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Coastal Mining and its Influence on Coastline Stability

Laurie Barwell

Opposite page: Artisanal sand mining near Mombasa, Kenya. © Laurie Barwell.

INTRODUCTION

In UNEP/ Nairobi Convention Secretariat (2009) it is reported that the coastal regions of Sub-Saharan Africa are generally endowed with non-renewable mineral resources such as pyrochlore, gypsum, barites, iron ore, clay, apetite, galena, manganese and semi-precious stones. These occur where geological processes have contributed to concentrating certain deposits with examples being the rich diamond fields off the southern African west coast and the titanium-rich dune fields and sandy shores of various parts of East Africa including Madagascar. It is further reported in UNEP/ Nairobi Convention Secretariat (2009) that the geological exploration of the WIO region is far from comprehensive so that unknown deposits are likely to exist. In cases where mining for minerals is indeed undertaken, there are reported examples of major environmental changes.

As denoted in UNEP/ Nairobi Convention Secretariat (2009) the central drivers of the economy of the coastal areas and the countries of the WIO, in general, include maritime trade, tourism, fisheries, agriculture, mining and other industries and a large percentage of the GDP (see Chapter 1) of the WIO region is generated within the immediate vicinity of coastal towns and cities. The local, national and regional economy is often associated with the infrastructure required by tourism and the ports that form the trade links to international markets.

Infrastructural development results in heavy dependence on natural resources, including the basic components of building material, namely cement, sand and coarse aggregate (stones) for concrete and mortar, and clay for bricks (ASCLME 2012a–i). Dune fields and beaches located closer to river deltas consist of quartz sand and may contain other minerals, more frequently heavy minerals. In other areas, many of the beaches are composed of shell and coral fragments that are of organic origin and are known as carbonaceous sands. DHI and Samaki (2014) report that both live coral rock in shallow waters and onshore fossil coral limestone occur along large stretches of the WIO coastline and are seen as a useful source of building material where the larger boulders sizes are used as building bricks / stones and when broken, can be mixed into concrete as stones and sand. The traditional practice of baking coral rock and crushing the residue to be used as cement is also widely practiced in areas in the WIO region especially in the southern Tanzania coastal region as reported on in DHI and Samaki (2014).

Collectively, the sand and coarse aggregate (stones) material is known as aggregates and further categorized as fine aggregates (grains smaller than 1 cm) and coarse aggregates when larger. The availability of such aggregates along the coast is often seen as a 'free' resource along with the demand from the construction industry offer opportunities for entrepreneurs in both the formal and informal sectors along the whole supply chain (Pikey undated). This is especially noticeable in the Small Island Developing

States (SIDS) where, even though sand and limestone deposits exist, there are inherent challenges in formally sourcing building materials for the building industry (UNEP/ Nairobi Convention Secretariat 2009).

Sediment washed down rivers during floods is deposited within the coastal system and thereby contributes to the coast's natural ability to buffer against sea surges and erosion during storms. In untransformed systems, accretion processes balance the coastal erosional processes and the coastline exists in a state of dynamic equilibrium (Tinley 1985). Transformational pressures in the form of overexploitation, modification and loss of habitats and uncontrolled development or encroachment onto the dynamic beach and coastal system have resulted in environmental degradation including a reduction of the natural dampening effect against sea surges during storms that coral reefs, beaches and dunes have (Roger 2002). The total sum of these factors has a negative impact on coastal communities and often on the countries at large (Masalu 2002).

Some of these impacts include catchment degradation due to poor land-use practices including agriculture and uncontrolled mining activities such as sand excavation from rivers and the destruction of riverine habitat for solar salt production (DHI and Samaki 2014). This can result in increased sediment and silt load in rivers, causing coastal accretion and in places the smothering of habitats such as coral reefs UNEP/ Nairobi Convention Secretariat (2009). The die-off of coral results in a reduction of the protection that such reefs offer to the adjacent coastline against the forces of the sea. On the other hand, coastal erosion has occurred in places due to the coastal system being starved of its sources of sand. This is often due to anthropogenic activities. Such activities include the construction of dams in river courses (which trap sediments); aggregate mining in rivers and from foredunes, beaches and the shoreface; and the sterilisation of the littoral sand source located in dune cliffs and foredunes due to development encroachment (Tinley 1985). In many cases, the construction of harbour infrastructure including breakwaters and/or the dredging of shipping entrance channels has interrupted, reduced or totally changed the natural alongshore sand transport system (USACE 1984).

Natural and human derived driving forces

Since it is implied that coastal mining may have a contributory effect on the stability of the coastline as observed in the form of either coastal erosion or accretion in places (UNESCO 2000, Government of Kenya 2009, ASCLME 2012a–i, DHI and Samaki 2014), this chapter focuses on coastal mining within the context of the physical (abiotic) part of the coastal system. In particular, the influence of coastal mining on the coastal sand system, as an anthropogenic driving force, is assessed as a proxy of the state of the coast in this context. Note that the biotic, economic and societal components of the coupled coastal system are described in other sections of this book.

The types of coastal mining activities in the WIO countries considered in the context of the chapter are:

- Quarrying of coral rock and limestone for cement manufacturing and course aggregates for concrete and road building;
- Artisanal sand mining from the catchment, floodplains, river banks, estuaries and lagoons;
- Informal removal of sand from beaches and foredunes;
- Formal mining of minerals from titaniferous sands; and,
- The production of sea salt from saltpans typically located on estuary flood plains (ASCLME 2012a–i, DHI and Samaki 2014).

The coastline erosion and accretion can result in significant shoreline change (UNEP/ Nairobi Convention Secretariat 2009). Even though coastal erosional trends can be part of the normal coastal processes, the observed erosional trend in parts of the WIO countries is thought to be as a result of anthropogenic activities, as well as episodic storms (which are in part thought to be driven by climate change). The resultant impact on critical habitats, coastal infrastructure, agricultural land and human settlements have been shown to be significant in places, with the impact being accentuated where the shoreline is characteristically low lying and highly erodible such as where dune cliffs and sandy beaches occur. A comprehensive study in Mozambique has confirmed the vulnerability of low lying and erodible coastlines to the effect of episodic storms under existing and future projected climate scenarios (Theron and others, 2012).

DHI and Samaki (2014) report that, in Tanzania, coastal mining at community level is mainly focused on sand and gravel mining, salt production and coral mining. They further report that sand and stone quarrying along beaches, coastal water- courses and other areas are considered important livelihood activities to a point that infor-

mal (un-regulated) sand mining has become a big local industry. As confirmed in research undertaken by Masalu (2002), these informal activities create a range of jobs and local income with resultant socio-economic opportunities and challenges. However the activities can, and often do, result in localised accelerated and / or severe coastal erosion, extensive environmental degradation and an increase in the risk from the forces from the sea on coastal properties which in turn can lead to decreased economic activities, job losses and extensive long-term costs to the local economy.

Changes in accretion to the coast occur as a result of either a change in sediment loads from rivers and estuaries, due to poor land-use and management practices; changes in nearshore processes (such as engineering structures) and/or the re-suspension of sediments in the nearshore by rough seas, often associated with cyclonic conditions (Tinley 1985). As shown in Box 27.1 the natural driving forces that influence the stability of the coastline are: (1) alongshore sand transport; (2) cross-shore sand transport; (3) wind-blown sand transport; and, (4) river flow transporting sediment and silt. The underlying condition is the existence of suitable sand supplies. A further consideration is the effect of future climate change on the wind regime and the sea level.

Human actions directly influence the stability of the coastline

As depicted in Box 27.1, all the sand sources and sinks are linked to one another and thereby form a coastal sand system that is in a natural state of ever-changing equilibrium (USACE 1984). This implies that if a removal from or addition of sand to a system component occurs, it affects all of the other parts of the system and a new equilibrium is formed. Anthropogenic actions, defined as Pressures (in the DPSIR framework), are shown as A to E in Box 27.1 and can influence the stability of the coastline in the short-, medium- and long-term.

In this chapter the state of the coast and the impact and significance of coastal mining activities on the short- and long-term shoreline dynamics are assessed in the context of the coastal sand system as it exists in the WIO coastal belt. This area has large stretches where sediment (sand) occurs along coastal shorelines where it exists in dynamic equilibrium with wave, current and wind-driven processes to form the coastal sand system (USACE 1984, USACE 2004), as depicted in Box 27.1.

Criteria for assessing the state and level of impact on the integrity of the coastal sand system

Building onto the assessment approach followed by Theron and others (2012), in Mozambique, and responding to the typical DPSIR framework (Kristensen 2004) as applied in the context of coastal mining activities in the WIO region, an assessment framework for reflecting the state and level of the residual impact on the integrity of the coastal sand system due to coastal mining is here defined and depicted in Table 27.1. The focus of the assessment is on the residual impact of coastal mining on the integrity of the coastal sand system as a regulating ecosystem service and an integral component of the social-ecological system that prevails within the coastal belt of WIO countries. Seven key elements of the complex system were crystallized from the work reported by Masalu (2002) and the Box 27.1, and are shown in Table 27.1, where the associated criteria for assessing the residual impact are also shown. The qualitative rating and associated numeric score are included.

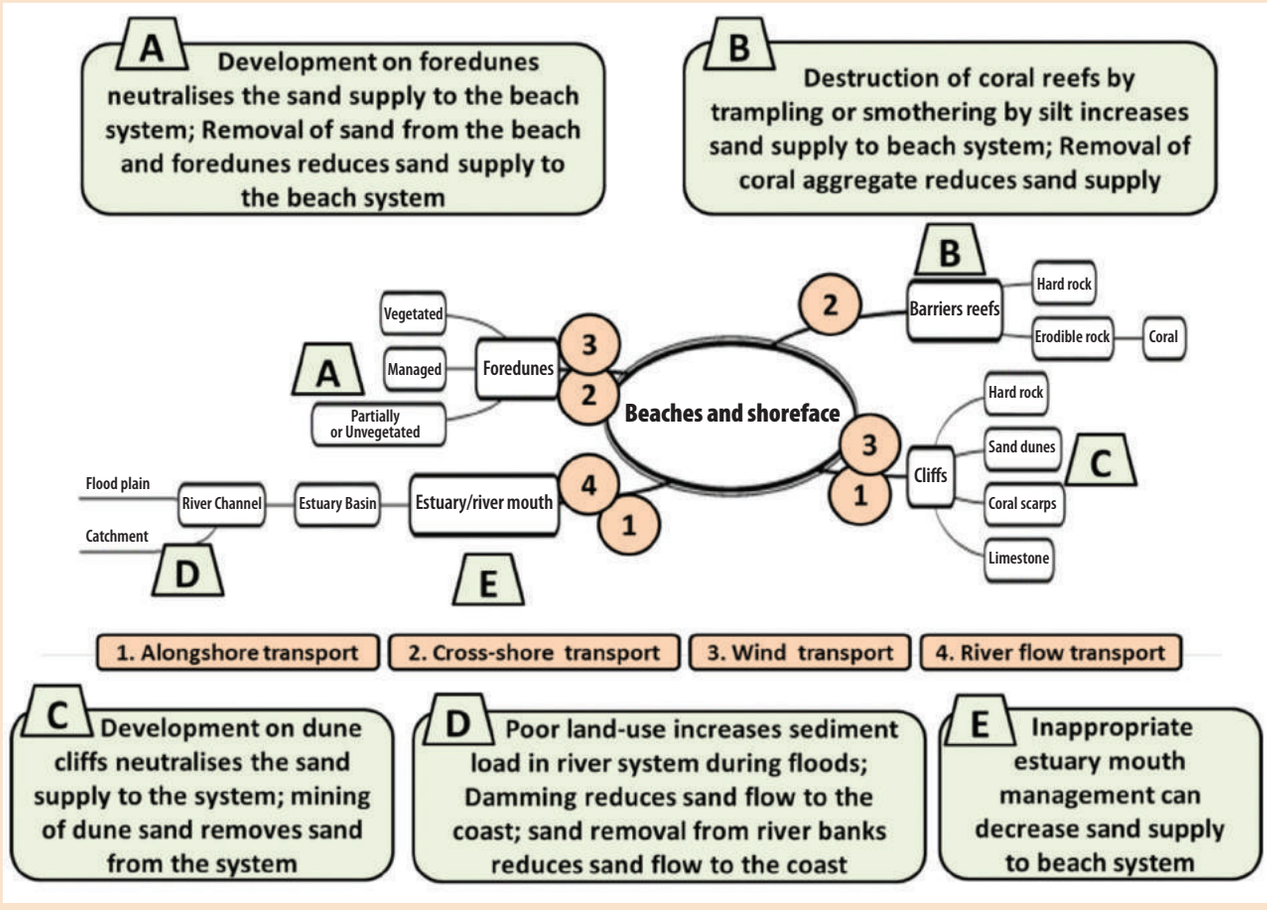
ASSESSMENT OF THE STATE OF THE COASTLINE

Although the National Marine Ecosystem Diagnostic Analysis (NMEDA) series of country specific reports prepared by the UNDP (ASCLME 2012a–i) include basic summaries of the available information on mining activities in the WIO countries under consideration, very little quantitative data are available on coastal mining. This necessitated the use of a similar method to the tried-and-tested assessment approach followed in Mozambique where a qualitative approach was employed for the assessment of the risk and vulnerability to climate change in data- and information-poor contexts (Theron and others, 2012).

The qualitative assessment method, as adapted from the Theron and others (2012) approach, consisted of the following steps:

- No field research, site visits or new data gathering activities were carried out;
- As evidence on which the assessment is based, recent country specific literature (scientific, consultancy and management papers, books and reports) was sourced using the Internet. For the WIO countries the most useful was found to be the ASCLME series published by UNDP (ASCLME 2012a–i). It was impossible to limit the literature to only peer-reviewed work as this would have made no sense given the lack of this qualitative research work;

BOX 27.1. A TYPICAL COASTAL SAND SYSTEM



Elements of the typical coastal sand system and the main natural mechanisms and anthropogenic activities that cause sand to be moved within the system (adapted from Tinley 1985)

Key:

A, 1 & 2: Sand is fed into the littoral zone when high seas erode coastal dune cliffs and then moved alongshore and cross-shore by nearshore currents. Another source of sand arises through the continuous abrasion of boulders and pebbles through wave action impacting on erodible rocky cliffs, reefs and pebble beaches.

A, 2 & 3: Where onshore winds dominate, sand is blown off the beach and foredunes into dunefields. In places, it is moved beyond the reach of storm-waves into the area landwards of the primary dune system, hence it is removed from the coastal sand system. Figure 27.1 illustrates this typical transversal profile of a naturally developing sandy coast. The sand 'stored' in the beach and foredune areas provide a natural buffer against the forces of the sea whereas the sand in the central dune area is important as a reserve under future sea level rise scenarios. Where the geomorphology is suitable, sand from these dune fields bypasses a headland to, in time, join the littoral system either directly into an adjacent bay or into a river. In places, a portion of the sand budget is drained from the shoreface into submarine canyons and thereby removed from sand system.

B, 1 & 2: Coral reefs grow under suitable conditions and coral sand is formed when corals die-off or are broken by wave action thereby forming a source of sand to adjacent beaches. The coral sand is moved across-shore and alongshore. In the nearshore area (seaward of the barrier reefs when present) the sand typically forms a shoreface stretching from the beach (or reef) to about 10 m water depth. Sand in the nearshore area is reworked by waves, currents and wind to form connected environments such as beaches and foredunes. At accreting shorelines, the foredunes mature (through the ongoing establishment of a succession of vegetation) and in time form central and backdune areas that show little change. Where the coastline is in an eroding state, the foredune forms a steep scarp with little or no hummock dune zone.

D, 4: Alluvial (mainly siliceous) sand originating in river catchments is washed downstream during river floods to be deposited in river and tidal deltas at the coast.

• Each document was subjected to keyword-based searches using each of the five identified coastal mining activities as keywords;

• The search results were rated in terms of the published content and significance of data and/or information. The ratings were thus derived for the seven elements and associated state / impact descriptors listed in Table 27.1;

• In many cases there is a lack of information in the published documentation and the specific cells in the tables are consequently shown blank;

• A qualitative rating / score was determined against the scale depicting the state of impact ranging from Very Low (VL) to Very High (VH) with associated scores of 1 to 5 to allow for a comparative analysis across countries and for mining activity type; and,

• The scores are reflected in Tables 27.2 to 27.7 and a *normalized* score (given out of a maximum of 5) was calculated for each element. This allows comparative deductions to be carried out across the countries, mining activities and mining activities.

Ideally, given the data-poor environment, the rating criteria and descriptors depicted in Table 27.1 should be defined and the rating (Step 4) achieved by consensus within a panel of experts representing the various components of the coastal socio-ecological system assessment as well as the various mining activities. Furthermore, the rating / score should be agreed to after observing the actual activities on site.

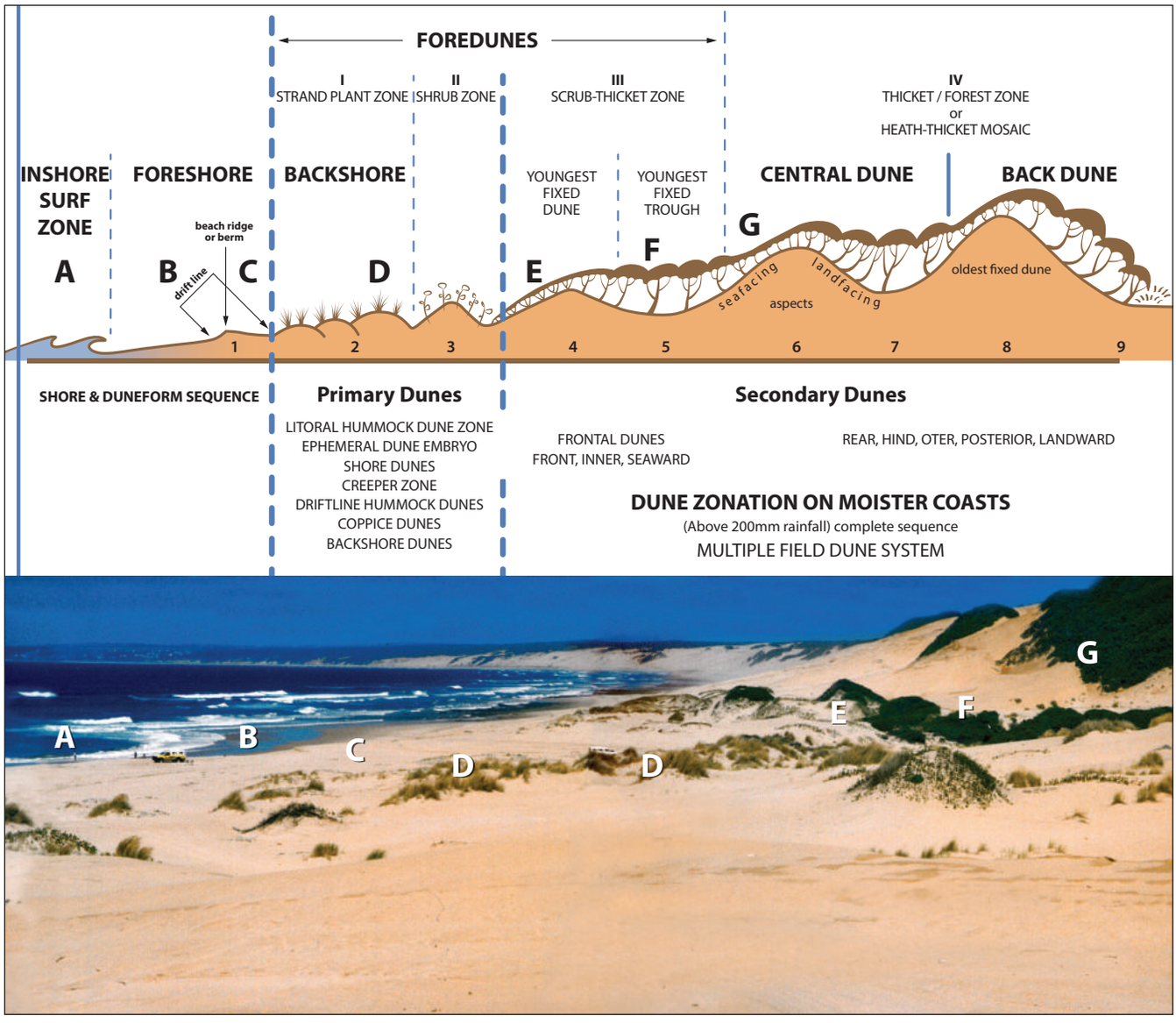


Figure 27.1. Typical transversal profile of a developing sandy coast showing geomorphological units and the different terminology used to characterize the coastal zone. (adapted from Tinley 1985 in Barwell 2011). Photo © A. Theron.

Table 27.1. Criteria for assessing the impact of drivers and pressures on the coastal social-ecological system.

#	Element	Criteria for assessing residual impact (qualitative assessment based on interpretation of available literature)					
		Rating:	**VL**	**L**	**M**	**H**	**VH**
		Score[1]:	**1**	**2**	**3**	**4**	**5**
1	Scale of mining activities in the context of the coastal sand system		Remotely if at all	Indirectly and controlled	Indirectly and uncontrolled	Directly and controlled	Directly and uncontrolled
2	Sustainable growth potential of the mining activity		Insignificant	Low	Medium	High	Very high
3	Societal benefit potential (jobs) of the mining activity		Significant / far reaching job gains	Direct job gains	Neutral	Direct job losses	Indirect job losses / far reaching
4	Economic benefits of the mining activity		Significant / far reaching	Direct benefit	Neutral	Direct cost to economy	Indirect cost to economy
5	Mining activity on the coastal sand system		Insignificant	Indirectly and controlled	Indirectly and uncontrolled	Directly and controlled	Directly and uncontrolled
6	Policy governing the mining activity		Explicit	Adequate	General	Non explicit	Not clear / lacking
7	Level of capability to control the mining activity		Mature	Competent	Growing	Embryonic	Lacking

Note 1: The score of 1 is associated with a residual impact rating of VL (Very Low) scaling up to a score of 5 for a residual impact rating of VH (Very High).

ASSESSMENT RESULTS

The assessment results for the identified types of coastal mining activities in each country (as reflected in available literature) are depicted in Tables 27.2 to 27.6. Table 27.7 shows the overall residual state and impact of the collective coastal mining activities on the coastal social-ecological system of each of the countries as well as the overall score (normalised).

Referring to the assessment criteria in Table 27.1, Table 27.2 depicts the residual impact of the current scale of coral rock and limestone quarrying. It can be seen that the scale of impact of such mining by the formal sector is considered to be *remotely if at all* (score 1 – Table 27.1). No information is available on informal quarrying although mention is made of some community based activities in Somalia resulting in an impact rating of *directly and uncontrolled* (score 5). Note that the scale of impact on the biotic system (for example important habitats and/or specific species) may be significant but this is not considered in this assessment as the focus is on the abiotic components of the coastal sand system.

From the literature it is determined that there is a *high growth potential* (score 4) for formal mining in the countries assessed. This is mainly due to the under-utilization of known resources. The sustainable growth potential for informal quarrying is considered to be *insignificant* (score 1) in Kenya, Mozambique and Tanzania (mainly due to the associated expense as well as the existence of good policies.

Since natural resources are underexploited in Somalia there is a *very high growth potential* (score 4) in the formal sector. Due to the unstable situation in Somalia, the potential for uncontrolled growth in the informal activities is *very high* (score 5) if market demand exists. This results in a *direct benefit* (score 2) rating for the economy at a local level but *neutral* (score 3) on a national and regional scale.

In Table 27.3 it can be seen that the residual impact of the current scale of terrestrial and river sand quarrying in the formal sectors is considered to be *indirectly and controlled* (score 2). The artisanal component (informal sector) is rated as *indirectly and uncontrolled* (score 3).

The literature review suggests that there is a *high* potential (score 4) for sustainable growth in both the formal and informal sectors in the countries where information is available. In Somalia the potential is *low* (score 2) due to the current limited demand and lack of infrastructure. Since natural resources are under-exploited in Somalia there is a *very high* (score 5) growth potential in the formal sector and due to the unstable situation the potential for uncontrolled growth in the informal activities is *very high* (score 5) if local market demand exists. This results in a *direct benefit* (score 2) at a local level but *neutral* (score 3) at the national and regional scales.

The residual impact of the current scale of beach sand mining is shown in Table 27.4 as being *remotely if at all*

Table 27.2. Coral and limestone quarrying for cement manufacturing and aggregates.

WIO Country	Current scale of coastal mining activities		Sustainable growth potential		Societal benefit (Job creation)		Economic benefit			Significance of impact on the coastal sand system		Policy on coastal mining	Level of capability to control
	Formal	Informal	Formal	Informal	Local	National	Local	National	Region	Local	Region		
Comoros												1	3
Kenya	1		4	1	2	1	2	1	3	1	1	1	3
Madagascar	1		4		2	1	2	1	3	1	1	1	3
Mauritius												1	3
Mozambique	1		4	1	2	1	2	1	3	1	1	1	3
Reunion (France)													
Seychelles												1	1
Somalia	1	5	4	5	2	3	2	3	3	5	3	5	5
South Africa	1		4		2	3	2	3	3	2	1	1	3
Tanzania	1	5	4	3	1	1	1	1	1	3	3	1	3
Normalised score	1	5	4	3	2	2	2	2	3	2	2	1	3

Table 27.3. Terrestrial and river sand quarrying (including from hills, river banks, estuaries and floodplains).

WIO Country	Current scale of coastal mining activities		Sustainable growth potential		Societal benefit (Job creation)		Economic benefit			Significance of impact on the coastal sand system		Policy on coastal mining	Level of capability to control
	Formal	Informal	Formal	Informal	Local	National	Local	National	Region	Local	Region		
Comoros												1	3
Kenya	2	3	4	4	2	3	2	3	3	3	1	1	3
Madagascar	2	3	4	4	2	3	2	3	3	3	1	1	3
Mauritius												1	3
Mozambique	2	3	4	4	2	3	2	3	3	3	1	1	3
Reunion (France)													
Seychelles												1	1
Somalia		1	2	2	4	4	2	3	3	3	1	5	5
South Africa	4	5	4	4	2	3	2	3	3	5	1	1	3
Tanzania	2	3	4	4	2	3	2	3	3	3	1	1	3
Normalised score	2	3	4	4	2	3	2	3	3	3	1	1	3

Table 27.4. Beach sand (including sand from foredunes).

WIO Country	Current scale of coastal mining activities		Sustainable growth potential		Societal benefit (Job creation)		Economic benefit			Significance of impact on the coastal sand system		Policy on coastal mining	Level of capability to control
	Formal	Informal	Formal	Informal	Local	National	Local	National	Region	Local	Region		
Comoros		5	1	1	5	5	4	5	3	5	1	1	5
Kenya	1	3	1	1	5	5	4	5	3	5	3	1	3
Madagascar	1	3	1	1	5	5	4	5	3	5	3	1	3
Mauritius												1	3
Mozambique	2	3	4	4	5	5	4	5	3	5	3	1	3
Reunion (France)													
Seychelles		5			4		4			5		1	1
Somalia	1	5	4	5	4	4	2	3	3	3	1	5	5
South Africa	1	1	1	1	4	4	4	5	3	5	3	1	3
Tanzania	1	3	1	1	5	5	4	5	3	5	3	1	3
Normalised score	1	4	2	2	5	5	4	5	3	5	2	1	3

(score 1) for the formal sector. The scale of current beach sand mining by the informal sector is considered to be *direct and uncontrolled* (score 4) in the countries where information is available.

From the literature reviewed, there is an *insignificant* growth potential (score 1) for formal and informal beach and foredune sand mining in the countries where information is available. This is thought to be due to a resource constraint prevalent at coastal cities where there may be a market demand. In places, it is difficult for artisanal miners to gain access to the beach and foredunes because of the existing development on the beachfront. In many countries, restricting this activity is seen as a priority and available policies are implemented and policed.

The exception appears to be Somalia where there appears to be a *high to very high* growth potential due to the current underutilization of known resources and uncertainty about the existence of suitable policy and a lack of controlling capability. Although there is a lack of beach and foredune sand in many of the coastal cities in Mozambique where the effects of coastal erosion are noticeable, the potential to utilize the extensive sand deltas at major river mouths does exist thus attracting a score of 4 (*high*).

Many of the sandy parts of the shoreline within the WIO region are utilized for tourism with many resorts located adjacent to sandy beaches. These resorts offer

many direct and indirect job opportunities. Often the resort infrastructure is located directly on the foredune and thereby reduces the storm buffering potential of the foredunes. The depletion of beach sand due to mining has a large potential impact on the local economy through direct job losses (score 4) and far reaching job losses (score 5) at a national scale. Regionally the impact is neutral (score 3).

The assessment of the specific residual impact of beach and foredune sand mining activities on the various components of the coastal sand system (Figure 27.1) shows a rating of direct and uncontrolled (score 5) due to the scarcity of beach sand resource in most of the WIO countries. The only exception is Somalia where the impact is assessed to be indirect and uncontrolled (score 3) due to a lack of market demand. Removal of beach and foredune sand has an insignificant impact on the regional coastal sand system.

Table 27.5 summarizes the residual impact of the mining activities related to extracting minerals from titaniferous sand dunes. Being a formalized activity under strict control, the scale is scored at 2 (indirect impact and controlled). No information could be found on informal activities. Available geological information indicates a *high* growth potential (score 4) for the formal sector with an *insignificant* (score 1) potential for the informal sector due to the highly specialized nature of mineral extraction and post-mining management. Job creation potential is rated as being *significant* and far reaching at a local level thus scoring a 1 and *neutral* (score 3) at a national level. A strong positive residual impact on the local economy is indicated through a *direct benefit* (score 2) rating. With mining activities typically located a distance inland from the shoreline and well controlled through monitored environmental management plans, the impact on the coastal sand system is considered to be *indirect and controlled* (score 2).

Table 27.6 shows the residual impact of salt works development typically on estuary floodplains where natural mangrove stands are typically removed to create large expanses of saltwater pans where salt is formed during the evaporation of seawater in the pans under controlled conditions. Being a formalized activity under strict control, the scale is scored at 2 (indirect impact and controlled). No information could be found on informal activities but the impact from informal solar salt works are rated as being *indirect and uncontrolled* (score 3). In many of the WIO countries a large number of estuary floodplains exist where the sustainable growth potential for both formal and informal salt extraction activities is rated as *medium* (score 3). Note that the scale of impact on the biotic system (for example important habitats and/or specific species) may be a lot more and this is not considered in this chapter.

In Table 27.7 it can be seen that the overall residual impact of the current scale of coastal mining within the context of the coastal sand system from both the formal as well as the informal sectors is considered to be *remotely if at all* (Table 27.1). The literature suggests that there is a medium to high growth potential for formal mining in various countries. This is mainly due to the under-utilization of known resources. High scores reflect the opportunity for economic growth due to the controlled formalization of mineral extraction from titanerifous dune sands, formal quarrying of limestone and coral rock (for cement and coarse aggregate) as well as sand from identifiable areas within the coastal belt.

The societal benefit is reflected in terms of the potential for job creation since the lack of formal economic opportunities was identified as one of the root causes of resource over-exploitation and environmental degradation. The results show that at a local level, coastal mining offers direct job gains as well as having significant / far reaching job gains due to the demands generated by the coastal industries and tourism. The impact at a national level is mainly deemed neutral since, even though formal coastal mining activities may be an important activity in a specific country, the impact is not more or less than the other sectors where jobs are concerned. A similar situation exists for the residual impact on the local, national and regional economy where the rating falls into a band between of *direct benefit* (score 2) to *neutral* (score 3).

When examining the assessment of the specific residual impact of coastal mining activities on the various components of the coastal sand system (see Box 27.1), it can be seen that the overall rating for the WIO region is deemed to be *indirect and controlled* (score 2) at a local scale and *insignificant* (score 1) at a regional scale. It is important to read this specific assessment score in conjunction with the assessment of the scale of the mining activities as well as considering the existence of coastal management and mining policies and the capability to implement the said policies. These are rated as being *adequate* (score 2) in most countries for the former and *growing* (score 3) for the latter.

Table 27.5. Mineral-rich (titaniferous) sand dunes (for example Ilmentite, zircon, rutile).

WIO Country	Current scale of coastal mining activities		Sustainable growth potential		Societal benefit (Job creation)		Economic benefit			Significance of impact on the coastal sand system		Policy on coastal mining	Level of capability to control
	Formal	Informal	Formal	Informal	Local	National	Local	National	Region	Local	Region		
Comoros													
Kenya	2		4	1	1	3	2	1	1	2	1	1	3
Madagascar	2		4		1	3	2	1	1	2	1	1	3
Mauritius												1	3
Mozambique	2		4	1	1	3	2	1	1	2	1	1	3
Reunion (France)													
Seychelles												1	1
Somalia			4	1	1	3	2	3	1	3	1	5	5
South Africa	2		4	1	1	3	2	1	1	2	2	1	3
Tanzania	1		3	1	1	3	2	1	1	2	1	1	3
Normalised score	2		4	1	1	3	2	1	1	2	1	2	3

Table 27.6. Solar salt works located on estuary / river floodplains (includes Mangrove removal).

WIO Country	Current scale of coastal mining activities		Sustainable growth potential		Societal benefit (Job creation)		Economic benefit			Significance of impact on the coastal sand system		Policy on coastal mining	Level of capability to control
	Formal	Informal	Formal	Informal	Local	National	Local	National	Region	Local	Region		
Comoros													
Kenya	2	3	3	3	2	3	2	3	3	2	1	1	3
Madagascar													
Mauritius												1	3
Mozambique	2		3		2	3	2	3	3	2	1	1	3
Reunion (France)													
Seychelles												1	1
Somalia	1	3	4	4	2	2	2	2	3	3	1	5	5
South Africa	2		3		2	3	2	3	3	2	1	1	3
Tanzania	2	3	3	3	2	3	2	3	3	2	1	1	3
Normalised score	2	3	3	3	2	3	2	3	3	2	1	2	3

Table 27.7. Overall residual state and impact for all coastal mining in the WIO countries

WIO Country	Current scale of coastal mining activities		Sustainable growth potential		Societal benefit (Job creation)		Economic benefit			Significance of impact on the coastal sand system		Policy on coastal mining	Level of capability to control
	Formal	Informal	Formal	Informal	Local	National	Local	National	Region	Local	Region		
Comoros		1			1	1	1	1	1	1		1	2
Kenya	2	2	3	2	3	3	3	3	3	3	1	2	3
Madagascar	1	1	2	1	2	2	2	2	2	2	1	2	3
Mauritius												2	3
Mozambique	2	1	4	2	3	3	3	3	3	3	1	2	3
Reunion (France)	0	0	0	0	0	0	0	0	0	0	0	0	0
Seychelles		1			1		1			1		1	1
Somalia	1	2	4	3	3	3	2	3	3	4	1	5	5
South Africa	2	1	3	1	2	3	3	3	3	3	2	2	3
Tanzania	1	2	3	2	2	3	2	3	2	3	2	2	3
Normalised score	1	1	3	1	2	2	2	2	2	2	1	2	3

CONCLUSION ON THE ASSESSMENT

Understanding the activities (the drivers of change) and their underlying social and economic pressures (the root causes), result in an assessment of the current state of the coastal sand system. Estimating the net effect of coastal mining activities on the coastal sand system can then lead to a qualitative conclusion on the contribution of coastal mining and the associated impact on the coastal abiotic system.

Reflected as a residual impact, the overall state of the current scale of coastal mining on the abiotic coastal system from both the formal as well as the informal sectors is rated as VERY LOW for the WIO countries where information is available. Note that the scale of impact on the biotic (for example important habitats and/or specific species) and social/cultural/historic perspective may be a lot more as this is considered beyond the scope of this chapter.

In some of the WIO countries, the under-utilisation of known resources leads the growth potential for formal mining to be assessed at a medium to high level. The high scores reflect the opportunity for economic growth due to the controlled formalization of mineral extraction from titanerifous dune sands, formal quarrying of limestone and coral rock (for cement and coarse aggregate) as well as sand from identifiable areas within the coastal belt. The oppor-

tunity exists for current infrastructure to be used to export high quality building sand to the island countries from areas where sustainable sources exist.

RESPONSE AND POLICY CONSIDERATIONS

The following pointers can be considered for incorporating into existing policies that relate to managing of coastal mining activities in WIO countries:

- The available literature (for example ASCLME 2012a–i) shows that explicit policies that relate to coastal mining activities do exist in most of the WIO countries under consideration. A policy of explicitly sharing good practice within the WIO region could be strengthened.
- The information indicates that the level of capabilities to control the mining activities fall in the *mature* to *competent* categories. A policy of active succession planning and multi-national skills development will secure a sustainable research and management capability within the WIO countries.
- It appears that (some) authorities are finding it challenging to implement policies especially in areas where informal mining activities prevail. A policy that guides the utilisation of a valuable natural resource should be formulated when more detailed quantifiable research is undertaken. The opportunity exists to implement actions that inform and educate the public and managers on the functioning of the coastal sand system and its importance as a natural protection against existing and future, climate change enhanced, forces from the sea.
- The importance and value of the coastal sand system as a regulating ecosystem service within the coastal social-ecological system should be acknowledged and recognised in coastal zone management policies. For example, a coastal hazard level should be defined and coastal development (including mining activities) restricted to beyond the littoral system to ensure that the buffering services can be sustained within the projected climate change scenarios.
- The opportunity exists to use the sand that is left over from commercial heavy mineral mining activities in Kenya and Mozambique as a commercially exploitable natural resource for export to WIO countries where this resource is limited. A policy of ensuring the direct participation of current artisanal (informal) sand miners in the whole value chain of this venture would enhance the socio-economic benefit across the whole WIO region at a local as well as national level whilst ensuring the integrity of the coastal sand system.

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