Placing sediment budgets in the socio-economic context for management of sedimentation in Lake Inle, Myanmar

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Abstract In soil erosion and sedimentation research in developing countries, there is a need for scientists to direct increased attention to quantifying mechanisms and rates of sediment movement and objectively demonstrating their impacts. Soil erosion and sedimentation in the approx. 3800 km^2 Lake Inle catchment, Myanmar have been of both local and national concern, given the significance of the lake to the economy, environment and culture. Sediment budgets that include a focus on different sedimentation rates in various sink environments around and in the lake were constructed for this lake catchment. The sediment budgets showed that deltas stored more than half of the sediment transported to the lake area, and that, despite the relatively smaller storage mass, the highest specific storage was found at river mouths. Socio-economic assessment identified diverse perspectives on the impacts of sedimentation. Of those perspectives, increasing difficulty in water transportation was recognized as a common, significant problem among stakeholders. Proposals for management of sedimentation therefore emphasize that priority should be given to controlling sedimentation at river mouths.

Key words sedimentation; sediment budget; socio-economic assessment; Lake Inle; Myanmar

INTRODUCTION

"Soil erosion is Asia's most serious natural resource problem, and is equally severe in southeast Asia, South Asia, and the People's Republic of China." This is a statement made in the Environmental Policy of the Asian Development Bank (ADB, 2002). The ADB defined this policy presumably in the context of mainstreaming of "poverty reduction" in the international development community, which has been driven by the well-known initiative "Poverty Reduction Strategy Papers (PRSPs)" by the IMF and the World Bank. The ADB (2002) therefore further stated in the policy that "Asia's rural poor are almost wholly dependent on agricultural land, and the degradation or loss of cropland places their livelihoods at serious risk". Certainly, there is ample evidence that agricultural land-use enhances soil erosion and off-site sedimentation (Sidle *et al*., 2006); however, such statements or political narratives on the status and impacts of soil erosion and off-site sedimentation have invited reflective questions. Reviews by Walker (2002) and Forsyth & Walker (2008) provided growing evidence, predominantly from northern Thailand, that is inconsistent with the simplified accounts of soil erosion and sedimentation. First, although it is commonly assumed that there is no erosion under forest, this is not the case; ground cover, rather than canopy, is the chief determinant of erosion. Second, even in the case that forest clearing has taken place on steep slopes, soil erosion does not always occur at unacceptable levels. Very high permeability of actively cultivated soils and rapid development of crop and weed cover occasionally prevent soil erosion. In addition, the residual effect of the forest on organic matter and soil aggregation is also likely to cause low erosion rates (Sidle *et al*., 2006). Third, non-agricultural sources, particularly roads, are often responsible for a significant proportion of increased soil erosion on mountain slopes. Fourth, downstream sediment impacts that are based on aggregated estimates of on-site erosion in upstream areas are possibly inflated. Limited on-site estimates may not represent soil erosion rates at the catchment scale, and sediment can be stored in numerous parts of the landscape, such as hillslopes and stream channels. Finally, benefits may arise from soil erosion. For instance, soil erosion on up-slope fields can make a significant positive contribution to down-slope fertility. These reviews invite substantial improvement of soil erosion and sedimentation research in developing countries, particularly for scientists to improve biophysical assessment of soil erosion and sedimentation, i.e. sediment movement, by quantifying mechanisms and rates of sediment movement and objectively demonstrating their impacts.

Sediment budgets are a conceptual framework for examining the relationships between sources, sinks, river transport, catchment yield, and land use (Wasson, 2002), providing a useful and powerful approach to quantify mechanisms and rates of sediment movement. Sediment budgets can take many forms, describe many scales, and incorporate varied levels of precision, depending on which form of budget will be most effective for addressing particular scientific or management questions (Reid & Dunne, 2003). From the management perspective, information on soil erosion and sedimentation in large catchments and the role of land-use are important, and comprehensive budgets are required (Walling *et al.*, 2001). Occasionally, the characteristics of sink environments have also considerable importance for management purposes. To fulfil these requirements, different approaches have been developed. First, sediment sourcing, which employs geochemical tracing for identification and quantification of sediment sources, has been applied in construction of sediment budgets. Application of sediment sourcing in sediment budgeting has a specific advantage in analysing the effects of land-use on sediment movement. Also, this makes sediment budgeting in large catchments (>1000 km^2) achievable with feasible levels of resources and effort. Second, although relatively less attention has been given to this, a detailed survey of rates of sediment storage in various sink environments may be applied in sediment budgeting.

The impacts of changing sediment fluxes vary in different geomorphic, ecologic, and socio-economic settings. The impacts are often problematic, although they can be beneficial. Debris flows sometimes cause serious disasters (e.g. Sidle & Chigira, 2004), sediment trapped in reservoirs reduces the economic value by reducing water storage capacity (e.g. Palmieri *et al.*, 2001), river incision due to anthropogenic effects, such as of dams, causes disturbance of ecosystems through alteration of habitats (e.g. Ligon *et al.*, 1995; Bravard *et al.*, 1997), and sedimentation (often together with low water flow) of the river channel can obstruct river transportation (e.g. Furuichi, 2006). Alternatively, sedimentation may enhance agricultural productivity if it deposits nutrients on agricultural land (e.g. Blaikie & Brookfield, 1987), and fluvial sediments, particularly sands, are occasionally utilized as an important resource for construction purposes (e.g. Forsyth & Walker, 2008). What is important in assessment of the impacts of changing sediment movement is therefore to place the biophysical status in a socio-economic context.

By focusing on a lake catchment in a developing country in southeast Asia, this paper first describes the sediment budget of the lake catchment, and identifies the problems and benefits of sedimentation through socio-economic assessment. The results of the identification of the problems and benefits are then reviewed, based on the sediment budgets as well as related biophysical features of the lake catchment. Finally, measures for control of sedimentation in the lake are proposed.

THE LAKE INLE CATCHMENT, MYANMAR

The catchment of Lake Inle, located in the central eastern part of Myanmar and forming part of the Salween River Basin, has long been reported to be facing severe soil erosion and sedimentation (Thompson, 1944; Miller, 1999). This is of both local and national concern, given the significance of the lake to the economy, environment, and culture. The lake plays an important role as a reservoir for major hydropower stations downstream. The natural beauty and unique local culture attract many foreign and domestic tourists to visit the lake area. The marsh around the lake provides habitats for water birds including “near threatened” and “vulnerable” species (Forest Department, 2004). One of the ethnic minorities, the Inthar, lives on the lake and their livelihoods depend largely on the natural resources of the lake.

The catchment area of Lake Inle is approx. 3800 km^2 and its total relative relief is about 1200 m. Four major rivers drain the Lake Inle catchment: from the north, Nanlet Chaung (the word *chaung* is Burmese for river), Negya Chaung, Kalaw Chaung, and Upper Balu Chaung (Fig. 1). In this study, the catchments of these four rivers will be called “sub-catchments” designated by the name of the river (e.g. the Nanlet sub-catchment). Forests in the catchment have been extensively cleared; forests with dense canopies remain on less than 10% of the catchment. Mountain slopes are cultivated occasionally up to the tops of the mountains. Shifting cultivation exists on mountain slopes, but information on its spatial extent or the cycle of land use was not obtained. Grazing also exists, largely for raising cattle for agricultural use, but goat grazing is not seen. Gullies are widely observed in the catchment. GIS analysis of the gully distribution, which was determined using aerial photos taken in 1983, facilitated the calculation of gully density in the Lake Inle catchment. This was estimated to be 128 m km^{-2}. However, gully density varies in the sub-catchments (76–367 m km^{-2}), most probably reflecting geology and soils. Catchment geology is predominantly Paleozoic and Mesozoic, and is characterized by large areas of limestone and dolomite on which extensive gully networks are typically developed. Limestone/dolomite and clastic rocks (sandstones to shale) often form inter-layered sections, and inter-bedded clastic rocks are also found. The southwest monsoon between May and October brings most rain to the region, and the Lake Inle catchment receives an annual rainfall of between 1000 and 2100 mm, depending on the location in the catchment. Generally, there is more rainfall at higher altitudes in the catchment.

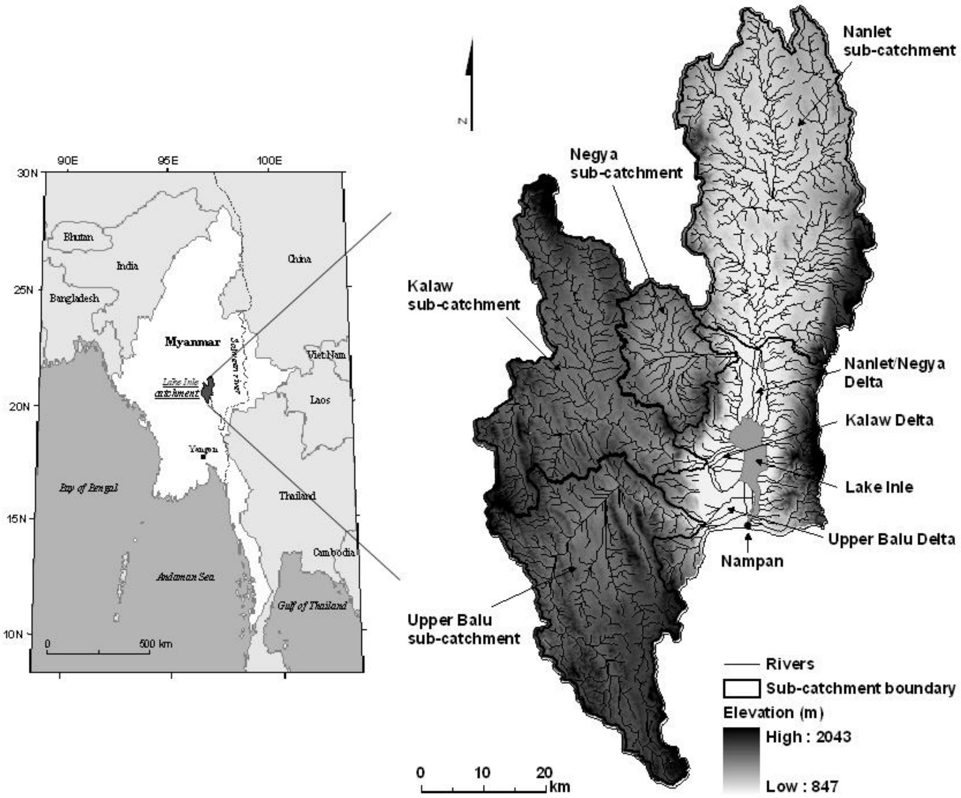

Fig. 1 Location, river networks and sub-catchments of the Lake Inle catchment. The river networks were drawn using SRTM-3 data (DEM) and modified based on topographic maps.

Lake Inle has an approximate dimension of 18 km (north–south axis) by 5 km (east–west axis). The surface of Lake Inle is at an altitude of 884 m a.s.l., and the average depth in the deepest area of the lake is approx. 3.1 m, with a 1.5 m seasonal fluctuation. The average volume of water in Lake Inle is estimated as 158.2×10^6 m^3. The four major rivers have developed three deltas at the margin of Lake Inle (Nanlet Chaung and Negya Chaung share one river mouth and one delta). The Kalaw Chaung and Upper Balu Chaung Deltas are, in particular, “hand-shaped”, comprising several distributaries.

Using topographic maps surveyed in the 1930s, aerial photos from 1983, and a Landsat image from 2000, areas of fluvial flood plains, deltaic flood plains, deltaic marsh, and lake open water were identified (Fig. 2). Areas of low gradient land connected to the deltaic flood plains (swamp) within 15 m vertical difference (slope is <2%), were recognized as fluvial flood plains, which are mostly used for cropland or paddy with irrigation canals. Swamp areas (shown on the topographic maps) were classified as deltaic flood plains, which are largely used for paddy. Deltaic marsh comprises natural floating vegetation, non-floating vegetation, and floating gardens (typically tomatoes are grown). In the sediment budgeting analysis described in the following section, areas of "fluvial flood plains" and "deltaic flood plains" are recognized as "delta", "deltaic marsh" is called "marsh", and the area of "lake" in the previous classification (Fig. 2) is divided into "river mouth" and "lake". "River mouth" designates an area around the point where a river meets the lake (d = ~1 km).

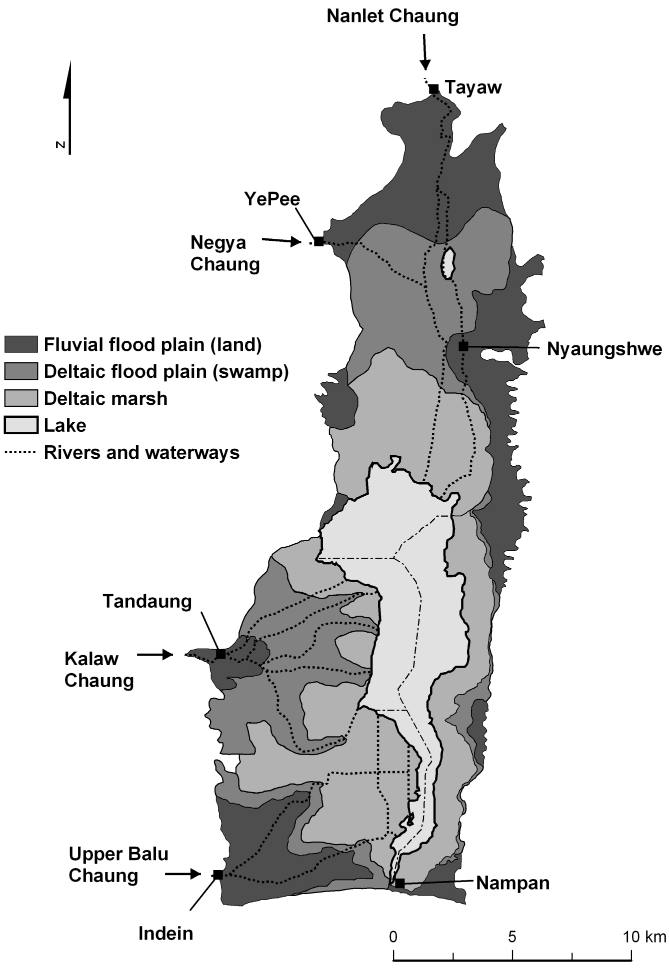

Fig. 2 Land classification of the lake area of the Lake Inle catchment.

SEDIMENT BUDGETS

The chief strategy in the framework of developing sediment budgets for the Lake Inle catchment was to address two major issues of sediment management in the catchment, namely sedimentation of the lake and deltas, and erosion of topsoil (surface wash or rill erosion) and subsoil (gully erosion). Therefore, the spatial variation of sedimentation in the lake and deltas and the contribution of topsoil and subsoil (sediment sourcing) were emphasised. Data derived from sediment sourcing, measurement of sediment yields, and analysis of sedimentation rates were synthesized for construction of the budgets. Details of the method of sediment budgeting employed are provided by Furuichi (2007). Here, we show the sediment budgets developed for the Upper Balu sub-catchment (Fig. 3) and the entire Lake Inle catchment (Fig. 4).

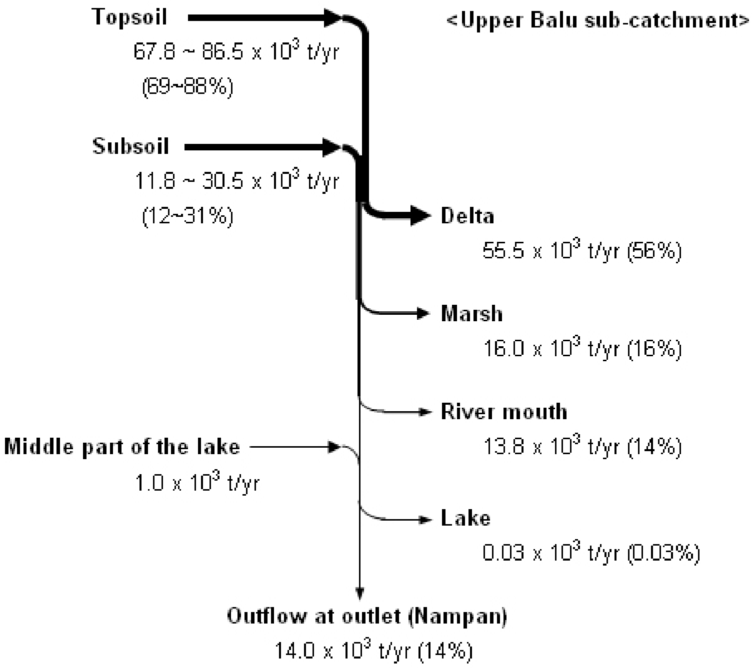

Fig. 3 A sediment budget for the Upper Balu sub-catchment in 2005. Inputs are shown on the left, storage on the right, and output at the bottom. The sum of inputs from topsoil and subsoil is 98 300 t year^{-1}.

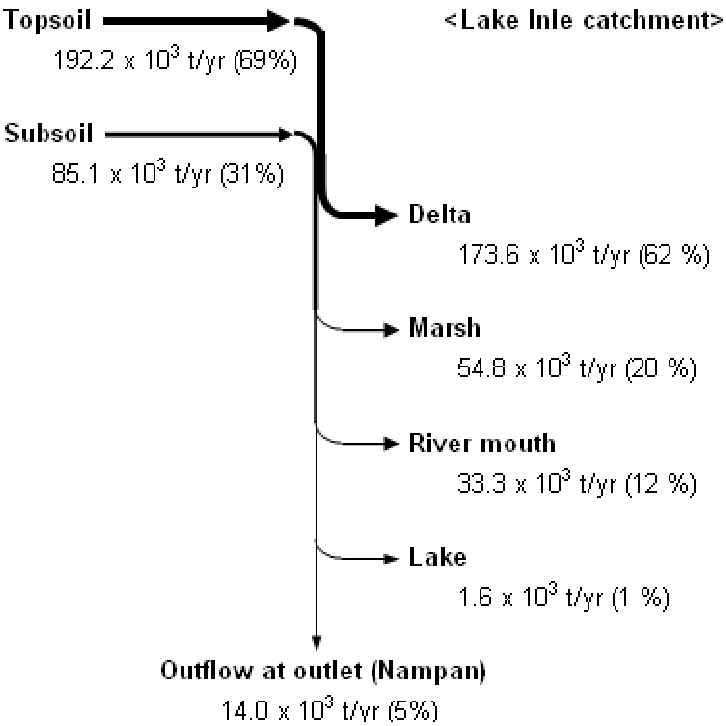

Fig. 4 A sediment budget for the Lake Inle catchment in 2005. Inputs are shown on the left, storage on the right, and output at the bottom. Total inputs are 277 300 t year^{-1}, total storage is 263 300 t year^{-1}, and output is 14 000 t year^{-1}.

In 2005, for the Upper Balu sub-catchment (813 km^2), the total input was 99 300 t $year^{-1}$. Of this amount, 98 300 t $year^{-1}$ was transported through the river and 1000 t $year^{-1}$ was delivered from the middle part of the lake. Based on data for the rainy season, topsoil and subsoil contributions had ranges between 67 800 and 86 500 t $year^{-1}$ (69–88% of the total input from the river) and 11 800 and 30 500 t $year^{-1}$ (12–31%), respectively. Total storage in the sinks was 85 000 t $year^{-1}$ (86% of the total of storage and output). Of that, 55 500 t $year^{-1}$ (56%) was deposited in the delta. The marsh, river mouth, and lake stored 16 000 t $year^{-1}$ (16%), 13 800 t $year^{-1}$ (14%), and 30 t $year^{-1}$ (0.03%), respectively. Despite the smaller absolute mass, specific sediment storage is highest in the river mouth (3900 t km^{-2} $year^{-1}$). Outflow at the outlet (Nampan) was estimated to be 14 000 t $year^{-1}$.

For the entire catchment of Lake Inle, total inputs from the four sub-catchments were 277 300 t $year^{-1}$, total storage in the sinks was 263 300 t $year^{-1}$, and output through Nampan was 14 000 t $year^{-1}$, indicating that 95% of the sediments entering the lake and delta areas was stored in the sinks and only 5% left the catchment. The topsoil contribution (69%) was more than double that for subsoil (31%). Deltas stored the largest amount of sediments among the sinks (173 600 t $year^{-1}$; 62%), followed by marshes (54 800 t $year^{-1}$; 20%). Although deposition at the river mouths accounted for only 12% of storage (33 300 t $year^{-1}$), the highest specific storage (3200 t km^{-2} $year^{-1}$) was found at the river mouths. Deposition in the lake was estimated to be 1600 t $year^{-1}$ (1%), and outflow at the lake outlet (Nampan) was 14 000 t $year^{-1}$ (5%). As mentioned earlier, one of the three key components of the construction of the sediment budgets was the analysis of sedimentation rates. Projections of the sedimentation rates over the last 50 years to the future enabled calculation of the time when the deltaic marsh and lake (Fig. 2) would be infilled. It was estimated that the deltaic marsh would be infilled in 120 years, and that the lake would disappear in approx. 2200 years (application of a possible higher sedimentation rates suggests this could be reduced to 700 years), if the sedimentation rates estimated in this study were uniformly applied to the entire lake and marsh areas and dredging did not occur.

SOCIO-ECONOMIC ASSESSMENT

Socio-economic impacts of sedimentation were assessed by interviewing people from various groups in the Upper Balu Delta in May 2006 (farmers, non-farm villagers, and dredgers). Interviews were in English and, when necessary, translated into Burmese by an officer of the Forest Department of Myanmar. The same questions were asked of all interviewees, except dredgers. Although dredgers kindly stopped working during the interviews, their time was limited. For farmers in the delta, the interviews involved three groups (seven people) in Indein-Phet village in the middle of the Upper Balu Delta. For villagers at the river mouths, the interviews involved six groups (nine people) in Ywama and Thale villages in the river mouths of the Upper Balu Chaung. For dredgers, the interviews involved three groups (five people) working in the waterways in Ywama village. Interviews typically took one to two hours (except for the dredgers). In addition, information on mechanical dredging by the Irrigation Department was provided from its Nyaungshwe Office in August 2005. An outline of the results was reported previously (Furuichi, 2006).

Farmers in the delta

The three deltas (Nanlet/Negya, Kalaw, and Upper Balu) have been extensively used for crops, including paddy. In over-bank flooding events, more sediment is deposited in areas close to the river and less in areas far from the river. The lateral difference of sedimentation rates results in a difference of land level within a delta, which influences land use. Land use in the Upper Balu Delta is classified into three types by the farmers, depending on land levels: swamp, paddy field, and crop land. The lower land, where water is deeper than that suitable for paddy, is designated swamp. The higher land, where a suitable water depth for paddy cannot be maintained, is designated crop land. Land with water depth between the lower and higher land (the middle land) is used for paddy. Because farmers want to expand paddy fields into the lower land, they want sediment to be deposited, in order to raise the land level. In combination with the fertility added by sediment, this situation generally influences their perspective on sedimentation. The farmers consider sedimentation as a benefit, rather than a problem, despite the costs necessary for dredging paddy fields and irrigation canals (2–5 days every year for dredging the irrigation canals). One farmer, however, considered sedimentation to be a problem because his lands are close to the river and increasingly cannot be used for paddy. Also, a farmer said "too much" sedimentation is a problem; an amount of sediment that provides adequate fertility to their paddy fields is enough. In addition, the farmers are clearly concerned about sedimentation problems for water transportation in the streams and river mouth. The agricultural produce is transported by water in the delta and lake area. Damage to the water transportation system has significant impacts on delta agriculture.

Villagers at the river mouths

Members of the Intha ethnic group have lived in the Lake Inle area since the 15th or 16th century (Al Ba Oo, personal communication: 23 May 2006). Their villages are situated around the end of the lake, in the river mouth, and in the delta. People who live in the lake and river mouth use small boats for local transportation, even between houses. The water transportation is an important component of the Intha's culture, tradition, and identity (Fig. 5(a)).

Villages around and in the lake have extensive networks of waterways. Especially in villages located near river mouths, the waterways are becoming shallower due to sedimentation (Fig. 5(b)). As a consequence, boats are often stranded in the waterways in the dry season. Each house has a small jetty for private boats. Due to sedimentation, villagers have to remove sediments from the jetties and minor waterways around the houses. Villagers hire labour to dredge the sediments typically twice a year, which costs annually 6000–10 000 kyats (the currency unit in Myanmar; a monthly salary of a local government official was about 9000 to 10 000 kyats in 2005). However, on the positive side, villagers have received benefits from sedimentation, mainly by raising and expanding the land inside the villages, enabling people to "walk" in a village and establish house gardens.

Villagers at the river mouths, who are mostly Intha non-farmers (handicrafts, such as goldsmithing and weaving, provide most of their livelihoods), are aware of the benefits of sedimentation for agriculture; however, the overall perspective of villagers at the river mouths is, without exception, that sedimentation is a serious problem for water transportation, related not only to costs and convenience but also to culture, tradition, and identity.

Dredgers

The main tasks of dredgers are: (1) removal of sediment from private jetties and minor waterways around houses (Fig. 6(a)), and (2) collection and transportation of sediment, mostly from the main

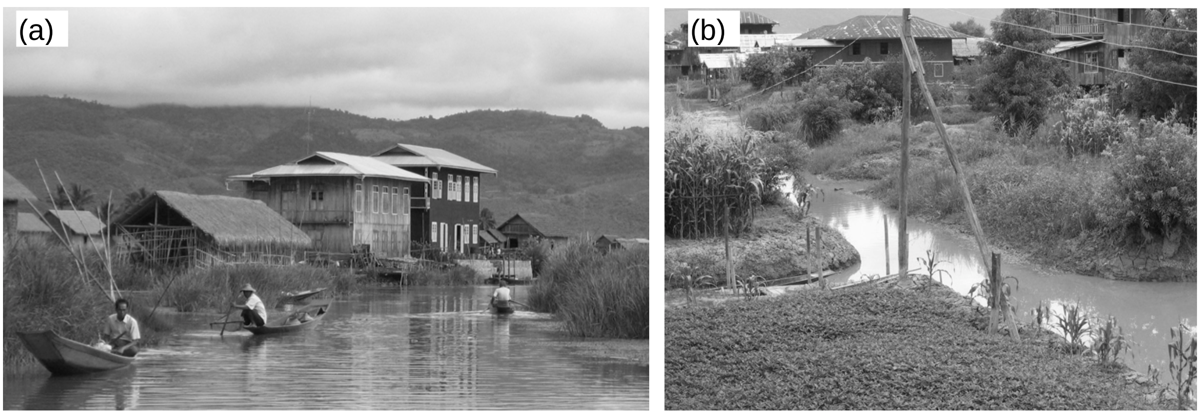

Fig. 5 Water transportation in an Intha village (a). Minor waterways in the Ywama village (b).

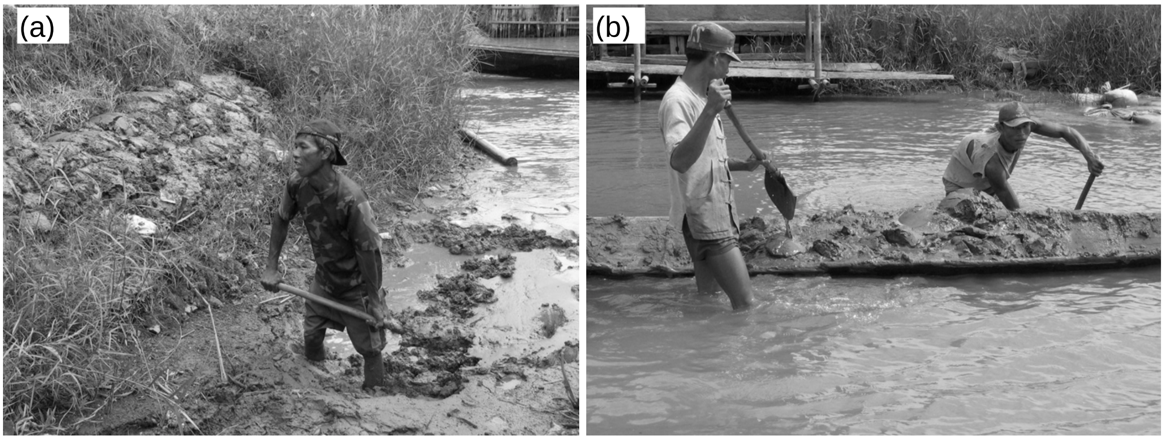

Fig. 6 Dredging a private jetty (a). Collecting fertile sediment in a main waterway in Ywama village (b). They carry the sediment to upstream crop land.

waterways, for raising and expanding land in the river-mouth villages and for improving fertility of agricultural land in the delta (Fig. 6(b)). Dredging is an occupation, either full-time or part-time (seasonal), in the river-mouth villages where severe sedimentation occurs (such as Ywama and Thale). There are approximately 7–8 full-time dredgers per village. Income of dredgers varies from 1000 to 2500 kyats per day, depending on work load (500 kyats per boat). Despite the income, the dredgers claimed that sedimentation is a problem for water transportation, suggesting that their jobs will change once the necessity of dredging has disappeared (however, we recognize that further investigation of the local economy and labour structure is necessary to confirm this inference), and they emphasized the importance of water transportation in their community.

Irrigation Department

Dredging the lake is the responsibility of the Irrigation Department and is carried out with two major aims, namely, retaining the water holding capacity and maintaining the main waterways. However, the costs limit its dredging works. The dredging is particularly important to secure the main waterways when a Buddha statue is carried by a large boat from one village to another village in and around the lake during a festival in October (interestingly, water level is usually highest in October). A machine has the capacity of dredging 34 m^3 $hour^{-1}$ of sediments. The department has three machines for the lake. The machines are used for 120 days a year. Assuming all three machines are operated for six hours per day, a simple calculation indicates that 73 440 t $year^{-1}$ (assuming a bulk density of 1.0 g cm^{-3}) of sediment is dredged by the Department. The sediment budget for the Lake Inle catchment in 2005 (Fig. 4) estimated that sedimentation in the river mouth environment was 33 200 t $year^{-1}$. The dredging capacity of the Department can therefore retain the current volume of the lake.

A consensus among the stakeholders

Despite the different perspectives on sedimentation of the various stakeholders in the Upper Balu Delta and in the Irrigation Department, a consensus exists among them; sedimentation is a significant problem for water transportation.

PLACING SEDIMENT BUDGETS IN THE SOCIO-ECONOMIC CONTEXT

Spatial variability of sedimentation

The sediment budget of the Lake Inle catchment (Fig. 4) revealed that more than 60% of the sediment mobilised from the catchment is deposited in the deltas. However, sedimentation generally provides benefits (fertility and land level increase) rather than problems for the farmers in the Upper Balu Delta. Dredging and clearing of canals is efficient and relatively cheap. Although total storage in the river mouths accounted for only 12% of the overall storage, the highest specific storage was found in river mouths. The sedimentation in river mouths will be further intensified as levees along delta streams become higher through natural processes and/or human activities. This situation is partly observed in the field. Farmers dam-up streams and introduce water into paddy fields, but they break down the dam and close water-gates between a stream and paddy fields when they finish growing rice. The closure of the gates prevents too much sedimentation of present paddy fields. Sedimentation in the lake body itself accounts for only 1% of the total storage, and is not a socio-economic issue.

As peoples' perspectives in the Nanlet/Negya Delta and Kalaw Delta are unknown, distinctive physical features observed in the field have been used as the basis for the following inferences. Sedimentation problems caused by frequent over-bank floods are probably more serious in the Kalaw Delta than in the Upper Balu Delta. Part of a main stream in the Kalaw Delta has been artificially diverted, presumably for reducing the impacts of over-bank floods. Sedimentation in the river mouths of both Kalaw and Nanlet Chaungs is probably considerable and the Irrigation Department is dredging those areas. For the Nanlet Chaung, the straight paths of the delta-streams, which result in higher flow velocities, may enhance the efficiency of sediment transport.

Water holding capacity

Lake Inle currently holds an annual average of 158.2×10^6 m^3 of water. It has been estimated that it will take between 700 and 2200 years for the lake to be completely filled with sediment. This could suggest that the rate of decrease of the lake volume caused by sedimentation, and the resulting impacts on hydroelectricity generation and the livelihoods of the local people are not currently serious issues. However, it is important to recognise that the decrease in the volume of the lake could become more problematic in the future in response to changes in the relative amounts of storage accounted for by the different sinks and changes in the sediment yields from the sub-catchments. A decrease of relative storage in the deltas, due to natural processes (e.g. increase of levee height) and sediment management in these areas (redirection of the river flow directly to the lake), is likely to result in increased storage in the river mouths and in the lake, which could lead to a major change in the rates of sedimentation in the lake body. Increases in sediment yield from the sub-catchments and thus increases in sediment input to the lake could also occur, due to intensification of land use (decrease of fallow land is likely to result in higher soil erosion rates due to less vegetation cover) and climate change (increase of amount and intensity of rainfall).

MANAGEMENT OF SEDIMENTATION IN LAKE INLE

Based on the biophysical and the socio-economic assessments, the following measures are proposed for management of sedimentation:

Delta and river mouth of Upper Balu Chaung

(1) Sedimentation in the delta is a low priority.
(2) Priority should be given to controlling sedimentation at river mouths.
(3) Measures should focus on maintenance of the waterways. Formulation of a master plan to maintain the main and minor waterways at the river mouths may be beneficial. The physical data and analysis provided by this study will offer the scientific base.

Entire lake

The rate of change in lake volume caused by sedimentation is currently not significant. This may, however, alter in the future, depending on changes in sediment yield from the sub-catchments (intensification of land-use and climate change) and changes in the relative importance of storage in the different sinks (increase of levee height and redirection of water flow directly to the lake).

Deltas and river mouths of Nanlet/Negya and Kalaw Chaungs

Overbank sedimentation in the Kalaw Delta and intensive sedimentation at the river mouths of both Kalaw and Nanlet Chaungs should be given a high priority for control. However, socio-economic information in these areas needs to be gathered before control strategies are developed.

CONCLUSION

This study of Lake Inle has provided two important findings of wider relevance for sedimentation studies in developing countries. First, it has been shown that the various stakeholders had different perspectives on sedimentation. Sedimentation brings a benefit for one group of people, while it causes a problem for other groups. Second, the construction of sediment budgets afforded a means of disaggregating the sedimentation process by showing the spatial characteristics of sedimentation in the lake area. The latter represents a meaningful contribution to developing a better understanding of soil erosion and sedimentation for sediment management, since Forsyth & Walker (2008) claimed that "there is a need to disaggregate the diverse processes involved in soil erosion and deposition to see where problems are caused and how they may best be addressed". The disaggregation made it possible to integrate biophysical features with socio-economic perspectives. Although a reduction of the lake volume caused by sediment infill, which will lead to a decline of its reservoir function and the disappearance of an important and beautiful lake, has been the major concern, it was concluded that the lake will not shrink to a critical extent due to sedimentation within a short-term period. Rather, the more local impact of sedimentation, and more particularly its impact on water transportation, was seen to be more problematic for the local society. The establishment of sediment budgets confirmed the relative severity of sedimentation, where waterways are important sediment sinks.

In this study, we have attempted to demonstrate the importance and value of an interdisciplinary approach to an environmental geomorphic issue, using simple methods. Methodology has always been a fundamental issue in interdisciplinary studies and the methods applied in this research hopefully provide a useful example. This contribution did not provide a comprehensive description and discussion of the cause of sedimentation, namely, soil erosion on the catchment hillslopes and subsequent transport of eroded materials, although substantial efforts were given to sediment source analysis for constructing the sediment budget. This is partly because of the perceived need to understand the socio-economy of sedimentation, and soil erosion therefore received less attention. The remaining data and sediment management within the entire catchment will be presented and discussed elsewhere.

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