



## **Natural hazards, road development, increased vulnerability and risks in the Nepal Himalayas**

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The construction of new roads in developing countries such as Nepal attracts populations who find facilities and opportunities in a roadside location. This in turn might expose them to hazards (i.e. landslides, debris flows, gullyng, floods) that become all the more dangerous since incoming population have no awareness of potential threats. Conversely, the construction of roads favours outmigration from unstable mountain slopes that may lead to reactivation of landslides due to interruption of stabilization control (terracing) by village communities, as observed in Central Nepal Himalayas. For instance along the Kali Gandaki road, built without proper concern of geotechnical constraints and opened to traffic in 2008, forthcoming occurrence of landslides and debris-floods can easily be foreseen. The main landslide trigger is the highly seasonal southwest monsoon, bringing precipitation exceeding 5 m.y<sup>-1</sup>, which favours soil saturation and high pore pressure in densely shattered or clay-rich rock material. In addition, strong dynamic coupling between steep mountain slopes and riverbed, characteristic of these confined Himalayan valleys, makes new settlements sites (fluvial terraces and cones) and roads vulnerable. In fact, the evolution of the Kali Gandaki valley, like many others, is characterized by a great unsteadiness, with rapid alternation in both time and space of debris erosion and aggradation (Fort et al., 2010). Repeated observations at representative study sites provide a better understanding of the functioning of the landform system at very short time scale (a few hours to a few years). We illustrate this with a few examples where slope instabilities are susceptible to dam the Kali Gandaki valley, induce backwater flooding and/or trigger landslide dams outburst floods, hence to cause high material and possibly human losses. These examples, together with others of similar or greater magnitude (along the Sun Kosi and Trisuli Khola valleys), underline the interaction between road development followed by rapid urbanization on the one hand, and increased vulnerability for both the inhabitants and travellers on the other hand. Continuous updating of detailed natural hazards maps should be recommended as a straightforward tool to pinpoint and monitor the endangered spots, so that to preventing an increase of damages and fatalities. More generally, we acknowledge the expansion of road network in Nepal as a good way to open landlocked Himalayan valleys and favour exchange of goods between complementary environments (tropical South Asia vs continental Central Asia). Conversely, road development reinforces the functional vulnerability that may arise from any traffic interruption along these strategic and trading link roads between China/India and Nepal. Indirect economic drawbacks may additionally come from discouraged tourism and resulting disuse of until then very attractive trekking routes. Eventually, any aggravation of natural hazards due to climate change (i.e. monsoon strengthening) -still a matter of debate- questions the maintenance of such roads for the coming decades.

Reference: Fort Monique, Cossart Etienne, Arnaud-Fassetta Gilles, 2010. Hillslope-channel coupling in the Nepal Himalayas and threat to man-made structures: the middle Kali Gandaki valley. *Geomorphology* 124, 178-199.