Soil Erosion in South and Southeast Asia: A Review

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Abstract

Knowledge of soil erosion is a key requirement for land use planning and the assessment of environmental impacts of agricultural practices. Dramatic changes in climate, edaphic and land use during the last decade increase the vulnerability of the soils to erosion in the South and Southeast Asian region. Runoff and soil erosion have been studied extensively in the region throughout in many natural ecosystems and farmlands. Various land management strategies during the last few decades have increased land degradation posing severe limitations on the sustainable use of agricultural land. This review synthesizes the research activities that have been conducted in the field of soil erosion in the South and Southeast Asian region during the last fifteen years. Research activities occurred on an extensive range of methodologies and at different spatial and temporal scales. Furthermore the effectiveness of improved conservation practices on managing soil erosion and sediment yield at catchment scale are also discussed.

Introduction

South & Southeast Asia covers a large land area with diverse ecoregions, land uses & management practices (Lal, 2004). The region has a tropical humid climate and the tropical rainforest is the major form of natural vegetation. More than 94 % of the area suitable for agriculture in South Asia has already been cultivated, leaving little provision for agricultural expansion (Atapattu and Kodituwakku, 2009). The region has a variety of soils that vary in origin & fertility, with utlisols as the dominant soil order (FAO-UNESCO, 2004). Heavy rainfall combined with agriculture on hillsides has led to erosion, reducing agricultural productivity of upland farming systems. The eroded material deposited in the lowland has created large areas of alluvial soils adequate for farming. Water erosion which covers 21 % of the total land area (46% of the total degraded area) has become the main type of erosion in the region. The highest rate of erosion were recorded in Indian subcontinent (> 90 mil ha), Philippines (10 mil ha) and Indonesia (22.5 mil ha). Moderate to extreme water erosion (as a percentage of total land area) were recorded in Pakistan (12.5 %), Thailand (15 %) and Vietnam (10 %). Loss of top soil was the most common subtype of water erosion followed by terrain deformation (gullying, landslides *etc.*) (Figure 1) (Lynden and Oldeman, 1997).

Factors affecting soil erosion

Cramb *et al.* (2000) identified the following soil erosion factors as important for South & Southeast Asia (vary according to the spatial scale):

- High rainfall intensities
- Presence of hill slopes/cultivation in steep slopes (Fig. 5)
- Seasonally dry periods
- Presence of naturally erodible and unstable soils
- Timber harvesting (Fig. 3)
- Overgrazing
- Deforestation (Fig. 2, Fig.3 and Fig. 4)
- Slash and burn (Fig. 2)
- Agriculture intensified land use
- Population growth

High soil erosion rates in the region (Fig. 1) is related to soil & site characteristics & to the high intensity of monsoon storms (Siddle *et al.*, 2006). Importantly, shifting cultivation & forest conversion to commercial agriculture has led to trigger more erosion in the region (Fig.s 2-4).

Impacts

Both on-site and off-sites impacts have been reported: increased on-site sediment yields from terrestrial catchments (Nauta *et al.*, 2003), leading to an deterioration of the region's coastal ecosystems. Off-site impacts include siltation, water flow irregularities, reduction of irrigation water, agrochemical run-off and subsequent water pollution. Organic matter depletion has become a severe problem in many upland farming systems that adopt shifting cultivation, which enhances erosion by heavy precipitation during the monsoon season. Intensive cultivation in hilly uplands results in topsoil crust formation, leading to decreases in soil available water, and limiting vegetation growth, especially in seasonally dry sites. All these factors reduce soil fertility and crop productivity.

Adopted erosion control strategies

In attempt to manage soil erosion in the region, researchers have evaluated the efficacy and practicality of passive & active erosion control strategies. These include alley cropping, contouring, strip cropping, grass barriers, conservation tillage, minimum tillage and hedgerow intercropping (Fig. 7A-C) (Shively, 1999). Selection of appropriate soil conservation methods for low income smallholder farmers is critical to reduce the rate of soil erosion as well as to increase crop productivity. The potential impact of soil conservation on yield may be a key factor that affects the value of soil conservation investments (Shively, 1999). Soil conservation strategy adoption by upland farmers is not a function of the farming system type or income. Despite the role of conservation practices being well established in reducing water runoff at the plot scale, extrapolation to a large scale has been less understood and verified.

Severity of soil erosion

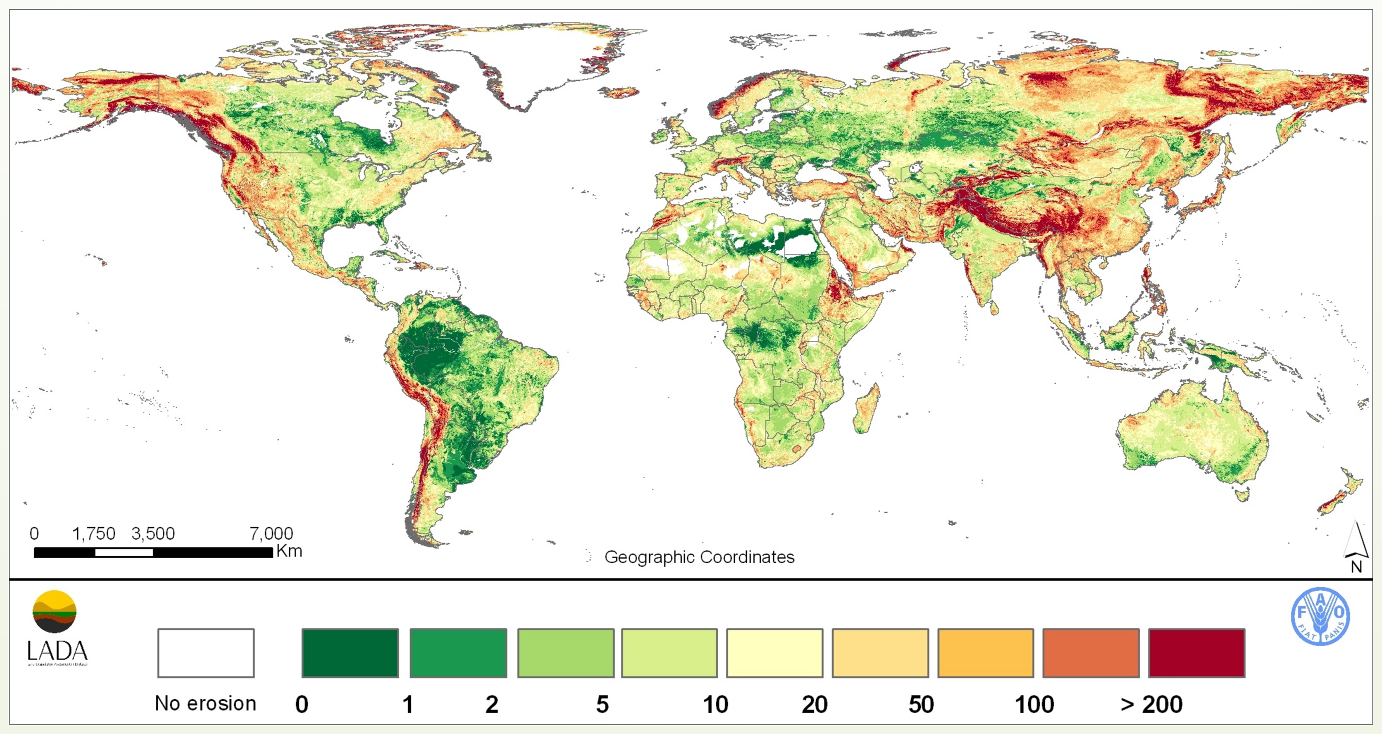

Fig 1: Predicted Soil loss in ton/ha/year based on GLADIS (using USLE equation) (Source: Nachtergaele *et al.*, 2010)

Major soil erosion factors

Fig 2: Slash and burn farming (MALAYSIA. Sarawak, Borneo, South East Asia) (Source: http://nigeldickinson.com/gallery/albums.php)

Fig 3: Timber harvesting (Sri Lanka) (Source: Sri Lanka - blogger)

Fig 4: Deforestation (Wilpattu Forest complex, Sri Lanka) (Source: vikalpa.org)

Fig 5: Cultivation of tea in steep slopes (Central highlands of Sri Lanka) (Source: Organic Loose Tea From Ceylon)

Soil erosion assessment – modeling approach

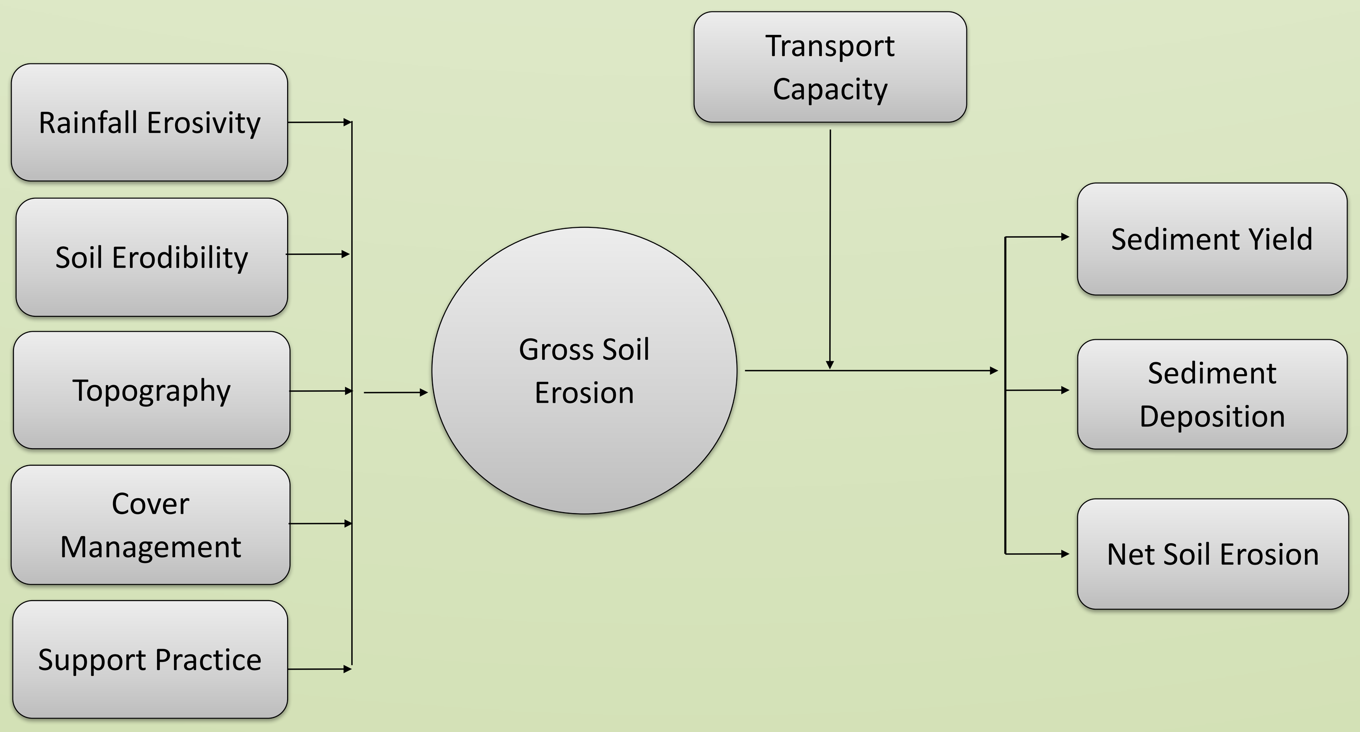

Fig 6: Conceptual model for the assessment of soil erosion and sediment yield using the Revised Universal Soil Loss Equation (RUSLE) and SEDD model.

References

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Modeling soil erosion

Many models have been applied to predict water runoff, soil erosion & sediment yield for current & possible future land use & climate conditions in South & Southeast Asia. Among the empirical models, RUSLE (Fig. 6) in combination with GIS is used broadly at both plot & catchment scales. In addition, ERDID, TEST (Van Dijk *et al*, 2005) and MMF (Morgan, 2001) have been widely adopted in the region to estimate runoff & sediment yields. Apart from the adaptation of empirical models, regional simulation studies demonstrated the importance of hydrological & sediment connectivity as affected by vegetation patterns (eg. AnnAGPNS, CLSM, BTOPMC, HES-HMS), terrace removal or failure, and rainfall condition. An important finding supported by the modeling studies is the variability (spatial and temporal) of runoff as a function of rainstorm conditions.

Challenges

- Development of multidisciplinary studies to facilitate spatial variation of runoff & erosion rates at plot and catchments scales.
- Improvement & calibration of EI_{30} K factor within RUSLE.
- Conducting catchment scales sediment studies by applying sediment fingerprinting to quantify & integrate changes in upstream sediment sources & delivery
- Studying the influence of soil & vegetation factor relationships.
- Development of models to study the impact of climate change on soil erosion & sedimentation process.
- Determining long-term economic impact and farmer livelihood from implementing soil conservation practices.

Soil conservation methods

Fig 7 (A) alley cropping in the Sri Lanka dry zone, (B) contour hedgerows on a tea plantation in the Sri Lanka Upcountry, and (C) home in the Sri Lanka Upcountry.