Negotiation-support toolkit for learning landscapes

Editors
MEINE VAN NOORDWIJK
BETHA LUSIANA
BERIA LEIMONA
SONYA DEWI
DIAH WULANDARI

WORLD AGROFORESTRY CENTRE
Southeast Asia Regional Program

Van Noordwijk M, Hairiah K and Harja D. 2013. Rapid landslide mitigation appraisal (RaLMA): managing trees for improved slope stability. *In:* van Noordwijk M, Lusiana B, Leimona B, Dewi S, Wulandari D (eds). *Negotiation-support toolkit for learning landscapes*. Bogor, Indonesia. World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. P.126-130.

21 Rapid landslide mitigation appraisal (RaLMA): managing trees for improved slope stability

Meine van Noordwijk, Kurniatun Hairiah and Degi Harja

Trees can protect slopes from landslides, but can also be a risk factor. Rapid Landslide Mitigation Appraisal (RaLMA) explores local knowledge and the science of landslides and their relationship to trees. The result is an analysis of which trees have complementary functions in protecting slopes. However, not building houses in the likely pathway of landslides remains the primary way to avoid human loss of lives.

Introduction

Major landslides have become have become almost yearly phenomena in Southeast Asia, killing hundreds of people and causing major economic damage.

Heavy rainfall on wet soil on hill slopes can trigger the movement of large amounts of soil. The root systems of forest vegetation and trees play an important role in holding the soil together and the removal of trees and subsequent decay of tree roots may be part of the reason behind the growing number of landslides in the region. Ironically, trees contribute to the build-up of soil that eventually becomes too heavy for the steepness of the slope. Landslides, or slope instability, can also be caused by the construction of roads and other structures that interfere with the paths of water flow down a slope.

In public discussions, landslides in Southeast Asia are often attributed to deforestation. However, other factors need to be considered when it comes to understanding landslides and how to prevent them.

A. No one would notice landslides (which are a natural part of soil–vegetation processes, especially on geologically young soils in steep terrains) if there were no people living nearby. People can become victims of landslides simply by being in the wrong place at the wrong time.
B. The increased use of a landscape by people normally involves reducing tree cover and increasing infrastructure, which may intensify the occurrences of landslides. Where the slope incisions of roads lead to slope instability, the correlation with the loss of tree cover is only indirect.
C. Tree roots play a real role in protecting the soil profile and the decay of tree roots and tree felling eventually increases the risk of landslides.

Only in case C does it make sense to expect that tree planting will reduce the risk of landslides once the young trees have established their root systems.

The complexity of the relationship between the causes and effects of landslides, the destruction of evidence by the landslide itself and the occurrence of landslides after cases of extreme rainfall make it desirable to have a relatively fast and inexpensive appraisal method that can be used by local natural resource managers to take precautionary measures and/or to respond to early signs of slope instability. Changing rainfall patterns in the light of global climate change make the need for such tools even more urgent.

Objectives

RaLMA is designed to provide a basic understanding of the way tree roots can contribute to slope stability and how tree and agroforestry management can enhance or maintain slope stability and protect people and ecosystems from the damage caused by landslides.

Steps

1. Conduct a spatial analysis of the landscape and gather data on the recent history of land-cover change. This includes identification of the area; characterization of the soils and of the potential planes of weakness in the soil profile; characterization of the geological substrate and of the process of soil formation (including colluvial soils derived from previous slope instability); characterization of the slope and recent changes in land cover; and characterization of climate and extremes in rainfall distribution.
2. Explore local ecological knowledge (LEK) of cause and effect relations, local regulations concerning changes in tree cover and local people's preferences about trees in the landscape.
3. Explore policy-maker's ecological knowledge (PEK) of cause and effect relations; considering whether existing land-use plans take landslide risk into account and investigating stakeholders' preferences and aspirations with regard to the presence of trees in the landscape;
4. Explore modellers´ ecological knowledge (MEK) of site-specific risks and of the likely timing of response to mitigation actions. It is important to bear in mind that trees on slopes have both positive and negative effects on stability. Negative effects include:

   a. the aboveground biomass adding weight and wind exerting a lateral force; and

   b. highly porous soil supported by active soil fauna feeding on the litter layer increases infiltration and the likelihood of positive pore pressure after heavy rainfall.

   The positive effects include

   a. binding topsoil into a root mat that either moves as a whole, or stays in place; and

   b. the anchoring of this rooted layer to the subsoil through vertical roots.

   Whether the effects are positive or negative depends on the species and age of the tree and the type of tree management involved (see Figure 21.1).
5. A synthesis of the outputs of the steps, which can inform local negotiations between the different stakeholders involved in landscape management.

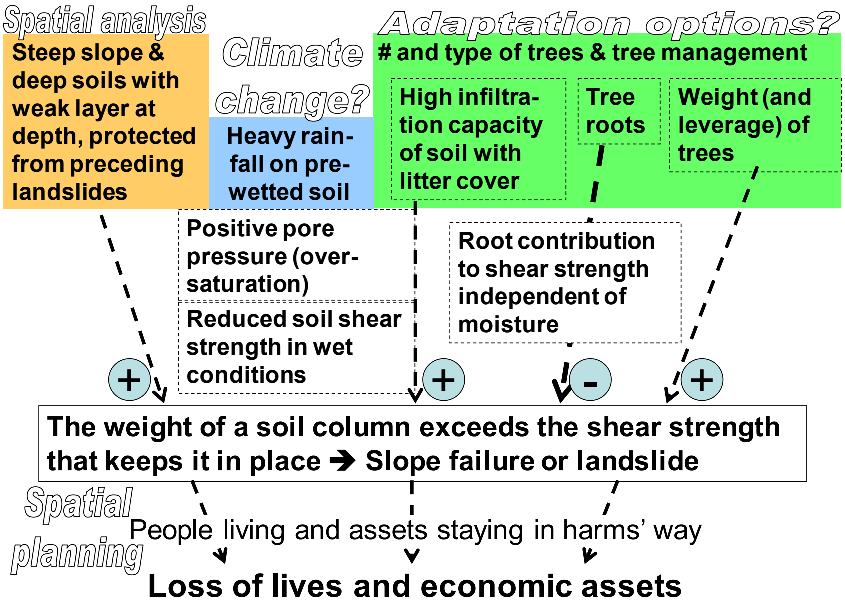

Figure 21.1. Schematic diagram showing the relationships between landslides and soil, climate and vegetation

Compiling parameters for MEK of trees and landslide risk:

- Survey of tree species and tree population density in the landscape in relation to signs of previous landslides.
- Inventory of proximal tree root architecture of the major species that grow in the area to assess soil binding and soil anchoring properties; two tree root indices —Index of Root Anchoring (IRA) and Index of Root Binding (IRB)—can be used to evaluate tree suitability for stabilizing slopes.
- Standardized strength measurement of tree roots in relation to their lignin content.
- Estimation of dynamic root pattern at the hill-slope scale using the SExI-FS and the IRA and IRB parameters derived from the survey.

Case study

Case studies from different parts of Indonesia (West Lampung, West and East Java) suggest a number of options for implementing a 'right tree in the right place' management approach to mixed agroforestry systems. Such an approach can help to reduce the risk of landslides on slopes and can be combined with biomass carbon storage as a contribution to climate-change mitigation.

Research was carried out between January and May 2008 in the Bukit Sentul area of the Bogor district in West Java. The research took place in areas that had been classified as being at high risk of landslides. Based on geological maps and the recent occurrence of landslides, the survey focused on the Ciherang and Cibadak sub-catchments and was followed by an inventory of tree species and population density in the selected area.

Four types of landslides occurred in the village of Karang Tengah: 1) overland; 2) slope failure (topple); 3) creep; and 4) road-cut. Sixty percent of the total were superficial landslides. Factors affecting landslides were found to include rainfall intensity, topography (slope > 45%) and features of the soil profile: the existence of bedrock or compacted soil layer as a sliding plane; and the existence of unstable soil layers, such as sandy loam layers in the subsoil, with a low soil shear strength owing to higher sand content.

Figure 21.2. Durian tree protecting, through its superficial roots, a slice of land from sliding

Vegetation in the study area was dominated by homegarden types of agroforests with banana (non-woody), *Maesopsis eminii* (an introduced timber species), *Pangium edule* (a source of oil and spice), *Ceiba pentandra* (kapok) and *Sandoricum koetjape* (a local fruit tree) dominating. The highest tree population density was found in agroforestry systems near the scarps of overland landslides. The weight of the aboveground tree biomass probably increased the risk of landslides.

The local fruit tree species, 'duku' (*Lansium domesticum*), 'kemang' (*Mangifera kemanga*), 'limus' (*Mangifera foetida*), 'mindi '(*Melia azedarach*) and durian (*Durio* sp) (Figure 21.2) played a relatively important role in anchoring the soil (where the IRA was higher than 2.0). A mix of tree species with deep roots, and of ground cover species with intense and strong fine roots, provided the highest slope stability in the area.

The SExI-FS model was able to simulate the role of trees in reducing the risk of landslides through the quantification of the IRB and IRA of species in a tree plot (Figure 21.3). The simulation showed that increasing plot density over the optimum size did not significantly increase root binding.

The combined results of the LEK, MEK and PEK studies helped inform discussions concerning the choice of species while at the same time taking into account direct economic gain, the local utility of species and landslide risk.

The primary recommendation that might be given by advisers visiting a village at risk of landslides would be to look for another location for the village but the options for doing so are limited. Maintaining the tree root mat of the village homegardens, avoiding houses with rigid walls that collapse under pressure and encouraging traditional flexible building materials such as bamboo may help to reduce the risk to locals in the short term.

Figure 21.3. RaLMA process and 3D reconstruction using SExI-FS

Key reference

Hairiah K, Widianto, Prayogo C, Kurniawan S, Harja D, Khasanah N, van Noordwijk M. 2008. *The role of trees outside forest in anchoring soil and reducing landslide risk during high rainfall episodes.* TroFCCA project on the role of tropical forests in climate change adaptation.

The landscape scale is a meeting point for bottom–up local initiatives to secure and improve livelihoods from agriculture, agroforestry and forest management, and top–down concerns and incentives related to planetary boundaries to human resource use.

Sustainable development goals require a substantial change of direction from the past when economic growth was usually accompanied by environmental degradation, with the increase of atmospheric greenhouse gasses as a symptom, but also as an issue that needs to be managed as such.

In landscapes around the world, active learning takes place with experiments that involve changes in technology, farming systems, value chains, livelihoods' strategies and institutions. An overarching hypothesis that is being tested is:

> Investment in institutionalising rewards for the environmental services that are provided by multifunctional landscapes with trees is a cost-effective and fair way to reduce vulnerability of rural livelihoods to climate change and to avoid larger costs of specific 'adaptation' while enhancing carbon stocks in the landscape.

Such changes can't come overnight. A complex process of negotiations among stakeholders is usually needed. The divergence of knowledge and claims to knowledge is a major hurdle in the negotiation process.

The collection of tools—methods, approaches and computer models—presented here was shaped by over a decade of involvement in supporting such negotiations in landscapes where a lot is at stake. The tools are meant to support further learning and effectively sharing experience towards smarter landscape management.

World Agroforestry Centre
ASB Partnership for the Tropical Forest Margins
AARD
Federal Ministry for Economic Cooperation and Development
Norad
IFAD Enabling poor rural people to overcome poverty
CGIAR Research Program on Forests, Trees, and Agroforestry