Sustainable Agriculture and Natural Resource Management
Collaborative Research Support Program

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Trip Report: Bolivia & Ecuador

1-21 April (Bolivia) and 22-28 April (Ecuador)

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Purpose of Trip: Visit with PROINPA and INIAP collaborators to view the SANREM field sites, review soil and plant sampling regimes and protocols, train the laboratory staff in the protocols for microplate analysis for inorganic N and available P, and establish a data management plan.

Sites Visited: PROINPA Cochabamba, and Tiraque region, Bolivia;
INIAP Santa Catalina, Guaranda, Illagama, and Alumbre, Ecuador.

Description of Activities

SANREM Bolivia

The duration of my stay in Bolivia was from April 2 to April 20. At the request of PROINPA SANREM Project Manager Pablo Mamani, I stayed one week longer than originally intended. The primary reason was for the three days lost in La Paz spent securing the release from the customs office for laboratory equipment that I was bringing for PROINPA. I very much appreciate the assistance I received from the La Paz–based PROINPA staff in helping with that process. An additional day was also lost due to the national holiday on April 6.

Once in Cochabamba, I worked closely on a daily basis with Team Bolivia (Pablo Mamani, Ana Karina Saavedra and Edino Gonzalez). Most of this work focused on training Ana Karina and Edino on the laboratory protocols for microplate analysis of available nitrogen and phosphorus, and establishing a data management plan. Considerable time, however, was also spent reviewing the protocols for measuring saturated soil hydraulic conductivity and water holding capacity, as well as refining the field experiment treatments and methods for the following field season.

I was very impressed with Pablo's management of the SANREM project activities and the commitment of the primary SANREM team (i.e., Ana Karina and Edino). The SANREM group also receives a good level of support from the broad-based PROINPA field staff in Tiraque and

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Anzaldo regions. All in all, this is indicative of the strong level of commitment to the SANREM project by the PROINPA administration, namely the Director of PROINPA, Dr. Antonio Gandarillas.

The primary CAPS experiments and the associated satellite experiments at the three field sites in the Tiraque region look very good. At the "15 Octubre" site, the primary CAPS experiment is in the second year of the rotation after successfully implementing the three cover crop and potato treatments in 2011. As planned, the above biomass of the oat-vetch cover crop was measured, and removed from one of the two treatments where it was present (the control treatment did not have a cover crop). This treatment combination will enable us to evaluate 1) does the oat-vetch cover crop improve the subsequent potato crop productivity over the traditional fallow systems, and if so 2) is it necessary to retain the cover crop biomass in the field or can it be removed and used as animal forage. After the cover crop – fallow phase, a potato crop was planted in October of 2011 and harvested in late February. These data are in the process of being analyzed by Team Bolivia. Following the harvest of the potato crop, Team Bolivia seized the opportunity to establish an oat cover crop to precede quinoa, which will be the next cash crop (Figure 1). The oat cover crop should: 1) help sequester available nutrients remaining from the previous cover crop treatments; 2) may serve as an additional indicator for the contribution of the cover crop treatments to the fertility of the soil; and 3) provide vegetative soil cover during the winter months. Although we expect that the oat biomass will be considerably less than if it had a full season to establish, it nonetheless should make an important contribution to the CAPS emphasis of the experiment.

Additional satellite experiments at the 15 Octubre field site include 1) Direct Seeding Quinoa into oats, 2) testing of *Bacillus* strains to improve phosphorus uptake in potato, and 3) Optimizing Irrigation regimes for potato. In the direct-seeded quinoa experiment initiated by Ana Karina, there is a very obvious cover crop effect, with quinoa plants being much larger in the cover crop/direct-seeded treatment compared to the traditional fallow/tilled treatment (Figure 2). This effect is likely due to the nutrients provided by the cover crop, but does demonstrate that quinoa can be established directly into cover crop residues without tillage. At the time of my visit, the quinoa was not yet ready to be harvested. In the *Bacillus* experiments, the potatoes had already been harvested. Pablo indicated that the most obvious effect of the *Bacillus* additions was earlier potato flowering. Soils samples were taken on regular basis throughout the development of the potato crops and the newly introduced available phosphorus protocols will help determine if this change in phenology was due to higher level of available phosphorus in the *Bacillus* plots. Team Bolivia is in the process of analyzing the yield data from this experiment. Finally, the preliminary assessment of the irrigation optimization experiment was there was potential to reduce the intensity of the irrigation regime without a significant reduction in potato yields. However, a more thorough analysis of these data is necessary before any conclusions can be drawn.

At the other two field sites in the Tiraque region (Sank'ayani Alto and Cebada Jich'ana), the initial establishment of the oat –vetch cover crops for the primary CAPS experiment (that failed in 2010/2011) was outstanding. At both sites, there was a good balance between the oat and vetch components of the cover crop and I estimate the total biomass will approach 10 Mg ha^{-1} (Figure 3). Here, the treatment where the cover crop was to be removed from the field to be used for forage had just been completed (Figure 4). For the treatment where the cover crop residues where to be retained in the field, I encouraged Team Bolivia to terminate the cover crop with herbicides rather than cutting by hand. My rationale for this approach was that it would: 1) save considerably on labor; and 2) help keep the cover crop residues in place over the winter months. Team Bolivia agreed, and I worked with them to establish an appropriate herbicide (glyphosate + 2,4 D) application rate and to calibrate their sprayers (Figure 5).

In addition to the primary CAPS experiment at these two sites, Team Bolivia had also been collaborating with the Centro de Investigation en Forrajes (CIF) to evaluate different grass forage species to be used in conjunction with vetch. Although these data are still being analyzed, these experiments will provide valuable information on how to best optimize the intensive fallow phase of the CAPS cropping systems for soil fertility contributions and forage quality. Other collaborative activities initiated by Team Bolivia include the work with Centro de Investigacion, Formacion, y Extension en Mecanizacion Agricola (CIFEMA), where their collaborative focus is on the development of quinoa planter that can operate under high residue, conservation conditions.

As part of the 2011 growing season, Team Bolivia also conducted two field days for farmers in the Tiraque region. Here they had the opportunity to show case the various CAPS treatments, and get gender-based survey assessment of the farmer perceptions of CAPS. It was interesting to learn that farmers in general were interested in the cover crop systems, but mostly as a source of forage for their animals. This will be a potential dilemma if it is necessary to retain the cover crop residues in the field to achieve the CAPS goals of improving soil quality and crop productivity.

The laboratory training for the microplate determination of available nitrogen and phosphorus went quite well, considering the limited analytical chemistry experience of Team Bolivia. Given that lack of experience, I felt it was important to move through the protocols slowly and thoroughly, taking special attention to explaining why each step was occurring. As such, multiple practice runs for each of the protocols were performed. Both Ana Karina and Edino quickly adapted and exhibited considerable initiative to further adapt and improve the protocols (Figure 6). With this training, I am confident that Team Bolivia will be able to move ahead very soon on analyzing the back-log of soil samples that currently exists.

Finally, a data management plan was established with Team Bolivia. The following preliminary structure for the data files was agreed upon (bolded fields indicate separate directories).

1. **Field Site** (include files for baseline site information, such as longitude/latitude, site history, soil descriptions, etc).
    - **a. Year** (include files for weather data)
        - i. **Experiment** (include experimental objectives and hypothesis, design and plot maps, and pictures).
            1. **Soil Data**
                - a. **Chemical Properties**
                - b. **Physical Properties**
            2. **Plant Data**
            3. **Survey Data**

Key issues that I emphasized were:

1. Include indicator values for treatment, replication, year, etc.
2. Include sample units
3. Include notes on sample dates, sample protocols, and pertinent observations, such as non-uniform crop stand, pest pressures, treatment failures, etc.

I am in the process of looking into a “Drop Box” like data access systems so that all SANREM team members will have access to the data.

SANREM Ecuador

My work week began with Team Ecuador on April 23. April 23-25 were spend traveling to and from Guaranda and visiting the SANREM field sites with Victor Barrera and other members of Team Ecuador. Pablo Mamani, from SANREM Bolivia, was also in Ecuador during this time, and accompanied us to the field sites (Figure 7).

At the lower watershed (Alumbre) field sites, all three SANREM experiments looked very good and were proceeding as planned. The primary crop at this time was corn, which established well under the various reduced tillage regimes (Figure 8). Interestingly, under the conventional tillage regime, there was considerable corn stand reduction (Figure 9), apparently due to birds eating the seeds. In the reduced tillage regimes, weeds were controlled with an initial application of glyphosate just prior to planting, followed by an application of atrazine. Atrazine is a relatively inexpensive residue herbicide that tends to be quite effective in corn. However, it is also a potential contaminate of surface and ground waters that can adversely affect aquatic life. In time, we probably want to consider alternatives to this herbicide group.

At the upper watershed (Illangama) field sites, soil erosion was evident in all of the CAPS treatments (Figures 10 & 11), although was somewhat reduced in the treatments that contained water catchment ditches, reduced tillage and cover crop residue retention. Apparently, rainfall had been higher than normal in this region (Barrera, personal communication). As such, some of the replicates for the CAPS experiments were not accessible due to the roads being washed out at the time of the visit. With this level of erosion potential in the Illangama region, pasture (Figure 12) and perennial systems will be the best defense against soil lost. When cash crops such as potatoes, fava bean or small grains are being grown, inclusion of CAPS components, particularly the catchment ditches, seems imperative.

April 26 & 27 were spent in Quito working at the Santa Catalina experiment station with Dr. Soraya Alvarado, Arnulfo Portilla and other members of the soil science group. The reagents sent from the US that were necessary to conduct the microplate analysis of available nitrogen and phosphorus were still being held by customs. Administrators from INIAP, with the assistance of Jeff Alwang from Virginia Tech, were working to procure their release in the near future. However, I was able to demonstrate the use of the microplate using an alternative colorimetric protocol for ammonium determination. In addition, I did do a step-by-step review with Arnulfo and Soraya of the protocols for available nitrogen and phosphorus that we intend us in the future. Once Arnulfo has completed his undergraduate thesis, he will be the person primarily in charge of running these analyses. He is quite capable and I am confident that once he has the time to dedicate to these tasks that he will quickly be able to reduce the current backlog of samples associated with SANREM experiments. Soraya was confident that better progress on the analysis of the plant and soil samples would be made this next year after Arnulfo’s graduation.

The afternoon of April 27 was spent discussing the data management plan with Soraya and Victor. Both agreed that the data management plan outlined for SANREM Bolivia was also appropriate for SANREM Ecuador. Victor volunteered to be responsible for its implementation.

Suggestions and Recommendations

1. Gallagher needs to be in regular contact with the Teams in Bolivia and Ecuador to ensure that progress is being made on the analysis of the soil and plant samples from the SANREM experiments. Gallagher has all the necessary reagents and laboratory facilities at Presbyterian College, and could help trouble shoot any issues that may arise with these protocols
2. A “Drop Box” type file sharing needs to be established for the data management plans for both countries. Gallagher will follow up with Alwang to see if such a network can be established through Virginia Tech.
3. Gallagher and Stehouwer will need to assist both Teams in the analysis and consolidation of the plant and soil data.

Key Accomplishments

1. Successfully trained members of Team Bolivia and Team Ecuador in the laboratory protocols for the microplate analysis of available nitrogen and phosphorous.
2. Visited all the SANREM field sites (except Anzaldo in Bolivia), reviewing and adjusting the experimental designs, soil and plant sample protocols, and discussing the relevancy of the data obtained to this point.
3. Established a preliminary data management plan with Team Bolivia and Team Ecuador
4. Helped to facilitate collaborations between Team Bolivia and Team Ecuador.

Appendix: Daily Log

April 1, 2012: Drove from Clinton SC to Greenville/Spartanburg International Airport to pick up a rental car. Drove from the Greenville/Spartanburg International Airport to the Charlotte Douglas International Airport.   I departed from Charlotte to Miami, then on to La Paz. I departed from Charlotte so that my entire itinerary to La Paz would be with American Airlines and hopefully lessen the chance of delayed checked baggage that had occurred in all previous trips. Part of my checked baggage included the Chromate microplate reader and accessories for the PROINPA Soils Laboratory.

April 2, 2012: Arrived in La Paz with no issues, as did my checked baggage. However, the laboratory equipment was confiscated by the customs agents, claiming that import tariffs would likely need to be paid. I was put in contact with people from the PROINPA La Paz office, where they assisted me in dealing with the customs office.

April 3-4, 2012: Numerous steps were required to secure the release of the laboratory equipment from the customs office, including a copious amount of paper work and payment of tariffs. The equipment was released late in the day on April 4. Numerous members of the PROINPA staff worked with me through that entire process. With equipment in hand, I booked a flight for Cochabamba.

April 5, 2012: Traveled to the Tiraque region to visit the SANREM field sites. I was accompanied by Pablo Mamani (project director), Ana Karina Saavedra and Edino Gonzalez. We toured all three field sites in this region. Also collected cover crop samples (vetch/oat) with the PROINPA field staff.

April 6, 2012: National holiday.

April 7-8, 2012: Weekend.

April 9, 2012: In the morning, Team Bolivia gave an update on the progress on the field samples, sample analysis and data analysis. We began the review of the protocols for the chemical and physical soil quality indicators.

April 10, 2012: I instructed Ana Karina and Edino on the preparation of the reagents for the micropplate analysis of ammonium, and the use of the Chromate Microplate Reader and the Electronic Multichannel Pippett

April 11, 2012: Travelled to Tiraque and worked with Team Bolivia to calibrate their backpack sprayer for the application of glyphosate + 2,4 D, which was used to terminate the cover crop in the CAPS treatment were the cover crop residues were to be retained in the field.

April 12, 2012: Continued the training for the microplate analysis of available nitrogen.

April 13, 2012: Preformed trial runs on field samples of the analysis of available nitrogen.

April 14-15, 2012: Weekend

April 16, 2012: Refined available nitrogen protocol to reduce error. Reviewed new protocol with Ana Karina and Edino.

April 17, 2012: Out sick with food poisoning.

April 18 – 19, 2012: Trained Ana Karina and Edino in the protocol for microplate analysis of available P.

April 20, 2012: Reviewed the sample processing priorities and established a data management plan with Team Bolivia. Departed for La Paz later that evening.

April 21, 2012: Departed for Quito.

April 22, 2012: Weekend.

April 23, 2012: Picked up from the hotel by Victor after he retrieved Pablo from the airport. We all traveled first to the INIAP Santa Catalina Station, then on to Guaranda.

April 24, 2012: Toured the lower watershed (Alumbre) field sites with Team Ecuador and Pablo.

April 25, 2012: Toured the upper watershed (Illagama) field sites with Team Ecuador and Pablo. Returned to Quito.

April 26-27, 2012: Worked with Dr. Soraya Alvarado and Arnulfo Portilla on the microplate analysis of available nitrogen and phosphorus. Also established a data management plan with Soraya and Victor.

April 28, 2012: Returned to the US, via Miami - Charlotte – Greenville.

Figure 1. In the main CAPS experiment at the “Octubre 15” site in Bolivia, oats was established as a cover crop following the potato harvest in February. This cover crop should help scavenge nutrients from the oat/vetch cover crop that preceded the potato crop, and provide winter cover before quinoa is planted next spring.

Figure 2. At the “15 Octubre” field site, quinoa was direct seeded into an oat cover crop (back of picture) compared to conventionally tilled soil where the cover crop was removed (front of picture).

Figure 3. The oat/vetch cover crop at Sank'ayani Alto and Cebada Jich'ana sites in Bolivia did very well this season, after having completely failing last year. This success puts to rest the concern from last year that winter conditions at the Sank'ayani Alto site might be too severe for establishment of the vetch.

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Figure 4. As part of the primary CAPS experiments in Bolivia, the above ground biomass of the oat/vetch cover crop will be removed in one of the three treatments, and ostensibly could be used for animal forage. Yields in the following potato crop next season will be a good indicator if removal of this forage was detrimental to soil fertility.

Figure 5. In the primary CAPS experiments in Bolivia, treatments where the cover crop residues are to be retained on the plot, the cover crops will be terminated with herbicides.

Figure 6. By the end of the training period, Edino and Ana Karina, from Team Bolivia, could independently carry out the microplate protocols for available nitrogen and phosphorus.

Figure 7. The SANREM field sites were visited by Gallagher (left) and by Pablo Mamani (second from left) from SANREM Bolivia, guided by the field manager Luis and project leader Victor.

Figure 8. Corn planted directly into an oat/vetch cover crop. Catchment ditches and perennial vegetation strips were also part of this CAPS treatment.

Figure 9. In the conventional tillage treatments, corn stands were reduced considerably by birds eating the corn seeds before emergence could occur.

Figure 10. Under all the CAPS treatments in the upper water shed site (Illagama),erosion events were common.

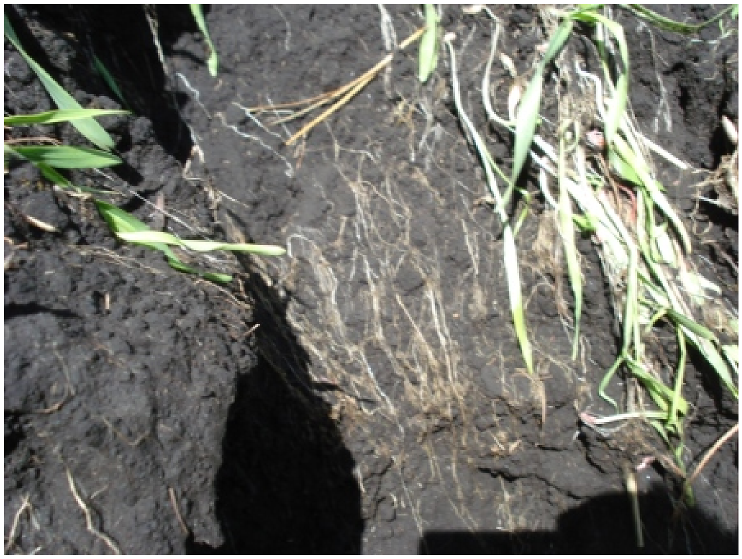

Figure 11. Even with an oat cover crop in place, erosion in the upper water shed experiments in Ecuador occurred. Here, roots from the oats have been exposed by the erosion.

Figure 12. Given the erosion potential in the upper watershed in Ecuador, pasture system are likely to be the most sustainable, but staple crops such as potato, fava beans, and small grains will not be produced.