Conservation Agriculture as a Potential Pathway to Better Resource Management, Higher Productivity, and Improved Socio-Economic Conditions in the Andean Region

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Host-Country Partners: Ecuador

- Instituto Nacional de Investigaciones Agropecuarias (INIAP), lead partner
- International Plant Nutrition Institute (IPNI)
- Secretaría Nacional de Ciencia y Tecnología (SENACYT)
- Universidad Estatal de Bolívar (UEB)
- Escuela Superior Politécnica del Chimborazo (ESPOCH)
- Secretaría Nacional del Agua (SENAGUA)
- Gobierno de la Provincia de Bolívar (GPB); Alcaldía de Guaranda y Chillanes
- Sistema de Información Geográfica Agropecuaria (SIGAGRO-MAG)
Host-Country Partners: Bolivia

- Foundation for the Promotion and Research of Andean Products (PROINPA), lead partner
- Universidad Mayor de San Simon
- Centro Regional Avaroa
- Sindicato Agraria Tiraque, Alcaldía de Tiraque
- USAID Food Security Program, Fundacion Valles
US Partners

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- Rob Gallagher, Crop and Soil Sciences, Penn State
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- Richard Stehouwer, Crop and Soil Sciences, Penn State
- Wills Flowers, Entomology and Biological Control, Florida A&M
- Jorge A. Delgado, Soil Plant Nutrient Research Unit, USDA/ARS, Fort Collins, CO
Other Partner

- CIAT, Cali Colombia
Project Objectives

- Identify and evaluate production practices and farming components that can be assembled into CA production systems for Bolivar, Ecuador and Tiraque, Bolivia;

- Validate candidate CAPS in terms of impacts on: soil health, soil retention and carbon and other nutrient balances; sustained productivity; profitability; risk bearing; the environment; compatibility with household livelihood strategies; and social conditions including gender considerations;

- Promote adoption of the most appropriate CAPS by identifying mechanisms to increase their profitability;
Project Objectives

- Design and evaluate mechanisms for disseminating results to similar areas;
- Evaluate overall impacts of the research along several dimensions including soil health, productivity, economic, social and environmental; and
- Strengthen the capacity of government and non-government institutions to develop and disseminate CAPS in the Andean regions of target countries.
Conservation Agriculture

- In its purest form, CA is based on three principles: (i) minimum or no mechanical soil disturbance; (ii) permanent organic soil cover; and (iii) diversified crop rotations
- We view CA as a continuum running from a single or small number of practices to a full-blown CAPS
- **Our proposal**: investigate alternatives to increase agricultural productivity in a sustainable fashion through improvements in soil health, better rotations, cost-effective and sustainable pest and nutrient management, and improved water management. Off-farm innovations can also raise incomes and reduce the stress on the natural resource base
- **Key point**: we are working beyond the trinity of the pure form of CA
“Other” CA Components: Our Project

- Bio-inputs to increase soil productivity
- Pest control methods to increase profitability
- Agro-forestry: control erosion, manage water, income diversification and biological diversity

Economic considerations:

- Costs and profitability of CA: beyond the production system
- External costs and benefits: mechanisms to capture these
Sites: Chimbo, Ecuador & Tiraque, Bolivia
General Conditions in the Chimbo Sub-watershed

- Provide between 30 and 40% of the total water into the Guayas River.
- Three distinct ecological regions (paramo, high plain and subtropical).
- Range from 300 to 4500 meters in elevation and receive between 500 and 4000 millimeters of annual rainfall.
Environmental Conditions in Sub-watersheds

- High rates of erosion contribute to sedimentation and turbidity in surface water.
- Reduction in water levels and flows caused by deforestation and expansion of the agricultural frontier.
- Less water available and more variability in rainfall in recent years.
Two Micro-watersheds

- Illangama:
  - High elevation, more rainfall, cold and frost
  - Predominantly indigenous

- Alumbre:
  - Lower elevation, semi-tropical
  - Mestizo families
Potato-Dairy System
Illangama Microwatershed
Additional Information--Illangama

- High organic content of soil (14% on average)
- Phosphorus is limiting factor

Needs:
- Means of intensifying the pasture component of the potato-pasture rotation to get more out of potato;
- Means of intensifying the annual crop rotations which include quinoa, faba and oats in rotation with potato and pasture;
- Means of increasing available phosphorus to improve potato yields; and
- Appropriate perennial strips to improve soil retention.
Maize-Bean System
Alumbre Microwatershed
Landholdings are relatively high.

Soils are highly degraded and susceptible to erosion.

Means are needed to increase soil retention, improve soil health, while increasing food security, diversifying agricultural systems, and increasing returns to agriculture.
Management Alternatives: Prior SANREM Phase

- Improved pastures with deviation ditches
- Potato cultivation in contours
- Management of improved pastures
- Reduced-tillage maize
Soil Management Alternatives

- Strip cultivation
- Deviation ditches
- Native plants as live barriers
- Contour planting
Preliminary Research Activities

- Evaluation of:
  - Cultivation systems and ground cover, tillage options and rotations in potato
  - Tillage options in faba beans
  - Cultivation systems and ground cover, tillage options and rotations in hard maize
  - Varieties and tillage practices in soft maize
- Development of a suitable silvopastoral system using native species of trees and bushes: Yagual (*Polylepis racemosa*), Quishuar blanco (*Buddleja incana*) y Lupina (*Buddleja coriacea*).
Example: Potato Experiments

• **Factors being considered:**
  
  Erosion control: \( S_0 \) = with deviation ditches  
  \( S_1 \) = without  
  
  Tillage: \( L_1 \) = conventional  
  \( L_2 \) = reduced  
  
  Rotations: \( R_1 \) = oats-vicia and forage mix  
  \( R_2 \) = forage mix  

• **Number of treatments:** 8  
• **Number of repetitions:** 3  
• **Experimental design:** Partial divided
Example: Preliminary Experiments Hard Maize

• Factors being considered:
  Erosion control:  \( S_0 = \) with deviation ditches
                 \( S_1 = \) without
  Tillage practices:  \( L_1 = \) conventional
                    \( L_2 = \) seeding with sticks
  Rotations:  \( R_1 = \) with peas
              \( R_2 = \) with bush beans

• Number of treatments:  8

• Number of repetitions:  3

• Experimental design: Partially divided
# Variables and Indicators

<table>
<thead>
<tr>
<th>Variables</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Erosion reduction</strong></td>
<td>Depth of eroded soil</td>
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<tr>
<td></td>
<td>Total weight of eroded soil</td>
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<tr>
<td></td>
<td>Apparent density</td>
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<td></td>
<td>Soil moisture content</td>
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<tr>
<td></td>
<td>Compaction</td>
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<tr>
<td></td>
<td>Nutritional content (macro and micro)</td>
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<tr>
<td></td>
<td>Nutrient uptake by plant and crop</td>
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<tr>
<td></td>
<td>Number of plants harvested</td>
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<td></td>
<td>Dry yield</td>
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<tr>
<td><strong>Effects on nutrient dynamics</strong></td>
<td>Fertilizer efficiency</td>
</tr>
<tr>
<td></td>
<td>Biomass production and total C and N content</td>
</tr>
<tr>
<td></td>
<td>Available phosphorus</td>
</tr>
<tr>
<td><strong>Economic factors</strong></td>
<td>Costs by cost component</td>
</tr>
<tr>
<td></td>
<td>Production and productivity</td>
</tr>
<tr>
<td></td>
<td>Values of production</td>
</tr>
<tr>
<td></td>
<td>Values of nutrients and C</td>
</tr>
</tbody>
</table>
Additional Experiments

- Identification of suitable perennial hedgerows appropriate for maize/beans-based rotations;
- Annual crop systems that are less reliant on purchased inputs;
- Improved cover-crop management regimes;
- Introduction of additional perennial crops such as avocados, citrus, guava and higher-valued woody tree species
Field Trials in Alumbre Ecuador: Tillage and Deviation Ditches
Bolivia

Departament of Cochabamba

Sub-watershed “Jatun Mayu” river
Conditions in Tiraque, Bolivia

- Research site located in southern Tiraque Province, 70 Km from Cochabamba
- Between 3000 and 4200 masl, with slopes between 10 and 25% in areas under cultivation and between 20 and 40% in pastured areas.
- Comprised of 14 communities, with a population of approximately 3,000
- The area is semi humid, with approximately 550 mm of annual rainfall, and cold climate
### Characteristics Bolivia: 3 Zones

<table>
<thead>
<tr>
<th>Zone</th>
<th>Characteristics</th>
<th>Main crops</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower zone</strong></td>
<td>3000 - 3200 (masl)</td>
<td>Potato, faba bean, pea, maize, wheat, barley, oat, quinoa grain &amp; vegetables</td>
</tr>
<tr>
<td></td>
<td>Characteristics: 2 communities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intensive agriculture in rain season and under irrigation</td>
<td></td>
</tr>
<tr>
<td><strong>Middle zone</strong></td>
<td>3000 - 3200 (masl)</td>
<td>Potato, faba bean, barley, oat, pea, oca tuber &amp; some vegetables</td>
</tr>
<tr>
<td></td>
<td>Characteristics: 10 communities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Agriculture in rain season and under irrigation</td>
<td></td>
</tr>
<tr>
<td><strong>Higher zone</strong></td>
<td>3800 - 4300 (masl)</td>
<td>Potato, faba bean and potato seed in higher places.</td>
</tr>
<tr>
<td></td>
<td>Characteristics: 2 communities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Agriculture only in rain season. Low temperatures</td>
<td></td>
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</tbody>
</table>
SANREM CRSP
Delimitación de la Sub-cuenca Jatun Mayu
Conditions in Bolivia

- **Major problems facing producers in area:**
  - Low soil fertility caused by low soil organic matter, pathogen buildup, and long-term soil loss
  - Soil loss is a growing problem caused by inappropriate production technologies, removal of soil cover during dry season, and erratic rainfall
  - Water availability and changing rainfall present problems to producers
  - Our assessment is that current cropping systems will not be sustainable and, in the long run, the productivity will be lowered if these problems are not addressed.
  - The project has prioritized investigations into cover crops to protect soil loss, manage soil humidity and develop soil health over time
  - These cover crops and rotations need to fit into the predominant potato systems
## Lower and medium watershed – design 1

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>fallow/pasture</td>
<td>fallow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>oats – residue harvested</td>
<td>sudan grass harvested</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>oats – residue retained</td>
<td>sudan grass retained</td>
<td>Quinua Reduced tillage</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>oat/Vetch – residue harvested</td>
<td>sudan grass/legume harvested</td>
<td></td>
<td>Fava Reduced Tillage</td>
</tr>
<tr>
<td>5</td>
<td>oat/vetch – residue retained</td>
<td>sudan grass/legume retained</td>
<td></td>
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</tbody>
</table>
Other Research Components

- Development of a nitrogen index tool to facilitate farm planning
- SANREM Internship Program (research opportunities for UG students)
- Tradeoffs analysis: on/off-farm, productivity-environment
- Tool to identify adoption propensities
N – Index:
Inputs and Outputs

Algorithms used by the N-Index are published in:
Delgado et al., 2008. Ecol. Eng. 32:108-120
Monitoring & Impacts

- **Soil health:**
  - Minimum data set: ME recommendations
  - Timing of changes—when do we expect to observe differences?

- **Productivity and profitability:**
  - Costs of production for each practice/each experimental treatment
  - Timing and duration of measurement
  - Profitability
    - Increase local demands
    - Reduced input costs
    - Producer organizations and market access
Off-farm Impacts

- **Water quality and run-off**
- **Payments for environmental services**
  - Water quality, reduced sedimentation
  - Carbon sequestration
  - Potential value capture for adopters—institutional barriers to this capture
- **Adding up—aggregation**
  - End of project—adoption and spread
Ecuador: Major Floods in Low-lying Areas 2009

- Agricultural losses due to floods exceeded $160 M (MAGAP, 23 February 2009).

- More than $1 B needed for rehabilitation of damaged infrastructure and other costs in the flooded regions (MICSIE, 5 March 2009).
Monitoring physical processes

- Seven meteorological stations installed in Ecuador sub watershed
- Seven water flow measurement sites
- Training project personnel and local stakeholders
Vulnerability mapping

- Based on GIS overlays of variables including: slope and erosivity, current land uses, soil cover, population pressures, others.

- More than 3664 ha in Illangama and 2259 ha in Alumbre are “highly vulnerable”.

- Local governments have begun process of reforestation in vulnerable areas and water-sensitive areas.
Thank you!

Chimborazo Volcano, Ecuador