137Cs and 210Pb derived sediment accumulation rates and their role in the long-term development of the Mkuze River floodplain, South Africa

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A B S T R A C T

Wetlands are well known to act as sinks for sediment and chemicals in the landscape. Within the Mkuze River floodplain in northern KwaZulu-Natal, South Africa, deposition of clastic sediment occurs predominantly in close proximity to the river channel, resulting in the formation of levees. Over time, this leads to channel avulsion, a process that may be accelerated by the activities of hippopotami whose trails create hydraulically favourable pathways. Sedimentation rates, determined using the isotopes 210Pb and 137Cs, indicate that the Mkuze River floodplain is a relatively rapidly aggrading system that should experience frequent avulsion, with average short-term rates in the order of 0.25 to 0.50 cm/y. Sediments on the floodplain are also an important sink for solutes, which concentrate in the groundwater and precipitate out because of evapotranspiration. Over long timescales, chemical sedimentation affects the landscape by influencing salinity, vegetation distribution, hydrological flows, and local topography. The Mkuze River floodplain is an actively evolving system, which continues to aggrade as a result of the combination of clastic and chemical sedimentation. In a region characterised by a strong annual water deficit, temporal patterns of clastic and chemical sedimentation are likely to exert influence on the long-term development of wetland systems elsewhere in southern Africa. This study, the first on sediment accretion rates using 210Pb and 137Cs dating for a southern African wetland, demonstrates that radiotopic methods are an important tool that can be applied toward fully understanding wetland formation, evolution, and functioning in the region.

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1. Introduction

One of the benefits of wetlands is their ability to act as sinks for sediment and chemicals in the landscape. Sedimentation within wetland systems has traditionally been investigated by considering only clastic deposition (Sanchez-Carrillo et al., 2001; Harter and Mitsch, 2003). However, studies carried out in the Okavango Delta have shown that ~450,000 tonnes of chemical sediments accumulate annually in the wetlands of this system (McCarthy and Ellery, 1998), amounting to over twice the clastic load and, thus, the dominant form of aggradation. Within the Okavango Delta, chemical sedimentation occurs predominately as a result of evapotranspiration. With ~96% of the water entering the Okavango Delta being lost to the atmosphere, solutes in the groundwater concentrate to levels that eventually result in the precipitation of minerals, such as CaCO3 and SiO2. Mineral precipitation causes volume increase and expansion in the soil that plays a role in modifying the topography of the landscape (McCarthy and Metcalfe, 1990), while the development of highly saline groundwater results in marked vegetation zonation (McCarthy and Metcalfe, 1990; McCarthy et al., 1993). Similar chemical accumulation processes, although on a more limited scale, have also been documented on the Nyl River floodplain, South Africa (Tooth et al., 2002).

Floodplain wetlands are common features of rivers in southern Africa, but have been insufficiently investigated from a geomorphological perspective. Despite the fact that these wetlands fulfil important hydrological and geochemical functions in a region of strong seasonal water deficit, knowledge on such systems is limited to a few case studies (e.g. Tooth et al., 2002; Tooth et al., 2007; Grenfell et al., 2009). Recent studies of sediment, groundwater and porewater geochemistry have identified the Mkuze Wetland System as an important sink for solutes (Humphries et al., 2010; Barnes et al., 2002). This system, representing South Africa's largest freshwater wetland area, forms part of the iSimangaliso World Heritage Site and plays an ecologically important role in filtering sediment from water entering Lake St. Lucia. Sedimentation processes on the Mkuze River floodplain are, hence, of vital importance in understanding the role that the system plays in trapping material within the landscape.
Radionuclides, such as lead-210 ($^{210}\text{Pb}$, $t_{1/2} = 22.3$ y) and cesium-137 ($^{137}\text{Cs}$, $t_{1/2} = 30.2$ y), are the most common and reliable method employed to calculate short-term (years to decades) sediment deposition and accumulation rates in estuarine, fluvial, and lacustrine environments (Robbins and Edgington, 1975; DeLaune et al., 1978; Benoit and Rozan, 2001; Kim, 2003). However, most such studies have been conducted in countries in the Northern Hemisphere. Only limited radioisotope research has been carried out in the Southern Hemisphere, in part because of the low fallout of $^{210}\text{Pb}$ and $^{137}\text{Cs}$ and associated difficulties in obtaining concentrations that are above analytical detection limits (Owens and Walling, 1996; Bonotto and de Lima, 2006). Cesium-137 is particularly difficult to detect south of the Equator, as most nuclear testing took place in the Northern Hemisphere. Consequently, Southern Hemisphere investigations have been confined primarily to Brazil (Sanders et al., 2006) and Australia (Pfitzner et al., 2004), with very few similar studies in southern Africa. This study represents the first attempt known to the authors to derive sediment accumulation rates using $^{137}\text{Cs}$ and $^{210}\text{Pb}$ in a southern African wetland. The study describes and examines processes of clastic and chemical sedimentation on the Mkuze River floodplain and considers their implications for the long-term evolution of the wetland system.

2. Regional setting

2.1. Background

The Mkuze Wetland System (27°38′ S, 32°26′ E.), located east of the Lebombo Mountains on the Maputaland Coastal Plain in northern KwaZulu-Natal, South Africa (Fig. 1), lies ~330 km north of Durban.

The system covers an area of ~450 km² and includes a variety of different wetland types, ranging from seasonally flooded swamps and riparian floodplains to permanent wetlands and shallow lakes (McCarthy and Hancox, 2000). The large size of the system, its environmental heterogeneity, species richness, and the fact that it has been relatively undisturbed by human activities make it an important ecosystem in the region (Stormanns, 1987; McCarthy and Hancox, 2000).

2.2. Climate

Northern KwaZulu-Natal is subtropical with hot, wet summers and mild, drier winters. A marked gradient in rainfall exists across the coastal plain, decreasing from about 1000 mm/y at the coast, to 600 mm/y in the Mkuze Game Reserve west of the study area. Approximately 60% of the rain falls during the summer months and is usually attributed to cold fronts moving northward along the coast (Watkeys et al., 1993). Flooding is seasonal and is usually associated with cutoff low pressure systems or occasional tropical cyclones that typically occur during December and January (Watkeys et al., 1993). Mean monthly temperatures vary between ~30 °C in summer and 25.5 °C in winter. Annual evaporation is high (~1800 mm) and, together with transpiration losses, results in a large annual moisture deficit (Schulze, 1997).

2.3. Geological history

The Mkuze River flows within a shallow, narrow valley that becomes progressively broader eastward. North–south oriented drainage lines enter this valley on its northern margin, feeding floodplain lakes such as the Muzi, Yengweni, and Mdlanzi. The

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formation of the Mkuze River floodplain has been strongly influenced by periodic sea level changes. During the last glacial maximum (18,000 BP) sea level was lowered ~120 m relative to the present level, exposing much of the continental shelf and causing rivers on the coastal plain to incise deep valleys along pre-existing tectonic lineaments (Ramsay and Cooper, 2002). Subsequent sea level rise during the Holocene prompted the blocking of major rivers and resulted in the backflooding of these incised valleys. Unconsolidated shelf deposits were eroded and deposited to form some of the highest coastal dunes in the world. Dune cordons impart great control on drainage patterns and wetland development.

Water table of the coastal dunes is elevated relative to the coastal plain and this causes the inland flow of subsurface water into interdunal depressions, which recharge lakes and wetland swamps (McCarthy and Hancox, 2000). Valley infilling continues at present resulting in aggradation and the eastward progradation of the Mkuze River floodplain (McCarthy and Hancox, 2000). The advance of the floodplain has blocked off the original interdune tributaries, giving rise to the linear lakes associated with the floodplain.

2.4. Hydrology

Surface inflow via the Mkuze River is the primary hydrological input to the floodplain, draining sedimentary strata of the Dwyka, Ecca, and the lower Beaufort groups of the Karoo sequence, as well as Pongola granites and rhyolites in the Lebombo Mountains. Due to the seasonality of rainfall, the Mkuze River and floodplain are characterised by infrequent flood events, interspersed with longer periods of low (~1 m³/s) or no flow. Flooding usually occurs in December and January in response to summer rainfall but is highly variable. The most severe flooding event in recent history occurred in 1984 and was associated with Cyclone Domoina, which caused water levels in the Mkuze River to rise by up to 12.7 m above its present level (Watkeys, 1997).

During periods of flooding, water breaches the levees of the Mkuze River and inundates the floodplain. This plays an important role in recharging floodplain lakes, which also receive water from groundwater-fed streams located in interdune valleys north of the Mkuze River (Fig. 1). Overbank flooding of the Mkuze River is the primary input of sediment onto the floodplain. Clastic sedimentation takes place mainly in close proximity to the river channel, causing localised aggradation and the development of distinct levees.

The hydrological regime of the Mkuze Wetland System has been affected by the construction of two canal systems. In the late 1960s, Lake St. Lucia experienced hypersaline conditions as a result of severe drought. In an effort to increase the freshwater supply to the lake, authorities excavated the Mpmpe Canal (Fig. 1) with the purpose of drought. In an effort to increase the freshwater supply to the lake, aggradation and the development of distinct levees. Place mainly in close proximity to the river channel, causing localised aggradation and the development of distinct levees.

2.5. Vegetation

The Mkuze River is fringed by fragmented patches of dense, species-rich, riverine forest characterised by trees such as Ficus sycomorus, Rauvolfia caffra, Voacanga thouarsii, and Blighia unijugata (Storrmans, 1987; Patrick and Ellery, 2006). The floodplain is characterised by open grassland dominated by Echinochloa pyramidalis, while Acacia xanthophloeus fringe many of the floodplain lakes. The more permanently wet areas are dominated by various reeds and sedges, such as Phragmites australis and Cyperus papyrus (Patrick and Ellery, 2006).

3. Methods

Fieldwork was conducted between June 2005 and August 2007. Sediment samples were collected along three transects (T1–T3) orientated from the Mkuze River to the floodplain margin (Fig. 1). Transects were established to cover the three different reaches of the floodplain, i.e. upper, middle, and lower reaches (Fig. 2). Samples were obtained by hand auger (six holes along T1, four holes along T2, and five holes along T3) to a depth of ~5–7 m. Sediment was collected at vertical intervals of 0.5 m, or where there was a visible change in soil characteristics, and stored in sealed polyethylene bags. Topographic elevation along transects was surveyed using a dumpy level (centimetre-level accuracy), and auger location sites were recorded using differential GPS with a remote base station (accurate to 20 cm in the x and y fields). Particle size distribution was determined by a Malvern Mastersizer 2000 Laser Grainsize (measuring range: 0.02–2000 μm), using ultrasound and sodium hexametaphosphate to ensure complete sample dispersion. Organic content was removed from samples prior to particle size analysis by loss on ignition at 450°C (Ball, 1964).

Two pits (A and B), ~85 cm deep, were excavated by hand on the floodplain (Fig. 1). Pits were located in the backswamps of the middle and lower reach, ~50 m from the river channel. Samples from each pit were sectioned at vertical intervals of ~2 cm; and each increment was then air-dried, weighed to determine bulk density, and sieved to <125 μm. Measurements of 137Cs and 210Pb were made on a total of 29 samples by gamma ray spectrometry using a low-energy Ge gamma spectrometer. All activities were determined using HYPERMET, and all errors were determined from counting statistics and the error associated with the HYPERMET curve-fitting routine (Phillips and Marlow, 1976). Total 210pb was measured by its emission at 46.5 keV and supported 210pb by the weighted average decays of 226Ra daughters at 295, 351, and 609 keV. Excess 210Pb was calculated as the difference between the measured total 210Pb at 46.5 keV and the estimate of the supported 210Pb activity. Cesium-137 was determined using its gamma emission at 661 keV. The distribution of excess 210Pb with depth was used to calculate vertical accretion rates using the CRS model (Oldfield and Appleby, 1984).

4. Results and discussion

4.1. Regional topography and sediment characteristics

Sediment characteristics and channel morphology allow the floodplain to be divided into three reaches (Fig. 2). Floodplain sediments from the upper reach (west of Mpanza Lake) are particularly coarse, comprising primarily fine and medium sand (60–70%). The channel is relatively wide (~15 m) and deep (~4 m) and associated with high, well-developed levees. In the middle reach (between Mpanza Lake and Tshangwe Lake), the channel becomes highly sinuous, with decreases in both channel width and depth. Channel dimensions continue to decrease downstream, such that in its lower reach (downstream of Tshangwe Lake) the channel is <10 m wide and <1 m deep. Sediments here are dominantly silt (up to 90%).

Although typically unusual, the downstream changes shown by the Mkuze River are similar to those among many ephemeral rivers in semi-arid Australia which commonly terminate in ‘floodouts’ (Tooth, 1999, 2000). Decreasing channel dimensions downstream are a consequence of evapotranspiration and transmission losses from the river to the surrounding floodplain. Decreasing discharge and stream power results in a lower potential for bed and bank erosion, such that large channels cannot be eroded or maintained. As discharge decreases downstream, river competence also declines, reducing the
Fig. 2. Topographic profiles and location of auger points along transects T1, T2, and T3.

Fig. 3. Sand–silt–clay ternary diagram showing the downstream (upper to lower reach) distribution of floodplain sediment samples.
size of sediment which can be transported. As a consequence, floodplain sediments become gradually finer downstream, from predominantly sand or silty sand in the upper floodplain to sandy silt or silt in its lower reaches (Fig. 3). In the upper reach, dense vegetation, which flanks the Mkuzè River channel, plays a crucial role in reducing the ability of floodwater to transport suspended sediment, thus further promoting deposition near the channel. Finer particles (silt and clay) are transported farther downstream and deposited in the lower reaches of the system, with significant volumes of coarse material only likely to reach this area during exceptional floods.

4.2. Sedimentation rates

Sediment accumulation rates were calculated for both pits using \(^{210}\text{Pb}\) and \(^{137}\text{Cs}\) activities (Fig. 4). Excess \(^{210}\text{Pb}\) showed good exponential decay to 18 cm in pit A and 8–14 cm in pit B, with activities below these depths both highly variable and often below detection. The inventory for \(^{210}\text{Pb}_{\text{ex}}\) at pits A and B were 26 ± 9 and 37 ± 9 dpm/cm\(^2\), respectively, and comparable to 24 dpm/cm\(^2\) (Kading et al., 2009) and 21 dpm/cm\(^2\) (Ivanovitch and Harmon, 1992) reported in other South African systems. Average sedimentation rates using \(^{210}\text{Pb}\) were obtained by plotting the linear regressions of \(\ln\left(^{210}\text{Pb}_{\text{ex}}\right)\) activities against depth for both pits (Fig. 5; Table 1). Similar sedimentation rates of 0.26 cm/y and 0.21 cm/y for pits A and B, respectively, were obtained.

Total \(^{137}\text{Cs}\) in all samples was very low, with many samples below the analytical detection limit. Calculated \(^{137}\text{Cs}\) inventories for pits A and B were 1.5 ± 0.3 and 4.2 ± 0.7 dpm/cm\(^2\), respectively. The low inventory is consistent with other measured inventories for southern Africa reported by Collins et al. (2001), Owens and Walling (1996), and Foster et al. (2005). Low \(^{137}\text{Cs}\) levels are due to fallout having been significantly lower in the Southern Hemisphere than in the Northern Hemisphere, with contemporary \(^{137}\text{Cs}\) inventories in North America and Europe commonly ranging between 12 and 24 dpm/cm\(^2\) (Walling and He, 1999; Alvarez-Iglesias et al., 2007). The weapons fallout peak is typically difficult to discern in sediment records from the Southern Hemisphere, with profiles generally being characterised by several peaks of smaller intensity, the largest occurring between 1964 and 1966 (Pfitzner et al., 2004; Foster et al., 2007).

Accumulation rates of \(^{137}\text{Cs}\) were calculated by dividing the depth above the deepest detectable \(^{137}\text{Cs}\) peak by the number of years elapsed since 1965 to the time of core collection. Pit A shows two significant \(^{137}\text{Cs}\) events, with peaks in activity at depths of ∼7–11 and 17–23 cm (Fig. 4). The latter peak is attributed to fallout from weapons testing in 1965, giving a sedimentation rate of ∼0.40 cm/y. This then dates the first peak to ∼20–25 years ago, when the area experienced widespread flooding in 1984 from tropical Cyclone Domoina. The detection of \(^{137}\text{Cs}\) in the surface sediments despite the fact that there has been little or no atmospheric deposition of \(^{137}\text{Cs}\) for over 20 years suggests bioturbation or an occasional influx of redistributed sediment from the floodplain. In pit B, the excess...
Vertical distribution of $^{210}$Pb and $^{137}$Cs in pits A and B.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>$^{210}$Pb Supporting $^{210}$Pb (dpm/g)</th>
<th>$^{210}$Pb Excess $^{210}$Pb (dpm/g)</th>
<th>Error $^{210}$Pb (dpm/g)</th>
<th>$^{137}$Cs Supporting $^{137}$Cs (dpm/g)</th>
<th>$^{137}$Cs Excess $^{137}$Cs (dpm/g)</th>
<th>Error $^{137}$Cs (dpm/g)</th>
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</table>

* $^{95}$BD = below detection ($^{210}$Pb detection limit = 0.3 dpm/g; $^{137}$Cs detection limit = 0.05 dpm/g).

$^{210}$Pb and $^{137}$Cs data suggest that the upper 8–22 cm is well mixed and may all be contemporaneous. The first major peak in activity at 21 cm is assumed to represent the weapons fallout peak, giving an average sedimentation rate of $\sim$0.5 cm/y. The 1984 flood peak is difficult to discern but may have happened between 8 and 16 cm (corresponding to 16–32 years ago).

Sediment mass fluxes were calculated from the average bulk density (0.85 g/cm$^3$) of samples (Table 2). Values derived from $^{137}$Cs are higher than those calculated using $^{210}$Pb, suggesting possible compaction of surface deposits or errors in the assumptions used in deriving sedimentation rates. Based on both sets of data, average sedimentation rates over the last 50–100 years appear to be in the order of 0.2 to 0.5 cm/y. However, deposition on the floodplain is likely to exhibit spatial variability, with areas closer to the river channel experiencing slightly higher deposition rates (resulting in the formation of levees); while areas near the floodplain margin, where sediment supply is limited, are likely to have lower accretion rates. Nevertheless, calculated sedimentation rates are comparable with other available estimates of aggradation. Data from a core taken during construction of the lower Mkuze bridge (∼200 m upstream from pit A) show 42 m of sediment. Assuming that valley infilling started ∼6500 years ago (McCarthy and Hancox, 2000), this is equivalent to a sedimentation rate of around 0.65 cm/y. It is plausible that average sedimentation rates on the floodplain have declined over time, possibly in response to valley infilling or from the diversion of water upstream that now results in less sediment being carried to the northern portions of the floodplain.

4.3. Clastic sedimentation and controls on avulsion

Channel avulsion is a common process on large floodplain wetlands worldwide (McCarthy et al., 1992; Assine, 2005) and is considered to be driven predominantly by aggradation rate (Bryant et al., 1995; Ashworth et al., 2004). Frequent avulsion events (1.5 to 3.0 k/y) appear to be characteristic of moderately to rapidly aggrading systems (>1 mm/y), while very slowly aggrading systems (<0.1 mm/y) typically experience infrequent (<0.3 k/y) avulsion (Tooth et al., 2007 and references therein). With an approximate sedimentation rate of 2–5 mm/y, the lower Mkuze River floodplain represents a relatively rapidly aggrading system that should undergo frequent avulsion.

Past avulsion events on the Mkuze River floodplain are clearly evident, particularly in the middle reaches where abandoned channel levee complexes elevated above the surrounding floodplain can be identified (Fig. 6A). Avulsion in the region is known to have been responsible for the formation of a number of the minor, irregularly shaped lakes associated with the floodplain, which are isolated by the levees of abandoned channels (Watkeys et al., 1993). Further investigations to determine long-term sedimentation estimates using other techniques (e.g. optically stimulated luminescence) will provide additional information on late Quaternary changes, particularly with regard to channel dynamics and avulsion rates.

The diverse wetlands on the Mkuze River floodplain provide habitat to a variety of wildlife, including hippopotami (Hippopotamus amphibius L.). The role of these animals in determining the course of

Table 2

<table>
<thead>
<tr>
<th>Sample site</th>
<th>$^{210}$Pb Sedimentation rate (cm/y)</th>
<th>$^{210}$Pb Accumulation rate (g/cm$^2$/y)</th>
<th>$^{137}$Cs Sedimentation rate (cm/y)</th>
<th>$^{137}$Cs Accumulation rate (g/cm$^2$/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pit A</td>
<td>0.26 (0.18–0.42) $^{*}$</td>
<td>0.22</td>
<td>0.40</td>
<td>0.34</td>
</tr>
<tr>
<td>Pit B</td>
<td>0.21 (0.12–0.81)</td>
<td>0.18</td>
<td>0.50</td>
<td>0.42</td>
</tr>
</tbody>
</table>

* Calculated at the 95% confidence interval.
a new channel during avulsion is well documented in the Okavango Delta (McCarthy et al., 1998). On the Mkuze River floodplain, hippos move from the lakes to the surrounding floodplain to graze, resulting in the formation of an extensive network of trails, which are particularly evident on the upper and middle reaches. Repeated movement along these paths creates favourable pathways for water flow that may erode into deeper channels. Hippo trails play a particularly prominent role in influencing the location of avulsion courses when they create depressions within the main channel levees, enabling water to leave the main channel without overtopping the crest of the levees. In 1986 the Mkuze River experienced a particularly large avulsion event when flow from the channel was altered by a private farmer who excavated a canal between the Mkuze River and Tshanetshe Lake (Fig. 6B). The canal was created by enlarging an existing hippo trail with the intention of increasing water supply for crop irrigation. The canal has subsequently been subjected to rapid erosion resulting in it capturing most of the water that previously flowed down the Mkuze River course. However, although initiated by human activity, Ellery et al. (2003) believed that channel avulsion was probably inevitable at this point on the floodplain because of the substantial difference in elevation between the Mkuze River and the hippo trail.

Avulsion processes on the Mkuze River floodplain share similarities with the Okavango Delta (McCarthy et al., 1991) in that channels become super elevated above the surrounding floodplain and produce a gradient flow that favours avulsion. Changes in channel course play a prominent role in determining patterns of water and sediment movement within the landscape. On the Mkuze River floodplain, avulsion has radically redistributed flow and sediment from the northern to the southern side of the floodplain, bypassing large areas of backswamps and lakes. Under normal flows, the original channel and floodplain is unlikely to be inundated on a regular basis. Reduced overbank flooding and longer periods of dessication in the northern sections of the floodplain are likely to result in the loss of wetland habitat, particularly backswamps and reedbeds. Avulsion location is important in determining its influence on the landscape. In the upper reach, channel avulsion typically has a regional effect, contributing significantly to changes in sediment deposition patterns. In the middle and lower reach, avulsion effects tend to be more local, with short segments of new channel being formed.

Fig. 6. Aerial photographs illustrating past avulsion events: A) Abandoned meander typical of the middle reach; B) The canal created by enlarging an existing hippo trail which led to flow being diverted from the northern to the southern side of the floodplain.
4.4. Chemical sedimentation and its implications for regional geomorphology

Overbank deposition during floods builds levees, which enables areas of shallow water to collect in the adjacent backswamps for extended periods following flood events. Due to high evapotranspirational losses, groundwater becomes increasingly concentrated, ultimately leading to the precipitation of minerals such as CaCO₃ and amorphous silica and to the neoformation of Fe-smectite (Humphries, 2008). Chemical sedimentation is favoured by surface water and groundwater recharge which increases hydrological residence times. In areas of significant chemical accumulation, concentrations of up to 13 wt.% CaCO₃ and 15 wt.% Fe-smectite may be found (Humphries et al., 2010).

Overall, aggradation on the Mkuze River floodplain can thus be viewed as a combination of clastic and chemical sedimentation (Fig. 7). These sedimentation processes are likely to be influenced by seasonal variations in rainfall and discharge. Clastic sedimentation is likely to predominate during the high rainfall summer months when the Mkuze River regularly overtops its banks. Chemical sedimentation is expected to occur preferentially during the drier winter season, when solutes concentrate in the groundwater under reduced flushing (Barnes, 2008).

Such chemical precipitation processes are similar to those widely documented in the Okavango Delta (McCarthy et al., 1993). As on the Okavango fan, chemical sedimentation has potentially important consequences for the Mkuze Wetland System. Large evapotranspirational losses, particularly by deep-rooted *Acacia xanthophleba* (fever trees), result in local groundwater reaching salinity levels in excess of 20 mS/cm (Humphries, 2008; Fig. 7). Given that the major hydrological inputs into the system are relatively dilute (<1 mS/cm), such high sediment and groundwater salinities must play a role in determining vegetation distribution on the floodplain. Mineral precipitation, particularly that of Fe-smectite, must also influence sediment hydraulic conductivity and thus hydrological flows. Ongoing work is attempting to identify more clearly the role of evapotranspiration on vegetation distribution and diversity.

Over long timescales, cumulative chemical accumulation may also affect the landscape within a wetland by altering topography (McCarthy et al., 1993; Troxler Gann et al., 2005). In the Okavango, large evapotranspirational losses by trees results in the subsurface precipitation of solutes causing soil swelling and the expansion of ‘islands’ (McCarthy et al., 1993, 1998). Similar tree islands have been documented in the Everglades, USA (Troxler Gann et al., 2005), which form as a result of nutrient accumulation (mainly phosphorus). The creation of local topographical highs influences the response of the floodplain ecosystem to flooding and contributes to ecosystem diversity. Given sufficient time, chemical precipitation is likely to represent a significant mechanism of accretion on the Mkuze River floodplain, particularly as it does not occur uniformly over the floodplain but rather in localised areas.

5. Conclusions

Floodplains are dynamic features in the environment, whose existence and development reflect the imprints of past and current sedimentation processes. Active sedimentation is common to almost all wetlands, and while clastic deposition is commonly focused upon, chemical sedimentation has the potential to play an important role in wetland systems. This is particularly relevant for wetlands in environments where strong evaporative demand can lead to the precipitation of large quantities of minerals such as CaCO₃ and SiO₂. In such systems, regional geomorphology and ecology are ultimately shaped by the interplay between clastic and chemical sedimentation.

In general, knowledge of sediment dynamics in wetland systems is poor, particularly in southern Africa. This study represents the first successful attempt to measure sediment accumulation rates in a southern African wetland using 137Cs and 210Pb isotopes. The ability to gain insight into the depositional history of such systems using radioisotopic methods may be an important development toward a fuller understanding of wetland formation, evolution, and functioning in the region.

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