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Summary

Wetlands in South Africa

Origins of wetlands in South Africa

South Africa belongs to an ancient landscape which has significant recent tectonic activity and is located in a very high mean elevation. The mean rainfall is very low comparing to the global average, but the potential evapotranspiration is very high. Regarding the combination of these factors, wetlands should hardly occur under these conditions which means that most of them are somehow connected to streams (Ellery et al., 2009). The geological activity had a huge impact on the origin and distribution of wetlands in South Africa. Only the most important processes will be described here in terms of the Kromme River Catchment. Rifting occurred along the southern Cape about 450 million years ago, and it extended into KwaZulu-Natal region. As a result mudstones and sandstones of the Cape Supergroup were deposited in the resulting rift valley basin. 300 million years ago the rift started its closure, and the rocks of the Cape Supergroup began to fold, forming the Cape Fold Belt in which the Kromme River Catchment is also situated. Furthermore there were two uplifts in southern Africa that have a profound impact on the climate in the region. The first occurred around twenty million years ago when the eastern part of the subcontinent rose by about 250 m and the western part by about 150 m. The second was around five million years ago when the eastern subcontinent further rose by about 900 m while the west by only about 100 m. It resulted in a reduced rainfall in the interior part as the air masses originating over the Indian Ocean hit the elevated eastern escarpment and lost much of their moisture (Ellery et al., 2009). The uplifts had also resulted in increased erosion in the interior due to the increased river gradients arising from tilting of the African Erosion Surface.

Wetlands

The main concepts from which at least one has to be exhibited in order to be a wetland:

- Hydrology:
    - A land is covered by water or has saturated soil at some time when the soil is biologically active
- Saturated soil (Hydric soil):
    - Hydric soil- reduction occurs i.e. the soil has been depleted of oxygen
    - Redoximorphic features- features formed by the process of reduction, translocation and oxidation of Fe and Mn oxides
- Hydrophytic vegetation:
    - Hydrophytes –plants have adapted to grow in the anaerob condtions of hydric soils

“A piece of land is therefore a wetland when the period of saturation is sufficient to allow for the development of hydric soils which in normal circumstances support, or would support, hydrophytic vegetation” (Collins, 2005).

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The main difference

The South African wetlands are characterized by low ratios between precipitation and potential evapotranspiration (Tooth and McCarthy, 2007). This characteristic makes them different from most wetlands located in northern temperate regions, since they are mainly dependent on rainfall to get their water supply. The rainfall provides this supply in different ways; either in the form of runoff (surface flow, river flow) or contributes to the recharge of groundwater which enters wetlands (subsurface flow) or directly falling on the wetland (Ellery et al., 2009).

The Kromme River Catchment

<u>Climate</u>

The mean annual rainfall is around 600 mm and the mean annual potential evapotranspiration is 1800 mm and that means that the wetlands are mainly groundwater driven.

<u>Geology and soils</u>

The aforementioned geological activity contributed that the Kromme River has a catchment with steep slopes where the river does not meander, but the flow comes with a high erosive energy.

The parent material i.e. the underlying rock type or the recent deposits are the primary factors determining the physical and chemical nature of the different soil types. In the case of the Kromme River Catchment the soils are mainly acidic lithosol soils derived from sandstones and shales of the Table Mountain Group (Cape Supergroup). ->It means that the soils are poor in nutrients-> fynbos vegetation

<u>Wetlands in the Kromme River Catchment</u>

Three main peat basins, wetlands are valley-floor channeled marshes (Kotze and Ellery, 2009):

- Basin 1: Kromdraai or Upper catchment-> Krugersland sub-basin 1-4 and Companjesdrift sub-basin 1-2-> the Eerstedrif River enters the floodplain in Companjesdrift sub-basin 2 -> therefore it is a naturally high-impact area
  Tierkloof, Poortkloof-tributaries of Basin 1
- Basin 2:
- Basin 3: Schaapdrift

<u>Hydro-geomorphology</u>

- Drainage system

The Kromme River Catchment has a trellis drainage system i.e. the river flows along a strike valley and the smaller tributary rivers feed into it from the steep slopes on the sides of the mountains. This drainage system is a characteristic of folded mountains and the routes of rivers are determined by the presence of softer and resistant rock formations. The tributaries enter the main river at about 90 degree angles and that causes the trellis-like pattern. From wetter the south side there are six large and five smaller tributaries that enter the main channel, and there are seven large and numerous short, mainly temporary tributaries that enter from the dry northern side (Kotze and Ellery, 2009).

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- Structure and processes

There are strong linkages between geomorphology, hydrology and vegetation where geomorphic processes controlling and shaping wetland structure and dynamics ->they strongly affect the distribution of water-> thus affecting wetland functions and services.

Alluvial fans are specific features in the Kromme as a result of the drainage system->built up from the delivered sediment by the tributaries and they function as 'sediment blockage' which decreases the velocity of the main stream. It made possible for wetlands to develop between the alluvial fans since originally wetlands are found where surface water is slowed down and spread out (diffuse flow).

Erosional (degradational) and depositional (aggradational) processes-> both processes occur continuously and naturally, in the case of a natural system they are in balance

- Depositional processes: three kinds of sedimentation can occur, but not always all of them are present in a wetland
  - Clastic: -> mainly at the head of the wetland where the ability of stream to carry sediment load is decreased-> results in increased gradient
    In most wetlands there is a net accumulation of clastic sediment
  - Organic: ->peat accumulation where a little or no clastic sediment input and slowly flowing water-> usually located behind the clastic sediment deposit to reduce the difference in elevation (backswamp)
  - Chemical: particularly important sedimentation in SA-> because the rainfall <potential evapotranspiration-> chemical are in solution->when water is lost through transpiration they are deposited in the wetland. Wetland plants do not take up everything-> the remaining solutes saturate and precipitate out of solution and accumulate in the soil-> vertical expansion of soil volume-> lowering of gradient in the upstream direction

The three forms of sedimentation are interrelated and they have feedback to each other: e.g. excessive clastic sediment in the proximal part of the wetland steepen the gradient in a downstream direction-> increased flood at the distal part of the wetland->increased peat formation->increased chemical formation->thus maintain the overall gradient

- Natural erosional processes occur (Ellery et al., 2009)
  - if the surface of the wetland is steepened longitudinally by prolonged sedimentation and ultimately exceeds a critical threshold of slope stability
  - when a tributary enters to the main stream through a wetland-> alluvial fans elevated , the continuous sediment delivery results in that the gradient increases at the end of the deposit-> higher velocity, the water is more erosive and the wetland erodes

<u>Vegetation</u>

In the catchment (Mucina and Rutherford (eds.), 2010):

- Tsitsikamma Sandstone Fynbos
- Kouga Sandstone Fynbos

- Kouga Grassy Fynbos
- Langkloof Shale Renosterveld
- Eastern Inland Shale Band Vegetation
- Eastern Coastal Shale Band Vegetation
- Southern Afrotemperate Forest

In the wetlands:

- Palmiet dominated

  The characteristics of palmiet:

    - palmiet vegetation is able to decrease the energy of flow, and it occurs on the gradient up to 3% (!), usually wetland vegetation between 0,01-1 %
    - palmiet builds up very fine peat, accumulation rate 0, 3- 0,7 mm depth peat/year due to anaerobic condition, the depth can be up to 4,5 m that can be 7500 years old
    - 1 m^3 peat can store 700 l water- it works as a natural sponge, store rain water and releases it steadily over time
    - palmiet does not like shadow and it is used to <u>nutrient poor waters</u>
    - Peat and sediment (sand, clastic) layers vary because of the flood events, there are also ash horizons indicating the historical occurrence of fire->regional droughts can occur->lowered water table-> exposure of peat->susceptible to burning

Wetland health and erosion gullies

- Erosion gullies -> they determine the wetland health the most
- Kromme historically had no or very small amount of gullies-> human activities are causing them, particularly the drainage of wetlands
- The road in the Kromme used to be the road between Port Elizabeth and Cape town and it was built on alluvial fans ->Bridges, roads resulted in gully and sheet erosions and increased sedimentation
- Valley-bottom valleys are particularly susceptible to gully erosion (Ellery et al., 2009).
- Differences between natural channels and erosion gullies (Macfarlene et al., 2009):
    - Natural channels exists for longer time-> they are characterized by a combination of erosion and deposition in about equal quantities, or the deposition is greater.
    - Erosion gullies: primarily erosion features
- The impacts of erosion gullies:
    - Originally wetlands are found where surface water is slowed down and spread out = Diffuse flow BUT when erosion gullies evolve-> changes in hydrodinamics[1] i.e. the diffuse flow becomes concentrated flow-> higher velocity-> the favourable environment (deposition of sediment, anaerob condition, high organic matter) for a wide range of chemical transformation cannot develop

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Decreased removal of chemical solute

[1] The flow and fluctuation of water once it is in the wetland (Collins, 2005)

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Flood risk at downstream
Gullies can result in that the peat dries out and got fire-> peat burns for years

Wetland health based on the WET-Outcome-Evaluate

There are three main peat basins where erosion structures had been erected to fight against erosion. To assess the effectiveness of these constructions WET-Health and WET-EcoServices have been conducted to see whether these constructions resulted in improved state of wetlands and improved functioning.

Basin 1- still intact, overall health very good-> largely natural with few modifications

Basin 2 and 3- extensively transformed: cultivation of pastures and orchards: Hendrikskraal and Hudsonvale

The greatest degree of transformation has occurred between Companjesdrift and Jagersbos->about 75% of the smaller marshes have disappeared completely

Ecosystem services considered

Direct benefits

Water (data is needed)

- Downstream: drinking water
- Upstream: drinking water, irrigation->interview

Livestock grazing

- Cattle grazing in the wetland-> cattle like the young leaves of palmiet
- Converted wetland areas into pasture

But the Kromme River wetlands have little direct economic value to inhabitants-> grazing potential is very low and wetlands are not directly used for their products (Kotze and Ellery, 2009).

Indirect benefits

Flood prevention (Based on the interview with Prof. Fred Ellery)

When talking about flood attenuation is mainly about people in downstream. Regarding the people living upstream the flood attenuation service in the upper catchment of the Kromme has increased, because the erosion gullies taking the water away quickly, previously the water stayed longer in the wetlands, but a lot of parts of the wetlands are lost. Therefore there is less flood in upstream, but it is likely that there are more floods in downstream.

Data can be required:

- Interview with farmers: increase of decrease in the flow?
- Base flow data from Water Affairs- they have Gauging station and measure flow regularly along the Kromme -> historical data
- Data about water levels in the Churchill dam, rainfall
- Dry season is the best to see the changes in the flow
- Dry season->what is the change in the flow at the Dam in relation with rainfall
- Alternative indicator: compensation to farmers for floods (In upstream they are likely to get less)
- Alanna did research on the streamflow responses to different land uses-> but she cannot give data yet

Erosion control

- South Africa's surface is eroding continuously due to the high elevation-> the wetlands here are different from the ones in Europe. Erosion is a natural process.
- This service is usually not taken into account because erosion may result naturally (Ellery et al., 2009) (see wetland processes).

Water purification

Water quality is influenced by the following factors:

- Climate
- Temperature
- Mean annual precipitation, seasonal variations in precipitation ->the amount of water flowing in the river at different times, the degree of dilution of natural and anthropogenic constituents
- Geomorphology of the landscape
    - -> the gradient of the river-> turbulence of the river-> the amount of oxygen and other gases dissolved in water
    - ->the gradient of erosion (erodibility of soil is also important)-> the turbidity and the quantity of suspended material in the water)
- Geological formations -> chemical compositions-> different quantities and proportions of ions (including nutrients)- <u>> in the case of the Kromme River Catchment</u>: sandstone and shales of the Cape Supergroup->very little soluble material is present->less can be leached out-> waters are usually very low in conductivity and in nutrients
- Biota: phytoplanktons and microbes that can affect water quality
    - Combined effects of photosysnthesis and decomposition->can determine both the pH and the amount of oxygen presents in the water
    - Catchment vegetation->organic compounds can be leached into the water->affects pH and inhibit microbial activity
- The bulk of dissolved materials is derived from rain in which the major ions are sodium and chloride
- Anthropogenic drivers:

Land management practices that influence water quality

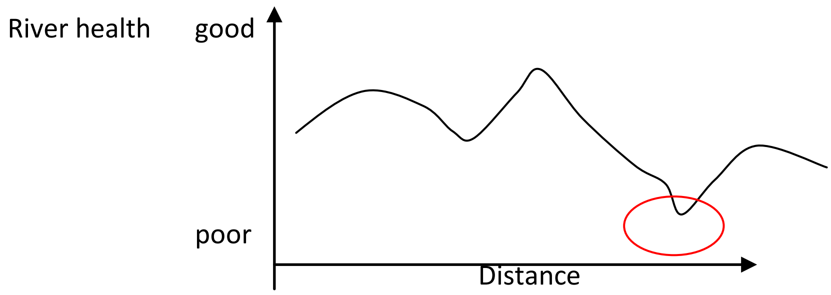
- land use practices: fertilizer, pesticide use
- pollution sources, timing
- burning pasture areas and fynbos on the slopes in the upper catchment-> no vegetation cover-> topsoil is wash away with the runoff-> causing sedimentation in the river
- burning wetland vegetation-> for new leaves that animal likes (e.g. palmiet)-> destroy vegetation & trampling river banks causes erosion

In general wetlands have a potentially high sensitivity (Macfarlene et al., 2009):

- If they are located in a naturally nutrient-poor catchment (e.g. with a sandstone-derived catchment)
- MAP/PET ratio is high

Ideas to measure/assess water quality :

1) Instead of measuring water quality above and below a wetland, it would be better to do on localized sites (local case study), for example, by choosing a land use type such as orchard, or dairy and focusing on only one wetland basin. Then the water quality could be measured in the influent water of the basin and above and below of the chosen land use, finally measuring the effluent water flowing out from the basin.
2) If choosing the method measuring the water quality above and below a wetland basin, it is very important to consider the mass-balance. This case is quite complicated, because you measure concentrations in terms of chemical compounds, but it is also very important to calculate the mass balance.
3) Bioassessment- River Health Program



Getting data from the River Health Program and maybe the distance can be used as an indicator-> the distance from certain land uses and the wetlands.
Bioassessment inside the wetlands is useless due to the lack of oxygen (low dissolved oxygen because of the anaerob conditions and macro invertebrates need oxygen.

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Sediment trapping

Sedimentation occurs continuously and wetlands are just temporarily store sediments, if too much sediment accumulating the wetlands starts to erode (see erosion control)

- Types of sediments (Ellery et al., 2009) and the amounts in the Kromme River Catchment:
  - Clastic: the particles of clay, silt, sand, cobbles and boulders
    - Bedload: transported by being rolled or bouncedalong the bed of the stream-> **large amount**
    - Suspended: transported in suspension in the water column- typically silt and clay sized-> **small amount**
  - Organic: partially to highly decomposed plant material
  - Dissolved: all of the dissolved material present in flowing water, including solutes
    - Nutrients: N, P-> **low** BUT If increased amounts-> due to farming activities: dung of the cattle, fertilizers etc.->increased primary production vegetation
    - Detrimental:
      potassium, sodium, chlorine, silica solutes-> **low** BUT If increased amounts mainly due to pesticides, but also herbicides-> no effects on growth or detrimental effects

Nutrient removal (Collins, 2005)

- Related to the gaseous cycle
- Sources of nitrogen: point source-> sewage, non-point source-agriculrure
- Organic or inorganic forms of N can enter wetlands
- The most determining step is the rate at which organic N is mineralized to ammonium (inorganic)
- In the aerobic layer
  Organic N->mineralized into ammonium->nitrification into nitrate –both ammonium and nitrate can be taken up by plants->removed from the water column

  In the anaerobic layer (reduced soil)
  ->once the ammonium is depleted from the aerobic layer-> ammonium diffuses upward from the deeper anaerobic layer to the upper aerobic one due to the concentration gradient->then it is oxidized again into nitrate
  -> at the same time nitrate goes to the deeper anaerobic layer and reduced into ammonium (ammonification by nitrate ammonifying bacteria) ->conserves total nitrogen in the soil

  Or denitrification by denitrifying bacteria takes place and nitrate reduced to N gas through a series of redox reactions (nitrate->nitrite->nitrous oxide->dinitrogen gas) N2 is released to the atmosphere-> removes N from the soil

  Denitrification is dependent on the presence of nitrate

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<u>Phosphorus removal</u> (Collins, 2005)

- Related to the sedimentary cycle
- Inorganic phosphorus is bound to suspended solids and sediments by sorption (to oxides, hydroxides, ferric (Fe^{3+}) ion, aluminum, and calcium carbonate). ->when the suspended solids settle-> the sorbed phosphorus is removed from the water column-> if the sorption sites is saturated-> they cannot bound more phosphorus
- Under reduced conditions-> phosphorus is released-> if there are no vegetation-> phosphorus diffuses back to surface waters
- If vegetation is present under reduced conditions-> plants assimilate a part of the prhosphorus (phosphorus is most bioavailable at slightly acidic to neutral pH (Mitch and Gosselink, 2000)
- The P is not bioavailable when:
  - Sorption of insoluble phosphates with ferric iron, calcium, and aluminum under aerobic conditions
  - The adsorption of phosphate onto clay particles, organic peat and ferric and aluminum hydroxidesand oxides
  - Binding of P in organic matter as a result of its incorporation into the living biomass of bacteria, algae, and vascular macrophytes

<u>Biodiversity</u>

In the case of South African wetlands: natural biodiversity (excluding invasive alien plants) <-> water purification

Water purification service is often more appreciated than having high natural biodiversity.