

## Positive impacts in soil and water conservation in an Andean region of South America: Case scenarios from a US Agency for International Development multidisciplinary cooperative project

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### GLOBAL CHALLENGES ARE EXEMPLIFIED IN THE ANDEAN REGION OF SOUTH AMERICA

Several papers have questioned whether we will be able to achieve food security in the face of the many challenges this century brings, including climate change, an ever-increasing world population, depletion of water resources, soil desertification, and deforestation. Conservation agriculture (CA) shows high potential as a means of adaptation to and mitigation of climate change-related stressors. More generally, the application of soil and water conservation practices will help protect and strengthen soils and ensure that agricultural systems have a sustainable means of providing food security (Delgado et al. 2011; Lal et al. 2011). The Andean region of South America is one of the regions of the world that faces the challenge of increasing agricultural production while conserving soil quality and maintaining sustainability. Barrera et al. (2010a) reported on some of the challenges facing the Andean region, such as small and shrinking farm sizes, poor soils, erratic rainfall, and cultivation of areas (especially in high slopes) exposed to high erosion rates (figure 1). A large segment of the population in this region is dependent on the potato crop as a main staple, and the intensive cultivation of the potato crop at planting and during harvesting, followed by a low amount of crop residue covering the soils (figure 2), contributes to systems that are highly susceptible to erosion.

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**Figure 1**

Impacts of erosion in cultivated fields of the Illangama watershed, Ecuador, located at an altitude of 3,400 m. As can be seen in the photo, a lack of conservation practices has contributed to higher erosion rates and to the loss of the more productive soil surface horizon, exposing a less fertile subsoil below.



**Figure 2**

Harvesting potato varieties in an Andean field site at low altitude (area of Tiraque, near the site of Cochabamba, Bolivia).



**THE POTENTIAL TO APPLY CONSERVATION AGRICULTURE TO ADDRESS ENVIRONMENTAL CHALLENGES AND DEVELOP SUSTAINABLE SYSTEMS**

Virginia Polytechnic Institute and State University (referred to as Virginia Tech) has been leading a USAgency for International Development Sustainable Agricultural and Natural Resource Management (USAID SANREM) project in the Andean region of South America. The project has involved several institutions in the United States, Ecuador, and Bolivia. The project, a continuation of a prior project starting in 2004, is focused on development and evaluation of CA production systems in this region. The areas selected are representative of a typical Andean region: the upper Chimbo River area in central Ecuador, and Tiraque, near Cochabamba in Bolivia. Both of these watersheds are under extreme pressure from agricultural production activities, and along the hills, areas impacted by severe soil erosion can readily be found.

This project focuses on the development, testing, and diffusion of sustainable CA systems. With these systems, yields could be improved and nutrient cycling increased while minimizing adverse impacts to soil quality and improving soil health. Conservation Agriculture is rooted in basic principles such as maintaining the surface soil cover to reduce erosion and retain soil moisture, utilizing a diversified

crop rotation (which provides benefits such as increased yields and better nutrient cycling), and minimizing the disturbance of the soil (which contributes to increased soil organic carbon). Components of the research in Ecuador are presented in table 1.

The project follows a two-pronged approach: (1) rigorous evaluation of the impacts of the CA system and (2) active encouragement of participation by local farmers. As a part of the evaluation of system components, scientists measure soil physical, chemical, and biological parameters; soil loss; and impacts on household incomes and livelihood systems. Results from these measurements indicate that in the short term CA has equal or higher yields than traditional farmer practices and, mainly due to labor savings through reduced tillage, has lower costs. For example, although short-term potato yields in the CA system in both Ecuador and Bolivia are slightly lower than with conventional tillage, labor savings and biomass yields from cover crops more than make up the difference. As only three years of soil data are available, we are unable to document changes in soil health. However, yields in the CA trials have increased over time, and we expect that in the long term, as soil health improves, CA profitability will only increase.

The second project component, farmer participation, is particularly important because farmers are able to provide their insights into system elements that may or

may not be successful; ultimately successful diffusion depends on their perceptions. As profitability and impacts of CA on soil health are gradually measured by researchers, participation of farmers in the research process ensures acceptance of research findings. One approach to encouraging this participation is farmer field days where technical personnel visit with local farmers (figure 3). At these events, farmers can share experiences and learn about ongoing research.

**CASE SCENARIOS IN THE ILLANGAMA WATERSHED IN ECUADOR SHOWING THE POTENTIAL FOR TECHNOLOGY TRANSFER IN CONSERVATION AGRICULTURE ACROSS THE ANDEAN REGION OF SOUTH AMERICA**

The Illangama watershed in Ecuador is at about 3,400 m (11,155 ft) above sea level. The great majority of the soils across this watershed are reported to be Andisol (loam soils) with an acidic soil pH of 5.2 to 5.3 and high soil organic content at the surface (10% to 14% organic content). These soils are highly susceptible to erosion since slopes are >20% (in some cases even >50%). This susceptibility grows as areas are deforested and converted to agricultural uses, and soils can be severely affected to the point where the parent material starts emerging and the farmers abandon the site (figure 4a). It is important to conserve these fragile soils susceptible to erosion in order to maintain sustain-

**Table 1**

**Description of Conservation Agriculture Production Systems in two cultivation systems in Ecuador.**

<b>Characteristic</b>	<b>Illangama subwatershed (upper watershed): potato–pasture system</b>	<b>Alumbre subwatershed (lower watershed): maize–beans system</b>
Soil conservation practices	With and without deviation ditches	With and without deviation ditches
Tillage	Conventional and reduced	Conventional, reduced, and no-till
Rotation 1	Potato, barley, faba, and forage mix*	Hard maize, bush beans, hard maize, peas, and hard maize
Rotation 2	Potato, barley, oats-vetch, and forage mix	Hard maize, bush beans, hard maize, oats-vetch, and hard maize
Management	Soil use (fallow, grass with residuals removed, grass with residuals retained), fertilization with nitrogen and cover crops (faba and quinoa). Intensive pasture management (improved forages) with overseeding of clover.	Tillage options (conventional and reduced), cover crops (peas, oats-vetch, maralfalfa– <i>Pennisetum</i> sp., and native trees). Use of maralfalfa and fruit trees in contours to form live barriers.

\* Improved forage mix was identified during prior research.

### Figure 3

Jorge A. Delgado, soil scientist (USDA Agricultural Research Service), and Carlos Monar, agricultural engineer (Universidad Estatal de Bolivar), visited with farmers during a field day about the importance of conservation practices and soil quality. The field day was conducted at the Illangama watershed, Ecuador.



ability in the region. The predominant crop rotation is a traditional 4- to 5-year pasture rotation followed by a potato crop. Conservation practices, such as minimum tillage potato, have great potential to significantly reduce erosion in this region (figure 4b).

SANREM experiments take place on farmer fields, and in a recent visit to this site, it was clear that the research and diffusion efforts are having significant positive impacts on local farmers. During the visit, agricultural engineers Luis Escudero, Carlos Monar, and Moazir Celleri; stu-

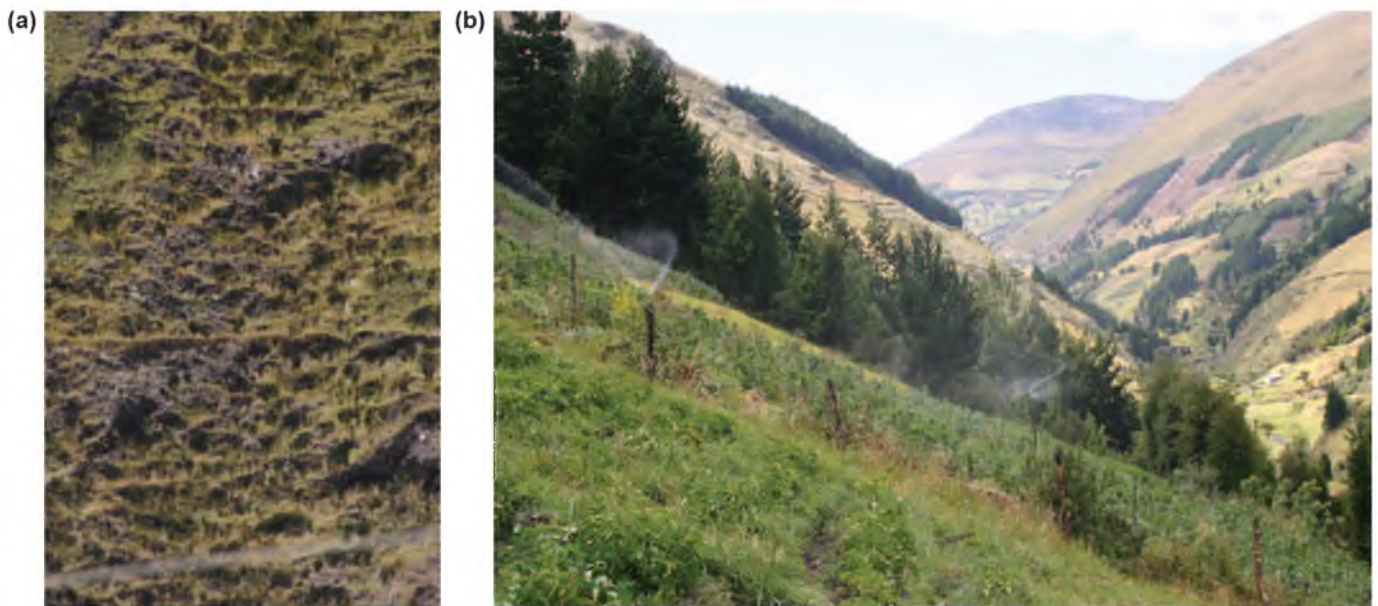
dents Rosa Arevalo and David Moposita; and USDA Agricultural Research Service (ARS) soil scientist Jorge Delgado discussed with farmers the project and the effects it is having on them and their neighbors. Maria Palag and Matias Paguay, whose farms are participating in SANREM research, reported significant positive advances in food production (personal communication, August 18th, 2011).

The USAID project has demonstrated that by diversifying the crop rotation and adding leguminous grains and/or a mixture of nonleguminous and leguminous forages, potato quality and yields are increased, as reported by farmers (Maria Palag and Matias Paguay, personal communication, August 18, 2011) (figure 5). Additionally, farmers are also using new potato varieties and more inorganic fertilizer, but in personal communications with them, they also acknowledged that they are getting better potato responses when planting follows a leguminous grain crop.

Similar positive responses of potato following a cover crop have been reported in Colorado, United States, by Delgado et al. (2007) and Essah et al. (2012) for potato grown in the San Luis Valley of Colorado. Keith Holland, a San Luis Valley farmer, reported increases in potato yield

### Figure 4

(a) Example of an abandoned farm site that was severely eroded and (b) a field site where minimum tillage potato studies are being conducted by the US Agency for International Development at the Illangama watershed, Ecuador, at 3,400 m above sea level.



following a cover crop in the September 2011 issue of the USDA ARS *Agricultural Research* magazine (O'Brien 2011). These commercial studies in the San Luis Valley and the Andean region of South America reveal that on-the-farm demonstration studies are a key method for transferring technology to farmers, who see the positive results from the ongoing studies conducted at their farms and immediately incorporate the results into their practices so they can reap the benefits of the research.

Another significant benefit of the USAID demonstration project in the Andean region has been to show the benefits of conservation practices, such as diversifying crop rotations, planting in sections, using minimum tillage and/or zero tillage, and using buffers and water collection channels protected with buffers to reduce the effects of erosion (figure 6). All of these project-introduced practices are helping to develop sustainable systems and even increase economic returns for farmers in the region. For example, the farmers Maria Palag and Matias Paguay report that these practices and new technologies have helped increase the milk production from 3 to 4 L (0.8 to 1.1 gal) per cow to 6 to 8 L (1.6 to 2.1 gal) per cow (Maria Palag, personal communication, August 18, 2011) and that the potato production has doubled to tripled (Matias Paguay, personal communication, August 18, 2011). Across the watershed, average yields in crops and animal production have increased dramatically as a result of the SANREM interventions (Barrera et al. 2012).

An additional positive impact of the USAID project is that local farmers are now diversifying their crops with cash crops, such as quinoa and horticultural crops. The use of new cash crops for the region, in conjunction with the use of more effective irrigation systems for these high-value crops, can contribute to higher economic returns for farmers. Minimum tillage and/or zero tillage also looks like a promising practice at the Luis Ilba farm, where tomatoes are being planted using minimum tillage. The USAID project contributed to the implementation of new conservation practices that promote sustainability, such as the use of

### Figure 5

Jorge A. Delgado, soil scientist (USDA Agricultural Research Service; left), and Carlos Monar, agricultural engineer (Universidad Estatal de Bolivar; right), visited with farmer Maria Palag (center) about the importance of conservation practices and soil quality and positive responses observed in her farm due to implementation of conservation practices. They spoke during a field day conducted at the Illangama watershed, Ecuador.



crop rotations, minimum tillage, improved irrigation management, and grass buffers (Barrera et al. 2010b). These conservation practices have been shown to be effective in increasing economic returns for farmers and contributing to food security.

### THERE IS A NEED FOR NEW TOOLS THAT CAN HELP ASSESS THE BENEFITS OF CONSERVATION PRACTICES FOR SUSTAINABILITY

There is a need to develop bilingual tools (English/Spanish) that can be used to assess the effects of conservation practices on nitrogen fertilizer inputs, nitrogen use efficiencies, soil quality, and conservation. For example, the Mexico Nitrogen Index is a bilingual tool that has been used to assess nitrogen management practices in Mexico (Figueroa-Viramontes 2011a, 2011b). We adapted the Mexico Nitrogen Index to Ecuador and Bolivia and added a sustainability index to assess the effects of conservation practices on soil sustainability in the Andean region of South America. The tool was developed in the programming language Java™ and can be run on any Windows®-based personal computer. A smartphone application was also recently developed for the Nitrogen

### Figure 6

Example of use of grass buffers in combination with water collection ditches across the slope as a key soil and water conservation practice in the US Agency for International Development studies conducted at the Matias Paguay farm located in the Illangama watershed, Ecuador, at 3,400 m above sea level.



Index. The new Ecuador and Bolivia Nitrogen Index with a sustainability index has been transferred to users in both countries (figure 7). A training workshop was conducted in Ecuador for users of the tool. For details on the Nitrogen Index, interested readers could review publications by Delgado et al. (2006, 2008), De Paz et al. (2009) for a Mediterranean region of Spain, and Figueroa-Viramontes et al. (2011b) for Mexico. Figueroa-Viramontes et al. (2011a) also published a user manual in Spanish describing how to apply the Mexico Nitrogen Index. The Nitrogen Index can be downloaded from the Nitrogen Tools webpage of the USDA ARS Soil and Plant Nutrient Research Unit (<http://www.ars.usda.gov/npa/spnr/nitrogentools>).

As part of the USAID and USDA partnership, cooperators from Ecuador and Bolivia (Ana Karina Saavedra, Carlos Monar, and Luis Escudero) traveled to the USDA ARS Soil Plant Nutrient Research Unit in Fort Collins, Colorado, United States, as visiting scientists to be trained in the use of the Nitrogen Index (figure 8). At the same time, these visiting scientists contributed to development of a soil sustainability index that could be applied

to the Andean region and added to the Nitrogen Index. The soil sustainability index was adapted from the Maryland Soil Quality Assessment Book ([http://soils.usda.gov/sqi/assessment/files/MD\\_card.pdf](http://soils.usda.gov/sqi/assessment/files/MD_card.pdf)) (figure 9). Several qualitative factors are used in ranking the impact of conservation practices on soil sustainability in the Andean region. The soil sustainability index considers the number of earthworms in the top soil, soil color, visible root, crop residue, erosion, and compac-

tion. It also considers aggregates, burning of residue, plowing direction (if any), slope, and contour lines (figure 8). The sustainability index is currently being evaluated, and future changes will be made to it as needed.

### SUMMARY

The USAID, SANREM, and Virginia Polytechnic Institute and State University project has made and continues to make an excellent impact, specifically showcas-

**Figure 7**

Nitrogen Index 4.4 (2012 version; written in the programming language Java) is available in the English and Spanish languages. The tool will also be available soon in the Portuguese language.



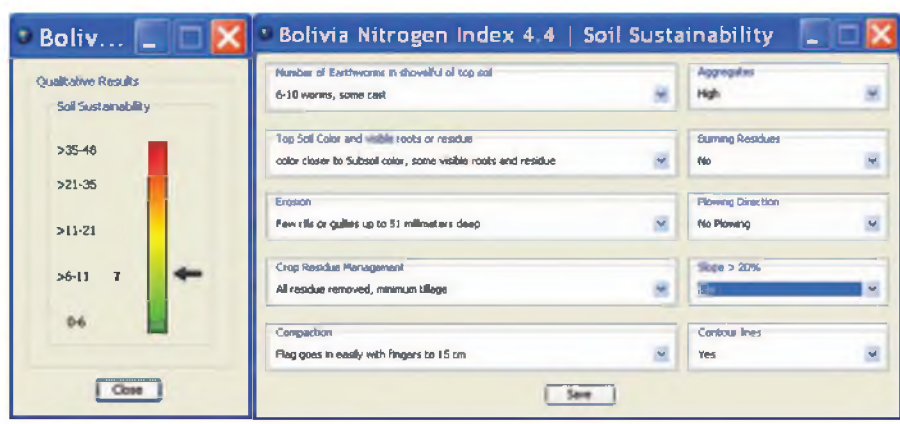
**Figure 8**

Jorge A. Delgado (left) Ana Karina (left center), Luis Escudero (right center), and Carlos Monar (right) test the potential use of nitrogen management models, such as the Nitrogen Loss and Environmental Assessment Package with Geographic Information System capabilities (NLEAP GIS-4.2) and the Nitrogen Index, at the USDA Agricultural Research Service, Fort Collins, Colorado, United States, facilities.



**Figure 9**

Sustainability Index for South American cropping systems.



ing the positive results of soil and water conservation (Barrera et al. 2010a, 2010b, 2012). This project has strong international cooperation between the United States, Ecuador, and Bolivia. The project has contributed to the implementation of conservation on the ground in the Andean region of South America, based on strong partnership with local institutions, universities, and farmers. Farmers have been a key component of this success by allowing the implementation of demonstration projects on their farms under local commercial farming operations. Personal visits with farmers revealed that these types of projects can contribute to the training of additional local farmers, with field days that show the benefits of these studies. These newly implemented conservation practices are helping reduce the risk of erosion and potentially increasing economic returns for the farmers as well as promoting sustainability of local systems.

With the challenges we will be up against in the twenty-first century, such as climate change and growth of the human population, soil sustainability will be key in efforts to achieve food security and soil and water conservation across all global sites. This USAID project serves as an example of positive impacts in sustainability at the farmer level (Barrera et al. 2010b).

#### DISCLAIMER

Manufacturers' names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of a given name by the USDA does not imply approval of that product to the exclusion of others that may be suitable.

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