of the development of systems diagrams is given in Pollard et al. (2008a). Firstly it encourage people to think beyond their own boundaries of expertise or interest, and requires and examination of drivers, determinants and outcomes – and in particular of the multiple drivers and outcomes so prevalent in complex systems. Secondly it allows the team (including the wetland users) to share a common – but not necessarily identical – understanding, providing the basis for more complex discussions (i.e. talking 'from the same page'). Such a basis facilitates a move from single solution approaches to a more nuanced and integrated approach. It also means recognising that the project objectives (e.g. wise use, sustainability) can be achieved in a number of different ways. Finally it allows the participants to draw a virtual but appropriate boundary around the work with clear reasons for this. For example, a range of national policies will inevitably impact on the wetland in question but these may be so uncertain currently that they were 'excluded' from the analysis but noted. All of this places a different emphasis on indicators.

Having such a systems view in place facilitates identifying the various components of the system and gaining clarity on *definitions* so that one chooses indicators more appropriately. This was particularly true in the case of 'wise use', 'governance' or 'sustainable use' as key concepts. For example developing indicators for governance meant asking questions about *what type of governance* (wise, effective, for natural resources) and in turn this required searching for indicators of *effective governance,* which also required getting to the heart of these meanings in a collective way. Importantly, it is pointless developing such indicators without the involvement of the people who will use them and so adequate processes need to be developed to ensure this. In many of areas, significant amounts of literature will be available and it is incumbent on practitioners to examine experiences that are emerging from other work. A substantive literature review is recommended so as to develop both principles and indicators.

Another critical outcome of developing a systems view of the area of concern is the elucidation of what is known – or not known – about the system, thus making explicit the *gaps* that may constrain the development of indicators for monitoring. Decisions then need to be taken as to whether or not these gaps can be addressed and if not what the implications might be. For example, in Craigieburn it was evident that issue such as governance and baseline soil fertility needed to be better understood before appropriate indicators could be developed.

In the field, a critical step in developing a general, collective overview is to start by mapping the area and if community involvement and buy-in are fundamental to the aims of the work, this should be done with or by them (see Section 5.3.3). Zoning of the micro-catchment facilitates discussion not only regarding landuse attributes but also provides the basis for discussion regarding governance and management. In Craigieburn for example, governance issues express themselves differently according to whether land typology; residential, dryland fields, wetland plots or commonage. Thereafter the general condition of the wetland can be described using the key areas of concern (often arrived at through community discussions) as suggested in Table 5.3. Subdividing the area into natural clusters may facilitate the work, especially if the wetland is large. Nonetheless although people may describe the cluster in which they work, or with which they are familiar, it is essential that they visit all areas to get a sense of the wider condition, issues and threats. An important step in this process is zoning of the wetlands into ecological zones according to criteria that the wetland users recognise themselves, albeit implicitly (see Section 5.3.4). The external facilitator can check this for parity against commonly accepted technical descriptions. This is important because people frequently distinguish different landuse practices and indicators of wetland condition in each. At the same time, general discussions regarding governance – using the framework described in Chapter 4, together with the landuse typologies – raises interests and thinking around key governance issues and alerts the facilitator to potential areas of future work.

As stated, the above process allows for a collective understanding of the macro-context. However, as attention turns to different components of the system (e.g. governance, land use or plant production) the description of context will be more detailed (that is, one 'drills down' in trying to understand that particular aspect). The macro-assessment, which may be modified in an iterative process as new understanding comes to light, ensures that one does not lose sight of the inter-linkages in the system.

6.2.2. Principles and frameworks for the development of indicators

Principles, drawn both from field-based experience and from the literature provided an important scaffolding for the development of indicators. These principles for wise and effective governance and landuse practices (see Tables 4.1 and 5.2 respectively were discussed with Craigieburn residents and others and used to develop frameworks, used as heuristics, to organise key concepts, support learning for change and for the development of indicators. The 'body-of-governance' (Figure 4.1) and 'the-hand-of-change' (Figure 5.3), were based on the concept that 'every farmer has a body/ hand" and can thus use this to aid recall of the principles. Each of these frameworks was used to guide the development of the vision, objectives and indicators. From this, the group is in a better position to develop indicators based on both local knowledge and expert inputs.

It is strongly recommended that the development of indicators be done within the context in which they will be used. The preceding discussion provides an overarching process for the collaborative development of indicators based on an overall understanding of context, vision and key principles and objectives so that each indicator can be clearly linked back up the hierarchy the overarching principle(s) in question. In addition to this, the framework used for the development of indicators as thresholds of potential concern or TPCs (see Table 5.6) offers a structured approach to selecting indicators (together with a clear rationale) as well as identifying associated thresholds (upper an/or lower limits). These are important because they address the variability that is inherent in complex systems (see Chapter 1). In many cases it becomes clear through this process that these thresholds are unknown, highlighting the need for judicious interpretation, further research or even ultimately calling into question the appropriateness of the indicator.

Once identified, an approach for testing and refining indicators must also be developed and cases of this are provided in both Chapters 4 and 5. We suggest that an invaluable step was the use of these indicators as the basis for self-assessment by farmers but using a modified approach to accommodate lower literacy levels than that required for the more formal appraisal process. Some important pointers for successful use of the approach that emerged were as follows:

- Sound preparation is essential (especially that of translation). Smooth sequencing is essential to avoid confusion. Farmer confidence and familiarity with the process is likely to improve with repetitive use.
- Assessments are more successful if conducted in-field
- Assessments must be done with individuals not groups
- Chose appropriate metaphors (for example, some farmers had never seen a traffic light (see Figure 5.4) making the explanation of the metaphor difficult).
- The approach was seen as enjoyable so it was easy to engage farmers. We found that farmers were nervous and fearful of more formal approaches. The combination of methods was useful.
- Farmers enjoyed being involved in the assessments and were not shy to comment. The greater the involvement the more likely is the success of the approach.

6. 3. Concluding Remarks

Indicators can be developed for a multitude of purposes and the literature on and experience thereof is extensive and diverse. In this project we have focused on the development of indicators of the wise use of wetlands for use by practitioners, with a specific focus on the community themselves. We have also attempted to develop indicators based on a holistic approach, drawing on a wide range of knowledge including previous research, research undertaken as part of the project and information from the literature. It is also in recognising complexity of systems, evident in their variability and dynamism, their multiple drivers and inter-linkages that vary across scales that one also recognises that there may be multiple ways to arrive at an objective; in this case improved wetland and livelihood integrity. Essentially then, the development and use of indicators forms part of an adaptive planning process that supports learning-by-doing but that is sufficiently structured so that each indicator can be 'tracked back' to higher-order objectives which themselves are based on an understanding of context and underlying principles.

Given the preceding discussion it is clear that a central component of the work lies in a principles-based approach. In many cases, whilst the indicators are context specific and cannot simply be transposed to another system, the higher-order principles are sufficiently robust to apply beyond the borders of a single wetland. For example, since the principles discussed in Chapters 4 and 5 are drawn from the wider discourse (of land reform and governance of communal lands as well as soil and water conservation and wetland management respectively), we suggest they could be applicable in other areas providing they are field tested.

Although we have focused on governance, wetland health and sustainable practices, other initiatives may want to adopt additional areas of focus as appropriate. This may include for example, micro-catchment health or livelihood assessments. In any of these cases the process set-out above is recommended. An integrative model that indicates the groups understanding of inter-linkages constitutes an important starting point.

In summary, the central tenets of the outlined approach to the development and testing of indicators can be summarised as follows:

- Users are involved in the derivation of the indicators and consequently have an understanding of their relevance.
- The indicators are based on an understanding of context and a recognition of wetlands as complex, linked, dynamic systems with socio-economic, environmental and political drivers and attributes.
- Deriving indicators is based on clear principles that are consistently applied. It is suggested that these are sufficiently robust to be used in other communal wetlands but this requires testing.
- Wise use and sustainability can thus be achieved in a number of ways
- The users are involved in and responsible for assessing their own practices which can be compared.
- The outcome of the use of indicators is to assist future learning that is appropriate and responsive to real needs.

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Appendix A

Weeds and plant species identified as problematic in Craigieburn

Richardia brasiliensis (Brazil pusley or Mexican richardia, locally known as Skekenini), *Bidens biternata* (Blackjack), and *Striga asiatica* (Witchweed) were identified by the Craigieburn farmers as problematic plants. *R. brasiliensis* and *B. biternata* were both introduced to South Africa from South America whereas *Striga asiatica* is indigenous to South Africa. *R. brasiliensis* and *B. biternata* are stated by numerous authors to be prevalent in cultivated and disturbed areas. A number of other weed species were common in the cultivated plots, such as *Ageratum conyzoides* (Blue weed or invading ageratum), *Commelina benghalensis* (wandering Jew), and a species of the genus *Oxalis* (Sorrel).

These nuisance plants, termed weeds can interfere with the growth of crops either directly through competition for water, light, space and nutrients or indirectly by harbouring insects or diseases. *B.biternata* has been implicated as alternative hosts for 'verticillium', a fungus disease that attacks several crop plants, including potatoes and tomatoes (Bromilow, 2001). *C. benghalensis* is a very common weed in South Africa, is a strong-competitor for moisture, particularly in maize. The plant has burrowing runners, which makes it a difficult weed to control through manual weeding, as any parts that break-off can grow into plants. *Oxalis* is a non-competitive plant that does not cause crop loss, however some species are carry-over hosts of rust (leaf disease) in maize. Oxalis is difficult to control as it produces underground stems (stolons) and/or bulblets. *A. conyzoides* are common weeds of annual crops and can invade perennial crops such as sugarcane. They are fairly easy to control by cultivation and pre-emergence herbicides, however the control of mature plants is difficult (Bromilow, 2001).

Most maize crops, both in the wetland and in the upland plots showed a moderate to low infestation of *Striga asiatica*. *S.asiatica* is a semi-parasitic plant on maize, sorghum and sugarcane; it has bright green to yellow-green leaves and brilliant orange-red to red flowers. Bromilow (2001) states that this weed can cause substantial reductions in crop yields. The seeds of the plant germinate in the presence of strigol[41], which is produced by the roots of the host plant. Improved soil fertility will lead to a reduction in the level of infestation of the parasitic plant *S.asiatica* on maize and sorghum (Corbeels et al., 2000), through improving the host-plant's ability to resist infection by *S.asiatica*. The healthier and the more well-developed is the root system of the host plant, the greater is its capacity to resist infection by *S.asiatica.* All the maize crops infested with *S.asiatica* showed severe to moderate nutrient deficiency (phosphorus, nitrogen, potassium, magnesium and zinc). Additional control of *S.asiatica* can be obtained through intercropping beans with maize/sorghum, by planting the beans ahead of the maize, or by using an annual rotation of beans with maize/sorghum. This will reduce the level of *S.asiatica* infection over time as the roots of beans produce strigol (the chemical stimulus for the germination of the *S.asiatica* seed), but as beans are not a host plant of *S.asiatica*, the plants will die shortly after germination. Growing beans as a green manure crop will further accelerate the reduction of the *S.asiatica*, as the green

[41] Strigol is a witchweed seed germination stimulant

manure crop will improve soil fertility as well as stimulate the *S.asiatica* seeds to germinate and die (Bromilow, 2001).

Weeds have a certain set of characteristics that enable them to persist in an area making them difficult to control. These include efficient methods of dispersal, the ability to establish itself easily, rapid and efficient reproduction, rapid growth, a well developed and deep root system, adaptability (being able to easily invade a wide range of ecological niches), the ability to withstand unfavourable conditions, and being an aggressive competitor. *B. biternata* has been categorized as a successional species as it has an efficient method of germination in the form of dense mats, which allow for a uniform and shallow germination of seedlings. One *S.asiatica* plant can produce up to 500 000 seeds, which can lie dormant in the ground for up to 15 years and in unfavourable conditions it can develop and grow normally underground (Bromilow, 2001). *R. brasiliensis* is a sprawling perennial (Chandran and Singh, 2003).

Ronchi and Silva (2006) investigated the effects of competition of seven weed species on the growth of coffee plants under greenhouse conditions. The results demonstrated that *R. brasiliensis* and *B. biternata* caused a severe decrease in growth of the coffee indicated by a decrease in stem diameter, plant height, leaf number and shoot dry matter. This reduction was found to be directly proportional to the density of the weed plant. These adverse weed effects on coffee growth were concluded by Ronchi and Silva (2006) to be a result of competition mainly for essential nutrients and light, since soil moisture was almost constantly available. Moreover, it was found that *B. biternata* imposed the strongest competition for light since it quickly developed simultaneously in leaf area and height (showing a dense canopy), factors that allow weeds to be better light competitors. Chandran and Singh (2003) state that further studies are required to provide information on the competitive biology of *R. brasiliensis* and its management.

Appendix B

Herbaceous plants collected from Craigieburn wetlands (Dec 2008)

1. *Acalypha villicaullis*
2. *Acanthospermum australe or brasilum **
3. *Agathsanthemum bojeri subsp. bojeri*
4. *Agathsanthemum bojeri subsp. bojeri **
5. *Ageratum conyziodes*
6. *Bidens biternata **
7. *cf. Ageratum conyzoides **
8. *cf. Ceratotheca triloba*
9. *cf. Fimbrisbylis complanata*
10. *cf. Helichrysum nudifolium*
11. *cf. Rothia hirsute*
12. *cf. Setaria megaphylla*
13. *cf. Spilanthes mauritiana*
14. *cf. Xanthium stumarium * (young)*
15. *Cleome monophylla*
16. *Commelina cf. diffusa subsp. scandens*
17. *Cyperus cf. rotundus subsp. rotundus var. rotundus*
18. *Cyperus compressus*
19. *Cyperus cyperiods subsp. cyperiodes*
20. *Cyperus fastigiatus*
21. *Eriosema psoralioides*
22. *Euphorbia hirta*
23. *Euphorbia hirta **
24. *Helichrysum adenocarpum (maybe)*
25. *Helichrysum akhrixiifolium*
26. *Hemizygia petrensis*
27. *Kyllnga cf. melanosperma*
28. *Malvastrum coromandelimum*
29. *Mucuna curiacea subsp. Irritans*
30. *Nicotiana glauca * (maybe young)*
31. *Pentanisia pranelloides subsp. pranelloides*
32. *Pycnostachys urticifolia (maybe young) (but doubt it)*
33. *Ranunculus multifudus*
34. *Rhoicissus tridentate subsp. cuneifolia*
35. *Richardia brasiliensis **
36. *Sida cf. chrysantha*
37. *Sida chysantha*
38. *Sida cordifolia*
39. *Solanum pandurifurme*

40. *Tridax procumbens*
41. *Triumfetta pilosa var. tomentosa*
42. *Verbena cf. brasiliensis* *
43. *Verbena tenuisecta* *
44. *Vernonia oligocephala*
45. *Xanthium stumarium* *

Appendix C

Soil health and Crop nutrient deficiency

General crop nutrient deficiency symptoms and typical conditions

(www.unu.edu/env/plec/l-degrade/G-Ch_5.doc)

Essential Nutrient	Deficiency symptoms	Typical Conditions
Nitrogen (N)	Leaves (first older ones) turn yellow/ brown, plants are spindly, lack vigour and may be dwarfed.	Sandy soils under high rainfall conditions and soils low in organic matter, where leaching occurs.
Phosphorus (P)	Not easily detected from appearance. Where deficiency is severe plant will be stunted, the leaves will take on a purplish tint and the stem will be reddish in colour.	Acid soils rich in iron and aluminium oxides (i.e. red tropical soils)
Potassium (K)	Yellow/brown spots appear on older leaves and/or necrosis of edges.	More frequent on light soils (as K is concentrated in the clay fraction of soils).
Sulphur (S)	Leaves are stunted, with uniform chlorosis.	Sandy soils under high rainfall conditions.
Calcium (Ca)	Roots are usually affected first – growth is impaired and rotting often occurs. In vegetative growth, deficiency may show in distorted leaves, brown scorching or spotting on foliage or bitter fruit (e.g. apple) or blossom-end rot (e.g. tomato).	Acid soils, or alkaline or saline soils containing high proportions of sodium.
Magnesium (Mg)	Interveinal chlorosis, first on older leaves.	Acid, sandy soils in areas with moderate to high rainfall. Often occurs in conjunction with Ca deficiency.
Iron (Fe)	Chlorosis of younger leaves.	Calcareous soils, poorly drained and with high pH. (In neutral and alkaline soils P may prevent the absorption of Fe.)
Manganese (Mn)	Chlorosis of younger leaves.	Badly drained soils, over-liming or deep ploughing of calcareous soils can lead to Mn deficiency, as can the presence of high levels of Mg. The combination of high pH values (> 6.5) and high levels of organic matter can immobilise soil Mn.
Zinc (Zn)	Symptoms vary with plant type – in cereals young plants display purpling, whereas in broad-leaved plants symptoms include interveinal chlorosis, reduced leaf size and sparse foliage.	Soils with high pH. Available Zn is reduced by the application of lime or phosphates.

Soil health – Visual assessment for general crop nutrient deficiency symptoms and typical conditions

(www.unu.edu/env/plec/l-degrade/G-Ch_5.doc)

Essential Nutrient	**Deficiency symptoms**	**Typical Conditions**
Nitrogen (N)	Leaves (first older ones) turn yellow/ brown, plants are spindly, lack vigour and may be dwarfed.  	Sandy soils under high rainfall conditions and soils low in organic matter, where leaching occurs.
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