Turning rocks into soils from the Ecuadorian Andes to the Mexican transvolcanic sierra

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A volcanic tuff rock known as *cangahua* (Ecuador) or *tepetate* (Mexico) is found throughout the Andes. Problems have arisen as the layers of light but fragile soil that once covered the tuff have been lost for both natural (environmental) reasons and because of over-cultivation. When the soil is gone, the tuff is impermeable and sterile. Now, a project in Ecuador has determined that the tuff itself can be reclaimed and is supporting a programme that sends bulldozers to the tuff regions to break up the rock and create a new fertile soil.

Bulldozer, Province of Ibarra, Ecuador (Christian Prat)

Along the Andes – from Chile to the Mexican Sierras Madres – layers of hard volcanic materials cover large areas of the foothills. These materials have been given local names where they are found: *tepetates* or stone beds in Nahuatl in Mexico, *talpetate* in Central America, *cangahuas* or hard ground in Quichua in Colombia and Ecuador (Figure 1), *sillar* or *ashlar* in Spanish in Peru, and *toba* or *tuff* in Spanish in Chile (for simplicity, this report refers to the material as tuff).

The tuff layers cover a very large area: 30 700 km² in Mexico, 2 500 km² in Nicaragua, 15 000 km² in Colombia, 3 000 km² in Ecuador, areas inhabited by millions. Originally emitted

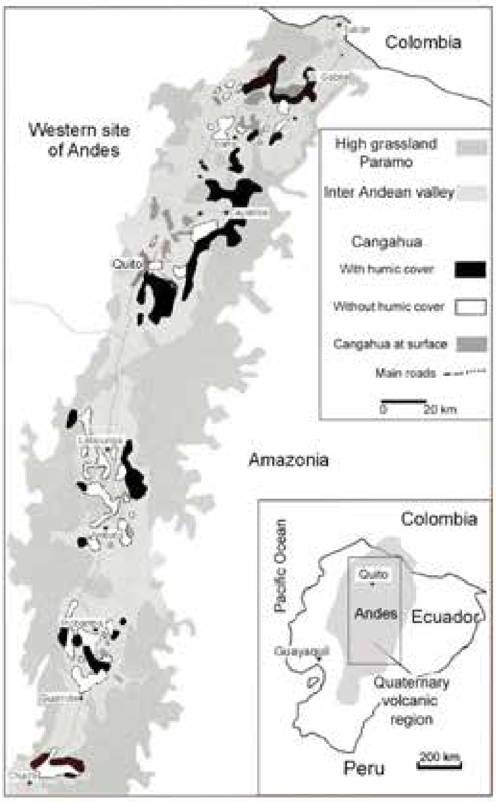

Figure 1: Location of the different types of *cangahuas* in the inter-Andean valley of Ecuador (Zebrowski et al.)

Cangahuas. Canton of Cangahua, Pichincha province, Ecuador (German Trujillo)

by phreatic magmatic-volcanic explosions, they have a thickness ranging from a few centimetres to several metres. They were buried beneath loose ashes, which turned to a fertile but fragile soil during the process of weathering.

Environmental (*e.g.* slopes, rains) or anthropogenic (*e.g.* overgrazing, agricultural mismanagement) erosion has made the topsoils disappear completely in many areas, revealing the hard tuff layers. These exposed tuffs are impermeable due to their high compactness and very low porosity.

Environmental. When aggressive tropical rains fall, the water runs off of the hard layers, concentrating and generating huge volumes of water downstream, destroying crops and causing flash floods which strongly erode soils. As the tuff materials are rocks, they lack soil organic matter or nutrients, except in isolated cracks. Sulfur and phosphorus are especially scarce in available form, while potassium can achieve high content. Obviously, the microbiological activity is residual, because micro-organism diversity is low. So, when the tuffs are exposed, the landscape looks like a sterile desert.

Anthropic. The anthropogenic pressure on the land can be very problematic. Instead of dealing with the sterile landscape, farmers have moved higher on the slopes of the mountains to reach new land with deep, fertile black soils, which forms the high-altitude ecosystems called *páramos*. *Páramos* play a key role in water resources, retaining huge volumes of water that are redistributed gradually, ensuring a permanent water supply for farmers and urban populations. But after they are used for cultivation, the soils become dry and, as a consequence, lose their capacity to retain water and resist erosion, repeating the processes observed downhill.

National and local policies have focused on reclaiming exposed tuff, *e.g.* in Mexico beginning in the 1970s and in Ecuador beginning in the 1980s. National and European funds supported research programmes for some 20 years yet, despite some success, governments gradually stopped funding them.

However, in recent years, Ecuador has recommitted. Its 2008 Constitution of the Republic State points out the obligation to protect soil and to recover eroded areas for sustainable agricultural productions, which contribute to food sovereignty of the country. In 2012 the government funded nine bulldozers, managed by the Secretary of Agriculture, for all provinces with exposed tuffs, and launched a new project focused on transforming tuffs into soils. The project is supported by the Global Environment Facility (GEF), with the Food and Agriculture Organization of the United Nations (FAO), Ecuador's Ministry of Agriculture, Livestock and Fisheries (MAGAP) and Ministry of Environment (MAE), as well as local programmes of some prefectures and municipalities.

While Ecuadorian small farmers can break 1 m^2 of tuff per day using a pickaxe, the quickest and effective way to form soils there is with bulldozers. These machines can fragment the tuff on 0.5 to 1.0 ha per day, even on slopes, if they are less than 50 percent steep. This work also integrates an erosion-control system by breaking the highly porous tuff and creating a physical support for plants.

The strategy is to establish an agro-ecological sustainable system by incorporating, as much as possible, organic residues, preferably composted, including fertilization and microbial activity. The first crop includes legumes and grasses that will later be buried as green manure. The next crop is fertilized with small amounts of mineral fertilizers, administered three times during the year, as well as with composted manure. This plus the incorporation of the crop residues (green manure) makes it possible to achieve regional yields of, *e.g.* oat, wheat or beans in one to three years and of corn in five years.

Through this method, after three to five years, from 40 to 90 Mg C ha^{-1} of carbon can be captured as soil organic matter, ten times more than found in European soils. In the context of global warming, this high potential of carbon capture provides an additional environmental service. At the same time, it also makes additional land available for agriculture, which prevents farmers from expanding to higher-level *páramos* seeking land for cultivation. Finally, it also avoids liberation of carbon dioxide (CO_2) thus reducing greenhouse gas emissions.

Different land uses (agave, crops, forests) of *cangahuas* turned to soil. Cayambe, Pichincha province, Ecuador (Christian Prat)

Research continues to identify and select the optimal micro-organisms, for example to improve crops, crop association and rotation, and allopathic interactions between crops, as well as the quality of manure, in order to find agro-ecological systems that are correctly adapted to the typical Andean crops (such as quinoa, lupine, chia, amaranth, vegetables and pastures). Where irrigation is not possible and a traditional use of the agaves exists, agave forestry is promoted, inspired by previous Mexican experiences (see p. 107). For example, the mezcal liquor obtained from agaves could be an additional income source for families. As this species (*Agavae americana*) reproduces through seeds, the authorities used the plant picking and seeding activities to reintroduce the traditional collective work, the *mingas*, and to put emphasis on pre-hispanic traditions to protect the environment.

All these strategies focus on participative works to offer opportunities to small farmers to produce highly profitable crops, helping them to emerge from poverty. This will allow peasants (including their children) to remain farmers, instead of migrating to the cities, where they will join the legions of unemployed. Creating new spaces of productive and living soils from volcanic hardpans located in the foothills of the Andes has changed the look from deserted landscapes into fertile fields, avoiding further environmental destruction, and giving small farmers and their children new opportunities to live quite well from their production.


Field work after bulldozer and tractor préparation, Ibarra Ecuador (Christian Prat)

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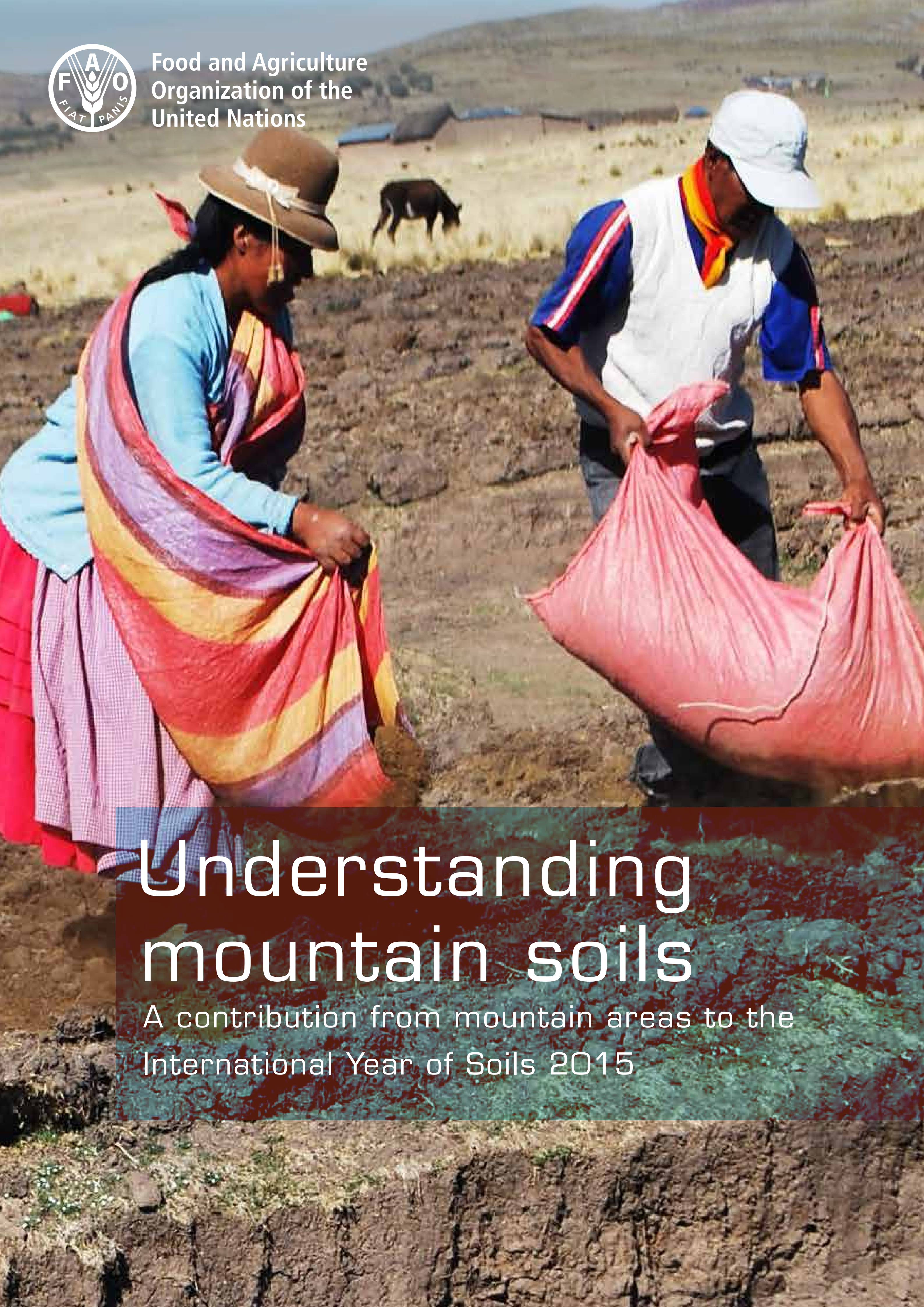

Understanding mountain soils

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In collaboration with the Mountain Partnership Secretariat,
the Global Soil Partnership and
the University of Turin

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2015

ISBN 978-92-5-108804-3

FAO information products are available on the FAO website (www.fao.org/publications)
and can be purchased through publications-sales@fao.org

Authors of case studies and introductory texts: international group of experts (for the names see list of authors)
Concept: FAO Mountain Partnership Secretariat, University of Turin
Layout: Roberto Cenciarelli
Editing: Nancy Hart
Proofreading: Caroline Lawrence

Recommended citation:
FAO. 2015. *Understanding Mountain Soils: A contribution from mountain areas to the International Year of Soils 2015*, by Romeo, R., Vita, A., Manuelli, S., Zanini, E., Freppaz, M. & Stanchi, S. Rome, Italy.

This publication is available from:
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