

Forests and landslides

The role of forests and forestry in the prevention and rehabilitation of landslides in Asia

Between 1950 and 2009 landslides claimed the lives of almost 18 000 people in Asia and affected approximately 5.5 million people (EM-DAT 2010). If statistics were available for landslide impacts caused by earthquakes, these numbers would be many times greater. Landslides cause social, economic and environmental damage. Forest and agricultural resources are lost; infrastructure and heritage sites are damaged or destroyed. Landslide material can block rivers and increase downstream sedimentation, increasing the risk of floods. With predicted changes in rainfall and climate in the coming decades and intensified development in sloping areas, landslides will pose increasing risks to life and property in Asia.

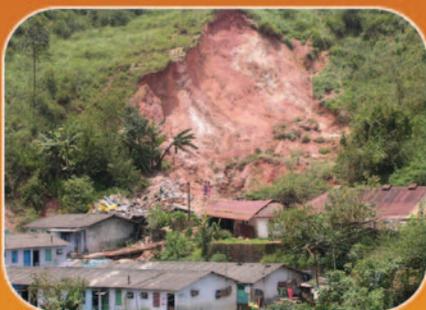
The number of landslides in Asia is high relative to other regions of the world. Asia has expansive sloping and mountainous terrain, predominance of highly erodible soils, rapid weathering of bedrock and volcanic material and high seasonal rainfall. In some parts of the region, frequent earthquakes exacerbate the problem.

Statistics show that landslides causing death or otherwise impacting people in Asia have increased more than five-fold since the 1970s, with 88 recorded landslides of this type resulting in 5 367 mortalities between 2000 and 2009 (see figure on page 3).

Low-income status and associated poverty appear to increase people's vulnerability to disaster. In general, poor countries have significantly higher levels of landslide mortality than wealthier countries due to inadequate planning and implementation of precautionary measures in the face of risk, poor infrastructure development and lower human development levels (ISDR 2009).

Trees and forests play important roles in reducing landslide risk through various mechanisms. Tree roots reinforce soil layers, anchor the soil to bedrock and form buttresses against soil movement. Trees also reduce landslide risk by lowering soil moisture levels - interception, evaporation and transpiration are the primary mechanisms. These mechanisms, and others, also make trees valuable in land reclamation following landslides. Furthermore, trees help to reduce soil erosion and can form an effective barrier against rock, debris and soil slips, as well as limiting landslide run-out distances.

Trees and forests can also increase landslide risk by imposing load on unstable slopes and via wind-related effects; they are unlikely to prevent or minimise deep landslides or slides on very steep slopes. However, they can make a positive contribution in various situations as this policy brief explains.



LANDSLIDE IMPACTS SET TO INCREASE

With population and infrastructure expansion, greater intensity of forestry and agricultural activity in sloping areas and projected increases in the frequency of extreme rainfall events, the incidence of landslides is set to increase in Asia. In temperate and tropical Asia, climate change is also likely to increase forest die-back and fire events, negatively affecting the ability of trees to stabilize soil layers.



THE POOR ARE MORE AFFECTED

With recognition of the disproportionate number of landslide deaths seen in poorer countries and among vulnerable populations, comes evidence that much can be done to avoid losses associated with landslides. Landslide risk has been mitigated successfully within and outside Asia; associated measures may well be adapted to further reduce hardship and suffering among the most vulnerable populations.

Forests and landslide prevention

How can forests help to prevent landslides?

By strengthening shallow soil layers and improving drainage, deep-rooted trees and shrubs can reduce the occurrence of shallow rapidly-moving landslides (Sidle et al. 2006). Forests can also play a role in attenuating and blocking debris flows and rock falls by forming a physical barrier against sliding and falling material (Guthrie et al. 2010). In shallow soils, roots may penetrate the entire soil mantle, providing anchors into more stable substrates; dense lateral root systems also stabilize soil surface layers against landslides. Transpiration from extensive tree canopies can also decrease soil water content and reduce landslide risk (Sidle et al. 2006; Dolidon et al. 2009).

Although woody vegetation may help prevent shallow landslides, forest cover has a lesser effect on deep-seated landslides, limited to soil drying through evapotranspiration. Forests on or overlying rapidly weathering bedrock, perched water tables, points of geographic convergence or very steep slopes and those opened up and exposed to gulying usually have higher levels of landslide hazard. In cases of continuous heavy rainfall or earthquakes the increased stability that trees provide is more frequently negated. Activity within these high-risk zones should be avoided or minimized, particularly if it involves forest clearing.

Land uses that increase slope instability include logging, road and trail construction and forest conversion. Roads contribute the largest landslide erosion losses compared to other land uses - one to two orders of magnitude higher than in undisturbed forests on steep land. Across much of rural Asia, upland roads are built without adequate

attention to engineering standards and often without adequate drainage. Mid-slope roads constitute the highest landslide risk due to subsurface water interception and overloading and undercutting of slopes.

Removal of forests on sloping land reduces rooting strength for up to two decades even with subsequent regeneration (Sidle et al. 2006). In temperate climates, landslide risk begins to increase when roots decay at around three years after timber harvesting and susceptibility remains high until around 15 years when regenerating roots mature. In tropical climates the rates of decay and regeneration are accelerated although shifting cultivation may slow regeneration due to soil nutrient depletion.

Conversion from trees to crops permanently reduces rooting depth and strength, while deep soils are also dried to a lesser depth and degree thus increasing landslide risk. Subsequent agricultural practices may also increase landslide risk in comparison with forests - tillage, terracing, low soil cover, reduced rooting depth and strength, and reduced transpiration. Agroforestry land uses, especially those that have a high tree component, can mitigate some of this risk.

Landslide types

Landslides encompass a wide range of phenomena including slumps, rock falls, debris slides and earth and mudflows. They may be shallow or deep-seated and are caused by changes in slope stability resulting from undercutting, such as from road construction, changes in water saturation, loss of forest cover or earthquakes.

Recent climatic trends

Changes observed in extreme events and climate anomalies in Asia over recent decades have included increased occurrence of extreme rainfall causing severe floods, landslides and debris and mud flows around the region. In China and Mongolia, rapid thawing of permafrost, largely due to rising temperatures, has caused more frequent landslides, affecting some high altitude forest ecosystems.



THE IMPLICATIONS OF CLIMATE CHANGE

Future trends

The close association between landslides, rainfall and other climatic variables make future changes in climate particularly important in estimating the future significance of landslides. Precipitation is expected to increase over most of Asia, particularly during the northern hemisphere winter. Studies project changes in the seasonal distribution of rainfall, with drier and/or longer dry seasons and shorter, more intense wet seasons. In South Asia, increased rainfall during the northern summer is expected; while in Southeast Asia little overall change is foreseen until 2040. An increase in occurrence of extreme weather events, including heat waves and precipitation events, is predicted in South Asia, East Asia and Southeast Asia. Increases in tropical cyclone intensities by 10-20 percent are also expected in Asia, while temperature is projected to increase by 0.7-1.8°C in South, Southeast and East Asia and by 1.5-2.9°C in the Tibetan Plateau and North Asia.

REHABILITATION FOLLOWING LANDSLIDES

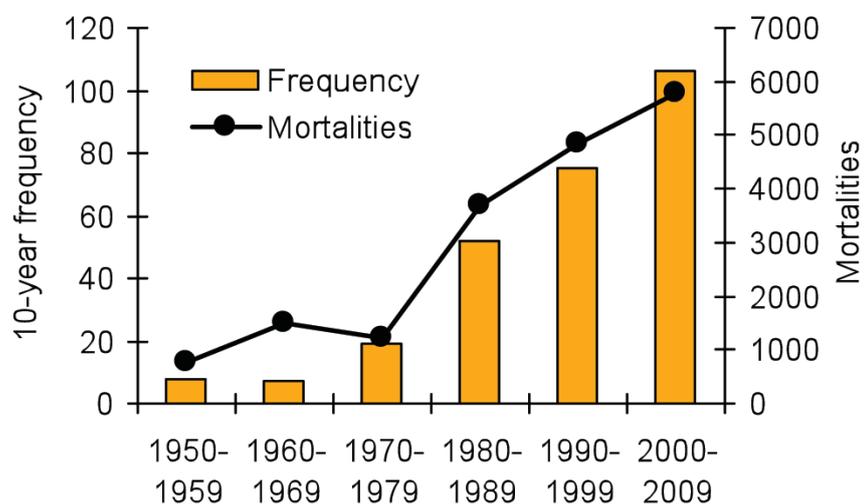
Timely stabilization of affected sites can help rebuild livelihoods and arrest further release of sediment to streams and rivers, averting continued economic and environmental impacts. Appropriate techniques to establish vegetation - the primary cost-effective means of rehabilitation - depend on the degree of disturbance and the status of the substrate. Slopes must also be sufficiently stable for tree seedlings to establish. Microbial biomass and nutrients take time to redevelop and different species may be more suited to new conditions than the previous vegetation. The use of exotic species may be necessary, if quick stabilization is required.

In addition to ecological issues, the choice of tree species will affect socio-economic benefits derived from the rehabilitated forest. In this context, consideration of the provision of goods and services to local communities and decisions over rights and exclusions make rehabilitation a challenging task. In particular, land tenure and regulatory environments prevailing in the target area are of key importance in determining the suitability of different slope stabilization options and the extent to which they will be supported, and therefore sustainable.

Impacts

Increases in extreme rainfall events are likely to directly increase the frequency of landslides in sloping areas, while cyclones/typhoons may induce landslides by toppling trees, exposing bare soil and increasing water infiltration and slope failure. Elsewhere, drier and hotter weather, together with increased road development and human activity in forest areas, is likely to raise the incidence of fire. Drought will increase the chances of devastating wild fire and forest die-back, which by removing or damaging forest cover will induce root decay, resulting in loss of slope stability.

Ten-year frequency of landslides and associated mortality in Asia



Source: International Disaster Database: <http://www.emdat.be>

Recommendations

The sustainable management of upland forests and agricultural land in Asia is hindered by steep slopes, high-intensity rainfall, dry seasons and highly erodible soils (Sidle et al. 2006). A range of other often more important impediments also exists including issues associated with governance and poverty. Maintaining permanent land cover in the face of demand for land and resources is becoming increasingly challenging in many countries as populations expand. As lowland forests are logged and population densities increase, more marginal - and often sloping - areas are also coming under increasing pressure in many countries. Road development and commercial agriculture are also expanding in sloping areas around the region.

In reducing landslide risk several key factors need to be taken into account:

- Landslides are highly localized and their negative impacts can often be avoided by zoning of high-risk areas and locating settlements and activity away from debris fans and steep slopes through rational land-use planning.
- Implementation of improved standards for road construction needs to be undertaken immediately to reduce landslide risk.
- Maintenance of forest cover is particularly important in areas prone to landslides. Typically these areas include slopes that are steep, concave or have perched water tables; and/or have soils with low cohesion or are shallow and cover bedrock. Retaining trees at the toe-of-slope along road and rail right-of-ways will reduce risk to these infrastructures.
- Forest health and vitality will be key factors in maintaining strong rooting systems in relation to stresses related to changing climate. Protection against surface erosion and gully formation is also important in reducing landslide incidence.

- Tree and shrub planting should be concentrated on high-risk slopes. Afforestation of an entire catchment, which would be expensive and may cause conflict with other land uses, is unlikely to be necessary. Shrubs have the benefits of trees without negative effects of weight and wind loading.
- Planting on steep slopes where slope materials remain unstable is inappropriate if complementary engineering works, such as contour trenching, are not used. Older seedlings preinoculated with appropriate symbiotic mycorrhizae have a better chance of becoming rapidly established and providing benefits to dependent economies and local livelihoods.
- Higher levels of plant diversity generally associated with natural regeneration, may increase slope stability above that offered by monospecific and single-age plantings.

Objectives such as enhancing biodiversity conservation, sequestering carbon and supporting local economic development may be entirely compatible with slope stabilization with trees and forests. As protection forests cannot be harvested for timber, other products and services available from standing forests should be sought.

Because sustainable management of forests is dependent on the commitment of a range of stakeholders, it is important that land tenure and regulatory environments in the target area are conducive to achieving land stabilization goals. As such, framework conditions may need to be modified to ensure that appropriate measures and associated processes are implemented successfully.

Find out more

This policy brief is based on a comprehensive technical report that can be found at:

<http://www.fao.org/asiapacific/forestry-publications>



References

- Dolidon, N., Hofer, T., Jansky, L. & Sidle, R. 2009. Watershed and forest management for landslide risk reduction. In *Landslides - disaster risk reduction*, pp. 633-649. Berlin, Springer-Verlag.
- EM-DAT. 2010. International disasters database: <http://www.emdat.be>
- Guthrie, R.H., Hockin, A., Colquhoun, L., Nagy, T., Evans, S.G. & Ayles, C. 2010. An examination of controls on debris flow mobility: Evidence from coastal British Columbia. *Geomorphology*, 114(4): 601-613.

- International Strategy for Disaster Reduction (ISDR). 2009. *Global assessment report on disaster risk reduction*. Geneva, Switzerland, United Nations.
- Sidle, R.C., Ziegler, A.D., Negishi, J.N., Nik, A.R., 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(1-2): 199-225.

Photo credits - Front: P. Durst, S. Kuriakose, J. Broadhead; Inside left: S. Braatz; Inside right: F. McDougall; Back: P. Durst.