SOURCE: KURNIATUN HAIRIAH

MUDDY RIVERS — LACK OF TREES?

Muddy rivers are a problem for some, especially the direct users of river water, and a solution for land lacking in fertility. The ancient culture of Egypt and most Asian paddy rice systems were based on muddy rivers. Yet, to many observers 'muddy rivers' are a symptom of serious land degradation that needs to be resolved. Most problems with river flow and water are, in the public eye, linked to trees, or a lack of them. Forest conversion often leads to erosion and muddy rivers, but only because the resulting land use is too open. There are many ways to protect soils without forest — once the key processes involved are clarified. Research results from Indonesia help clarify the potential role of trees in the landscape, outside of forest.

Key Findings

1. Focus on the river to identify the source of muddy waters

Much of the sediment in rivers derives from bank instability during peak flows, from landslides and from sediment in the river bed, rather than from current field-level 'erosion caused by deforestation.'

2. Muddy rivers have multiple causes

Increased sediment flux linked to agricultural use of landscapes can be due to footpaths, tracks and roads or to loss of riparian zone cover, rather than from current infield erosion.

3. Filter options

The sediment load of a river is usually less than the current amount of erosion from the hillslopes, as indicated by 'sediment transfer ratios' of less than 1.

4. Anchor & Bind

Tree roots, depending on their distribution and strength, bind surface soil (reducing erosion) and anchor top soil to subsoil (reducing shallow landslide risk). Landslide risk peaks a few years after tree removal, when tree roots have decayed.

Management Implications

1. Understand the actual causes of sediment flow before planning preventive and curative measures.
2. Don't expect the 'universal soil loss equation' to predict actual soil loss or its main causes.
3. Strategic positioning of sediment filters on hill slopes can drastically reduce the transfer of sediment into streams.
4. Select and maintain a combination of perennials (trees & grasses) for 'anchor and bind' effects on river banks and slopes.

Section 1. Is the main problem deforestation or a lack of trees in strategic positions?

Rapid deforestation and conversion to smallholder or plantation agriculture has exposed important watersheds across the humid tropics, while attempts to restore forest cover have had a low success rate, despite considerable public expenditure (1, 2). Most current public debate on watershed functioning in the tropics are framed within a forest/non-forest dichotomy. It is assumed that problems are due to deforestation, and reforestation will provide the answer. While the dichotomy can be valid in regions where land uses are dominated by segregation (Figure 1 – right end of x-axis), it is not the case in much of the tropics where integrated land uses are more pronounced. Agroforestry mosaics and 'trees outside forests', (Figure 1 – left end of x-axis) in the tropics, are extensive and are rapidly expanding in area. Their functions in soil and water flows are the focus of current research (3, 4). Where actual 'watershed functions' fall short of expectations, the first step should be reconciliation between different perceptions of reality: those held in the public domain, those embedded in local ecological knowledge, and those that are based on data and scientific analysis (5, 6). If one wants to understand the cause of 'muddy rivers,' focusing on the pathways of water flow and the river bed will provide direct evidence.

Over the past 5 years, ICRAF and partners have made a detailed analysis of the water and sediment flows in the Sumber Jaya region (Lampung, Indonesia), where the Way Besai flows through an area that lost most of its forest cover (60% in 1970, 12% in 2002) through conversion to coffee gardens and expansion of rice fields. The remaining forest is located on hill tops. The sediment load of the river is a concern of the local hydroelectric company.

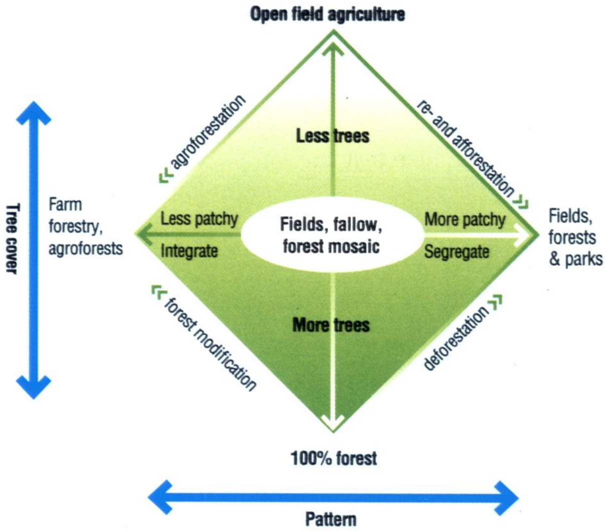


Figure 1. Two-dimensional perspective on land cover: the Y-axis of tree cover and the X-axis of distributional pattern (segregate or integrate) which has its maximum range of options for medium tree cover levels.

A soil survey of area in the 1930s concluded that the land was suitable for coffee, but not for paddy rice, because the silt load of the river was not enough to bring fertility to rice fields. Times have changed and the water of the Way Besai now often resembles coffee-with-milk; most of the sediment that colours the water is assumed to originate in the coffee fields.

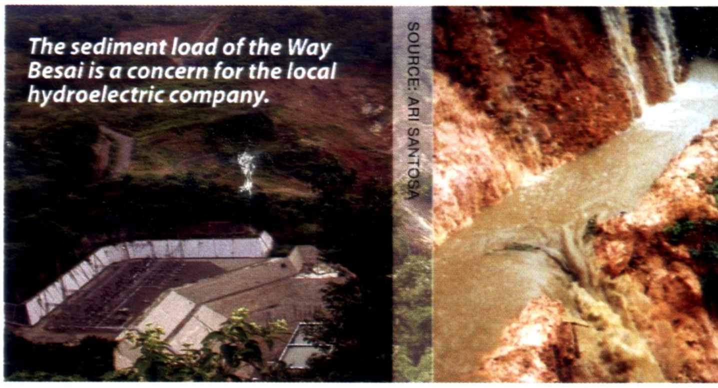
Section 2. Muddy rivers have multiple causes

The total sediment transport from an area is based on multiple sources and complex interactions. A 'sediment budget' provides a check on whether or not inflows and filter effects have been accounted for. A challenge is that a large part of total sediment transport takes place during a few large storms — at times when measurement equipment is vulnerable.

In the Way Besai and its contributing streams, sediment concentration increases with flow rate until all available material has been washed out and the water becomes clear again. At 19 test sites along the Way Besai, large differences in sediment load were observed between the different streams (Figure 2 and 3). This variation was not obviously linked to differences in land cover or slope, in contrast to what the widely used 'Universal Soil Loss Equation' suggests (which is in fact only quantifying surface erosion on hillslopes). The geological origin of the soils and the presence of internal sedimentation points in the various subcatchments explains much of the differences in sediment contribution. The availability of internal sedimentation areas or sinks upstream of test site 'B6' reduces sediment outflux out of 36% of the catchment

Sources of sediment in the Way Besai river are:

- erosion on hillslopes
- landslides and land-creep feeding soil into the river
- footpaths, motorbike trails, roads
- bank erosion along streams and rivers
- management of rice fields (especially 'puddling')
- mining operations (for sand, stones or gold) in the river bed



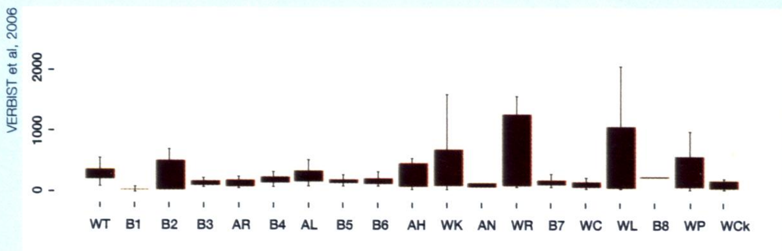
area (Figure 3; 7). Only relatively little sediment from a subcatchment like test site 'WT' — where thousands of people where evicted to restore watershed functions — is likely to reach the hydropower lake. The sediment contribution to the hydropower lake by small catchments, for example test sites 'WR,' 'WL,' and 'WP,' that are characterised by both a high sediment yield (mainly because of landslides and river bank collapse) and few internal sedimentation areas, is an order of magnitude higher. Obviously the strategic positioning of trees is much more important, for example in the riparian areas of those 'high risk' subcatchments than at the border of a relatively slow flowing river (7).

By the 1930s both catchment-level and plot-level research was undertaken in the then Dutch Indies to identify major sources of sediment. Limited budgets and practical difficulties led to the abandonment of catchment research. In cases where surface erosion is not dominant, wrong diagnoses were the result.

Bank erosion and shallow landslides may account for 50% of the total sediment load, although there is considerable uncertainty to date in the way the volume of soil 'on the move' is linked to above-average rainfall events.

Figure 2. Sketch of the main rivers in Sumber Jaya and the locations where sediment loads were measured.

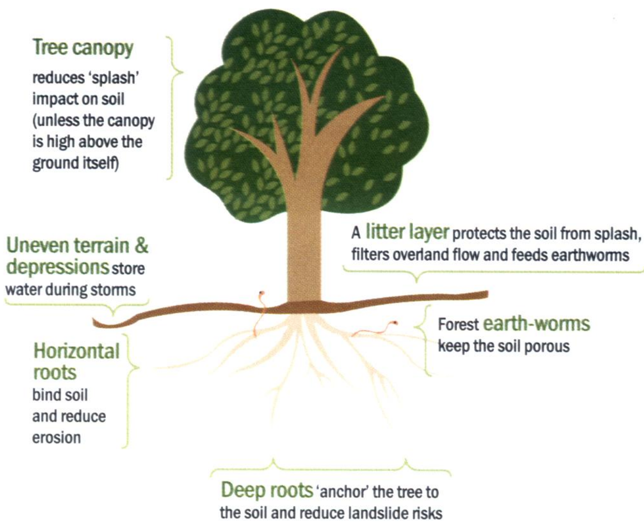
Figure 3. Boxplot of mean suspended sediment concentration collected for the 19 locations upstream of the dam in Sumber Jaya



Section 3. Filter options

The sediment load of a river is usually less than the current amount of erosion from the hillslopes because suspended soil particles in overland flow can be filtered and deposited along their pathway to the river. Sedimentation will occur in any zone that allows water to infiltrate (for example, due to worm activity or old tree root channels) or that traps soil particles among surface litter, grass or other 'contact cover.' Filter effects can be stimulated by leaving spontaneous vegetation in place along contours, through a combination of soil cover and stimulation of macro-porosity formation — just as happens in a natural forest (Figure 4). The rate of litterfall, and thus the formation of surface filter zones, is lower in a coffee garden than in a natural forest, but the residence time of coffee litter on the surface is similar to that of forest. As a result, only young coffee gardens lack a protective filter effect (8).

Figure 4. Summary of tree and forest effects on soil



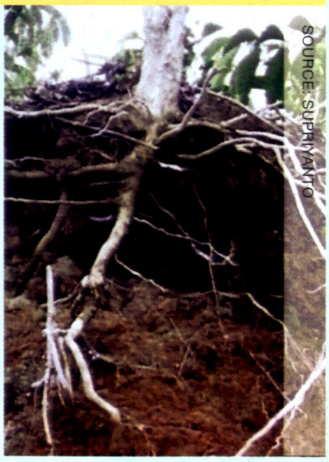
Section 4. Anchor & bind — trees can increase soil stability

Trees contribute to the stability of soils, helping to decrease the risk of shallow landslide, bank erosion, and soil loss due to run-off during peak rainfall events. Landslide risk peaks a few years after tree removal, once roots have decayed (9). Simple observation techniques, exposing the proximal roots at the stembase can clarify the two key roles of tree roots (Figure 4). Horizontal roots bind soil and reduce erosion. Deep roots 'anchor' the tree to the subsoil and reduce the risk of shallow landslides. Some trees and perennial grasses provide protection for topsoil, others anchor the upper layers to the lower ones. A combination of tree species and grasses will usually provide the best overall protection against shallow landslides. The rooting properties depend both on tree species and soil conditions, so local observations are needed to test literature results.

Tree root systems can reduce the risk of landslide and riverbank collapse

Deep roots anchor the tree and topsoil to deeper layers and increase the resistance to landslides under wet soil conditions

Superficial roots bind the topsoil



Future Implications

Current policies on 'watershed management' tend to focus on maintaining or restoring forest cover in the upper catchments. Estimates of sediment loss tend to be based on 'Universal Soil Loss Equation' (USLE) applied to the agricultural fields. Research results such as those obtained in Sumber Jaya, with similar efforts in Northern Thailand, Vietnam and Western Kenya, point at a more diverse set of 'causes' and consequently a richer array of opportunities for intervention (10). A key aspect of this work is the need for 'participatory landscape appraisal.' Relatively simple observation techniques for muddy rivers can be calibrated to obtain reliable data, that can be used for negotiations between stakeholders. Avoiding the 'knee-jerk' reactions that relate all problems to lack of forest is the first step needed. Yet, lack of appropriate trees in strategic landscape positions is often part of the issue.

References

1. Bruijnzeel LA. 2004. Hydrological functions of tropical forests: not seeing the soil for the trees? *Agriculture, Ecosystems & Environment* 104: 185-228.

2. Agus F, Farida and van Noordwijk M (Eds). 2004. Hydrological Impacts of Forest, Agroforestry and Upland Cropping as a Basis for Rewarding Environmental Service Providers in Indonesia. Proceedings of a workshop in Padang/Singkarak, West Sumatra, Indonesia. 25-28 February 2004. World Agroforestry Centre - ICRAF-SEA, Bogor, Indonesia (accessible from www.icraf.org/sea).

3. van Noordwijk M, Poulsen J and Ericksen P. 2004. Filters, flows and fallacies: quantifying off-site effects of land use change. *Agriculture, Ecosystems and Environment* 104: 19-34.

4. van Noordwijk M, Cadisch G and Ong CK (Eds). 2004. Belowground Interactions in Tropical Agroecosystems, CAB International. Wallingford (UK): 580 pp.

5. Jeanes K, van Noordwijk M, Joshi L, Widayati A, Farida and Leimona B. 2006. Rapid Hydrological Appraisal in the context of environmental service rewards. World Agroforestry Centre - ICRAF-SEA, Bogor, Indonesia, 56 pp. (accessible from www.icraf.org/sea).

6. Hoang Fagerstrom MH, van Noordwijk M and Nyberg Y (Eds). 2005. Development of Sustainable Land Use Practices in the Uplands for Food Security – an array of field methods developed in Vietnam. World Agroforestry Centre, Hanoi (Vietnam), 58 pp (accessible from www.icraf.org/sea).

7. Verbist B, Widodo RH, Susanto S, van Noordwijk M, Poesen J, and Deckers S. 2006. Assessment of Flows and Sediment Loads in a Largely Deforested Catchment in Sumberjaya, Lampung, Sumatra, Indonesia. Submitted to 3rd APHW conference, Bangkok. (www.thirdaphw.org) .

8. Hairiah K, Sulistyani H, Suprayogo D, Widianto, Purnomosidhi P, Widodo RH and Van Noordwijk M. 2006. Litter layer residence time in forest and coffee agroforestry systems in Sumberjaya, West Lampung. *Forest Ecology and Management* 224: 45-57

9. Sidle RC, Ziegler AD, Negishi JN, Nik AR, Siew R, Turkelboom F. 2006. Erosion processes in steep terrain – truths, myths and uncertainties related to forest management in Southeast Asia. *Forest Ecology and Management* 224: 199–225

10. Cohen MJ, Shepherd KD and Walsh MG. 2005. Empirical reformation of the universal soil loss equation for erosion risk assessment in a tropical watershed. Geoderma 124(3-4): 235-252.

This document is based on research in Sumber Jaya, Indonesia, and Northern Thailand is that is primarily funded by the Australian Centre for International Agricultural Research (ACIAR) and involves several Indonesian universities, and partners in Australia and Belgium. A synthesis workshop of ICRAF's key findings pertaining to water – tree – soil interactions was held in March 2006 in Nairobi, with local partners and ICRAF colleagues.

http://www.worldagroforestry.org/WATER

Contact: Meine van Noordwijk
World Agroforestry Centre (ICRAF)
ICRAF Southeast Asia
Jl. CIFOR, Situ Gede, Sindang Barang
PO Box 161, Bogor, Indonesia
Tel: +62 251 625415
Fax: +62 251 625416
Email: M.van-noordwijk@cgiar.org

World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

Credits:
Authors: Meine van Noordwijk, Bruno Verbist and Kurniatun Hairiah
Design: John Gikang'a
Printed: UNON Printshop