7.Recommendations

Understanding the climate-vegetation-landslide nexus can reduce risks associated with development in upland areas. With the uncertainties of climate change and its impacts, margins of safety need to be widened. Four complementary approaches are necessary to reduce risk and maintain slope stability:

1. Establish and implement guidelines for suitable land-use zoning in upland areas;
2. Establish and enforce standards of practice for slopes that have been altered by human activity;
3. Management of vegetation on natural slopes; and
4. Rehabilitation of landslide-affected lands and livelihoods and curtailment of off-site impacts.

7.1 Land-use zoning

Cases throughout Asia have shown that policies supporting total exclusion from upland forests are ineffective in preventing encroachment and forest clearing. Instead, land-use regulations should allow economic uses of forests that are compatible with landslide risk management objectives. Flexibility to allow for differences in degree of landslide hazard among slopes should be the aim, although this does require precise estimates of hazards at each location.

Delineating parcels of land based on their suitability for different uses with respect to slope stability may proceed in two stages:

1. The degree of landslide hazard is estimated based on current land use and the inherent properties of topography, geology, soils, vegetation, weather and other factors. Hazard zones are classified with the support of GIS and remote sensing technologies, together with models to estimate slope stability. Maps of the hazard zones are produced to guide appropriate land use. Also, vulnerable land, infrastructure or settlements within or below highly hazardous zones are identified.
2. Types of development or land use that do not reduce slope stability are specified for each of the identified zones.

Such guidelines are made available to planners and decision-makers when developing plans for upland areas.

7.2 Standards of practice

Altered or engineered slopes, such as those that result from the construction of roads, railways and other types of infrastructure, buildings or agricultural terraces, are susceptible to failure. The problems of concentrated water flow, increased water infiltration, ponding, loss of lateral support, etc. that cause landsliding must be addressed by the adoption of appropriate standards of practice. Soil bioengineering that utilizes the root reinforcement and hydrologic drying properties of trees and shrubs is a technology that is gaining acceptance as a cost-effective method of enhancing slope stability.

Standards for the construction of roads and railways need to recognize the roles trees and shrubs play in stabilizing slopes and emphasize their retention where possible. This is especially important at the toe of slopes, where trees provide lateral support for the upper slope and protect infrastructure from damage by smaller rock falls and landslides. Consideration of the age (especially stem diameter), width and density of the tree buffer is necessary.

Skid trails associated with logging and paths or trails established in and around agricultural areas also require special attention and measures to reduce risk and, in the case of logging, implementation of specialized techniques may be necessary.[63] Concentrated water flow, which leads to gullying and landslides, should be managed through alignment of trails along contours and other standard means. Planting or retaining trees below culverts and other seepage areas to provide root reinforcement and soil drying is also recommended. These measures apply equally in relation to roads and railways.

7.3 Vegetation management

Prevention of landslides requires management of vegetation at the landscape level. On natural slopes unaltered by construction or engineering, forest conversion to another land use is the most important factor determining changes in slope stability. Consequently, development plans for upland areas must consider the potential landsliding impacts of such changes in land use.

Policies to control development in upland areas, and especially headwater areas, have relied on the creation of protection forests and should continue, particularly in headwater areas where sedimentation from gullying and landslides is a key problem. Similarly, treeless slopes with high landslide hazard ratings should be targeted for protective forestation programmes and appropriate vegetation management.

In addition to direct control of landslide risk, vegetation management should be extended to controlling surface erosion. In addition to trees, shrub species should be included as they provide comparable soil reinforcement but with reduced negative effects associated with weight and wind-loading forces.

Because protection forests cannot usually be harvested for timber, other benefits that can be derived from standing forests should be focused upon. These could include production of non-wood forest products, such as fruits, with high local value, marketing of carbon sequestration capacity and water resources protection, ecotourism opportunities and so forth. Selection cutting of high-grade trees may be possible if large areas are not opened up and cable logging or other means to limit road and trail construction such as helicopter logging are employed.

7.4 Rehabilitation

Livelihoods, and associated natural resources, need to be quickly re-established after a landslide, while continuing offsite impacts also need to be managed. Landslide reclamation and rehabilitation of livelihoods requires financial resources and technologies to successfully re-establish vegetation. Although the task is difficult and not always successful, disaster relief funding is becoming increasingly available and forestry activities should not be overlooked both as a means to rehabilitate affected areas and restart economic activity.

As final word, landslide management and recognition of the role that forests and trees play should be integral parts of climate change adaptation and disaster risk reduction. Landslide incidence and associated impacts are expected to increase because of climate change and expanding development in upland areas. The impacts of landslides can be widespread, resulting in loss of life, settlements, infrastructure, agricultural land, natural resources, heritage sites and more. The key to minimizing the problem simply involves identification of hazardous slopes, management of vegetation and land use on these slopes, and implementation of best practices when altering slopes.