"Investing in Ecosystem Approaches for more Resilient Disaster Risk Reduction: The Case for Eco-Safe Roads in Nepal"

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SUMMARY

The 2015 Gorkha earthquake (M7.8), followed by a series of large aftershocks caused massive damage, thousands of fatalities, destroyed entire villages, severely impacted natural resources such as land and forests, blocked roads and had a profound impact on the country. The earthquakes also triggered thousands of landslides and cracks, creating concern for the upcoming monsoon seasons due to the higher potential for rainfall-induced landslides. One of the main issues currently facing the Government of Nepal and the population is how to manage landslide risk, which was previously a relatively neglected hazard, as compared to flooding although a real and increasing threat to people's livelihoods and resilience.

This paper describes current research being undertaken as part of the Ecosystems Protecting Infrastructure and Communities (EPIC) project (2012-2017) in the Panchase area of Western Nepal, near Pokhara to demonstrate the role of ecosystems – through low cost bio-engineering – as an effective way of stabilizing roadside slopes and increasing resilience. The purpose of this on-going study is to quantify the role of ecosystem services, through the use of bio-engineering species, for slope stabilization along earthen rural roads in the three project sites in Nepal. Our main research question is: how effective are various commonly used bio-engineering plants species in slope stabilization, considering climate change factors? Initial results demonstrate the multiple benefits that the roadside soil bio-engineering approach brings for both reducing erosion, and providing additional livelihood benefits to the community, thus increasing their resilience.

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1. INTRODUCTION

1.1 Background information

Among the natural hazards that occur regularly in Nepal, floods and landslides are by far the most serious ones, causing on average 100 causalities every year according to official statistics (MoH, 2013). The losses due to landslides between May to August 2014 were exceptionally heavy: 215 deaths and 255 missing persons were recorded with millions of USD in destroyed property and infrastructure. Yet, the official statistics clearly underestimate the impact of shallow landslides on livelihoods, as most economic losses are not even accounted for (Sudmeier-Rieux et al., 2013). In 1979, Laban estimated that 75 percent of all shallow landslides[1] in Nepal were natural. However three decades later, human activities, especially unplanned rural roads and irrigation canals without proper design, unsustainable agricultural practices, settlement in at-risk areas, and poorly maintained terrace fields are now the main triggers of shallow landslides (UNDP, 2011). These human-induced shallow landslides are being compounded by increasingly intense monsoon rains, likely due to climate change (Petley, 2010). Road construction is very much linked to development and a current boom in out-migration as roads facilitate transportation to/ from previously remote villages, thus constituting a life link for access to markets, employment and educational opportunities.

A majority of rural earthen roads are funded partially by local government authorities (Village Development Committees) and partially by communities themselves. They are usually constructed using a local bulldozer contractor with no technical or geological expertise. Such roads are commonly wiped out during heavy monsoon rains, requiring costly clearing with heavy equipment and increasing landslide risk and impacts to settlements, forests, water sources, agriculture lands, and infrastructure. Although the rural Nepali road network has rapidly expanded from 7,330 kms in 1990 to 51,000 kms in 2013 (DoR, 2013), the unplanned rural earthen roads remain impracticable during the monsoon season. Initial Environmental Impact Assessments are required for construction of such roads, yet enforcement and monitoring are inadequate owing to lack government monitoring. Government rules stipulate that all new rural roads must use 5 percent of the overall budget toward bio-engineering and drainage measures but this is rarely applied in a sustainable manner. Figure 1 illustrates an example where two unplanned rural roads were built in an old landslide area, reactivating the landslide and considerably accelerating the sedimentation process. The whole area is now at

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[1] Shallow landslides are considered <2-3 meters in depth for the Himalayan range (Dahal, 2006)

extreme risk of a deep-seated failure, while having caused significant loss of agriculture income.

Figure 1: Photo illustration of rural roads accelerating slope instability in Syangja District, Nepal. Credit: I. Penna

1.2 The economic costs of rural roads

Since the political upheaval and government decentralization in 2008, rural road construction has become a priority for the Government of Nepal. The total amount spent on rural road construction amounts to NPR 56 billion (over USD 600 million) annually, with communities contributing an estimated 12% of this total amount through their own savings, remittances and earnings from community forestry. The official plan is to expand the road network from 9 to 15 km for every 10,000 persons (Government of Nepal, 2012). This demonstrates the significance and priority given to connectivity as a vehicle for economic development and population mobility.

Certainly rural roads bring many benefits and are necessary communication links for improved access to markets, access to health care, education and employment. Less known are the environmental, economic and social costs of the unplanned (or conventionally constructed) rural earthen roads. Environmental costs include accelerated sedimentation of river ways and lakes, reducing water quality and reduced effectiveness of hydropower plants. Economic costs are due to the high loss of agricultural and forest land as seen in the image above. Social costs ensue directly from families having lost their agricultural lands and indirectly from the above mentioned environmental costs. Where appropriate, these costs could be significantly reduced by constructing and managing rural earthen roads using low-cost bio-engineering technology, which combines simple civil engineering structures with the use of locally available deep-rooted grasses and shrubs (Howell, 1999). High maintenance costs of conventionally constructed rural roads, or "grey approach" require annual use of earnings which could instead be used for other more productive purposes such as education, or livelihoods improvements. Hence, it is important to highlight that although bio-engineering measures may work for a majority of rural road segments, much greater measures must be taken to stabilize slopes if a road is constructed through an unstable slope, or should not be undertaken at all, as in the above case.

1.3 Quantifying ecosystem services for disaster risk reduction

The range of goods and other benefits that people derive from ecosystems are referred to as "ecosystem services" (Millennium Ecosystem Assessment, 2005). The benefits that people derive from ecosystems, or "ecosystem services", are often categorized into four types: supporting services: (i.e., nutrient cycling, water cycling and carbon sequestration); provisioning services: (i.e., food, fibre, genetic resources, medicines, fresh water; regulating services: (i.e., flood regulation, water filtration, pollination, erosion control, disease regulation; cultural services: (i.e, spiritual values, aesthetic, educational and recreational needs (Millennium Ecosystem Assessment, 2005).

In terms of disaster risk reduction, it is often claimed that healthy ecosystems both reduce vulnerability to hazards by supporting livelihoods, while acting as physical buffers to reduce the impact of hazard events, including erosion control and shallow landslides (Renaud et al., 2013). Ecosystem services are often referred to as "natural infrastructure" which can often be as effective in reducing the impact of hazard events, and is often less expensive than engineered infrastructure over time (Renaud et al., 2013). There are a number of studies related to the effectiveness of vegetation for slope stability and rockfall (Brang et al., 2001; Dorren et al., 2006; Papathoma-Koehl and Glade, 2013; Stokes et al., 2006). Nepal has a long tradition of roadside bio-engineering (Howell, 1999), although the practice is far from being mainstreamed for most road construction, especially rural roads (JICA, 2002).

In Nepal, some research has been conducted on bio-engineering plant suitability for slope stability (Lammeranner et al., 2006). However many of these studies are necessarily locally site specific as they depend on local topography, soil, hydrological and vegetation conditions. Few research projects have explored bio-engineering species in relation to increasing drought conditions and attractiveness to communities for livelihoods. Considering the magnitude of the roadside erosion and shallow landslide problem in Nepal, there is also a gap in the scientific literature quantifying the extent of erosion caused by unplanned rural roads and the role of bio-engineering for reducing this problem.

In addition, any rural road project in Nepal must inevitably involve concerned communities, who are the *de facto* road engineers, maintenance crews, beneficiaries and victims of the current rural road boom. They can also be considered local scientists, most often having very detailed knowledge of local conditions, plant species and general geological conditions of their locations. This knowledge can be extremely useful in parallel with "formal scientific knowledge" (Sudmeier-Rieux et al., 2012). Hence, all species used at the demonstration sites and test plots were selected in accordance with communities and local government, which also took records of plant survival rates in collaboration with project staff.

1.5 Study purpose and location

This paper describes current research being undertaken as part of the Ecosystems Protecting Infrastructure and Communities (EPIC) project (2012-2017) in the Panchase area of Western

Nepal, near Pokhara to quantify the role of ecosystems – through low cost bio-engineering – as an effective way of stabilizing roadside slopes and reducing the environmental, social and economic costs of rural unplanned earthen roads. The purpose of this on-going study is to quantify the role of ecosystem services, through the use of bio-engineering species, for slope stabilization along earthen rural roads in the three project sites in Nepal. Our main research question is: how effective are various commonly used bio-engineering plants in slope stabilization, considering climate change factors? Secondly, what are the economic costs and benefits of bio-engineered or "green roads" as compared to "grey" or conventionally constructed roads? For this extended abstract, we will be focusing on the first research question.

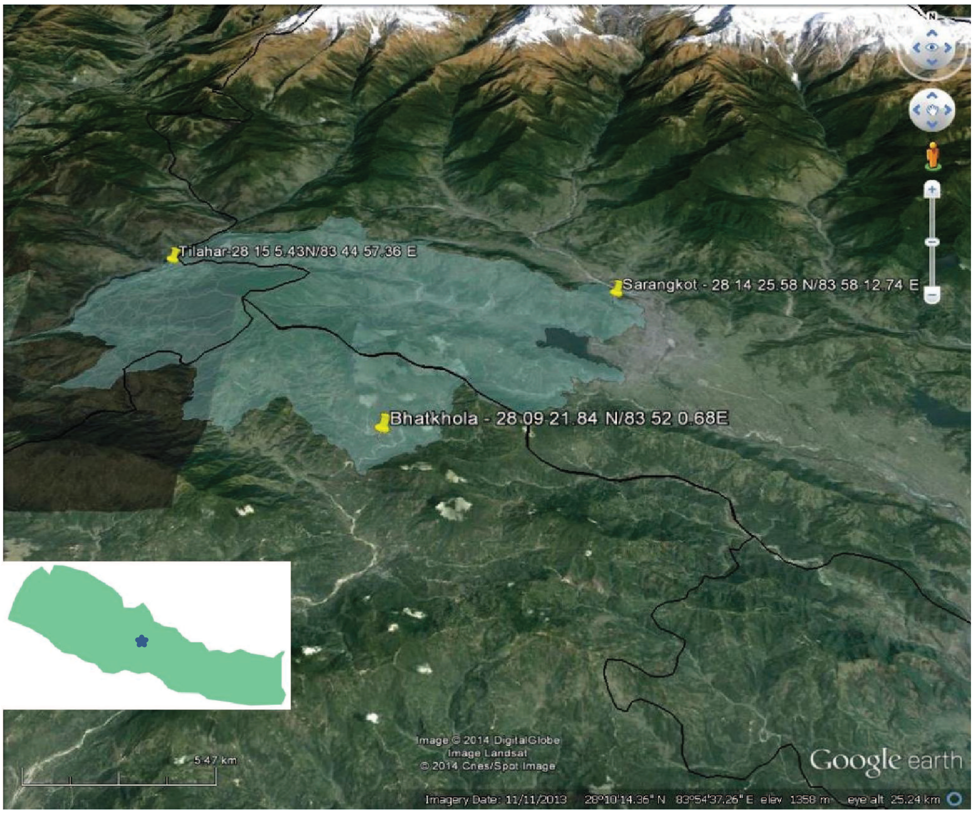

Figure 2: Map of EPIC Nepal project site (Kaski, Parbat and Syangja Districts). Based on Google Earth Image, 2013

The three demonstration sites are located in Tilahar (Parbat district), Sarangkot (Gharelu in Kaski district) and Bhat Khola (Syangja district) (Figure 2), the main districts of the Panchase area. These sites were selected mainly for their accessibility, motivation of communities to participate in bio-engineering activities, and acceptance by local government partner, the District Soil Conservation Office (DSCO) in all three districts. Main activities undertaken in each demonstration site consisted of: participatory mapping of the site, community-based identification of problem areas and solutions; establishment of low-cost engineering structures for drainage; selection of plant species with communities which generally selected a combination of bio-engineering grass species, e.g. (*Drepanosachyumfalcatum*), fast growing fodder species (*Alnus nepalensis*) and a variety of bamboo species, e.g. (*Thysanolaena maxima*). Each site was either a new road, or newly expanded road with barren road side slopes, ranging from 150 – 200 meters. A small (3 m x 3 m) test plot with a plexiglass window is being installed at each site along or adjacent to each slope to observe root development and drought resistance.


Figure 3. Phewa Lake and watershed with Pokhara in background. Observe large amounts of sediment being transported to lake. Credit: G. Leibundgut

Study area is situated in Nepal's Siwaliks/Middle hills, which is a moist sub-tropical zone with average annual temperature of 25°C. The geology is mainly siltstone, sandstones and weakly consolidated bedrock, highly prone to erosion and shallow landslides (Agrawala et al., 2003). This area also receives the highest amount of annual rainfall in Nepal, 4,500-5,000 mm, most of which falls during the short monsoon period, between June – September (Kaski DDC profile, 2012). Climate change predictions point to more intense and shorter monsoon periods (Sudmeier-Rieux et al., 2012) and a higher related incidence of shallow landslides (Petley, 2010). Phewa Lake, one of Nepal's largest tourist hubs, has over the past three decades decreased by 50 percent, mainly due to accelerated sedimentation rates, as well as climate related causes, and invasive plant species which are colonizing the lake (JICA, 2002).

2. METHODS

Research methods are interdisciplinary, spanning both social and physical sciences, with the common goal of quantifying ecosystem services for erosion and shallow landslide control and in economic terms. The research has three distinct yet inter-related parts: Quantify the role of vegetation for reducing erosion and shallow landslides through terrestrial light detection and ranging (LIDAR); Research which plant species are most effective for bio-engineering in this region in terms of root architecture, tensile strength and drought resistance through test plots in the three demonstration sites and based on community observations; and conduct an economic cost-benefit analysis of "grey versus green" rural earthen roads. This abstract will address the first two methods, which correspond to our first research question.

2.1 **LIDAR (or laser scanning)** provides high-resolution point clouds of the topography and has several applications that range from mapping topography, landslides or rockfall displacements, landslides in soils, to vegetation growth (Jaboyedoff et al. 2009;

Jaboyedoff, et al, 2010). Lasar scanning is based on the principle that a beam (or pulse series) is emitted and received, thus a LiDAR consists of a transmitter/receiver of laser beam and a scanning device. LIDARs can be both airborne- and ground-based that send out laser pulses that get back-scattered by various objects (ground surface, vegetation, man-made constructions etc.) and record the returning signal. The typical accuracy of the laser instrument is ±1.5 cm, within maximum distances of about 800–1,000 m and accuracy may be lower due to unfavourable conditions such as: poorly reflecting or very rough surfaces, parallel incident angles, bad weather conditions (rain or hot wind or fog), very bright ambient conditions, excessive range, etc (Jaboyedoff et al., 2010). It remains one of the most accurate and most relevant methods for monitoring soil erosion and vegetation growth. The three pilot sites were measured before any plantations were made, or barren soils and before the monsoon season (April, 2014). Plantations were made in strips along the demonstration site roadside segments, with plants selected from the most common bio-engineering species and in consultation with each community. One strip of slope (ca 2-3 meters wide) was kept barren for comparison of erosion rates with the vegetated slope segments. A second measurement was undertaken in November 2014 after the monsoon season and after most plantations had been made, enabling a comparison of the soil erosion rates and effectiveness of various plant types in reducing erosion. Results from this data set have thus yet to be analyzed. As part of the on-going monitoring of research sites and adjacent landslides, two more sets of measurements pre- and post-monsoon will be made.

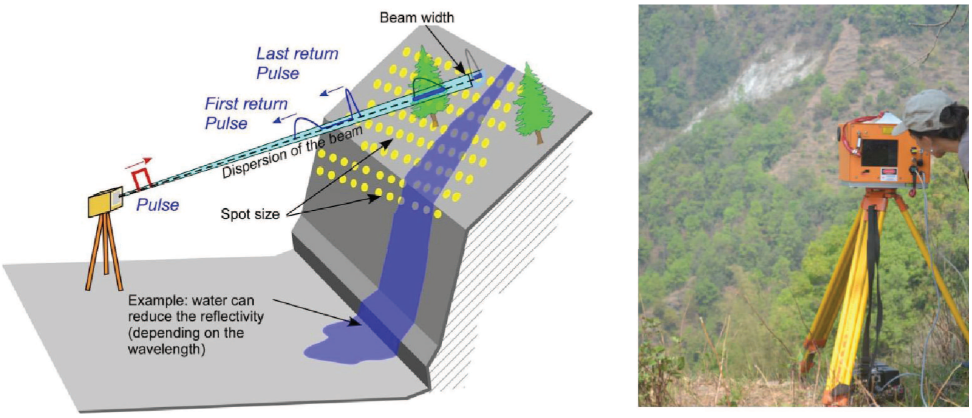

Figure 4. Principle of LiDAR measurement of a slope (Jaboydoff, et al., 2009); Right LiDAR measurement of landslide near the Kaski District demonstration site, Nepal 2014, Credit: S. Devkota

2.2 Establishment of test plots with different species at each pilot site, combined with community observations of drought-resistant species appropriate for bio-engineering. Triangulation between community observations about bio-engineering plant survival rates combined with the test plot results will allow a combination of local knowledge and scientific experiments. Acceptability and usefulness of the species to enhance livelihoods are important factors for promotion of bio-engineering species. The test plots are using a very simple design whereby 7 different but most common local species are planted along a small segment (6 x 3 m) of a slope, which is cut at the bottom and transected with a transparent and insulated plexi glass sheet, or rhizotrones (root windows). This simple technique enables measurements of plant growth, root architecture and easy removal of plants in order to measure root tensile strength and soil moisture (Stokes, 2013). Each plot will be watered and maintained until the 2015 monsoon, after which plants will be tested. In addition, communities, which are responsible for planting and maintaining each bio-engineering site and caring for the test plots, were requested to note and share their observations about survival rates and suitability of each species. Community-based observations were gathered during focus group discussions in each project site in November 2014.

3. RESULTS

As data are still being collected and analysed, of the three research objectives and methods, we will focus on initial observations bio-engineering plant effectiveness for soil stability and drought resistance. We here present a number of community observations of plant survival rates after the first monsoon season can be noted.

3.1 Bhat Khola, Syangja District

The Bhat Khola site is the largest in terms of the amount of land the community had designated for plantations (ca. 7500 m2). This area was a previously open grazing area and highly degraded, with three large (ca 20m x 2m x 2 m) gullies mainly emanating from the accumulation of water from the road and run-off from the compacted slopes. The road had been funded by the local government but built by the community 10 years ago. Every year a small budget is given to each community along the road for maintenance yet large gullies had formed and were starting to threaten two houses immediately below the slope (Figure 5).

Six months after the project started, over 1065 seedlings and 18 different species had been planted by the community on the pilot site with a survival rate of 50 percent of the seedlings. A survival rate lower than 70 percent should not be considered a success (Lammeranner et al., 2006), thus reasons for the low survival rate were analysed. Selection of species was made by the community in collaboration with DSCO, which supplied the seedlings in polybags. The seedlings were a combination of fodder trees, fruit trees for livelihood needs with bio-engineering grass species and a variety of bamboo species. Small check dams were constructed to control the largest gullies. Live check dams: vertical rows of bamboo seedlings were combined with horizontal bamboo sticks to reduce water flow and retain sediments in gullies (Figure 5).

For the plantations on the degraded slope, three species (*Vitexnegundo, Choerospondias axellaris* and *Michelia champaca*) had particularly low survival rates. The community gave several reasons for this relatively low survival rate. The first was incompatibility of the species for the soil type; soil compaction after decades of grazing; insufficient watering and weeding. A live fence had been installed to keep the animals from destroying the plants and the community was interested in expanding the plantations to other heavily degraded open grazing areas. Most notably, the drainage structures, together with the plantations have significantly reduced the amount of water going to the heavily reduced slope and the gullies are gradually recovering as measured by no new gully expansion. As the town is a thorough way, many upstream communities have observed the results and are requesting training to replicate the techniques in their villages. The total cost of the combined structural measures and plantations, including labor costs amounted to approximately 13,000-15,000 USD.

Figure 5. Left: Gullying in Bhat Khola site, below roadside in April, 2014. Credit: K. Sudmeier-Rieux; same site in November, 2014. Credit: G. Leibundgut

3.2 Gharelu, Kaski district

This village access road was initially funded and constructed by the community itself with some technical support by the Kaski DSCO, which provided materials for a gabion wall where a slope failure had started to appear. The EPIC project and community built a drainage system and planted 1,000 seedlings and 4 species on 1050 m2 along the roadside (Figure 6). Six months later, the vegetation growth was impressive low failure rate of 10 percent, mainly of two grass species (*Vetiverialawsoni* and *Vitexnegundo*) which were less easy to grow, according to the community due to poor soil quality. Gharelu village is where the first test plot was established in early September. One month later, only the commonly used bio-engineering bamboo species "broom grass", (*Thysanolaena maxima*) did not survive. Being known as a very hardy species, it was the only one that the community did not care for or water.

Figure 6. Left: Gharelu village, Kaski District after drainage structure and slope modification in April, 2014. Credit: K. Sudmeier-Rieux; Right: same site in November, 2014. Credit: G. Leibundgut.

However, all other species had a notable success rate, some measuring 2 m high after 5 months of growth after a relatively dry monsoon season (according to the community). The total project cost was around 6,000 USD.

3.3 Tilahar village, Parbat District

This road was funded by the local government and recently expanded to provide greater road access for upstream communities. It is situated right above a school with 800 students and large rocks were commonly falling into the school yard after the most recent road expansion (Figure 7). A drywall was built to stabilize the most instable slope and some smaller stabilization measures were undertaken such as fixing bamboo rods onto the upslope part of the road and planting “broom grass”, (*Thysanolaena maxima*). The survival rate was high but only this one plant species had been chosen by the DSCO. It was planted very sparingly and late in the season, thus the effectiveness on soil stability is questionable. This site was the most problematic as a slope failure occurred during the monsoon, blocking the road and creating damage to the road and in fact making it impassable. There seems to be confusion in this community whether the maintenance of the roadsides belong to the government or to the community which is thus not very motivated to engage and invest in bio-engineering activities. Project cost to date is 10,000-12,000 USD.

Figure 7. Left: Tilahar project site in April, 2014; Right: same site in November 2014. Tilahar school in background. Credit: K. Sudmeier-Rieux

4. CONCLUSIONS

As one of the poorest countries in the world, the Government of Nepal is struggling to provide many of the basic necessities to its population. Rural road construction continues to be a priority for rural development, however the current short-sighted quick construction mode is creating unnecessary social, environmental and economic costs that could be avoided by more sustainable road construction, which will create economies in the long run. Although this research is in its initial stages, by combining different types of research methods we can obtain more comprehensive results from state-of-the-art LIDAR monitoring of erosion and the effectiveness of vegetation for erosion control, to research on the effectiveness of different plant species for soil cohesion and drought resistance based on community observations and plot tests and an economic cost-benefit analysis of “grey versus green” approaches to road construction. However, there is huge gap of awareness about green, or “eco-safe roads” and how to make road construction more sustainable. It is expected that this study will contribute to shaping government policies and practices to reduce the impact of unplanned road construction.

5. ACKNOWLEDGEMENTS

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