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ScienceDirect
Geomorphology 87 (2007) 38–52
GEOMORPHOLOGY
www.elsevier.com/locate/geomorph

Sediment yield from gullies, riparian mass wasting and bank erosion in the Upper Konto catchment, East Java, Indonesia

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Received 20 August 2003; received in revised form 20 June 2006; accepted 20 June 2006
Available online 20 September 2006

Abstract

Upland watershed rehabilitation programmes in Indonesia have faced increased scrutiny for not delivering the desired reductions in downstream sedimentation rates. Partly this reflects the fact that conservation measures have not been widely adopted or maintained by upland farmers, mainly for socio-economic reasons. Another potential explanation is that sediment contributions by gullying, (riparian) mass wasting and bank erosion have been seriously underestimated or even ignored. This paper presents estimates of sediment contributions by gullies, riparian mass wasting and bank erosion in the upland volcanic Konto catchment, East Java. Runoff and sediment yield from gullies were studied in two areas with contrasting soils and land use. Gullies in the Maron area (few gullies, Andic Cambisols, maize and rice cultivation on stable broad-based terraces) were related to improper drainage of trails, roads and yards. In the Binangsri area (more widespread gullying, Eutric Cambisols, onion cultivation on forward-sloping terraces), gullying was further enhanced by the practice of downslope furrowing to promote field drainage. Estimated annual sediment yields from the two areas were strikingly different at 22–26 and 50–87 Mg ha^{-1}, respectively. Riparian mass wasting was estimated to contribute ca. 4% of total sediment yield at Maron and 8–19% in the main gully system at Binangsri, with the higher value in the latter case representing the effect of extreme rainfall in the latter half of the rainy season. Short-term wet season rates of gully wall retreat at Binangsri suggested a contribution by bank erosion of ca. 3% (8% including extreme events). As such, 11–27% of the annual sediment yield at Binangsri was estimated to have come from sources other than surface erosion. Substantial volumes of sediment (29–107 Mg km^{-1} of river length) were also added to streams bordered by irrigated rice fields (*sawah*) in non-gullied areas, mainly through the collapse of the lowermost terraces due to undercutting.

Keywords: Bank erosion; Gully erosion; Humid tropics; Mass wasting; Sediment delivery ratio; Sediment yield; Watershed management

1. Introduction

Partly in response to the (perceived) rapid siltation of Lake Selorejo, an important multi-purpose reservoir on the Konto-Brantas River system in East Java, Indonesia (Brabben, 1979), the Konto River Project was established in 1979 to 'develop a planning procedure for the establishment of a management model for forested land in densely populated upland watersheds on Java.' Marking a shift from primarily forestry-oriented to more watershed management-oriented activities during the third phase of the project (1986–1990), hydrological and erosion research was conducted between 1987 and 1990 in an attempt to quantify the chief sources of the

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doi:10.1016/j.geomorph.2006.06.041

sediment coming from the volcanic upland terrain drained by the Konto River and entering Lake Selorejo. The earlier lake siltation survey by Brabben (1979) had blamed indiscriminate agricultural practices on steep deforested slopes vulnerable to (surface) erosion as the chief cause of the sedimentation. Similar ideas formed the basis for the establishment of the 'Regreening Programme' launched by the Indonesian Government in the 1970s on Java. Within the latter programme, all state-owned forested land on slopes over 50% was to be reforested whereas various soil conservation measures (mostly bench terracing, gully plugs) were to be implemented on privately owned steeplands (Pickering, 1979; Anonymous, 1989). The Regreening Programme and other upland watershed rehabilitation programmes in Indonesia came under scrutiny in later years for not delivering the desired reductions in downstream sedimentation rates. Apart from socio-economic reasons underlying the lack of widespread adoption and maintenance of prescribed soil conservation measures by upland farmers (De Graaff, 1991; Purwanto, 1999), there were others arguing that contributions of sediment by natural geological phenomena like volcanic eruptions, earthquakes, landslides and bank erosion had not been taken into account (Diemont et al., 1991). Also, the importance of roads as potentially major producers of runoff and sediment was not given explicit attention at the time (Anonymous, 1989).

It goes without saying that a sound assessment of the chief sources of stream or lake sedimentation is important when designing and applying remedial measures. Yet, such studies are rare for the humid tropics although work by Turkelboom (1999) in northern Thailand and Purwanto (1999) and Van Dijk (2002) in West Java goes some way. The present paper summarises the main results of a recent re-analysis of the original data on runoff and sediment yield from gully systems, riparian mass wastage and bank erosion as collected by the Konto River Project between 1987 and 1990 (Rijsdijk and Bruijnzeel, 1990a,b, 1991). A companion paper (Rijsdijk et al., this volume) discusses runoff and sediment yields from impervious surfaces, such as roads, trails and settlements, as well as road-related mass wasting.

2. Description of field sites

Basic information on location, geomorphology, climate and land cover for the Konto catchment as a whole has been given in the companion paper (Rijsdijk et al., this volume; cf. Fig. 1). Soils in the area are volcanic and are classified (FAO, 1990) as Andisols (mountainous landforms), Cambisols (hilly landforms, plains) or Luvisols (irrigated plains; Nuffic-Unibraw, 1984). The observations on gully erosion and associated mass wasting were concentrated at two locations, viz. (i) the area around the hamlet of Maron in the hills above the Pujon intervolcanic plain (lower Coban Rondo sub-catchment; 1100–1300 m a.s.l.); and (ii) the Binangsri area in the Kayar sub-catchment in the foothills of Mt. Kawi (700–900 m a.s.l.). In addition, surveys of mass wasting along perennial streams were conducted along the lower and middle reaches of the Sayang sub-catchment in the northwestern part of the Konto catchment (700–900 m a.s.l.) and along the lower Coban Rondo river (see Fig. 1 for locations).

In the Maron/Coban Rondo area, gullying was infrequent and linked primarily to excess runoff from rural settlements and trails (cf. Rijsdijk et al., this volume). Rainfed agriculture in the area was practised on stable broad-based terraces showing modest runoff coefficients (on average 13% of rainfall) and sediment yields of 30–50 Mg ha^{-1} year^{-1} (Rijsdijk and Bruijnzeel, 1990a,b). In the Binangsri area, gullying was more widespread, due to a combination of a greater proportion of impervious surface area (Table 1) and poor conservation practices. The dominant crop at Binangsri was onion with cultivation in rows up and down the slopes and furrows in between to promote drainage on long, moderately steep (10–15%) forward-sloping terraces. Although runoff volumes from such fields were not determined separately it was clear from visual observations (numerous splash pedestals up to 10 cm high) and preliminary erosion pin measurements that surface erosion was very high. Average surface lowering was estimated at ca. 50 mm over 93 days during the 1989–1990 wet season (equivalent to an estimated on-site soil loss of about 600 Mg ha^{-1}). However, fields generally had a contour ditch and adjacent low bund constructed at their downslope end which acted as an effective sediment trap. As such, effective hillslope-scale surface erosion rates were much lower than the cited on-site rate (Rijsdijk and Bruijnzeel, 1991). Furthermore, landsliding associated with gullying in the area was much more frequent than at Maron, partly due to the more layered nature of the substrate (cf. Nuffic-Unibraw, 1984). As such, overall sediment yields were expected to be much higher for the Binangsri area, and to reflect a greater variety of sediment sources than at Maron. In the following paragraphs the measuring set-ups at Maron (Fig. 2) and Binangsri (Kayar sub-catchment) (Fig. 3) are described in more detail. Tables 1 and 2 provide additional information on site characteristics and types of measurement conducted at each site, respectively.