External costs of sand mining in rivers: Evidence from South Africa

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Abstract

The valuation of estuarine goods and services serves to highlight the degree to which estuaries contribute to human well-being and to show that the social cost of activities which contribute to estuary degradation could be greater than the private gains. We applied this notion to a list of estuaries in the eThekwini municipal area of South Africa to estimate private gains and social costs of sand mining enterprises. Sand mining in rivers is an important source of raw material for the construction industry, but impacts on sediment yield in estuaries, and therefore on estuarine functioning and service provision. We confirmed the presence of negative externalities in the sand mining industry that are not reflected in the market price of sand, implying that the sand resource is currently being over-exploited, to the detriment of estuarine ecological functioning and long term social well-being. These external costs are estimated at the estuary level for the study area. An assessment of the viability of

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alternative sand supply sources to serve the growing demand in the construction industry is consequently recommended.

Keywords: estuaries, sand mining, negative externalities, social costs, valuation

1 Introduction

Sand is an important input to the construction industry, especially in developing countries such as South Africa, where there is a pressing needs to provide infrastructure and housing. However, public concerns have been raised regarding the negative impacts on estuaries of increased sand mining in rivers in the eThekwini (Durban) metropolitan area of South Africa (Mather, 2007). Despite these concerns, permits for sand mining operations continue to be granted. These concerns were re-emphasized following large scale coastal erosion and associated damage to property caused by severe storms in 2006 and 2007 (Theron et al., 2008). Furthermore, sand mining has negative impacts on the aesthetics and ecological functioning of estuarine systems, with consequent adverse knock-on effects on key local industries such as tourism and fisheries.

The Council for Scientific and Industrial Research was contracted to investigate the costs and benefits of sand mining in the eThekwini jurisdiction, which was preceded and informed by an investigation of the impacts of dams and sand mining operations on sediment yield (Theron et al., 2008). Comprehensive catchment sediment yield modelling was employed (ACRU, (Rooseboom et al., 1992; Ma, 2006), enabling river specific yield estimates. The model was calibrated with field measurements (sediment grain sizes, mud and organic content, sediment densities, sand/mud fractions, suspended sediment concentrations and drainage characteristics) from four rivers in the eThekwini area (Mkomazi, Mgeni, Mdloti and Mlazi). ‘Natural’ sediment yield estimates were generated, which ranged between 480 000 and 720 000 cubic meters per year (based on a conservative range of 10 to 15 percent river sand load content and excluding the impacts of dams and sand mining). Accounting for the impacts of dams on sediment yield decreased the estimate by at least 33 percent (Theron et al., 2008). An aerial survey identified thirty-one active sand mining operations, extracting approximately 400 000 cubic meters of sand per year (a conservative estimate) in the eThekwini area (Theron et al., 2008). The estimated remaining sediment yield from rivers after accounting for the impacts of dams and sand mining in this area is a maximum of 15 percent (140 000 cubic meters) of the annual ‘natural’ yield (Theron et al., 2008). Thus, even at current rates of extraction, sand mining could result in virtually all of the sand entering the estuaries and beaches from upstream river catchments eventually being lost, while the ongoing approval of permits is likely to lead to an increase in extraction rates. Sand mining is therefore a consumptive or extractive use of the sand resource, in that the benefits of sand mining are based on the removal and sale of the resource, which precludes other, non-consumptive uses, such as tourism, fisheries, and erosion control. The consumptive and non-consumptive uses are therefore mutually exclusive. eThekwini municipality is therefore faced with a trade-off between sand mining and other uses of the resource. Authorities therefore face a choice to either allow the continuation of sand mining; or to lobby for alternative supply options (Theron et al., 2008).

This paper quantifies both the benefits and costs associated with sand mining in order to make the consequences of this trade-off more explicit, and to allow for a more socially responsible decision to be made. We argue that sand mining should only be allowed as long as the benefits of doing so outweigh the opportunity costs in terms of the goods and services foregone once the resource is depleted. This requires identification, valuation and comparison of all benefits (in terms of the value derived from sand mining) and opportunity costs (in terms of the value of the goods and services that would be lost if the resource were to be depleted). We start the analysis by reviewing the importance of valuation for resource allocation decision-making in the presence of externalities. We then describe the method used to value the opportunity costs of sand mining, and present the results. Finally, we discuss some implications and recommendations for mediating the conflicting interests.

2 Externalities in resource allocation decision-making

Market prices are often a poor indicator of the true value of basic resources such as sand, because of the existence of market failures such as externalities, i.e. the social costs and benefits of an activity that are not incorporated in market prices (Randall, 1983; Bromley, 2007; Ayres and Kneese, 1969). Profit-maximising firms are often biased towards accounting only for private costs and benefits (based on market prices), thereby often neglecting the social impacts of their decisions. In this case, the negative externalities associated with sand mining imply that the current market price of sand is likely to be an underestimate of its true value, which could lead to over-utilisation of the resource. It also seems likely that the issuing of mining permits will continue until these externalities are included in the decision-making process. Thus, intervention is required to ensure that prices reflect the full value of the resource, or at least that the externalities are accounted for.

Economic valuation often forms the basis of lobbying for the importance of sustainable use and/or conservation of natural resources, since decision-makers readily accept the concept and use value estimates to facilitate choices between trade-offs in evaluation processes (Birol et al., 2006; De Lange and Kleynhans, 2007; Turner et al., 2003; Farber et al., 2002; Balmford et al., 2002; Costanza et al., 1997; Howarth and Farber, 2002; Limburg et al., 2002). Also, when put in context, an understanding of the value of biodiversity will allow diagnosis of the causes of environmental degradation and biodiversity loss (Christie et al., 2006; Costanza et al., 2007; Edwards and Abivardi, 1998; Nijkamp et al., 2006; Nunes and Van den Bergh, 2001; Turner et al., 2003; Costanza, 1998; Costanza et al., 1997). This understanding is critical to identifying the opportunities and constraints that should guide planning and resource allocation decision-making through improved trade-off analysis and improved sustainable environmental management in general.

Monetary valuation employs simplifying assumptions to make reality less complex and consequently easier to quantify. As such those value attributes that are difficult to quantify are often neglected and consequently, a significant amount of richness and complexity is lost in decision-making processes (De Lange et al., 2008). Therefore, one of the challenges associated with valuation is to ensure that all possible externalities are identified and valued (Mander et al., 2002; Pavlikakis and Tsihrintzis, 2003; Munda, 2006; Munda, 1996). The opportunity-cost approach, which is applied in this study, gives reasonably accurate ‘shadow prices’, but is limited to marketed goods or services or those closely linked to marketed goods or services (Alberini and Cooper, 2000; Farinelli et al., 2005; Hoekstra et al., 2001; Loomis et al., 1998; Pearce, 1993; Pindyk, 2007; Wunder, 2007; Kaiser and Roumasset, 2002; Nieuwoudt et al., 2004; Patterson, 2002). We acknowledge these limitations and do not claim that our estimates are fully inclusive; but we argue that estimating opportunity costs is at least a step in the direction of greater inclusiveness as compared to relying solely on market prices.

3 Method

The benefits of sand mining were estimated based on the market price of sand at source, whereas the costs were estimated based on the opportunity costs of sand mining, i.e. based on the value of services that could be lost as a result of depletion of the resource. A utilitarian approach to the valuation of opportunity costs was adopted, whereby value derives from the relative usefulness (including both direct and indirect uses) of the resource in question. Such a perspective necessitates a list of drivers or "value attributes" which define the different uses of the resource and therefore the different components of its value. Each value attribute needs to be identified, quantified and then valued according to an acceptable method. A comprehensive valuation exercise would therefore include different valuation techniques for the different value attributes. An aggregation of the value of those attributes that are not mutually exclusive provides a value estimate for the resource in a specific use scenario.

A distinction can be made between use values (based on actual use of the goods or services in question) and non-use values (based simply on knowing that the resource exists). With regard to use values, estuaries provide a range of valuable ecosystem goods and services. A further distinction can be made between direct services provided by estuaries, including both consumptive uses (e.g. fisheries and the harvesting of raw materials such as reeds and wood for construction) and non-consumptive uses (such as swimming and boating); and indirect services (such as nutrient cycling, erosion control, habitat provision, and stream-flow and disturbance regulation) (see Table 1) (Cooper et al., 2003; Turpie et al., 2005).

These services are heterogeneous across space and time and are therefore not necessarily present in all estuaries or at all times. Thus, ideally, these value attributes should be quantified and valued using primary data. However, time and budget constraints precluded collection of primary data for this study, necessitating use of data from previous studies. A thorough review of the literature revealed no previous studies on the value of estuaries in the study area. Given the lack of site-specific data, data had to be inferred from studies of other estuaries in South Africa, and adjustments made based on the relative ecological state and size of the estuaries. Furthermore, a fully inclusive valuation would ideally include quantitative and monetary estimates for all of the attributes listed in Table 1. However, previous studies have focussed only on selected attributes, with no inclusive assessment of total estuary value conducted to date (Table 2).

The Knysna estuary is one of the few thoroughly studied estuaries in South Africa, and it was therefore decided to infer values for the estuaries in the study area based on the Knysna estuary, after making appropriate adjustments. A substantive (but incomplete) data set on value estimates for the various value attributes of the Knysna estuary was therefore obtained (Turpie et al., 2005; Lamberth and Turpie, 2003). Direct use values in the Knysna estuary were dominated by the contribution of the estuary to the offshore commercial fishing industry through provision of habitat and nursery facilities during certain stages of the life cycle (Lamberth and Turpie, 2003). Recreational values were estimated using the travel cost method (revealed preferences), and were assessed in terms of the tourism-related expenditure that could be attributed to the estuary (Turpie et al., 2005). Aesthetic values were estimated via the property market, in terms of the premium being paid for a scenic estuary view (Turpie et al., 2005). Subsistence values were estimated via structured interviews with the subsistence fishing industry (Turpie et al., 2005). Finally, non use (existence) values were estimated using the contingent valuation method. These values were summed to derive a value estimate for the Knysna estuary, and then disaggregated to a value of ZAR 888 826 per hectare (2008 South African Rands, USD1 = ZAR 8.89; inflated at 7.5 percent per annum).

In order to adjust Knysna values to the estuaries in the study area based on the different ecological state of the estuaries, we assumed that intact ecosystems would be able to provide goods and services (and therefore maintain and preserve their value attributes) far more efficiently as compared to degraded ecosystems. Estuary biodiversity importance ratings (Turpie, 2004) were therefore used to reflect the ability of the estuaries in the study area to provide goods and services (and therefore value) relative to Knysna. Due to the fact that Knysna estuary is ranked number one in South Africa in terms of biodiversity importance (biodiversity importance score of

100) (Turpie, 2004), value estimates for Knysna were considered as upper-level estimates. The above-mentioned per hectare value for Knysna was therefore weighted by the biodiversity importance scores of each of the estuaries in the study area relative to Knysna in order to derive a per hectare value estimate for each estuary. The weighted per hectare score was then multiplied by the area of the estuary (in hectares) to obtain the total value for each estuary in the study area subject to sand mining (see the second last column of Table 3).

For each estuary, however, not all of the value in the second last column of Table 3 is attributable to sand. Sand mining will therefore not result in a complete loss of estuary value, even if all the sand is depleted. The total estuary value is therefore an overestimate of the opportunity cost of sand mining. In order to extract the proportion of total estuary value attributable to sand, and that will therefore be lost should sand mining be allowed to continue, we made three key assumptions. Firstly, it was assumed that a third of an estuary's value derives from each of the supra-, inter-, and sub-tidal zones. Secondly, we assumed that the value of the supra-tidal zone does not depend on riverine sand supply, and will therefore not be affected should sand resources become depleted. On the other hand, in the long run, the value derived from the inter-tidal and sub-tidal zones is entirely dependent on sand supply. The value derived from these two zones could therefore be lost entirely should the sand resource become depleted. Thus, 66 percent of the value of the estuaries could potentially be lost should the sand resource be totally depleted. Thirdly, however, not all of the sand in the estuarine ecosystem is affected by sand mining, which generally takes place upstream of the estuaries and therefore affects only the sand originating from the catchment. It was assumed that this typically represents 70 percent of total sand yield in the estuary. The remainder, which is found in the lower estuarine reaches, originates from the sea, and is therefore not affected by sand mining. Thus, in the long run, we assumed that 46 percent (66% * 70%) of the total annual value of an estuary could be lost through sand mining at unsustainable rates (last column of Table 3).

4 Results

The per hectare value estimates in the last column of Table 3 were used to derive the opportunity cost of allowing sand mining to continue at current rates. To enable comparison with the direct value (benefits) of sand mining activities, the per hectare opportunity cost estimates in Table 3 were converted to a value per cubic meter based on the sand yield estimates (in cubic meters) and the estuary area (in hectares). Table 4 presents the results for the rivers in the study area. For example, within the Mkomazi river, ZAR 30.15 per cubic meter is derived directly from sand mining (based on the market price of the sand at source), at an opportunity cost of ZAR 109.86 per cubic meter of sand being taken out of the system. A higher opportunity cost is associated with more pristine river systems. The ‘external cost’ in the last column of Table 4 refers to the difference between the opportunity cost and the market price, and indicates the increase in market price that would be needed (by means of some form of government intervention, e.g. through a tax on sand mining) to leave decision-makers indifferent between the two options (mining and preservation). Negative values indicate badly degraded systems, implying that there are in fact potential external *benefits* associated with mining already badly degraded systems.

We acknowledge that the above-mentioned estimates only account for the direct (primary) costs and benefits of sand mining. In other words, multiplier effects (knock-on effects through the economy resulting from increased spending power) are not taken into account. However, since the failure to take multiplier effects into account applies equally to the cost and benefit side of the equation, it is not expected that this will bias the results in either direction. It could further be argued, however, that our analysis accounts for the external *costs* of sand mining (negative externalities resulting from loss of sand, such as loss of tourism and fisheries values); but fails to take into account the external *benefits* (e.g. the positive social externalities associated with more housing for the poor). However, given the significant external costs highlighted in Table 4, it is unlikely that sand mining will be justifiable even if positive externalities and multiplier effects are taken into account, especially in the more pristine rivers. In any case, it could be argued that there are other external costs associated with sand mining (e.g. the loss of the tourism and storm protection services provided by sandy beaches that would be incurred if the sand resource were depleted) that are not taken into account in the analysis.

5 Discussion and conclusion

Our value estimates for the estuaries in the study area support the notion that the opportunity costs of sand mining correlate with the ecological state of the estuaries in question as per the biodiversity importance scores presented by Turpie (2004). This is consistent with the notion that as the biodiversity and general state of a river or estuary decreases (for example, as a result of loss of sand); it will lose its ability to provide commercial, recreational and subsistence values.

We have found that broader society is subsidising a ‘discount’ (in the form of an external cost) on the true price of sand for the construction industry because of the presence of numerous negative market externalities associated with riverine sand mining. The market price is therefore an underestimate of the true value of the resource, which could lead to a situation where the resource is over-exploited. In the absence of intervention, the price is only likely to increase when the resource becomes scarce. However, by that time, most of the non-consumptive value attributes associated with the sand resource (including erosion control, tourism and fisheries) could be lost. Market prices therefore provide little incentive to lobby for mining restrictions in the absence of intervention.

Given the external opportunity costs associated with sand mining, it is therefore imperative that the perceived scarcity or price of the sand is artificially raised. One option is to introduce a volumetric tax on sand mining operations equal to the external cost associated with sand mining. This will partially internalise the external cost and increase the market price of sand to ensure that a more socially responsible volume of sand is mined. Setting an appropriate tax level, however, requires more fine-tuned estimates of the externalities than those presented here. An area-specific valuation of all the value attributes associated with the estuaries in the study area (as per Table 1), using primary data, is therefore recommended to verify the results of this study.

An alternative to a tax would be to allocate a volumetric quota on sand mining by limiting the issuing of sand mining permits, based on a function of the maximum yield as indicated by Theron et al. (2008). To ensure economic efficiency, this option could be followed by the establishment of a market whereby these permits can be traded amongst competing sand mining enterprises. In this case, more profitable enterprises would be willing to pay a premium for the mining permits based on their higher expected per-unit profit from selling the sand. The initial allocation and subsequent trading of permits should, however, be handled in a delicate manner. This latter approach is often preferred to a tax, because it avoids the need to estimate an appropriate level for the tax, which, as mentioned, requires substantial amounts of information. However, permit trading schemes require a relatively high degree of institutional capacity and are therefore not yet common in developing countries.

This study does not deny the importance of sand as an input for the construction industry. However, an increased demand from the construction industry is resulting in unsustainable mining rates, and a decrease in the stock of the resource. The relative scarcity of sand is directly related to the rate of mining, and given that mining is a consumptive activity, it is incompatible with a variety of non-consumptive uses associated with leaving the resource undisturbed, which often provide a higher value to society in the long term. This is at least true for those rivers where mining volumes exceed the yield. High opportunity costs suggest that an alternative source of sand supply (such as non-river land sources or even off-shore dredging) should be investigated. For example, it is expected that dredging would be preferable to sand mining, based on the high external costs associated with the latter (Theron et al., 2008). However, further investigation is required to verify this assumption, including an assessment of the external costs of dredging, and a comparison with the external costs of sand mining in rivers. It is therefore strongly recommended that the viability of alternative sources are investigated in order to serve the growing demand in the construction industry in a way that does not undermine the value of the resource to society.

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