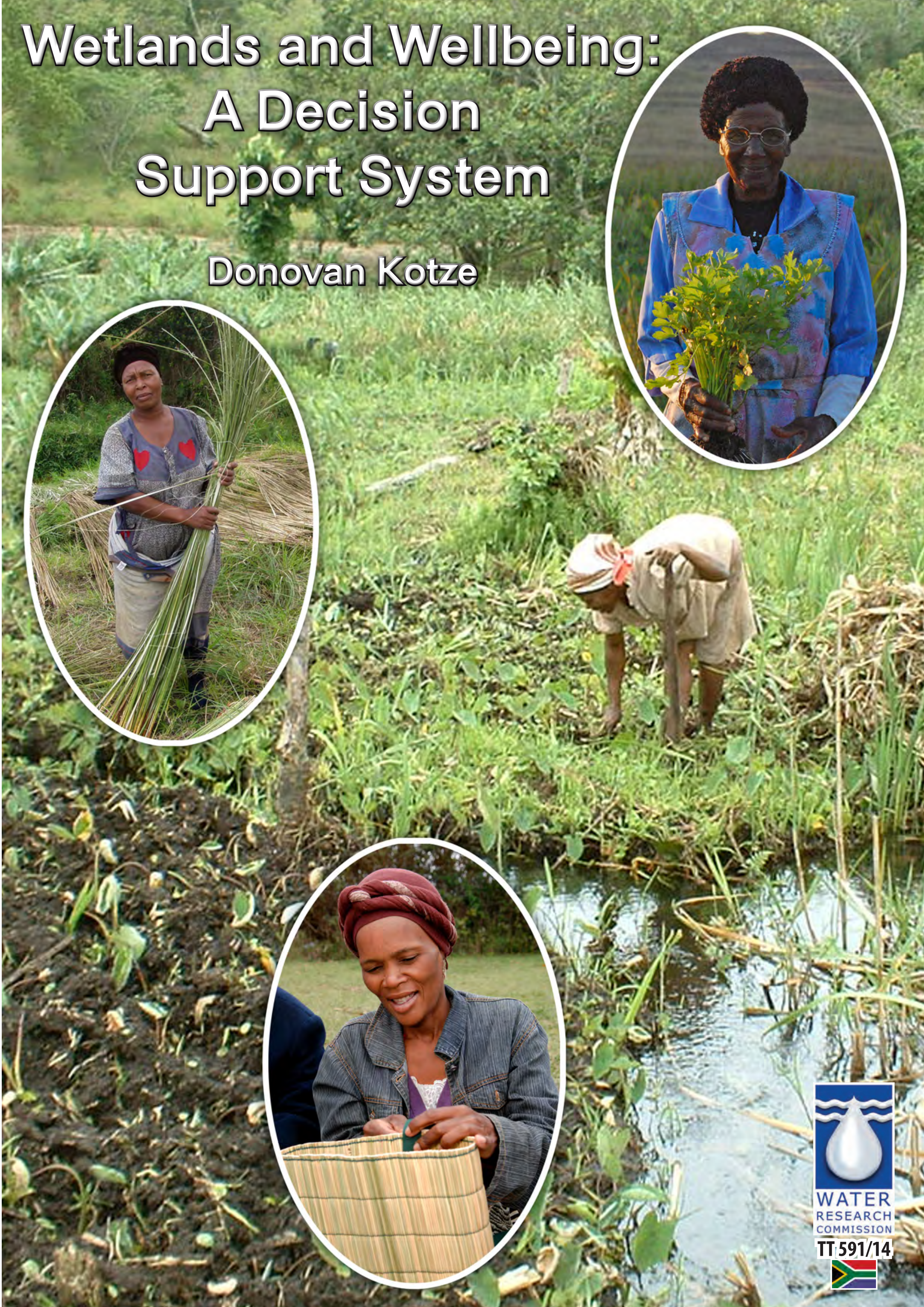
Wetlands and Wellbeing: A Decision Support System

Donovan Kotze



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Wetlands and Wellbeing:

A Decision Support System

Report to the

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by

Donovan Kotze

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Top – the River Pumpkin (*Gunnera perpensa*), a widely used medicinal plant which grows in wetlands and below – a small-scale farmer cultivating madumbes (*Colocasia esculenta)* in a patch of wetland.

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Acknowledgements

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Preface

This decision support system is a product of a research project entitled *Wetlands in South Africa: Their Contribution to Wellbeing* commissioned by the Water Research Commission and led by Duncan Hay and Associates. The work was conducted in association with colleagues at AWARD, the Inina Craft Agency, University of KwaZulu-Natal and WWF Mondi Wetlands Programme.

The focus here is on freshwater inland wetlands but the lessons are derived from and could equally be applied to other aquatic systems, particularly rivers, dams, lakes, estuaries and our coastline.

The decision support system comprises this narrative together with three Excel spreadsheets on the accompanying CD. One of the spreadsheets is for direct use and the other two provide illustrative examples of the application of the decision support system.

Also included in the CD are:

- The project's final technical report available as a hardcopy from the WRC
- An introductory handbook available as a hardcopy from the WRC
- A series of case-studies
- A large quantity of resource material on the subject

1. Introduction

How are wetlands to be managed for the best advantage and wellbeing of all its different users? In order to address this challenging question, a reasonable understanding is required of the suite of ecosystem services supplied by a wetland, and how the delivery of these services is likely to be affected by different land-use options within a wetland. Furthermore, it needs to be acknowledged that a wetland might also be impacting negatively on the wellbeing of some users. However, there is often a lack of detailed information about a particular wetland, including details about its use and users, with which to develop this understanding. In addition, key risks facing the delivery of services and opportunities that have not yet been realized need to be identified and addressed in the context of a resilient social-ecological system. A social-ecological system is a linked system of people and nature, and this is considered resilient where it is able to recover following a shock, for example a severe drought or a major flood.

In response to the above needs, a Decision Support System (DSS) has been developed for rapidly assessing, in the context of resilient social-ecological systems, the ecosystem services provided to the users of inland wetlands in South Africa. The DSS builds on WET-EcoServices (Kotze et al., 2009) and the system for estuarine wetlands (Bowd et al. 2012), particularly a series of spreadsheets developed by Myles Mander which forms part of the Bowd et al. (2012) system. The DSS is designed to assist with the following.

1. Assessing the supply of ecosystem services by a particular wetland (Section 2)
2. Exploring how different use-scenarios might affect the suite of ecosystem services supplied by a particular wetland (Section 2)
3. Assessing the current demand and use of the services supplied by a wetland (Section 3)
4. Identifying opportunities (for enhancing benefits) and risks to the provision of ecosystem services by a wetland (Section 4)
5. Assessing the costs, particularly to local people, of a wetland, for example provision of habitat for disease vectors (Section 5)
6. Identifying possible means of addressing the risks to, and costs of, a wetland and of realizing the most promising opportunities (Section 4 and 5)

It is envisaged that the DSS will be used in a Strategic Adaptive Management context. Items 1 to 5 can be used to play an integral part of the first and second components of Strategic Adaptive Management, namely “Setting the desired future condition” and “Exploring management options”. Item 6 is integral to the third component, “Operationalization”.

It is also envisaged that the DSS will be used in a multi-stakeholder context, including a well-facilitated open social process where different stakeholders and users develop a better understanding of how their individual land-use choices impact upon the wellbeing of other users of the wetland.

The DSS is designed to generate a preliminary scoring of several ecosystem services as inferred from the wetland’s hydrogeomorphic (HGM) type and the structural vegetation types (including cultivated lands) present in the wetland. The DSS comprises two components: (1) this document, which provides background information and detailed rationale for the scores assigned in the DSS, and (2) an accompanying spreadsheet which provides a means of capturing specific information about the wetland and its social context. The spreadsheet includes two example wetlands, Papenkuils and Mbongolwane, for which information has been captured.

The DSS is designed to be applied across a range of spatial/organizational scales from an individual wetland to a collection of wetlands within a sub-catchment or overall catchment. Given that in the national inventory, wetlands have already been identified according to HGM unit, it would be possible to use the DSS to assess the potential supply of wetland ecosystem services at a national level.

As emphasized for WET-EcoServices, it is perhaps just as important to note what the DSS is *not* designed to do, because users of the system must be fully aware of the limitations of the system.

- The system is not designed to assess the integrity (health) of a wetland or its importance for biodiversity conservation, and that in certain circumstances the direct use of a wetland by people may be in conflict with its conservation for biodiversity and vice-versa. If the purpose is to assess wetland health, readers are referred to WET-Health (Macfarlane *et al.* 2009) which provides a general assessment procedure at two levels of detail. Both levels generate a score for the present ecological state of the wetland according to the DWAF categories. For assessing importance for biodiversity conservation, users are referred to the guidelines included in WET-EcoServices, for example the presence of Red-listed species and the connectivity of the wetland to other natural areas in the landscape. The National assessment of Nel et al. (2011) is useful in placing the wetland in a broad biodiversity conservation context.
- Although the DSS assists in identifying key issues to be considered in a scoping report, it is not designed to quantify in detail the specific level of impact of a current or proposed development. This requires specialist input and a more detailed investigation than that undertaken at the rapid assessment level of this procedure.
- The DSS is not designed to provide a single overall measure of value or importance of a wetland, nor is it designed to quantify (in monetary or other terms) the benefits supplied by a wetland. The DSS only goes as far as to assist in assigning indices to these benefits for comparative purposes.

Finally it is important to emphasize that the DSS is not designed to take decisions itself but rather is a tool for building understanding of the relationship between people and wetlands and providing the basis for roleplayers to make more informed decisions themselves.

2. Supply of ecosystem services as inferred from the wetland's HGM type and vegetation

2.1 Overall approach

In situations where direct information on the supply of ecosystem services is limited, the DSS allows for a preliminary assessment as inferred from the HGM type of the wetland (Section 2.2) and the vegetation structural types in the wetland (Section 2.4). The rationale underlying the inferences is provided in Section 2.3 (HGM type) and Section 2.5 (Vegetation structure type). Users should familiarize themselves with this before carrying out the assessment. Four simple steps are required of the operator of the DSS in order to undertake a preliminary assessment of the supply of ecosystem services (Figure 1).

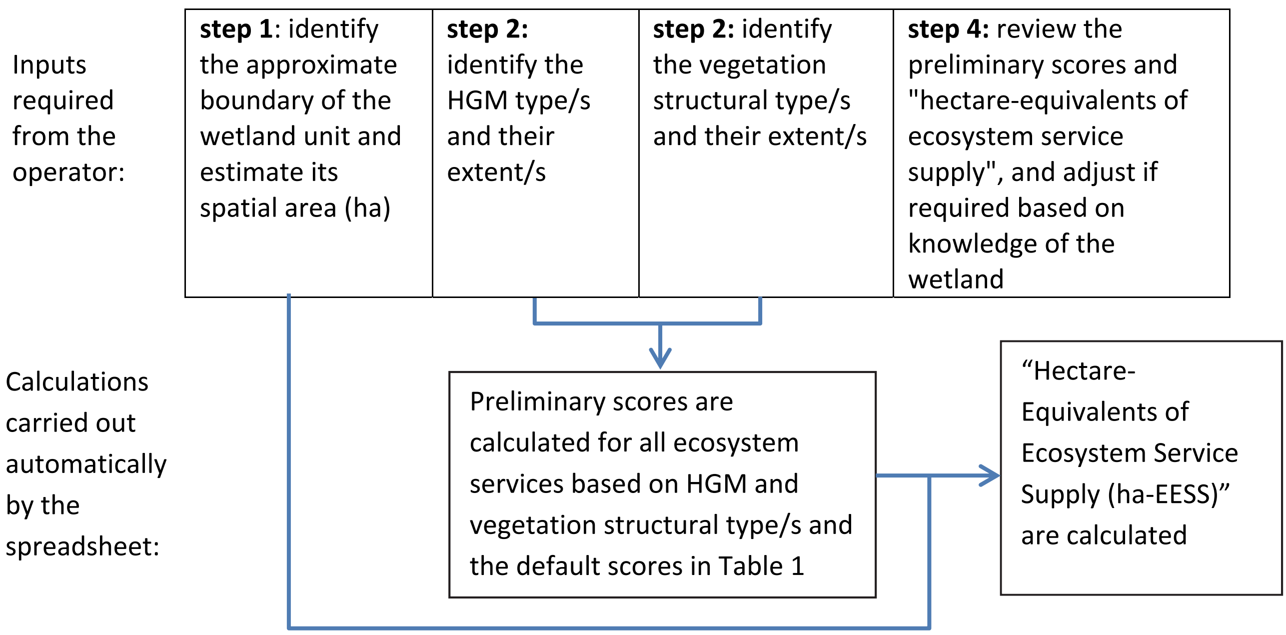


Figure 1: Steps required in the rapid assessment of the supply of ecosystem services by a wetland

The user manual of Ollis et al. (2013), which is very well illustrated, should be used to identify HGM types. It is recommended that if a wetland comprises more than one HGM type, ideally each HGM type should be assessed as a separate wetland unit. However, the spreadsheet makes allowance for assessing wetland units which contain multiple HGM types. Proportional area of these types needs to be estimated and the spreadsheet then automatically derives scores for the supply of ecosystem services based on an area- weighted average of the scores for the HGM types present in the unit.

Most wetlands comprise more than one vegetation structural type, requiring that in most cases a weighted average score be determined. For example, if a wetland unit comprised 60% of Short/medium grass and 40% of Tall, robust grass then the weighted average flood attenuation score would be ((2 x 60/100) + (3.5 x 40/100))/2 =2.6. If, in a second example, Short/medium grass was decreased to 10% and Tall, robust grass to 90% then the score would be ((2 x 10/100) + (3.5 x

90/100))/2 =3.4. By comparing these two examples it can be seen that the greater extent of tall robust grass, which is more effective in reducing the velocity of floodwaters, the higher the Vegetation score for flood attenuation. In the accompanying spreadsheet, the extent of the respective vegetation structural types is recorded and the weighted average is calculated automatically.

The HGM score and the Vegetation score are multiplied as follows to derive an overall score: Overall score = HGM score x (Vegetation score/4). Given that both the HGM score and the Vegetation score range between 0 and 4, the overall score has the same range. The rationale for combining the scores as a multiplier is that the HGM unit provides the underlying template affecting how a wetland functions and the services that it provides and the vegetation which occurs on the unit has a modifying influence. Let us assume that the two vegetation examples given in the previous paragraph were both in a floodplain wetland then the overall score for the first example would be 4 x 2.4/4 = 2.4 and for the second example it would be 4 x 3.4/4 = 3.4. However, if the two vegetation examples given in the previous paragraph were both in a channeled valley-bottom wetland (an HGM unit inherently less effective in attenuating floods than a floodplain) then the overall score for the first example would be 2 x 2.4/4 = 1.2 and for the second example it would be 2 x 3.4/4 = 1.7.

The scores assigned in Table 1 and 2 and the Overall score derived from these tables are independent of the size of the wetland unit. Nonetheless, it is assumed that for a given overall score for supplying a service, the larger the unit, the greater will be the supply. Thus, the final calculation in assessing the supply of ecosystem services integrates the Overall score derived from Table 1 and 2 with the size of the wetland unit delivering the service. The underlying assumption here is that all other factors being equal; the larger a wetland, the greater the delivery of a given service. In order to account for size, the concept of "Hectare-equivalents of ecosystem service supply" is introduced. This concept draws from the HGM approach (Brinson, 1993 and Brinson and Rheinhardt, 1996) but at a much coarser level, and without referring to specific reference wetlands. One hectare Equivalent of Ecosystem Service Supply (ha EESS) refers to one hectare of wetland belonging to an HGM unit and vegetation structural type combination delivering the maximum possible score (i.e. 4). For sediment trapping, for example, this could be an unchannelled valley-bottom wetland with palmiet vegetation.

To carry out the integration, the Overall supply score is first converted from a scale of 0 to 4 into a scale of 0 to 1 by dividing by 4. Next, the converted score is multiplied by the size of the wetland. Thus, if the wetland unit comprised an unchannelled valley-bottom wetland completely covered by palmiet vegetation (scoring 4 out of the maximum 4) and was 20ha, then for sediment trapping this would translate into 4/4 x 20 = 20 ha EESS. If the unit was an unchannelled valley bottom with annual herbaceous vegetation (scoring 2 out of the maximum 4), then this would translate into 2/4 x 20 = 10 ha EESS.

It is important to emphasize that Hectare equivalents of supply serve only as a general guide. For most of the ecosystem services assessed, particularly flood attenuation and sediment trapping, supply is very strongly related to the size of the unit delivering the service. However, for other services, notably tourism and recreation, while size certainly has an important bearing on delivery, other features, for example a magnificent scenic feature may to some extent override the influence of size of the unit. The issue of the effect of size of the wetland unit is discussed further by Kotze et al. (2009).

2.2 Preliminary scores for ecosystem services potentially supplied by a wetland unit based on the HGM type of the unit

Preliminary scores are given in Table 1 for all of the ecosystem services considered by the DSS based on the HGM type of the wetland unit. This same table is repeated on the first sheet of the accompanying Excel spreadsheet.

Table 1: Preliminary rating[1] of the ecosystem services[2] potentially supplied by a wetland based upon its hydro-geomorphic (HGM) type, as described by Ollis et al. (2013)

Regulatory services:	Flood attenuation	Erosion control	Sediment trapping	Phosphate assimilation	Nitrate assimilation	Toxicant assimilation
Floodplain wetland[3]	4	3	3.5	4	2	2
Valley-bottom wetland, channeled	2	3	3	3	2	2
Valley-bottom wetland, unchannelled	2.5	4	4	3	3	4
Seep with channeled outflow	1.5	4	1	1	4	4
Seep without channeled outflow	1.5	4	1	1	4	3
Depression, exorheic	1.5	1	1	1	2	2
Depression, endorheic	1.5	1	1	1	2	2

Table 1 continued:

Provisioning services:	Water supply	Grazing	Plants for crafts	Medicinal plants	Indigenous/ wild foods	Cultivated foods	Tourism & recreation
Floodplain wetland	3	4	3	2	3	4	4
Valley-bottom wetland, channeled	3	3	3	4	2	3	3
Valley-bottom wetland, unchannelled	3	3	4	3	2	3	3
Seep with channeled outflow	4	3	3	4	2	3	2
Seep without channeled outflow	2	3	2	3	1	3	2
Depression, exorheic[4]	3	3	2	1	4	2	3
Depression, endorheic	1	2	1	1	4	1	3

[1]The same range in scores from 0 to 4 is used as is applied by WET-EcoServices level 1 assessments.

[2]Although streamflow regulation has been omitted from the DSS, the scores for Water supply are likely to provide some indication of this service.

[3]A floodplain wetland is taken as typically comprising predominantly floodplain flat with floodplain depressions contained within the flat. If a particular floodplain unit is characterized by the very limited extent of depressions then this unit is probably best treated as a channeled valley bottom unless it is particularly wide (i.e. >500 m).

[4]Exorheic depressions generally experience flushing, which prevents the accumulation of solutes. However, under arid conditions this flushing will often be inadequate to prevent such accumulations, and therefore under arid conditions these depressions may need to be treated as endorheic in terms of water supply.

Note: the Rationale for the scores assigned for Regulatory services in Table 1 is given on page 23-25 in WET-EcoServices (Kotze et al. 2009). It should be noted further that a score of "0 or 1" in Table 1 falls within the "0" class of Table 3.1 of WET-EcoServices, which is defined as "Benefit unlikely to be provided to any significant extent".

While the ecosystem services included in the DSS are based strongly on those included in WET-EcoServices, two regulatory services, streamflow regulation and carbon storage, which are included in WET-EcoServices, were omitted from the DSS, mainly owing to the difficulty of inferring these based on the descriptors used. In addition, WET-EcoServices considers grazing, plants for crafts, medicinal plants and indigenous/wild foods all together as "natural resources", but from the perspective of livelihoods it was considered useful to consider them separately in the DSS.

2.3 Rationale for the scores assigned for provisioning services in Table 1

Water supply: A hillslope seepage feeding a stream channel is assumed to generally be maintained by a sustained supply of sub-surface water discharging to the ground surface. This type includes areas which would be referred to as springs, and it generally provides a reliable source of clean water. In contrast, seeps without channeled outflow are generally maintained by a less sustained supply of water, rendering these areas less reliable sources of water. The inward-draining character of endorheic depressions generally results in a concentration of solutes through evaporation in the wetland, leading to water which is naturally poor for human consumption.

Grazing: Many floodplains are occupied by a large proportion of seasonally flooded/saturated grasslands of high grazing value, particularly in the flat and shallow depression areas of the floodplain. The other hydro-geomorphic types tend to have a lower proportion of these grasslands, but nonetheless generally provide valuable grazing.

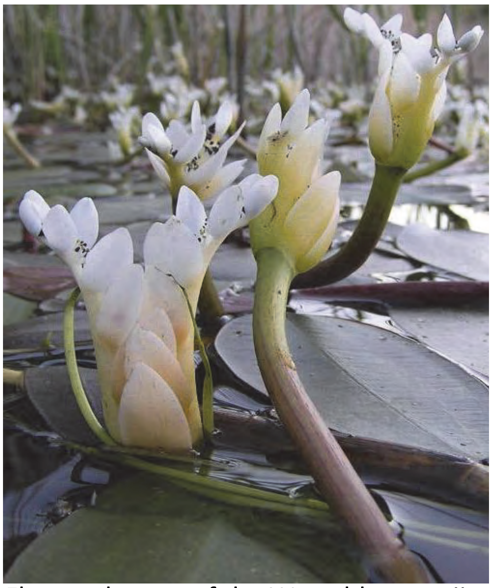
Plants for crafts: Unchannelled valley-bottom wetlands are generally characterized by permanent saturation and deep sediments, and the most prolific growth of fibrous plants that are typically used for crafts. In contrast, endorheic depressions and seeps without channeled outflow generally have the least prolific growth of fibrous plants.

Medicinal plants*:* Wentzel and van Ginkel (2012) list hydric species used for medicinal purposes according to preferred HGM type, which allows for HGM types to be scored according to their potential supply of medicinal plants. Channelled valley-bottom wetlands are scored the highest given that the greatest number of medicinal hydric species is listed as occurring in this HGM type. In contrast, depressions have the lowest number of listed medicinal hydric species.

Indigenous/wild foods: The main items of indigenous foods considered are fish and floating aquatic plants, particularly waterblommetjies (*Aponogeton distachyos*) and to a lesser extent the underground storage organs of water lilies (*Nymphaea* sp.). Frogs, including the bullfrog *Pyxicephalus edulis*, mammals, birds and insects, notably grasshoppers, are also considered. Key habitats for fish, floating aquatic plants, frogs and many birds are depressions, including isolated depressions, as well as depressions contained within floodplains, which are most important for fish. Mammals and grasshoppers are generally most favoured where grazing is good.

Cultivated foods: In scoring the HGM types according to their potential for the cultivation of food, the types are considered in terms of (a) supply of water and nutrients and (b) limitations in terms of salts or excess wetness. As explained for “Water supply”, endorheic depressions are often characterized by a high concentration of salts, resulting in their generally being unsuitable for cultivation. Exorheic depressions typically do not accumulate solutes to the same degree but deep flooding limits cultivation, at least seasonally. Unchannelled valley-bottom and seeps with channelled outflow are generally characterized by excessive wetness, which can usually be practically overcome, primarily through artificial drainage. However, while this may be relatively easily achieved for seeps, which are generally small, for large un-channelled wetlands with gentle longitudinal slopes, artificial drainage may require a considerable investment and also have potentially considerable environmental impacts.

Tourism and recreation: Two key linked features considered in scoring importance for tourism is the presence of open water and wetland-dependent birds. Open water areas are generally very limited or absent in Hillslope seepages and most extensive in depressions and the depression component of floodplains.



Flower clusters of the Waterblommetjie (*Aponogeton distachyos*)

River pumpkin (*Gunnera perpensa*) which is a widely used medicinal wetland plant, typically growing in seepage wetlands

"Education and Research" and "Cultural heritage", both of which are likely to be strongly related to the social context of the wetland, are not included in Table 1 and 2. It is considered inappropriate to single out specific hydro-geomorphic types for research value given that research is required for all types. It is also difficult to single out specific hydro-geomorphic types which are of particular cultural value. However, wetlands which store water, particularly those which occur in a relatively dry climate, where water is scarce, seem to feature most prominently amongst the wetlands with a high cultural significance. In addition, several of the crafts produced from wetland plants have cultural significance, for example traditional sleeping mats continue to play an important role in the exchange of gifts at many weddings in KwaZulu-Natal (Kotze and Traynor, 2011). Thus, "water provision" and "plants for crafts" could potentially be used as surrogates for cultural heritage.

2.4 Preliminary scores for ecosystem services potentially supplied by a wetland unit based on vegetation structural type

Preliminary scores are given in Table 2 for all of the ecosystem services considered by the DSS based on the structural vegetation type of the wetland unit. This same table is repeated on the first sheet of the accompanying Excel spreadsheet.

Table 2: Preliminary rating of the supply of ecosystem services by different vegetation structural types which might occur in a wetland

Regulatory services:	Flood attenuation	Sediment trapping	Erosion control	Phosphate assimilation	Nitrate assimilation	Toxicant assimilation
Natural/semi natural						
Short/ medium grass, primary[2]	2	2	3.5	2.5	3	3
Short/ medium grass, secondary[2]	2	2	3	2.5	3	3
Tall, robust grass	3.5	3.5	4	4	3.5	3.5
Short/ medium Sedges/ rushes/restios	2	2	3.5	3.5	3.5	3.5
Reeds, Phragmites	3.5	3.5	3.5	4	4	4
Reeds, Typha	3.5	3.5	3.5	4	4	4
Palmiet	3.5	4	4	3	2.5	4
Herbs, annual	1	1	2.5	1	2	1.5
Herbs, perennial	2	2	3	2	2.5	2.5
Geophytes	1	1	3	2	2	2
Forest	4	4	3.5	3.5	4	4
Shrub/thicket	4	4	3.5	3.5	3.5	3.5
Aquatic floating	0	0	3	2.5	2.5	2.5
Aquatic submerged	0	0	3	2.5	2.5	2.5
Cultivated, not flood- protected[3]						
Planted pastures	1.5	1.5	2.5	1	1	1
Sugar cane	3	2	2	1	1	0.5
Orchards	4	2	2	1	1	0
Vineyards	3	2	2	1	1	0.5
Annual crops	1	0	0	0	0	0
Cultivated, flood-protected[3]						
Planted pastures	0	0	2.5	1	1	1
Sugar cane	0	0	2	1	1	0.5
Orchards	0	0	2.5	1	1	0
Vineyards	0	0	2.5	1	1	0.5
Annual crops[4]	0	0	0	0	0	0

Table 2 continued:

Provisioning services:	Water supply	Grazing[1]	Plants for crafts	Medicinal plants	Indigenous /wild foods	Cultivated foods	Tourism & recreation
Natural/semi natural[2]							
Short/ medium grass, primary[3]	4	4	3	3	3	0	2
Short/ medium grass, secondary[3]	4	3	3.5	1	2	0	2
Tall, robust grass	2.5	2	3	1	2	0	2
Short/ medium Sedges/ rushes/restios	3	2.5	3	1	2	0	2
Reeds, Phragmites	1.5	1.5	2	1	1	0	2
Reeds, Typha	2	1.5	2	2	1	0	2
Palmiet	2	1	2	1	1	0	2
Herbs, annual	3.5	1	1	1	1	0	2
Herbs, perennial	3	1	1	3	1	0	2
Geophytes	3.5	1.5	1	4	1	0	4
Forest	1	1	2	3	2	0	3
Shrub/thicket	1	1	1	3	1	0	2
Aquatic floating	1.5	1	1	1	4	0	4
Aquatic submerged	1.5	0	0	0	3	0	3
Cultivated, not flood-protecte[4]							
Planted pastures	1	4	0	0	0	0	1
Sugar cane	1	0	0	0	0	4	1
Orchards	0.5	0	1	0	0	4	2
Vineyards	1.5	0	0	0	0	4	2
Annual crops[5]	1	1	0	0	0	4	1
Cultivated, flood-protected[4]							
Planted pastures	1	4	0	0	0	0	1
Sugar cane	1	0	0	0	0	4	1
Orchards	0.5	0	1	0	0	4	2
Vineyards	1.5	0	0	0	0	4	2
Annual crops[5]	1	1	0	0	0	4	1

[1]Some wetland areas which are permanently excessively wet are inaccessible to livestock. Thus, even though these inaccessible areas may support plants which can be grazed, this grazing is not available to the livestock.

[2]It is assumed that all of the natural/semi-natural vegetation structural types are subject to periodic flooding. However, if they are isolated from flooding, for example through berms, then the scores may need to be lowered.

[3]Seasonal dieback of vegetation, which typically occurs under frosty conditions, is assumed to take place. If this is not the case then the score should be reduced to 3.

[4]"Flood protected" refers to wetland areas which have been isolated from natural flooding through artificial berms and/or drainage furrows.

[5]Cropping is assumed to be carried out with conventional methods. If more environmentally sensitive methods are used, for example minimum tillage, then the scores may need to be increased. See Kotze (2010).

Note: the Rationale for the scores assigned for Regulatory services in Table 2 is given on page 23-25 in WET-EcoServices (Kotze et al. 2009)

2.5 Rationale for the scores assigned for the provisioning services in Table 2

Water supply: The DSS uses vegetation structural type to infer water supply based primarily on the evapo-transpirative loss typically associated with the type, which reduces water which can be supplied for human use. Inferring the supply of water by a wetland based on the structural vegetation type is complicated by the fact that some of the vegetation types typically associated with the most sustained presence of water have the highest levels of measured evapo-transpirative loss, which negatively influences water supply. This is not only a function of the water being most readily available for loss but is also influenced by the structure of the vegetation, principally by the transpirative area associated with the vegetation type. Swamp forest clearly has the highest area and the highest evaporative loss (Clulow et al., 2012), with the shortest vegetation types at the other extreme.

Grazing: Grasses, sedges, rushes and restios are generally much less useful for grazing if they are tall and very robust, owing to the high content of fibrous, structural material. Certain hydric graminoid (=grass-like, and includes grasses, sedges, rushes and restios) species are typically tall and robust and are of limited value for grazing, for example the grass *Miscanthus junceus*, the sedge *Cladium mariscus*, the rush *Juncus acutis* and the restio *Calopsis paniculata.* Primary wetland grassland with medium/short grasses is generally dominated by palatable species such as *Andropogon appendicularis* while secondary wetland grassland is generally dominated by less palatable pioneer species such as *Eragrostis plana*, which nonetheless have reasonable grazing value. Wetland forest and shrub are generally limited in terms of grazing value.

Plants for crafts: Due to their higher tensile strength, several of these pioneer grasses are very suitable for woven crafts. Most geophytes have relatively non-fibrous leaves and stems making them unsuitable for woven crafts, but there are some exceptions to this, for example *Gladiolus* and *Watsonia* spp., which have fibrous strap-like leaves.

Medicinal plants: Although there are very few graminoid plants used for medicinal purposes, primary wetland grassland with medium/short grasses generally supports geophytes and a diverse assemblage of indigenous perennial herbs, contributing to medicinal value. However, secondary grassland tends to have far fewer geophytes and a less diverse assemblage of indigenous perennial herbs, thereby reducing its value for supplying medicinal plants. Reeds and tall, robust graminoids also generally have few geophytes and a low diversity of indigenous perennial herbs. *Typha* spp. are reported internationally to have several medicinal properties (Akkola et al., 2011; Morton, 1975), but in South Africa their use for medicinal purposes appears limited. Wentzel and van Ginkel (2012) record a high incidence of medicinal plants amongst hydric/riparian trees and shrubs.

Indigenous wild foods: As indicated in Section 2.3, the main items of indigenous foods considered are fish and floating aquatic plants, particularly waterblommetjies (*Aponogeton distachyos*) and to a lesser extent the underground storage organs of water lilies (*Nymphaea* sp.). Thus, aquatic vegetation is scored most highly in terms of the provision of wild foods. Frogs, mammals, birds and insects, notably grasshoppers, are also considered. Mammals and grasshoppers are generally most favoured in vegetation types where grazing is good.

Cultivated foods: It is recognized that natural vegetation types can potentially be converted to cultivated lands. However, for the purposes of the DSS only currently cultivated areas are taken as supplying cultivated foods.

Tourism and recreation: For vegetation, the contrast, diversity of colours, textures, tones and structure of the vegetation was considered and whether it is characterized by bright and conspicuous flowers or leaves which turn vibrant colours (usually in the autumn). All of these features are considered to add to the beauty of the wetland.

Further background information and supporting references for some of the key provisioning services supplied by wetlands are given in Appendix A.

2.6 A demonstration example

The assessment framework provides a means of exploring how different land-use scenarios within a wetland might affect the range of different ecosystem services supplied by the wetland. This is illustrated with an example (Table 3). Let us assume that Scenario 1 was the natural condition for an area dominated by natural forest and Scenario 2 is the current situation where the natural forest has been completely converted to annual crops. Scenario 3 represents a possible rehabilitation scenario, where half the unit is returned to forest, some of the cropland is retained and some is converted to secondary grassland. This represents a potential compromise between supplying a diversity of provisioning services at a reasonably high level as well as not compromising too greatly on the regulatory services supplied by the unit.

The scores given in Table 3 are derived from the default scores given in Table 1 and 2 based on the calculations given Section 2.1. In Scenario 3 for flood attenuation, for example, the HGM type score is 4 and the vegetation structure type score is 2.5 based on the weighted average calculated as ((4 x 50/100) + (2 x 25/100) + (0 x 25/100))/3 =2.5.

Table 3: Ecosystem service scores for a demonstration example of a floodplain wetland under three different land-use scenarios

Ecosystem services	Land-use scenarios		
	Scenario 1 100% forest	Scenario 2 100% annual crops[1]	Scenario 3 50% forest, 25% secondary grassland, short/medium and 25% annual crops[1]
Flood attenuation	4.0	0.0[3]	2.5
Erosion control	3.0	0.0	1.9
Sediment trapping	3.1	0.0	2.2
Phosphate assimilation	3.0	0.0	2.1
Nitrate assimilation	1.8	0.0	1.3
Toxicant assimilation	1.5	0.0	1.1
Water supply	1.2	0.8	1.1
Grazing	1.6	1.0	1.5
Plants for crafts	1.5	0.0	1.4
Medicinal plants	1.5	0.0	0.9
Indigenous/ wild foods	1.5	0.0	1.1
Cultivated foods	2.2	4.0	1.0
Tourism & recreation	3.6	1.0	2.3

[1]In this example it is assumed that annual crops are protected from flooding, for example through berms, which totally isolate the cropped area from flooding.

In the accompanying spreadsheets, two contrasting wetland examples are provided for all components of the DSS. The first example is the Papenkuils wetland, Western Cape, which is a privately owned area located within the context of commercial wine farms and is close to the urban fringe. The second is the Mbongolwane wetland, KwaZulu-Natal, which falls within the communally-owned rural land of a Traditional Authority.

3. Demand for the ecosystem services

It is important to begin by emphasizing that the previous section examined the *potential supply* of ecosystem services. It did not include assessing the current use which is taking place, driven by the *demand* for the service. Assessing the current use and demand for wetland ecosystem services is now examined, guided by two inter-linked key questions:

1. What is the current level of utilization/beneficiation of the different services?
2. Who is using/benefitting from these services?

The first question is dealt with simplistically in Table 4. Assessment of use is complicated by the fact that a great diversity of uses/benefits is supplied by wetlands, requiring that different methods of assessment be applied. These different methods are comprehensively covered by Turpie and Kleynhans (2010) and Turpie et al. (2010).

Table 4: A simple framework for scoring the level of current use of the ecosystem services

Ecosystem services	Level of use[1]	Evidence of use/additional notes
Flood attenuation		See WET-EcoServices, Table 4.1, characteristic 8 to 12, for guidance in scoring the level of use.
Erosion control		See WET-EcoServices, Table 4.7, characteristic 5 to 8, for guidance in scoring the level of use.
Sediment trapping		See WET-EcoServices, Table 4.3, characteristic 3 to 5, for guidance in scoring the level of use.
Phosphate assimilation		See WET-EcoServices, Table 4.4, characteristic 5 to 7, for guidance in scoring the level of use.
Nitrate assimilation		See WET-EcoServices, Table 4.5, characteristic 6 & 7, for guidance in scoring the level of use.
Toxicant assimilation		See WET-EcoServices, Table 4.6, characteristic 6 to 8, for guidance in scoring the level of use.
Water supply		See WET-EcoServices, Table 4.10, characteristic 3 & 4, for guidance in scoring the level of use.
Grazing		Consider the extent[2], frequency and intensity of grazing.
Plants for crafts		Consider the extent, frequency and intensity of harvesting.
Medicinal plants		Consider the extent, frequency and intensity of harvesting.
Indigenous/ wild foods		Consider the extent, frequency and intensity of harvesting.
Cultivated foods		Consider the extent and duration of use (continuous cultivation vs. shifting cultivation).
Tourism & recreation		Consider the extent and frequency of use.

[1]Level of current use is given in relation to the supply, according to the following four classes: Nil (0), Low (1), Moderate (2), High (3) and Very high (4).

Table 4 does not address the question of potential risks that the current level of use might pose to the long term supply of the resource and to other resources in the wetland. This question is addressed in Section 4.

In addressing who is using the wetland, three different levels are examined (Table 5). When scoring for the local level, a minimum requirement is to identify the broad socio-economic context of the wetland, noting in particular the level of poverty, for example as determined by consulting Statistics South Africa. When scoring for the Catchment level, a minimum requirement is to (1.) check which Rainfall intensity zone (ranging from low to high) the upstream catchment of the wetland falls into, which affects the likelihood of floods occurring, (2) check for non-point sources of nutrients (for example fertilized crop or pasture land) and point sources (for example sewage or industrial outfalls, dairies, piggeries or feedlots in the catchment upstream of the wetland), and (3.) examine the area downstream of the wetland for infrastructure/property which would potentially be flooded and for water use (see Kotze et al, 2009). When scoring for the provincial level, consider whether the wetland unit is located with a tourism node/route or a water-stressed catchment, as identified by Department of Water Affairs.

In Table 5, dependency is scored on a very coarse scale and does not account for issues such as how benefits are distributed across gender or income classes. In addition, Table 5 also does not make explicit reference to the vulnerability of the local community. If a higher-resolution description is required then users are referred to Turpie (2010), which includes protocols for assessing vulnerability of the local community. Community vulnerability is scored in relation to five types of assets: physical, financial, social, human and natural. As an example, the Table for scoring physical capital is given in Table 6.

Table 5: A framework for scoring, at three different levels, the beneficiaries and their dependencies (modified from Bowd et al., 2012)

Ecosystem services	Local		Downstream		Provincial to national	
	Beneficiaries[1]	Dependency[2]	Beneficiaries[1]	Dependency[2]	Beneficiaries[1]	Dependency[2]
Flood attenuation						
Erosion control						
Sediment trapping						
Phosphate assimilation						
Nitrate assimilation						
Toxicant assimilation						
Water supply						
Grazing						
Plants for crafts						
Medicinal plants						
Indigenous/ wild foods						
Cultivated foods						
Tourism & recreation						

[1]The number of beneficiaries is scored on a coarse scale of 0, 1, 10, 100, 1000, 10 000, >10 000
[2]Dependency is scored on a scale of: 1=Minimal importance to wellbeing; 2= Moderately important for wellbeing; 3= Critical for wellbeing

Table 6: Scoring guidelines for the assessment of physical capital (From Turpie 2010)

Score	**0**	**1**	**2**	**3**	**4**	**5**
a. Health and sanitation infrastructure	Absence of clinics, sanitation systems					Enough clinics to serve community, most households have flush toilets
b. Transport infrastructure and access to markets	More than 2 days travel to formal shops and markets					A variety of formal shops and markets within the community
c. Farming infrastructure	None					Sophisticated irrigation systems
Physical capital score (guided by average (a,b,c))	**Non-existent**	**Very poor**	**Poor**	**Fair**	**Good**	**Very good**

4. Assessing opportunities and risks

Opportunities for increasing each of the respective benefits are scored in Table 7 and risks to these benefits in Table 8. Where level of use is low relative to supply (see Table 5), potential opportunities for increasing benefits may exist. Conversely, in the case of several ecosystem services, where use is high, then the risk of over-use is greatest. Risks may also arise from factors besides the use of that service, for example use of the wetland for cultivation may result in the loss of habitat suitable for medicinal plants, thereby threatening the use of these plants. Outside shocks, for example global climate change, present further risks to ecosystem services and the use of these services.

Table 7: A framework for scoring opportunities to specific ecosystem services

	Opportunity score*	Describe nature of the opportunity/s
Flood attenuation		
Erosion control		
Sediment trapping		
Phosphate assimilation		
Nitrate assimilation		
Toxicant assimilation		
Water supply		
Grazing		
Plants for crafts		
Medicinal plants		
Indigenous/ wild foods		
Cultivated foods		
Tourism & recreation		

*Opportunity is scored as: Nil/negligible (0), Low (1), Moderate (2), High (3), Very high (4)

Table 8: A framework for scoring risks to specific ecosystem services

	Severity of impact*	Likelihood of occurrence*	Describe nature of the risk
Flood attenuation			
Erosion control			
Sediment trapping			
Phosphate assimilation			
Nitrate assimilation			
Toxicant assimilation			
Water supply			
Grazing			
Plants for crafts			
Medicinal plants			
Indigenous/ wild foods			
Cultivated foods			
Tourism & recreation			

*Severity and likelihood are scored as:
Nil/negligible (0), Low (1), Moderate (2), High (3), Very high (4)

When scoring risks to individual ecosystem services, consideration should be given to the following:

- Land transformation (for example from natural to cultivated lands) both within the wetland and in its upstream catchment.
- Erosion, particularly in terms of headcut erosion advancing through a wetland unit.
- Over-utilization of resources, for example through physical harvesting or through livestock grazing.
- Changes to water inputs to the wetland, for example as a result of a planned dam upstream of a wetland
- Inappropriate fire regime, for example inadequate fire resulting in a naturally herbaceous wetland being invaded by forest or a fire frequency which is too high, allowing insufficient time for the natural vegetation to recover before the next burn.

For more information on these potential risks see WET-Health (Macfarlane et al., 2009) and WET-SustainableUse (Kotze, 2010).

When considering risks, it is important not to overlook institutional factors potentially threatening the resilience of the overall social-ecological system, for example absence of any monitoring and evaluation of use or a weak system of governance regulating use. Bowd et al. (2009; 2012) provide a more detailed framework for assessing risks/threats to natural resource use in the context of resilient social-ecological systems.

5. Potential costs of a wetland, particularly to local people

It is important to acknowledge that a wetland can contribute negatively to the wellbeing of its users, including the following potential costs.

- Provision of habitat for the invertebrate hosts of parasites implicated in the transmission of such important diseases as malaria and schistosomiasis (bilharzia) (Malan et al, 2009).
- Provision of habitat / roosting sites for crop pests, notably quelea birds.
- Provision of cover for criminals.
- Fire hazard, because wetlands generally accumulate fuel loads to a greater extent than adjacent non-wetlands, although wetland areas characterized by open water may act to halt the advance of a fire.
- Wetlands are often characterized, at least seasonally, by wide flooded areas, which increase the difficulty of crossing a valley floor by foot. In some cases there may be the additional hazard associated with dangerous animals such as crocodiles and hippos.
- In cases where houses are located in a wetland, periodic flooding (threatening life and property) and persistent dampness in the house (affecting the long term health of the inhabitants).

Children crossing a wetland in order to go to school.

Table 8 lists some potential situations where these detrimental effects are most likely to be encountered and then identifies some practical means of addressing these effects on wellbeing. Next it will be important to highlight how these negative effects are influenced by the type of wetland, its condition and its social-ecological context. For example, wetlands in an urban context tend to be more prone to the illegal dumping of solid waste than wetlands in a rural context.

Table 8: Potential costs of a wetland to people's wellbeing, situations where these costs are likely to be encountered and recommendations for addressing these costs

Costs	**Situations where the cost is most likely**	**Possible means of addressing the cost**
Habitat for invertebrate disease hosts	1) Tropical/subtropical regions of South Africa 2) Disturbed wetlands, particularly those with open drainage furrows and where predators of the hosts have been negatively affected.	Reduce the extent of human disturbance in the wetland (see Kotze 2010) and enhance the condition of the wetland (Kotze et al., 2009). See Malan et al. (2009) regarding integrated methods of addressing the hosts and the diseases.
Habitat/ roosting sites for crop pests	Large areas of *Phragmites* reeds located within landscapes with extensive cultivation of cereal crops.	Follow Best Practice for the control of Pests, and where required by legislation, work through the DAFF pest control programme.
Cover for criminals	Any tall vegetation (for example trees or reeds) occurring within densely populated areas with a high crime rate.	Work through appropriate fora such as the Community Policing Forum. In certain circumstances, regular mowing of the reeds may be an appropriate intervention.
Increased fire hazard	Herbaceous wetlands, particularly tall graminoids and reeds. Forest and open water tends to suppress fire.	Integrated fire-control programme. Work through appropriate fora such as the local Fire Protection Agency.
Difficulty of crossing	Rural areas in particular, where there are few existing road crossings which can be used.	Identification of alternative routes; the construction of a foot bridge over the wetland.
Flooding and dampness of property	Situations where properties are located within, or immediately adjacent to, wetlands. This is typically in urban areas, where space is generally limited.	Better planning of new developments. Low cost housing in particular continues to be located in wetlands, but the negative effects of this on residents can very simply be avoided in the future by proper delineation of wetlands and then locating all houses outside of these areas. In cases of degraded wetlands that have no hope for rehabilitation the infilling of the wetland in conjunction with rehabilitation of similar wetlands elsewhere that are more ideally located for restoration may be a potential solution but would require the necessary environmental authorization.
Pathogens and unpleasant odors in the wetland	Situations where wastewater is discharged into a wetland.	Deal more effectively with the wastewater at source. Integrated strategy to more effectively regulate pollution.
Solid waste in the wetland	Urban areas, where wetlands are often a "convenient" place to illegally dump.	Integrated waste management and anti-littering

A key principle underlying the recommendations in Table 8 is that they should support the resilience of the overall social-ecological system. For example, completely draining a wetland may deal with the detrimental effect it has in terms of habitat for invertebrate disease hosts but it is also very likely to compromise the resilience of the ecosystem in terms of buffering floods and nutrient loads. Thus, it would not be recommended, but rather a more integrated approach would be recommended.

As with benefits (services) supplied by a wetland, the social context of the wetland is likely to have an important influence over the costs "supplied" by a wetland. In some contexts, for example an urban low-cost housing context, local people may derive little provisioning services from a wetland but be subject to several costs, particularly if the wetland is degraded and pollution and illegal dumping are poorly regulated. In such cases, the long term resilience of the social-ecological system will probably need to focus primarily on addressing the environmental costs local people, particularly those whose houses are crowded very close to the wetland.

6. Conclusion

The DSS draws extensively from well-established tools, notably WET-EcoServices, and the rationale underlying the DSS is explicitly provided, which allows for the scientific basis of the system to be scrutinized. In addition the DSS has been applied in full to two case examples (see accompanying spreadsheets). Nonetheless, it is important to emphasize that the DSS has not been widely validated in the field. Thus, there is clearly a need to document application of the tool to sites across a diversity of biophysical and social contexts. It is anticipated that this will provide a useful basis for fine-tuning the DSS for different biomes, regions or ecotypes and for different social contexts.

For those already using WET-EcoServices, the DSS is not intended to replace WET-EcoServices, but rather to add new elements to its application and to help place it in the context of the overall social-ecological system. WET-EcoServices, which has not been revised since it was developed seven years ago. It is recommended that refinement of the DSS and WET-EcoServices be undertaken in concert, with some of the elements contained within the DSS potentially being incorporated into a revised WET-EcoServices or the two systems being consolidated.

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Appendix A: Background information on some key provisioning services

Grazing from wetlands

The value of wetlands for livestock grazing has been widely demonstrated (for example Morris *et al.*, 1989; Oellerman *et al*., 1994.; Richardson and Arndt, 1989). Owing to the favorable moisture conditions in wetlands, and probably also the higher soil fertility (Scotney and Wilby, 1983), the amount of forage produced in a wetland is typically much greater than that produced in the adjacent non-wetland areas and the quality is generally the same or better than non-wetland (Morris *et al*. 1989; Oellerman *et al*., 1994). Estimates by the Department of Agriculture over 4 years in Middelberg indicated that seepage wetlands were twice as productive as natural veld (cited by Turpie and van Zyl in Palmer *et al*., 2002). Using this figure they valued the replacement costs (gross, for fodder purchase) at R1800 per ha.

In some situations, however, the forage quality may be lower in the wetland compared with adjacent areas. One of the key factors contributing to this is the high proportion of poorly-digested structural material typically found in tall, robust wetland plants such as *Typha* spp. and *Phragmites* spp. (Howard-Williams and Thomson, 1985). While this applies to the mature growth of these species, the quality of the young growth is generally much higher (Duncan and D' Herbes, 1982). The excess water and very soft soil of some wetland areas renders them inaccessible for livestock, and therefore of little grazing value.

Fibrous plants harvested from wetlands for crafts and construction

The fibrous stems and leaves of many South African wetland plants, particularly sedges (Cyperaceae), rushes (Juncaceae) and grasses (Poaceae) are well suited for weaving. This has long been recognized in South Africa, where the country's indigenous cultures have an extremely rich heritage of crafts woven from wetland plants (Kotze and Traynor, 2011).

The principal areas where crafts are woven from wetland plants are in KwaZulu-Natal, especially in the Zululand and uThungulu regions, and the Pondoland region of the Eastern Cape. Weaving of wetland plants also occurs in the Northern Province, Mpumalanga Province, the Eastern Free State and in localized western areas of the Northern Cape.

Fibre-producing wetland plant species are generally suited to sustainable harvesting and cope well with regular and intensive levels of cutting, as they are generally fast growing and have a high capacity to recover (Cunningham, 1987; 2001). Nevertheless, the potential still exists for this activity to impact negatively on the harvested plants (for example Tarr *et al.,* 2004), depending on factors relating to: (i) the particular area of vegetation being harvested, (ii) the particular species being harvested, (iii) the method and intensity of the harvesting and (iv) other disturbances.

Medicinal plants harvested from wetlands

South Africa has approximately 200 000 Traditional Health Practitioners that utilise, *inter alia*, plants associated with both terrestrial and freshwater ecosystems for medicinal purposes, and approximately 30 million people make use of their services (Wentzel and van Ginkel, 2012).

Although some species are cultivated, most medicinal species are collected from the wild (Hamilton 2004) and this is likely to be so for wetlands.

Plants with medicinal properties are concentrated within certain families, which reflect their particular ecological adaptations, for example chemical defences against herbivores, fungi and pathogens (Horwitz et al. 2012). Medicinal plants harvested specifically from wetlands belong to a variety of different growth forms and taxa, including:

- **Trees and shrubs**. For example *Macaranga capensis*, which is used for treating, skin diseases and *Bridelia macrantha*, which is used for treating stomach aches, sore eyes, headaches and burn wounds.
- **Sedges and grasses** (Cyperacea and Poaceae). Although these taxa do not include many medicinal plants, there are a few exceptions, for example the sedge *Cyperus articulatus*, the rhizomes of which are used in several African countries in the treatment of headaches, migraines and stomach aches and has been demonstrated to have sedative properties (Rakotonirina et al. 2001).
- **Bulrushes** (Typhaceae). Several different plant parts from *Typha* spp. are used to treat a host of different conditions. Female flowers have been traditionally used in North America, the Middle East, India and China for external treatment to promote the healing of wounds and burns, and experimental investigation on *Typha domingensis* by Akkola et al. (2011) confirmed this remarkable wound-healing activity. The rhizome is stated to be detersive, astringent, stimulant, and is used as a diuretic in cases of retarded or painful urination; and even as a remedy for dropsy, dysentery, gonorrhoea and the measles (Morton 1975).
- **Herbs.** for example River pumpkin (*Gunnera perpensa*), widespread in montane and foothill seepages and marshes of southern Africa, is used widely to ease childbirth and promote the expulsion of the afterbirth in both humans and livestock, and the effect of *G. perpensa* rhizome extract on the contraction of uterine smooth muscle has been well demonstrated (Khan et al. 2004); Uxhaphozi (*Ranunculus multifidus*), widespread across many wetland types is used for treating coughs, sore throats, vomiting and diarrhoea; Ikhathazo (*Alepidea amatymbica*), widespread in montane and foothill seepages and damps grasslands of southern Africa, is used as a tonic and to treat coughs and chest complaints.

Plant species vary greatly in terms of their inherent vulnerability to over-harvesting, with the most susceptible generally being habitat-specific, slow-growing and those which are destructively harvested (Schippman et al. 2003). WHO, IUCN & WWF (1993) provide a framework for the conservation and sustainable use of plants in medicine, and highlights how no single sector can undertake the conservation of medicinal plants alone, but rather the task requires a team effort, involving a wide range of disciplines and institutions.

Wentzel and van Ginkel (2012) provide a comprehensive list of medicinal plants occurring in freshwater ecosystems that might be utilized for medicinal purposes**.** 230 medicinal plants occurring in South Africa's freshwater ecosystems are listed, including annual herbs, aquatic (submerged and free floating) plants, ferns, geophytes, grasses, perennial herbs, sedges, shrubs and trees. The perennial herbs were found to be the most utilised plant type, followed by trees, geophytes and shrubs.

Indigenous foods caught/hunted/harvested from wetlands

Of all of the wild foods supplied by wetlands, fish are probably harvested most widely across South Africa. Nevertheless, with the exception of a few wetlands such as the Pongolo floodplain, most South African wetlands support relatively small fish populations.

Frogs, including the bullfrog *Pyxicephalus edulis*, mammals, birds and insects, notably grasshoppers, are also hunted in some wetlands, but not to a great extent.

The most important wild food plant supplied by wetlands in South Africa are probably the flower clusters of waterblommetjies (*Aponogeton distachyos*) which are restricted mainly to the Western Cape, where they are well adapted to winter flooding and drying out during summer. Waterblommetjies remain a very popular traditional food in the Western Cape, and are grown commercially (van Wyk and Gericke, 2000). The underground storage organs of water lilies (*Nymphaea* sp.) are also eaten, but to a lesser extent than waterblommetjies.

A grasshopper caught for food in a wetland in the Mutale catchment, Limpopo province