An ecological monitoring framework for Intunjambili wetland in Zimbabwe

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1. Introduction

Wetlands are important in agricultural production in the communal lands of Zimbabwe, mainly because of their rich organic soils and abundant water resources throughout the year. They play a key role in rural livelihoods providing both direct and indirect benefits to rural communities. Of critical importance is perhaps the direct benefit of informal irrigation usually occurring without much capital investment. Communal farmers believe wetland cultivation requires drainage of excess water to enable root development and soil aeration. However, such land-use activities can be detrimental to the lifespan of a wetland and undoubtedly impact negatively on the multitude of ecosystem services that they provide. In addition to improper management, the fragility of wetlands in the southern parts of Zimbabwe is worsened by erratic rains and, in particular, extended periods of lower than average rainfall in recent years. This means that although wetland drying and degradation may be a function of both the climatic environment and human activity, there is need to map out strategies which will target at sustainable management of their viability through manipulation of the latter to ensure optimal use of the wetlands. This concept formed the basis of a research project '*Wetlands-based livelihoods in the Limpopo basin: balancing social welfare and environmental security*'. Understanding the linkages and achieving a balance between the welfare of people in Intunjambili and ecological processes within the wetland is critical in answering some of the project hypotheses.

Intunjambili wetland is part of the Tuli river catchment situated in the Matebeleland South Province of Zimbabwe, at 20° 27' South and 28 ° 41' East. The wetland is some 60 km south east of the Zimbabwe's southern capital of Bulawayo and covers a totall area of ~30 ha. About 180 households with a total population of ~ 512 use the wetland for various services and activities including gardening, provision of domestic water supply and recreational activities. According to the Zimbabwean soil classification, the soils of Intunjambili belong to the Fersiallitic Group (Nyamapfene, 1991). This group consists of moderately leached soils of the kaolinitic order, derived from granite. They have a low clay content (10%) in the top soil. The soils can be classified as Ferralic Arenosols (FAO, 1988) or simply Arenosols (World Reference Base, 1998). The large portion of the soils is hydromorphic due to the poor drainage.

The terms of reference for the ecological component of the project were:

a) Implement ecological assessments (dry and wet season) for the wetland. Establish the health of the wetland and suggest indicators that can be used to monitor wetland health

b) Define environmental security for the wetland based on local conditions of flora, fauna, wetland processes and processes of linked downstream environments, using described methods and draft manual
c) Recommend a framework for monitoring and analysis of data to assess changes in wetland health due to livelihood supporting activities overtime

2. Methodology

Wetland health is an interaction of processes taking places within the (i) hydrological; (ii) geomorphological and (iii) vegetational setup, in addition to flora and faunal composition that the wetland supports. Each of these has a set of direct and indirect measurable indicators. A rapid appraisal of Intunjambili was undertaken based on three days of field assessment during the dry season month of October. Emphasis was placed on land-use activities (gardens, arable fields and grazing) and general biodiversity (vegetation and fauna) of the wetland. A rough appraisal to dry-season water quality was also undertaken although there was a general appreciation that the quality of water is not static and varied over time.

Mapping of particular niches of interest and possible sites for future monitoring was done using a GPS (Garmin eTrex Legend personal navigator) accurate to within 4 to 10 m. Delineating disturbed (cultivated and cleared) areas, plantations, intact patches, grazing land and other prominent features such as dams and settlement was done using a recently constructed map of the wetland. Principles of WET-Health, a modular-based approach for evaluating and monitoring current ecological states of South African wetlands by Macfarlane et al. (2005), were used as a guide to wetland health assessment. WET-Health attempts to account for the key interactions that take place within the wetland (i.e. the hydrology, geomorphology and vegetation) and synthesize this information by evaluating a measurable set of wetland components. It was felt that WET-Health could be extrapolated to describe the Zimbabwean situation as the technique generally was designed to:

(i) provide possible indicators for wetland health
(ii) highlight the key causes of wetland degradations
(iii) both direct and monitor the effects of management interventions on wetland habitats.

In addition, personal observations and opinion played a significant role in the assessment. The health status of three key wetland components as identified by Macfarlane et al. (2005) namely the hydrology, geomorphology and vegetation, was evaluated by assessing the effect of modifications on each of the three components. Normally, this is done by comparing observed current conditions with benchmark conditions where benchmark conditions are defined as original conditions prior to human disturbance/ modification. However, in the case of Intunjambili, pristine niches to make comparisons were not available as the whole wetland had undergone some form of disturbance. No known reference material of the site describing the ecological state before human impact against which comparisons could be made was available. It should also be noted that wetlands are dynamic ecosystems that respond to environmental changes through space and time. However, relevant indicators of change were identified and explored for each of the three wetland components and termed baseline characteristics at start of monitoring.

2.1 Baseline information

Baseline characterization activities involved a general description of the hydro-geomorphological setting of Intunjambili wetland. Land-use activities during the dry-season period were noted and field verification of intact and disturbed (e.g. cultivated) patches done using an existing map of Intunjambili. Using the map, the wetland was delineated into four main sections (Section 1-4) (see Figure 1), and where necessary, descriptors for each were analyzed separately. Soils texture was determined using the finger-test method and the level of humification of the soils under different land-use activities assessed using a scoring system. An overview of the dominant vegetation types highlighting particular niches was also undertaken. During the vegetation identification process, dry season faunal species were also noted.

2.2 Health assessment: Hydrology

The wetland hydrological component centres on evaluating changes to water inputs as a result of changes to the wetland catchment and the degree to which natural distribution and retention patterns within the wetland have been altered. This was done following a detailed identification of activities (physical and from a delineated map) on reducing or altering water inputs (quantity and pattern). The impact of the identified stressors was evaluated using a scoring system. In addition, the degree and extent of canalization (artificial drains and erosion gullies) and modifications to existing channel likely to impact on changes to water distribution and retention patterns was assessed and noted. Measurements included depths; length; widths; sinuosity; roughness of the canals/ gullies/ drains/ artificially introduced channels. The major ones were mapped for use in the monitoring framework that will allow for identification of any new drains and checking of existing drains for signs of improvement/ degradation. Impending features to the wetland hydrological component (dams; weirs) were also noted.

The height of the water tables was not included in this assessment as it was felt that the existing hydrometric network of peizometers currently does not take into account ecological aspects. However, efforts were underway to install new one which might give a meaning to the impact of different land-use activities on the height of the water table. Water quality was not qualitatively assessed during the dry season appraisal. *In situ* quality analysis included:

i. determining the presence or absence of invertebrates
ii. evaluation of invasive plants are water weeds which are indicators of eutrophication,
iii. inventories of likely sources of point and non-point source pollution (soil fertility management practices), and
iv. spatial and temporal dynamics of aquatic fauna (identification of invertebrates; protozoa) and flora (algal species)

2.3 Health assessment: Geomorphology

This component focuses on the distribution and retention patterns of sediment within the wetland. In general, three types of sediment may enter and accumulate within and/ or leave the wetland at any one time. These may be (i) clastic sediment (mineral particles); (ii) dissolved sediment (material carried in solution in the water column); and, (iii) organic sediment (organic material). The geomorphic health was assessed following determinations of the nature of sedimentary fill in the wetland. This was complemented by an assessment of erosion hazard through identification of inherent features likely to influence sediment flow (longitudinal slope; soil type and vegetation cover) and assessment of the relationship between gullying and steepening of gradient looking out for any direct signs of deposition.

Based on the hypothesis that excessive sedimentation results in evident depositional features while excessive erosion leads to gullying, potential inputs and outputs of sediment to and from the wetland was assessed. The degree of deposition at the entry point of tributaries and/ or gullies into the wetland (usually fan-like lobe of mineral (clastic) sediments) was assessed. Other sediment loss pathways within the wetland were evaluated. The dynamics of soil organic matter in cultivated lands and erosion risk were evaluated under different tillage management regimes and land use practices. This involved identification of activities potentially contributing to increased or reduced sediment inputs (soil fertility management practices; grazing; bare ground; dumping). Activities within and surrounding the wetland that potentially reduce sediment inputs and promote wetland erosion were also evaluated.

2.4 Health assessment: Vegetation

Wetland vegetation is dynamic, responding to changes in climate, catchment activities and disturbance within the wetland. It may also take time to respond to changes with competitive processes slowly altering species mixes over time. Vegetation assessment involved characterization, identification and mapping of similar or homogeneous niches within Intunjambili. Undisturbed areas, areas of partial or complete disturbance constituted the nuclei of attention. The compositional integrity in undisturbed or partially disturbed zones involved identification of key indicators such as:

a. Encroachment by indigenous invasive species
b. Alien plant invasion
c. Replacement by introduced species (in field and gardens)
d. Encroachment by terrestrial/ dry land species
e. Increase in particular species (weeds; sedges; grasses). Grasses react either by increasing or decreasing.
    i. Decreasers are abundant in grazing areas and include palatable grasses. .
    ii. Increaser I: include grasses that are unpalatable, robust climax species that grow without any defoliation.
    iii. Increaser II: Such grasses increase due to the disturbing effect of overgrazing. They produce much viable seed and this can quickly establish on new exposed ground within the wetland

In addition, factors potentially affecting vegetation integrity were also evaluated.

Scoring impacts for all the three wetland components was done using the following definitions (MacFarlane et al., 2005):

- **i.** **Extent** - the proportion of the wetland affected by a given activity (%)
- **ii.** **Intensity (severity)** – the degree to which wetland characteristics have been altered within the affected area (%)
- **iii.** **Magnitude** – the actual impact in relation to the whole wetland of activity (activities) on the component being evaluated (%).

Magnitude score = Extent / 100 x Intensity

- **iv.** **Health** – reflects the degree of intactness, and is based on the magnitude of impact. The health score is obtained by subtracting the magnitude score from 100% (pristine / undisturbed).

3. Results of the health assessment of Intunjambili wetland

3.1 *General characteristics of Intunjambili wetland*

Intunjambili wetland is a floodplain-type of wetland located on a valley bottom with a well- defined stream channel between two hills. The slope is of the main wetland is gentle and water inputs are mainly from the sub-surface flow from adjacent hillslopes and from surface flow being fed via the main channel and its tributaries. During this dry season period in October, an active spring was observed recharging the wetland in Section 3). The soils show typical hydromorphy caused by poor drainage due to the poorly jointed underlying granitic bedrock.

The valley floor consists mainly of poorly-drained areas being permanently wet as well as semi-permanently wet, seasonally wet and temporarily wet and non-wet portions. The soils are generally sands and loamy sands ranging from light-coloured soils on the upper slopes (non-wet portions) to dark black organic soils in the permanently and semi-permanently wet sections.

Major land-use activities include vegetable gardening (18%), dryland fields (ploughed once a year during the rainy season) (30%), grazing (20%) and settlements (2%). Intact niches were not easily identifiable and constituted <1% of the total wetland area. Field verification showed that even the natural dryland vegetation outside the main wetland was secondary vegetation still in the process of recovering from a previous heavy disturbance such as overgrazing and deforestation. Three *Eucalyptus* plantations were observed in during the baseline appraisal Section 1 covering approximately 2% of landuse while the

Plate 1. Bird nests clearly visible above water sources within vegetable gardens

major features for Section 4 were a weir and a dam (~10% of utilizable area). The wetland supports many different vegetation types ranging from obligate hydrophytes (e.g. *Phragmites* spp.) grasses, weeds to dryland plant communities (e.g. *Acacia* spp) (details of these vegetation types will be described later). Several bird species, aquatic fauna (arthropods, amphibians, fish) and insects (grasshoppers, locusts, butterflies) were quite predominant in the wetland. Bird nests were clearly visible above some water wells.

Hydrology

a) Changes to water input quantity and pattern

Agricultural activities predominate in the Injunjambili wetland. Abstractions for irrigation are currently the main modifier to water inputs within the wetland (see Table 1). Irrigated land in the form of vegetable gardens constitutes more than 60% of total land and these vegetable plots could be found in all the four delineated sections (Sections 1-4). Irrigation water is diverted from the wetland via:

i. artificial drainage channels some of which are opened and closed according to the need of water demand
ii. drainage channels draining into wells for ease of access of irrigation water. This is found in almost every vegetable garden with some gardens having more than two of these.
iii. Flood irrigated portions particularly in Sections 1 and 3. Section 3 appears to have an uninterrupted supply of groundwater inputs as was evidenced by an actively flowing spring in one of the gardens.

Table 1. Potential impact of abstraction rates on water inputs in Intunjambili

Parameter	Section 1	Section 2	Section 3	Section 4
Extent of land irrigated with water abstracted from the wetland	Moderately high	Medium	High	High
Duration of irrigation	All year round	All year round	All year round	All year round
Prevalence of water conserving irrigation practices (wells)	High	High	Moderately low (includes permanently wet portions)	Very high (include the weir)
Prevalence of water conserving cultivation practices	Moderately low (ditches/ mulching)	Low (ditches)	Low (ditches)	Low (mulching/ ditches)

A large dam downstream benefits from all the wetland outflows. This dam is used for irrigation in Section 4, recreational activities such as fishing and supplying water to a downstream irrigation scheme outside the main wetland. The presence of the irrigation scheme outside the wetland implies that no return flows are likely to benefit the wetland. The overall extent of existing Eucalyptus plantations in Intunjambili may be classified as low ((<10%). It is perhaps the general location of the plantations (upland within Section 1) that may pose a threat to the quantity of water supplied by the wetland's catchment. Moreover, the high water demand associated with Eucalyptus trees implies that they have a significant, though indirect, impact in depleting underground water.

Heavy grazing pressure was evident during the period of assessment in October. Signs of trampling and bare patches as a result of loss of vegetation cover were apparent. Such activities and associated reduction in vegetation cover may have potentially increased surface runoff and reduced infiltration within the wetland. This can in turn, lead to less sustained sub-surface runoff and reduced infiltration. Settlements and upland fields are also present in the wetland, and occupy a significant proportion. Roads and footpaths are impacting on surface runoff as could be evidenced by development of rills and gullies particularly in the drier and dessicated parts of the wetland (Section 2).

Plate 2. Signs of trampling by grazing livestock within Intunjambili wetland

At the head of the wetland, numerous outcrops of termite mounds exist leading in to the main wetland along the grazing area (Section 1). These have the potential to impede the normal flow of water into the wetland, by re-directing normal water channels.

b) Activities potentially altering the pattern on water inputs

The general slope of the wetland is low (<1%) although a few sections from the south-western side have a slightly steeper slope (between 2-5%) and water inputs from this portions appear to be groundwater recharge from the foot of the kopje. Human activities top the list in altering the pattern of water distribution and retention patterns within the wetland. Vegetables are the predominant crops grown within the wetland (see Table 2) taking up > 95% of total cultivated dry-season land. The remaining small proportion (<5%) is allocated to cereals [maize – *Zea mays* (90% of the <5%] and wheat – *Triticum sativa*). None of the crops grown are specifically adapted to prolonged soil saturation implying that successful agricultural production is through drainage of excess water. The artificial drainage channels naturally extend beyond cultivated land and may feed into the main channel. This undoubtedly impacts on the extent to which water is distributed across the wetland surface and detained within the wetland.

Table 2. List of major-vegetable types grown within Intunjambili wetland

Common name	Scientific name	% cropped land
Covo	*Brassica oleracea*	>95
King onion	*Allium cepa*	<1
Tomatoes	*Lycopersicon esculentum*	<1
Rape	*Brassica oleracea*	<1
Mustard rape	*Brassica spp?*	<1
Green pepper	*Capsium annuum*	<1
Hot pepper	*Capsium frutescens*	<1
Sweet potato	*Ipomoea batatas*	<1
Garlic	*Allium sativum*	Insignificant

Artificial drains and erosion gullies both have potentially high impact on the distribution and retention of water within the wetland and impacts on the health of the wetland (Table 3). Sections 1 and 3 are moderately channeled, while canalization in Sections 2 and 4 can be described as moderately diffuse, although erosion gullies are more prevalent in the latter, and can be attributed to overgrazing and poor land management. Of notable interest is modification to the existing channel through a man-made diversion (Section 2/ 3) to promote confinement of water passing through the wetland. While this artificial drainage channel has a gentle slope and not sinuous, there is some high level of ponding along its length, which implies that water movement is slowed down as it passes through. There is enough vegetation on both the main and diverted channels likely to slow down the movement of water.

Other existing potential water loss pathways within the wetland include a dam and a weir downstream of the main channel within Section 4. The detained water is subject to evaporation. While data for mean annual rainfall (MAR) and potential evapo-transpiration (PET) for the area was not readily available, the area generally falls in Natural region IV of Zimbabwe (mean annual rainfall <450 mm, mean annual temperatures >28^{o}C), and it is safe to assume a low MAR:PET ratio, implying a high evaporative losses from both the weir and the dam.

Water quality was not qualitatively assessed during this dry season appraisal. The water in the non-cultivated sections of the wetland (main channel, ponds, spring) was clear in terms of turbidity. Murky water was apparent in wells and ditches within the gardens, a result of poor soil structure and activities such as deepening the wells to capture more water. Most of the open water sources within the wetland (main channel, ponds and wells) had a high activity of water arthropods. Encroachment of alien

Plate 3. Water contaminated with sediment in dug-out wells within vegetable gardens

invasive species was totally absent. However, natural invasive species within water bodies, *Nymphaea nouchali* and *Nymphaea mexicana* in particular, were evident at the dry season throwback boundary of the dam stretching for about 100 m into the dam waters. This is likely due to a high nutrient overload at the point where the wetland main channel enters the dam. The nutrients are evidently being washed away from the arable fields where there are high levels of mineral fertilizer use. Both true algae and blue-green types were also apparent, with a high proportion of the non-photosynthetic ones in drying-up ponds.

Plate 4. Evidence of human pollution to water bodies within Intunjambili wetland

Hydrological health assessment of Intunjambili wetland

Table 3. The hydrological integrity of Intunjambili wetland

Delineated portion	Extent of drainage (%)	Intensity of impact (%)	Magnitude of impact (%)
Section 1	20	60	12
Section 2	10	40	4
Section 3	30	55	16.5
Section 4	15	65	10
Score			**42.5**

The hydrological health of the wetland is therefore 100 – 42.5 = 57.5%, which falls into the Fair health category. A fair health category implies that the wetland has been moderately modified. A loss and change of natural habitat have occurred but the basic ecosystem functions are still predominantly unchanged.

Geomorphology

Current state of clastic and organic sediments

Geomorphic processes fundamentally control how water flows within the wetland and are characterized by both inputs and outputs of sediment. Visible signs of erosion are beginning to show within the wetland. However, more than 60% of the wetland is dominated by organic sedimentation. Clearly visible signs of clastic (mineral) sediments take occur in very small sections of the wetland, particularly where wet-season water ways and large drainage channels enter the valley floor and also where

Plate 5. A gully developing within grazing land

the main channel enters the dam. Clastic sedimentation could be attributed to the steepening of the gradient, runoff due to an increase in water volumes, and soil type which is generally loamy sand. Most of the artificial drainage channels show some limited erosion signs as a result of collapse and washing away of the banks.

No depositional features were evident while gullying was mostly attributed to sediment mining (in this case brick-making, soil for construction purposes) and trampling. It was not possible to estimate the extent of sheet erosion from the cultivated lands as this need specialized monitoring.

Plate 6. The impact of livestock pressure on the geomorphological integrity of Intunjambili wetland

The level of disturbance of organic soils through tillage is high (see Table 4). The fields/ gardens are ploughed using a mouldboard plough at least twice a year and soil under horticultural crops is turned-over (disturbance) using a handhoe at least one every fortnight. Such tillage practices lead to a greater exposure of the upper soil layers, leading to increased oxidation and dramatically increasing the wetting and drying rates. Thus, the degree of tillage can be an indirect measure reflecting loss of organic sediment within the wetland. Dessication via artificial drainage also contribute to accelerated oxidation and mineralization of organic sediments.

The importance of organic sediments

Deposition of organic sediments leads to a build-up of soil organic matter. Soil organic matter (SOM) is important in the functioning and productivity of all terrestrial ecosystems being the source and sink of nutrients. However, inherent SOM remains fragile in wetland ecosystems as this is exploited under different land use practices with hardly any replenishment. Thus, in order to maintain the geomorphic integrity of wetland ecosystems, soils need to be sustainably management through protecting and maintaining the SOM status.

Plate 7. Organic soils in some vegetable gardens within the wetland

The built-up and maintenance of SOM in Intunjambili is already threatened by the overall reduction and loss of natural vegetation, and poor organic matter management within the arable plots. This means that there is more offtake compared to inputs. In addition, physical removal of SOM through burning was apparent (Sections 1 and 2), and this is linked to increased evaporative losses and dessication of exposed soils. Another factor which cannot be manipulated but has great impact on the SOM status of Intunjambili is related to the environment. The wetland lies in an area where temperatures are naturally high for much of the year, and with the moist conditions prevailing, this leads to accelerated loss of organic carbon.

Table 4. The geomorphic integrity of Intunjambili wetland

Geomorphic parameter	Extent (%)	Intensity of impact (%)	Magnitude of impact (%)
Erosion	10	30	3
Depletion of SOM	70	60	42
Score			**45**

The geomorphic integrity of the wetland is 55% which falls into the Fair health category. However, the high figure implies that the geomorphic functions, particularly loss of SOM, have largely been modified and need monitoring.

Vegetation

At least three basic landuses were identifiable in terms of vegetation characteristics within the wetland. These were:

1. Arable land (includes gardens and wet-season arable lands). These areas can be classified as areas of total transformation. Almost total removal of indigenous vegetation being replaced by introduced species (see Table 2).
2. Grazing area (includes valley bottom permanently and semi-permanently wet and includes area covered by the main channel). This was mapped as areas of historical transformation although while the dam falls within this category, it has the potential to cause total transformation to vegetation types surrounding and beyond it.
3. Upland grazing land (only seasonally wet) – these are areas of intact vegetation with a high abundance of natural species and very little soil disturbance.

Plate 8. Complete replacement of natural wetland vegetation by vegetable crops

Because the composition of vegetation in wetlands is dynamic, changing in response to natural changes in water availability, it was necessary to assess vegetation using key indicators described by MacFarlane et al., 2005. Key indicators for evaluating vegetation communities included (a) encroachment by indigenous invasive species; (b) alien plant invasion; (c) replacement by introduced species (in field and gardens);

(d) encroachment by terrestrial/ dry land species, and (e) increase in particular species (weeds; sedges; grasses) (Tables 5-8).

The wetland has a number of indigenous tree species and shrubs in isolated pockets within the main wetland, or as scattered individual tree species deliberately left within arable fields for one reason or another. Some individual trees species like *Ficus sycomorus*, are protected because they provide fruit, while other like *Acacia nilotica* provides shade. Invasive indigenous species were many. These were favoured by a number of different disturbances or imbalances to the natural state of the wetland. Such imbalances included an increase in nutrients within the water bodies (e.g. *Phragmites* and *Nymphaea* spp.), increased or decreased wetness (some ruderal (weedy) species, or increased disturbance by livestock and man (see Table 7).

Table 5. Vegetataion types of introduced species in Intunjambili wetland

Name	**Common name**	**Form/ type**	**Species Category**
Allium cepa	King onion	Vegetable	Replacer; introduced; gardens
Allium sativum	Garlic	Vegetable	Replacer; introduced; gardens
Brassica oleracea	Covo	Vegetable	Replacer; introduced; gardens
Brassica oleracea	Rape	Vegetable	Replacer; introduced; gardens
Brassica spp?	Mustard rape	Vegetable	Replacer; introduced; gardens
Capsium annuum	Green pepper	Vegetable	Replacer; introduced; gardens
Capsium frutescens	Hot pepper	Vegetable	Replacer; introduced; gardens
Ipomoea batatas	Sweet potato	Vegetable	Replacer; introduced; gardens
Lycopersicon esculentum	Tomatoes	Vegetable	Replacer; introduced; gardens
Triticum aestivum	Wheat	Cereal	Replacer; introduced; gardens and dryland fields
Zea mays	Maize	Cereal	Replacer; introduced; gardens and dryland fields

Table 6. Vegetation types of indigenous riverine and dryland species in Intunjambili wetland

Name	**Common name**	**Form**	**Species Category**
Dovyalis caffra	Kei-apple	Spiny shrub/ small tree, bushveld, riverine	Indigenous; wetland

Name	Common name	Form	Species Category
Ficus capensis (F. sur)	Broom cluster fig	Semi-deciduous tree	Indigenous; riverine
Ficus sycomorus	common cluster fig	Semi-deciduous tree wit spreading crown	Indigenous; riverine
Syzygium cordatum	Water berry	Medium to large evergreen tree. Fruit deep purple when ripe, edible	Indigenous; riverine
Syzygium guineense	Water berry	Medium to large tall evergreen tree. Fruit purplish-black, edible	Indigenous; riverine
Acacia karoo	Sweet thorn	Tree with lender white spines bright yellow flowers	Indigenous; dryland
Acacia nilotica	Water thorn	Multi-stemmed shrub/ tree slender, backward deflexed spines, bright yellow flowers	Indigenous; dryland
Acacia robusta	Ankle thorn	Robust small to medium sized tree, spines short/ white. Creamy white flowers	Indigenous; dryland
Carissa edulis	Simple spined num-num	Spiny evergreen shrub/ small tree. Fruit edible	Indigenous; dryland
Combretum molle	Velvet bushwillow	Small to medium-sized semi-deciduous tree. Autumn leaves reddish/ purplish	Indigenous; dryland
Euphorbia ingens	Common tree euphorbia	Spiny, succulent tree up to 10 m high.	Indigenous; dryland
Grewia monticola	Silver raisin	Shrub/ small tree. Fruit edible	Indigenous; dryland
Grewia occidentalis	Cross berry	Shrub/ small tree. Fruit edible	Indigenous; dryland
Gymnosporia (Maytenus) senegalensis	Kraal spike-thorn	Spiny multi-stemmed shrub or small tree	Indigenous; dryland
Kiggelaria africana	Wild peach	Tree. Seeds black with bright orange-red covering	Indigenous; dryland
Mimusops zeyheri	Red milkwood	evergreen tree with edible fruits	Indigenous; dryland
Ximenia caffra	Sourplum	Sparely branched small shrub/ tree; spiny; fruit edible	Indigenous; dryland

Table 7. Vegetation types of indigenous invasive species to different wetland niches within Intunjambili

Name	Common name	Form	Species Category
Bidens pilosa	Black jack	Weed	Indigenous invasive; semi-moist environments
Galinsoga parviflora	Chickweed	Weed	Indigenous invasive; semi-moist environments
Oxalis latifolia	Salt weed	Weed	Indigenous invasive; semi-moist

Name	Common name	Form	Species Category
			environments
Tagetes minuta	Mexican marigold	Weed	Indigenous invasive; semi-moist environments
Amaranthus hybridus	Pigweed	Weed	Indigenous invasive; seasonally moist environments
Conyza albida	Fleabane	Weed	Indigenous invasive; seasonally moist environments
Eleusine indica	Rapoko grass	Weed	Indigenous invasive; seasonally moist environments
Cordia monoica	Snot berry	Shrub/ small tree on wetlands/ bushveld	Indigenous invasive; riverine
Cladium maricus	Sawgrass	Weed	Indigenous invasive; moist environments
Cyperus esculentis	Yellow nutsedge	Weed	Indigenous invasive; moist environments
Eriochloa meyeriana	Black-footed water grass	Grass	Indigenous invasive; moist environments
Fern?	Fern	Fern	Indigenous invasive; moist environments
Persicaria lapathifolia	Spotted knotweed	Weed	Indigenous invasive; moist environments
Persicaria senegalensis	Shakeroot	Weed	Indigenous invasive; moist environments
Aristida junciformis	Broom grass	Grass	Indigenous invasive; Increaser II; moist environments
Cymbopogon validus	Giant turpentine grass	Grass	Indigenous invasive; Increaser I; semi-moist environments
Andropon gayanus	Blue grass	Grass	Indigenous invasive; Increase I; moist environments
Cynodon dactylon	Couch grass	Weed	Indigenous invasive; dryland cultivated soils
Richardia scabra	Mexican clover	Weed	Indigenous invasive; dryland cultivated soils
Commiphora pyracanthoides	Common corkwood	Spiny shrub common on termitaria	Indigenous invasive; dryland
Solanum aculeastrum	Goat apple	Prickly shrub in dry places, near human habitation	Indigenous invasive; dryland
Arundo donax	Giant reed	Hollow stemmed water plant	Indigenous invasive; aquatic
Cyperus dives	Giant sedge	Weed	Indigenous invasive; aquatic
Cyperus eragrotis	Sedge/ rush	Weed	Indigenous invasive; aquatic
Cyperus flabelliformis	Umbrella plant	Hollow stemmed water plant	Indigenous invasive; aquatic
Cyperus sexangularis	Sedge/rush	Weed	Indigenous invasive; aquatic

Name	Common name	Form	Species Category
Eleocharis acutangula	Sedge	Hollow stemmed water plant	Indigenous invasive; aquatic
Juncus lomatophylus	Leafy juncos	Hollow stemmed water plant	Indigenous invasive; aquatic
Nymphaea mexicana	Yellow water lily	Small broadleaved floating plant	Indigenous invasive; aquatic
Nymphaea nouchalia	Blue water lily	Broadleaved floating water plant	Indigenous invasive; aquatic
Phragmites australis	Common reed	Hollow stemmed water plant	Indigenous invasive; aquatic
Phragmites mauritianus	Thatching reed	Hollow stemmed water plant	Indigenous invasive; aquatic
Schoenoplectus brachyceras	Water reed	Hollow stemmed water plant	Indigenous invasive; aquatic
Typha capensis	Bulrush	Hollow stemmed water plant	Indigenous invasive; aquatic

Table 8. Vegetation types of encroaching and alien species within Intunjambili wetland

Name	Common name	Form	Species Category
Aloe vera	Common aloe	Single-stemmed, spiny, succulent, bitter	Encroaching; dryland
Cereus jamacaru	Queen of the night	Tree with upright succulent stems	Encroaching; dryland
Opuntia ficus-indica	Sweet prickly pear	Succulent shrub/tree; Branches flattened to leaf-like structures	Encroaching; dryland
Dichrostachys cinerea	Sickle bush	Shrub to small tree, spines not paired similar in colour with branchlets, pink-yellow flowers	Encroaching; dryland
Gymnosporia buxifolia	Common spike-thorn	Spiny shrub-small tree, pioneer in disturbed habitats	Encroaching; dryland
Lantana camara	Lantana	Shrub	Alien; invasive; dryland

Factors affecting vegetation integrity

Several factors are responsible for the vegetation integrity of wetland. Within Intunjambili, cropping activities (gardens and dryland fields) had the largest impact. Much of the grazing land is dominated by grasses in the wetter sections, and dryland vegetation trees and shrubs in the seasonally wet portions. Burning of stover and excess biomass within cropped lands is practiced an organic matter management option.

Plate 9. Thickets associated with large termite mounds scattered along the main channel

However, there was no evidence on the actual impact of burning of the overall vegetation integrity at time of sampling and its impact could be defined as small to moderate. Canalization appeared to promote an increase in indigenous invasive wetland species. Other factors contributing to changes in vegetation are the existence of a dam, road infrastructure and sediment mining practices. Natural vegetation does show some signs of disturbance although the intensity could be described as moderate.

Table 9. Vegetation integrity of Intunjambili wetland

Responsible factor	Extent (%)	Intensity (%)	Magnitude/ Severity (%)
Cultivated land	50	80	40
Grazing land	20	60	12
Natural vegetation	20	20	4
Dam/ weir	7	100	7
Canalization	1	80	0.8
Roads	1	60	0.6
Settlements	1	60	0.6
TOTAL			**65**

The overall vegetation health category of the wetland could be described as fair at 65%.

Monitoring

The overall wetland health can be described as fair, but there is need to put in place some measures to sustainably manage it. Several fragile areas needing constant monitoring were identified (Table and it is advised that some form of protective measures be developed together with the community in an effort to halt potential damage to ecosystem services provided by the wetland. measures to protect Retention of water is a pre-requisite for the maintenance of wetland habitat. Multiple methods will be needed and used to achieve the sustainability of the wetland, combining participatory and qualitative methods with more quantitative methods. The quantitative methods will include water quality problems do not occur isolation since many activities within the watershed affect the quality of water resources. Water quality monitoring involves obtaining information on the physical, chemical and biological characteristics of the aquatic environment via observations, sampling and evaluation.

Table 10. Selected sites requiring monitoring in order to assess the overall integrity of the wetland

Description	**Section**	**Elevation (m asl)**	**Georeference**	**What to monitor**
Channel order 1 merger	1	1487	20.44873ºS: 028.68404ºE	Water quality and pollution; is the gully increasing or static?
Pristine land	3	1486	20.44862ºS:028	Changes in vegetational

Description	Section	Elevation (m asl)	Georeference	What to monitor
around natural spring			.68295ºE	composition may indicate disturbance or drying
Channel 2 along main channel	3	1485	20.44873ºS: 028.68395ºE	Erosion due to trampling, pollution from water use activities
Dam level throwback	4	1478	20.45018ºS: 028.67934ºE	Eutrophication; water quality in terms of nutrient load; invasive species
Weir	4	1480	20.44649ºS: 028.68090ºE	Water levels; water quality in terms of nutrient load
Main channel diversion	3/4	1484	20.44743ºS: 028.68276ºE	Water quality at point of diversion and exit from garden, point of merger; erosion risk; entry into main water channel (~25 m from weir) only likely when water level is high

Table 11.Erosion threat and portions requiring monitoring within the wetland

Type and Possible cause	Section	Position	Size
<u>In seasonally wet and permanently wet portions</u> 1 Sediment extraction for brick-making	1	20.44873ºS: 028.68404ºE	8 m diameter
2. Sediment extraction	1	20.45163ºS: 28.68587ºE	
3. Gully – manmade channel?	4	20.44767ºS: 028.68373ºE 20 m north of weir and 3 m from main channel	
4. Gully – water pathway, rills evident	4	20.44744ºS: 028.68357ºE, only 15 m from main channel	
5. Diverted water course	3/ 4	20.44662S: 028.68168ºE	>0.5 m deep at some points along its length; between 0.75 to 1.5 m wide
<u>In the non-wet portions</u> 1. Rill, trampling and water course	2	20.44635S: 028.68275ºE	11 m long; <0.3 m wide
2. Gully with typical fan-shaped clastic deposits due to water movement	2	20.44648S: 028.68369ºE	0.8 m wide at widest point and 0.25 m deep
3. Rill due to water movement and trampling	2	20.44670S: 028.68378ºE (directly opposite 2 above)	18 m long; < 0.15 m deep, wider on upper slope (0.25 m)

Table 12. Proposed monitoring framework for the overall integrity of Intunjambili wetland

Parameter	**Variable**
Hydrology and geomorphology	• Regular assessment of the overall drainage network paying particular attention to artificial drainage channel networks

Parameter	Variable
	• Impact of the drainage channel network on the retention and distribution of water in the wetland. (Wet-season dynamics; effect on bare patches) • Height of water tables in the wetland along different transects • MAP:PET (mean annual precipitation : potential evapo-transpiration ratio)
Water quality	• Detect significant trends in water quality - Spatial distribution of quality (number of sampling points paying particular attention to inlets and outlets points) - Temporal effects (frequency of monitoring) Water quality variables measured in the laboratory for pH; dissolved oxygen; conductivity; turbidity; suspended solid; nutrients; bacterial load and pesticides(in the case of domestic water) • Inventories of likely sources of point and non-point source pollution • Regular monitoring and assessment of water bodies (spring; stream i.e. flowing water; wells; underground water). • Spatial and temporal dynamics of aquatic fauna (identification of invertebrates; protozoa) and flora (algal blooms)
Land-use	• Soil management practices (including fertility management and tillage practices). Currently, the degree of soil disturbance is high, with four (4) ploughing episodes annum^{-1} in the vegetable gardens and handhoeing vegetable beds every fortnight. Extent of ploughpan • The effect of tillage on decomposition of organic sediments • Organic matter status on cropped, fallowed and grazed land • Degree of compaction on grazed lands • Impact of grazing of existing drainage channels • Extent and intensity of fire as a land management option • Test soils for nutrient status, (deficiencies and balances in crops); any likely changes in soil pH • Carrying capacity of grazing head
Flora	• Impact of cropping activities on vegetation. Any new cropped lands will definitely impact on the vegetation structure • Composition of the herbaceous layer in (i) cropped lands;

Parameter	Variable
	(ii) grazing areas within and outside actual water bodies; (iii) riverine vegetation structure • Status of species of particular interest (e.g. endemics; threatened species; alien plants with particular attention to the expansion and colonization of *Lantana camara*
Fauna	• The diversity of fauna in the wetland is wide including birds; insects; aquatic invertebrates and amphibians • Aquatic invertebrates gives an indication of water quality

Methods for monitoring

The existing WET-Health framework (MacFarlane et al., 2005) can be used as the basic guideline for monitoring the ecological integrity of Intunjambili. Inputting data into validation models can be used as an alternative approach to rapid monitoring.

Hyrology

- Height of water tables in the wetland along different transects can be monitored using existing peizometers. However the existing hydrometric network currently does not take into account ecological aspects.
- Methods of keeping water within the wetland should be devised and encouraged. This may include changes in cropping methods using water conservation structures, placement of crops during the rainy season, and introduction of water-loving crops such as rice and *Madhumbes*.

Landuse

- Cultivation and cropping does not seem to significantly impact on organic matter in wetland soils than does the wetness of the soil. However, poorly managed wetland gardening, which does not provide protection from erosion, and overgrazing, which removes vegetative cover, encourages surface run-off and reduces organic matter content.
- Poor management practices can result in an increase in the vulnerability of wetland to soil erosion and accelerated gully formation. Vegetable gardens and arable lands should be ploughed along the contours to minimize surface runoff and erosion.
- Conservation tillage practices should be evaluated and promoted.

Vegetation

- Permanently marked transects and a qualitative measure such as cover abundance may be used.
- A qualitative inventory carried out at the same time of the year as initial survey can yield useful data on local immigration or extinction of species represented by a few individuals
- From a conservation point of view, there are generally some species of particular interest. These are usually limited in population size and distribution across the wetland. This may provide good focal points for monitoring of threat qualitatively

based on measured changes in distribution or population size. Some species are under threat due to habitat destruction by grazing animals and subsequent invasion by exotics e.g. *Lantana camara,* which inhibits the establishment of indigenous species.

- Grasses react either by increasing or decreasing.
    - Decreasers are abundant in grazing areas and include palatable grasses l
    - Increaser I: include grasses that are unpalatable, robust climax species that grow without any defoliation.
    - Increaser II: Such grasses increase due to the disturbing effect of overgrazing. They produce much viable seed and this can quickly establish on new exposed ground within the wetland

Water quality

- Parameters such as pH and conductivity can be measured directly at source using appropriate meters of each measurement. A Secchi disc can measure turbidity *in situ*. Other physical and organic constituents are analysed in the laboratory using standard methodologies following laid-out sampling procedures. Most laboratories are equipped to carry-out such routine analyses.
- Invertebrate counts can be accomplished using dip nets and identification can be done *in situ* or representative specimens maybe collected for identification.
- Invasive plants are water weeds such as *Salvinia, Eichhornia , Azolla* or *Pistia* give indications of eutrophication

References:

Food and Agricultural Organization. 1988. Soil Map of the World. Revised Legend. World Soil Resources Report No. 60. FAO, Rome.

MacFarlane, D.M., Kotze, D., Walters, D., Ellery, W., Koopman, V., Goodman, P, and Goge, C. 2005. WET-Health: a technique for rapidly assessing wetland health. University of KwaZulu Natal, SAPPI, Working for Wetlands, Water Research Commission, South Africa.

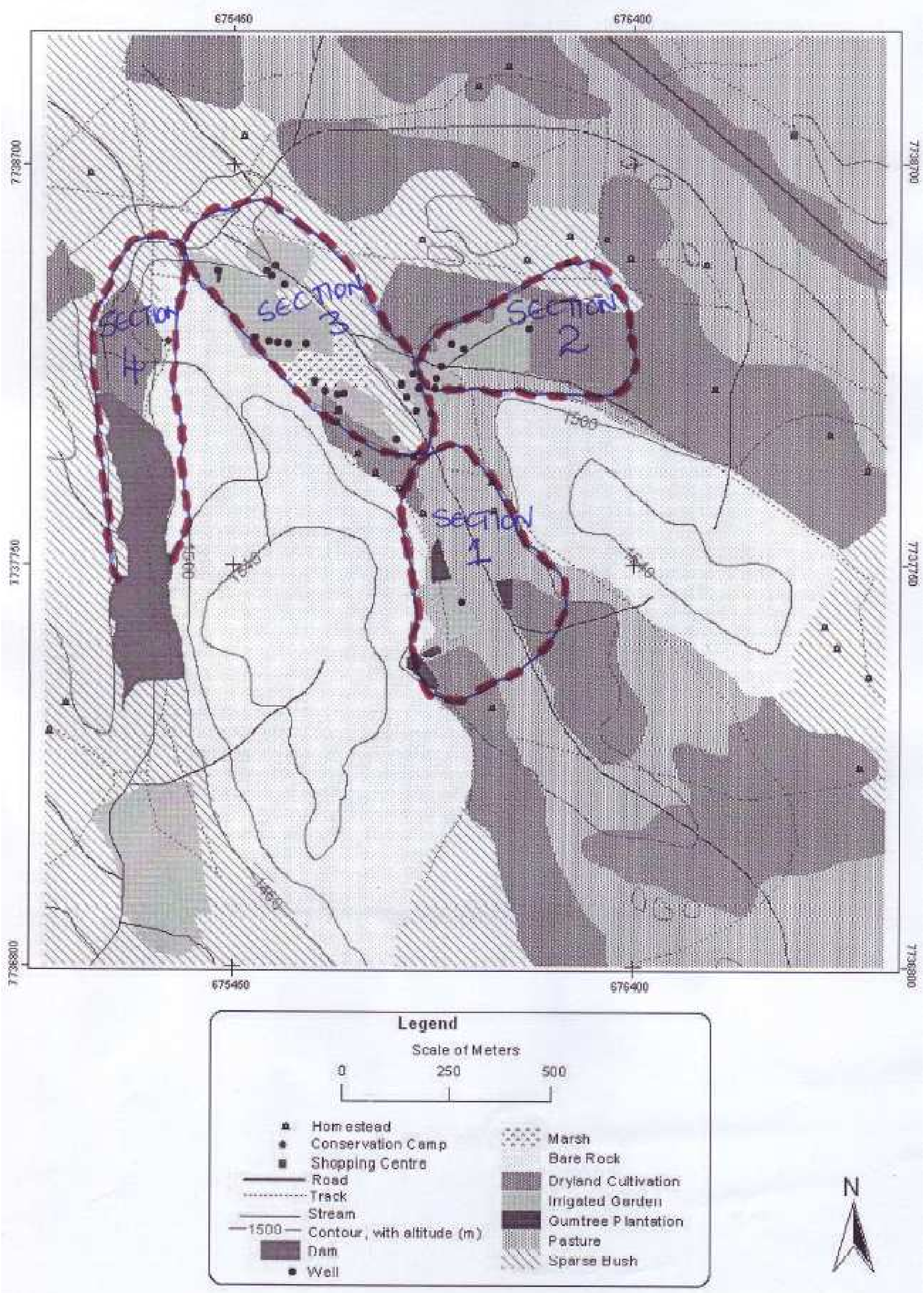
Nyamapfene, K. 1991. *Soils of Zimbabwe.* Nehanda Publishers, Harare, Zimbabwe. 179 pp.

Timberlake, J., Fagg, C. and Barners, R. 1999. Field Guide to the Acacias of Zimbabwe. CBC Publishing, Harare, Zimbabwe.

Van Wyk, B. and van Wyk, P. 1997. Field Guide to Trees of Southern Africa. Struik Publishers, Cape Town, South Africa.

World Reference Base for Soils, FAO/ISRIC/ISSS. 1998. World Soil Resources Report No. 84. Food and Agriculture Organization, Rome.

Land-use Land-cover Map of Intunjambili Wetland Matobo District, Zimbabwe



Land-use Land-cover Map of Intunjambili Wetland
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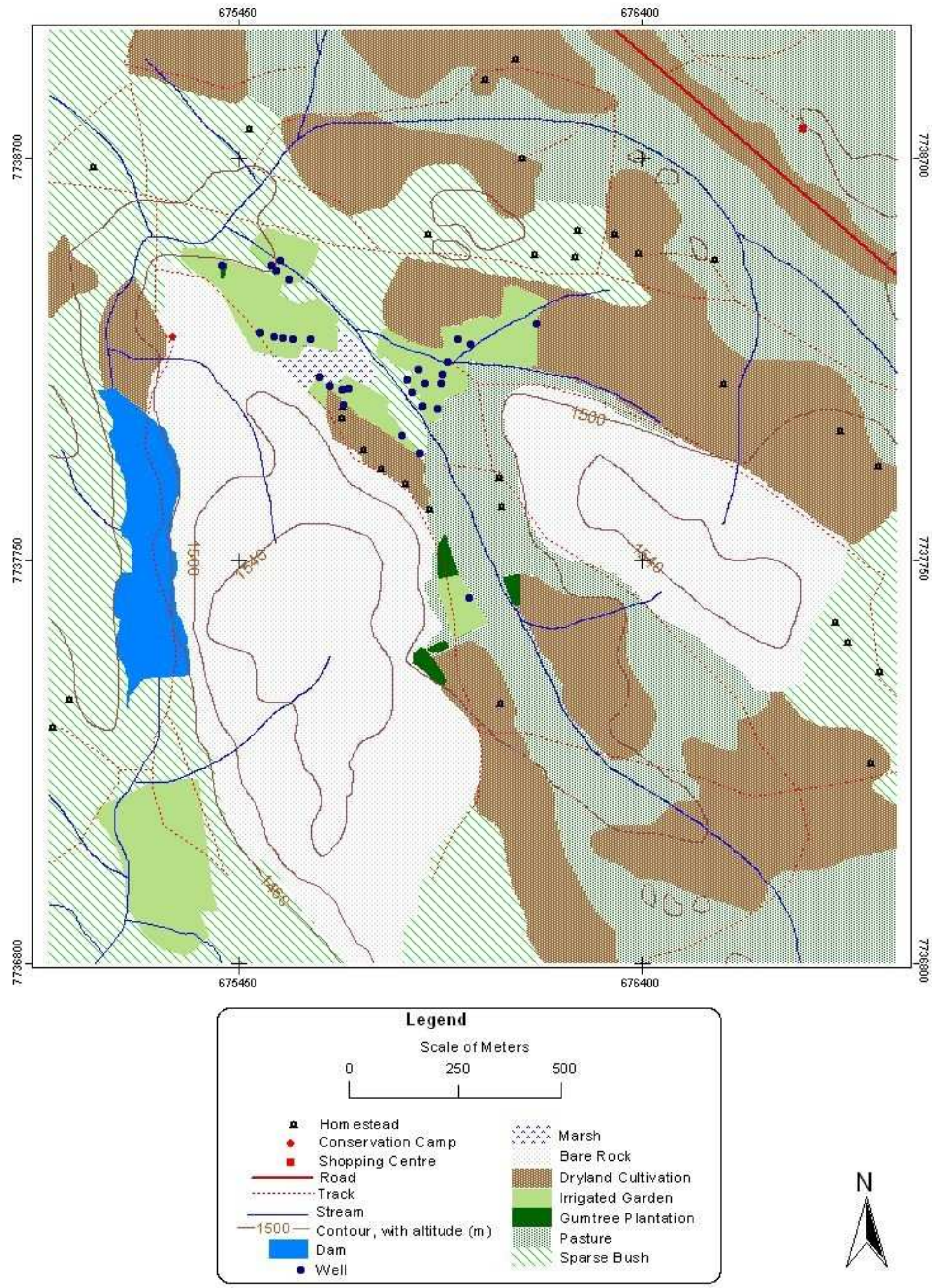

SECTION 1