Origin and geomorphology of the wetlands of Tanzania

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Summary

Wetlands are dynamic landforms which vary in both time and space. Tanzania's wetlands are classified according to the physiography and the environment in which they exist. Coastal wetlands, Rift *System* wetlands and the wetlands of highland drainage basins are the major groups. Coastal wetlands are formed *by* wave action and tidal influence; beaches and lagoons exist because of wave action; mudflats, marshes, mangrove swamps, estuaries and deltas are tidal in origin. Rift *System* wetlands occur in the rift depressions and are characterised *by* salt lakes, playas, swamps and short streams with inland drainage. The highlands are drained *by* long rivers originating in the inland catchments and ending in oceans or lake basins. On the way to their outlets, they form lakes, swamps and floodplains.

Wetlands occur due to a combination of high rainfall and the tropical climate of Tanzania which favours processes such as meandering of rivers and the formation of floodplains. The morphogenesis of Tanzania's wetlands is related not only to local processes but also to regional factors such as climate, tectonism and the eustatic sea level changes which occurred in the past.

Introduction

Natural wetlands are dynamic and short lived in geological time and have vanished and emerged since the formation of the earth. Areas which now supply limestone, coal, peat, phosphate, salts (evaporites) and diatomite were once wetlands. Today's wetlands are a source of food and cash but unfortunately also disease.

Tanzania's morphology has resulted from the interplay between geology and the tropical climate. ,Her position close to the equator means that winds are light. In the tropics, chemical weathering predominates and results in a preponderance of fine material and clays; weathering is rapid, resulting in a deep weathering front.

This paper explains the origin of the present natural wetlands of Tanzania. A general classification of Tanzanian wetlands is used to accommodate their diversity of formation and the morphogenetics of Tanzanian wetlands are discussed in terms of regional climate and tectonism.

Categories of Tanzanian wetlands

The natural wetlands of Tanzania are grouped into three categories according to their origins and land physiography. The definition of wetlands used in this paper follows that of the Ramsar Convention (see Introduction).

The first category is the coastal wetlands, which are coastal landforms, permanently or temporarily occupied by water. Examples include beaches, mudflats, salt marshes, mangrove swamps, estuaries, coastal deltas and coastal floodplains which lie less than 15m above sea level and which are directly influenced by the sea processes. The Rift System wetlands are the second category. They were formed as a result of rifting or formed in structures influenced by rifting and volcanism. This group includes lakes, pools, ponds, swamps surrounding the Rift Lakes, or ponds and other wetlands supplied by springs and streams associated with the Rift System. The third category includes the rivers and inland floodplains draining hinterland basins and terminating in oceans or in the large East African lakes.

Developnlent and geonl0rphology of coastal wetlands

The present Tanzanian shoreline was formed after the last ice age (10,000 years ago). The world climate has alternated between the cold climatic periods, the ice ages, and the warm climatic periods or inter-ice ages. Water was drawn from the sea during ice formation, resulting in a sea level fall; while the melting of ice added water to the interconnected oceans, causing the sea level to rise. As a result of the end of the last ice age, sea levels stopped rising 6,000 years ago. Thus the present sea outline is the result of such historical changes. However, since the establishment of a shoreline, the sea, through continuous tidal and wave action, has produced the present coastal landforms.

There are sea level changes unrelated to historical ice ages. Within the past century, sea level change has occurred within a band of -0.5 to +22 cm (Houghton *et al.,* 1990), attributed to the melting of low latitude glaciers and Antarctic ice, and thermal expansion of the ocean, as the result of global warming. This change is too small to have a significant effect on coastal topography and coastal landforms are formed by daily changes of the sea level resulting from the interplay between tides and waves. At a particular site, specific coastal landforms occur depending on the relative dominance between tidal currents and waves caused by wind.

Wetlands formed by wind waves

A beach is a gently sloping accumulation of sand or shingles, between low water spring tide and the highest point reached by wind waves. The sediments of a beach are well sorted because of the continuous winnowing by waves. Such material is supplied from local cliffs and other promontories, the offshore zone, dead organisms such as corals, molluscs, diatoms, and from sediments carried to the coast by rivers.

The beach profile

The beach profile depends on both the size of the beach sediments and the nature of waves reaching the shore. Coarse grain, sandy or shingle beaches tend to be steeper, with higher percolation rates, than those composed of fine sands. When a surge of wave water reaches the former type of beach, most of the water percolates through the sands thus reducing the volume of the backwash and producing a steep beach. On fine sand beaches, the percolation rate is low and the amount of water in the swash and backwash is almost equal. As a result, the same amount of sediments deposited on the beach by swash water are also eroded by the backwash and the beach tends to be relatively flat (King, 1972).
The type of breaking wave which dominates the shore will effect the beach slope. The wave breaking zone depends on wave height and depth of water, for instance in shallow water waves collapse far away from the shoreline. In order of increasing height, waves are classified as surging, collapsing, plunging or spilling. Surging breakers run close to the shore before breaking and push sands up towards the beach berm, resulting in a steep beach. On the other hand, spilling breakers become unstable in deep water and only a thin layer of water foam reaches the shore with insufficient energy to push the sand towards the berm, resulting in a flat beach.

Detached beaches and lagoons

Detached beaches enclose sea water to form lagoons and may form barrier islands. A rise in sea level, resulting in the drowning of beach berms, the movement of sand bars on-shore, or the formation and extension of spits results in the formation of barrier islands. Spits arc formed by longshore drift, caused by the action of oblique waves striking the shoreline. When an oblique wave reaches a deeply indented headland bay sequence, wave refraction causes an energy gradient along the shore with a shadow of low energy in the bay. Sediments build outward from the headland shore and enclose the bay to form a lagoon (Swift, 1976). Coastal lagoons in Tanzania may be formed by spit enclosure or by the formation of coral reef barriers.

Wetlands formed by tidal changes

Hayes (I 975) distinguished between tidal landforms and wind wave landforms and assumed that coastal areas which experience tidal ranges in excess of 4 m are dominated by tidal landforms. These landforms, caused by horizontal shift of material by the tides, are mudflats, salt marshes and mangrove swamps. When the tides interact with a river, an estuary or delta forms.

Mudflats and their morphology

Mudflats consist of fine grained silts and clay and are found between low tide and maximum high tide in areas sheltered from the open sea by barrier islands or sand bars. Aerial photographs show that mudflats dominate in Tanga District, from Kilanje Creek at Mtangata Bay northwards to the Kenya border. Southwards, mudflats with their backswamps support 16.5 km2 of mangroves in Mtwara within the shelter of Mnanka Island. In Nangurukuru, the Mavunji creek has mudflats and swamps covering a total area of 62 km2. The Mnazi Bay mudflats are sheltered from the open sea by the fringing coral reefs of Ras Mpura and Ras Mawala.

Mudflats slope gently (1:1,000 gradient) towards the sea (Pethick, 1984). The grain size of sediments on the mudflats decreases progressively towards the land. Upper mudflats are covered by water only at high tide; at the mid-tide level the slope increases and the deposited material becomes progressively more sandy towards the low tide mark. The special distribution of sediment size on mudflats and their morphology is explained by tidal wave movement. As the tidal flow moves landwards up the gently sloping mudflat, its velocity increases from zero, at low tide, to a maximum at mid-tide and back to zero at high tide when the entire mudflat is submerged. Coarser sediments settle as soon as the velocity starts to fall; sands settle more rapidly than clays. Most sediments are deposited landward because of fine sediment concentration and settling lag, thus the height of mudflats rises more quickly on the shoreward surfaces than on the offshore surfaces. Mudflats within creeks and sheltered by barriers rise from the creek towards the land.

Development of marshes and swamps

Salt marshes can be defined as vegetated mudflats which occur at a higher level, relative to mean tide level. Marshes are usually flooded only by the highest spring tides. As the mudflat grows, a critical point is reached when duration *of* tidal flooding decreases and the increased exposure allows vegetation *to* colonise the area. Factors influencing the colonisation of mudflats *to* form marshes include:

- the availability of suitable plant species able *to* withstand such a difficult environment;
- low velocity of the tidal current allowing plant seedlings *to* anchor on the mudflats;
- the availability of light for plant growth which, in turn, depends on the duration of tidal flooding and turbidity and salinity of tidal water.

Swamps arc permanently inundated marshes. Swamps may develop from marshes if there is a relative change between the sea and land levels, such as a rise of sea level or subsidence of land, and consequent sea transgression. The marshes of Tanzania arc covered by salt tolerant grass and scattered trees. Salt panning usually takes place on coastal marshes.

Mangrove swamps are found in creeks, estuaries, deltas and closed embayments where the influence of salt water prevails. Significant mangrove swamps occur at the mouth of the Rufiji River in the Coast Region, Ruvuma River around the Letoko distributary, and Kisiju near Bagamoyo.

Estuaries and coastal deltas

An estuary is the mouth of a river where a channel broadens out into a trumpet-like shape and within which the tide flows and ebbs. The shape of the estuary depends on the tidal range of the sea. A small tidal range results in a bar-built estuary where riverine sediments plug the river mouth, preventing the tidal flow from entering the river channel. A bay or lagoon forms where both river and seawater mix.

Drowned river valleys result when the rising sea levels submerge the river channel. Rias are formed when a deeply bisected area has been drowned and the resulting estuaries are steep sided and penetrate far inland.

Estuarine processes

The tidal current and river discharge influence the estuarine processes; those which control sediment transportation are the most fundamental to estuarine morphology. As the tidal wave enters the estuary, the velocity of the tidal current increases to a maximum at mid-tide, when only the central channel of the estuary is affected, and is at a minimum at high tide, when the suspended load settles in the upper part of the estuary. Thus more sediment is carried into the estuary than out and the upper part of the estuary becomes a sediment trap. High discharges by the fluvial channel occur during seasonal floods which are less frequent than tidal floods. Mudflats in the upper estuary accrete faster than lower mudflats.

A high tidal range, greater than 4 m, produces a funnel-shaped estuary. As the tidal wave moves upstream it loses energy rapidly because of friction, thus the seaward side of the channel is eroded wider than upstream.

Mixing of fresh and saline waters also controls sediment deposition in the estuary. High tidal range and low river discharge facilitate water mixing. As dense salt water moves into the estuary and mixes with fresh water there is a loss of volume and more seawater enters the estuary to compensate. The resulting residue current moves sediment to the estuary.

If mixing of salt water and freshwater is not substantial, a salt wedge penetrates the estuary. Freshwater rises over the salt wedge, leaving its bed load at the tip of the salt wedge. The suspended load moves towards the sea and is deposited as the velocity fal1s. This occurs when the flow of the river is high and tidal range is small; suspended sediment is deposited towards the sea resulting in the formation of a delta.

A typical estuarine environment is found where the Pangani River enters the Indian Ocean at Pangani Bay (Figure 1). The Pangani estuary is macro-tidal and has a typical funnel shape. At the entrance of the Rufiji River a delta has formed as a result of high sediment and fluvial water input and low tidal range. Sediments move offshore and wave currents redistribute the sediment over a wide, shal1ow

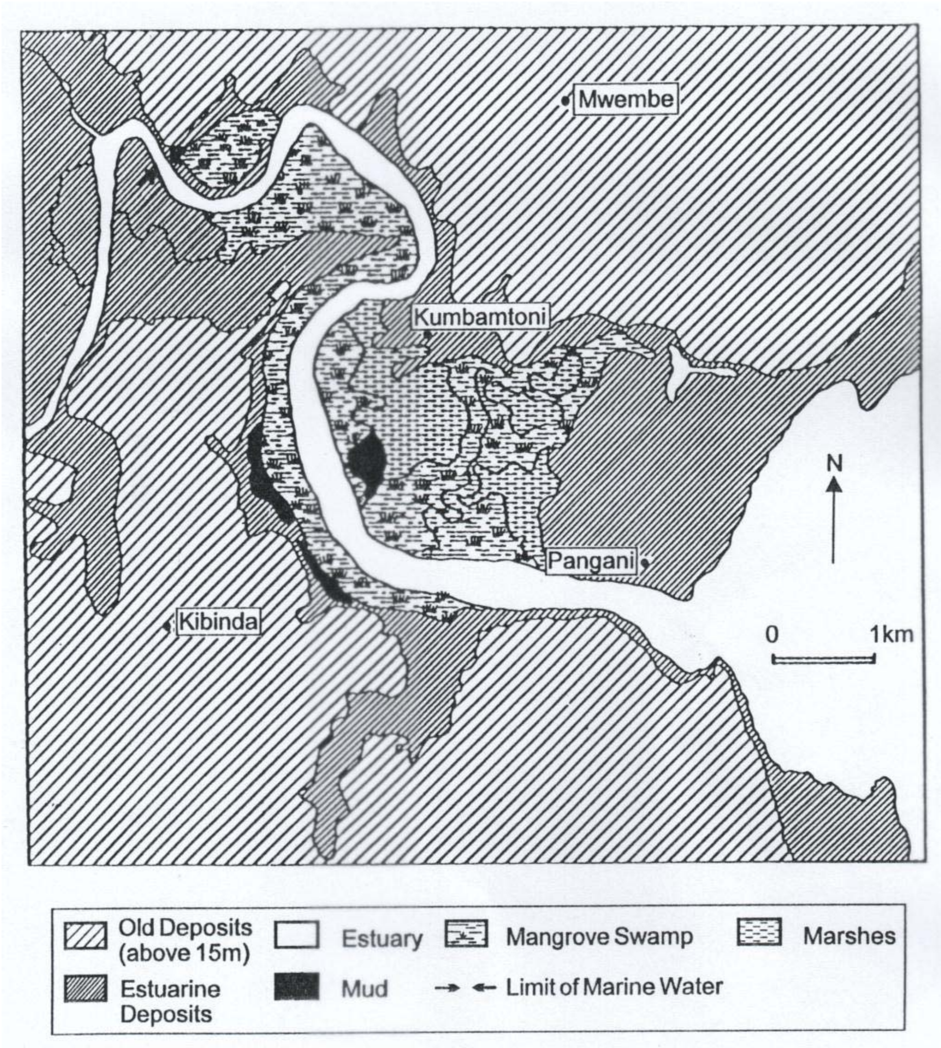

Figure 1 Extension of the Pangani estuary. The boundary between the land covered by old deposits and the estuarine deposits traces the drowned river valley, after the major rising of the sea level

area into which the delta is advancing. The deltaic flat land of the Rufiji River, approximately 1,400 km2, is covered by swamps and marshes which form a large wetland. A similar but smaller situation is found at the mouth of Ruvuma River in Mtwara Region.

Tanzanian Rift System wetlands

Any process which produces a depression in the landscape may lead to wetland formation if water supply and the nature of underlaying formations allow. Rifting and volcanism produce depressions and lines of weakness for water accumulation. Rifting, the result of faulting and upwarping, produces horsts, grabens or titled blocks which are curved by erosion to produce erosional and deposition sites for water accumulation. Faulting forms lines of weakness by shearing and shattering rocks; weathering and erosion then readily occurs and forms drainage lines.

Volcanic eruptions form craters and calderas. These circular depressive features may collect water and develop wetlands. Volcanism and faulting acts not only as the shaping agent of the earth's surface for accumulation of rain but can also supply water to the surface from deep sources. Some crater lakes are seen in Rungwe, Basotu and in the Ngorongoro Crater.

The East Africa Rift covers extensive parts of Tanzania. The sys'tem of troughs and faults runs southwards from Lake Natron to Dodoma in the Bahi depression (6°l0'S) and varies in width from 30 km to 90 km. On the western side, the Rift System covers the basin of Lake Nyasa, through Mbeya and Rukwa, to Lake Tanganyika. The wetlands in this area are lakes, short rivers, swamps and marshes. Typical examples of the small lakes with associated swamps arc Lakes Natron, Eyasi, Manyara, Rukwa and Balangida. These lakes arc bounded by fault scarps and, as they have no outlets, their waters are saline. Short rivers entering these lakes originate from tilted or upthrusted blocks in the Rift Valley. Some contain swamps in depressions; the Wembere River drains into Lake Eyasi, the Bubu River drains into the Bahi depression, and a number of small streams flow into Lake Rukwa.

The Rift Valley lakes fluctuate in size and consequently form playas and swamps on their fringes. Large areas of old Lake Rukwa have become swamps. The change in size of the lake may occur due to progressive infilling of the lake basin by sediments, change of climate, tectonic activity causing uplift and subsidence, or the development of drainage faults.

Faults ill the Rift System arc associated with deep seated springs which can be characterised by the temperature and salinity of the water (James, 1967). These springs may result in the formation of streams and swamps, such as the Itembu and Manyengi Swamps in Central Tanzania.

Wetlands of the highlands drainage basins

Highland drainage wetlands include the swamps and floodplains of the major rivers of Tanzania which originate in the highlands with high rainfall. The Pangani River drains the Kilimanjaro-Usambara uplands; the Wami River is fed from the Unguru Hills and part of central plateau; the Rufiji River, the largest in Tanzania, drains the southern highlands through its main tributaries the Little Ruaha, Greater Ruaha and Kilombero. In western Tanzania, the Malagarasi River has extensive swamps and floodplains along its valley and the Kagera River drains into Lake Victoria through the Kyaka, Minziro and Mwemange Swamps.

River channel morphology

Erosion, transportation and deposition by flowing water interact with underlying structures, lithology and land morphology to determine the shape of a river channel. Important features of the Tanzania rivers are meanders, braids, floodplains and backswamps.

Floodplains form when a river passes through low lying land and sediments accumulate by latera] migration of the river channel or by overbank deposition from flood water. Lateral migration occurs on both braided and meandering channels; the latter forms ox-bow lakes which eventually fill by overbank flow; braided channels form when a river is overloaded with bed material so that deposition occurs to form braid bars. If the river bank is easily eroded, the river meanders due to the infilling of older channels and erosion of new channels. Overflow during flooding causes accumulation of sediments on the banks to form barriers called levees. Levees may grow above the floodplain and areas between the levees and valley walls then become poorly drained, leading to the formation of backswamps.

The major TaT}zanian rivers have floodplains in their lower reaches, including the Rufiji, Ruvuma and Kagera Rivers. Striking features of the Rufiji River are meanders and ox-bow lakes (Figure 2). The Ruvuma River is characterised by a braided channel with a narrow floodplain. A large swamp occurs on the Malagarasi River, situated between the mobile belt and the craton, which may represent an area where rocks, weakened by folding and faulting, were selectively eroded and depressed.

Discussion and conclusion

The processes of wetland formation discussed in this paper are those found in Tanzania. However, some regional factors may also contribute to the formation of observed features. For example, beach sediments found on the Tanzania coast may be related to the process of weathering far inland. Due to a tropical climate with high humidity, weathering is essentially chemical and sediments originating from chemical weathering are usually of fine texture. These sediments are supplied to

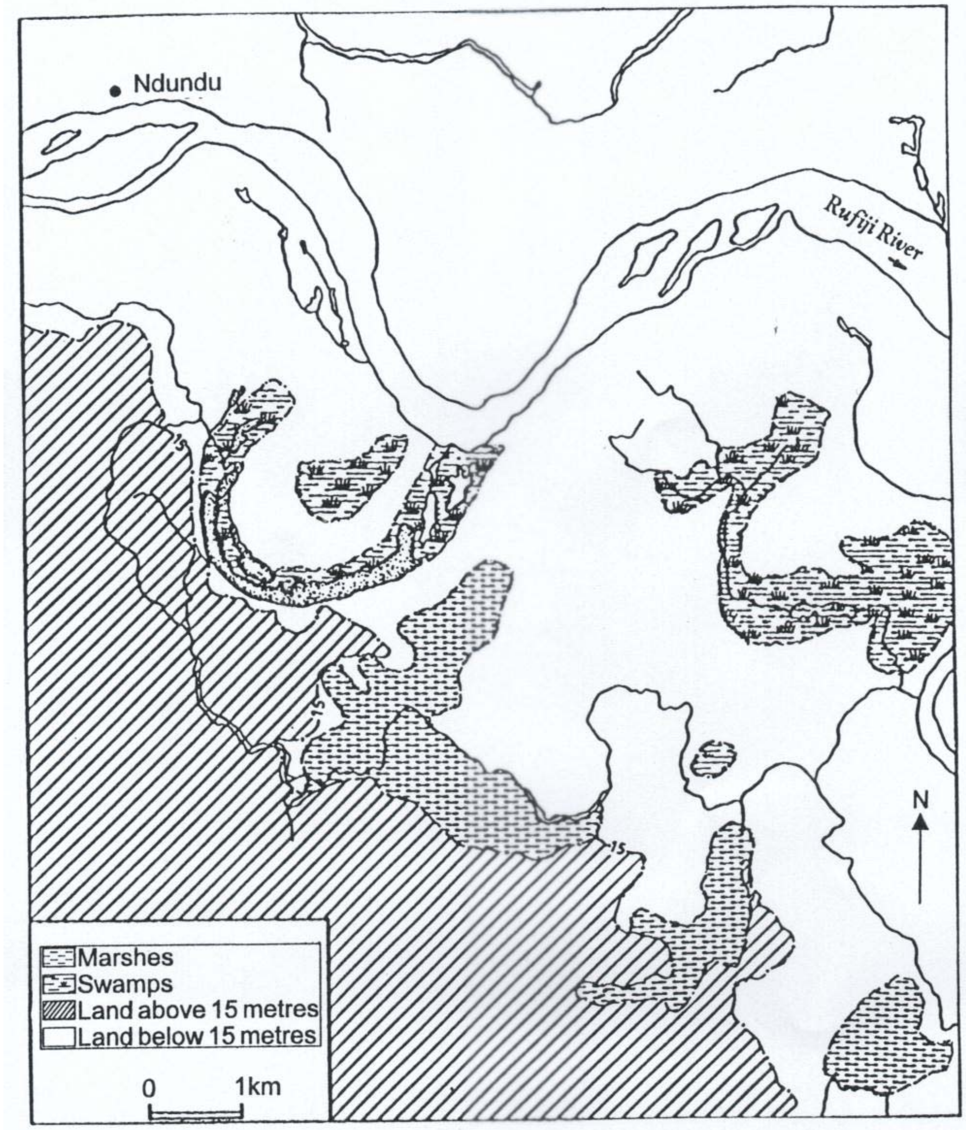

Figure 2 The lower Rufiji River floodplain at Ndundu, Rufiji District. The main river channel has migrated northwards, abandoning the older loops, left as ox-bow lakes, swamps and marshes

the coast by rivers and influence beach gradient. Therefore, the gently sloping beaches along the coast of Tanzania are a consequence of the interaction between climate and the rocks in the hinterland.

The small amount of sand carried by Tanzania's rivers, as a result of the preponderance of chemical weathering, accounts for the absence of large sand landforms on the Tanzanian coast, such as coastal lagoons with sand barriers.

The tropical climate favours the growth of coral which forms lagoons behind a coralline barrier reef. The creeks along the Tanzanian coast demonstrate the effect of tidal dominance over waves. Low wave energy along the Tanzania coast may be traced from its geographical position as Tanzania, being near the equator, experiences only light winds and no cyclones; absence of strong winds favours gentle waves which do not travel far into creeks to disrupt mudflat configuration. The inland wetlands have been influenced by the regional tectonism and climate. Enclosed water bodies and short streams are found in the Rift System. Rivers are loaded with fine grains and sands and have little capacity for erosion. Consequently, the long rivers from the highlands are interrupted by rock bars, waterfalls and rapids. On the low lying lands, rivers meander across the deeply weathered plains and, since they cannot erode all the regolith supplied by weathering, open basins and floodplains emerge. On the coast, these rivers form estuaries and deltas. Tanzanian estuaries are sites of subsidence (Msangi *et al.,* 1988).

The wetlands observed on the earth's surface result not only from the morphology of the land in which they occur but are due to regional tectonic and climatic influence.

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