Soils of the Firestone Center for Restoration Ecology

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Abstract

Understanding soil properties and taxonomy is essential for successful ecological management. Little soil research has been conducted at the Firestone Center for Restoration Ecology (FCRE) located in Barú, Costa Rica. In order to better understand land use history, soil genesis, and current soil morphology at FCRE, three soil profiles were described in detail based on a variety of physical properties. It was hypothesized that there would be an observable transition between possible valley Inceptisols and higher elevation Ultisols. There were observable differences between soil profile of different elevations along a transect, and tentative soil taxonomies were proposed. However, it was determined that additional chemical and mineralogical analysis for each diagnostic soil horizon is needed for accurate classification, including cation exchange capacity, clay minerology, percent clay content, percent soil organic matter, and more. Most of these data would require laboratory analysis, which is not currently available on site at FCRE. Despite these limitations, a tentative map of soil types at FCRE was created from twelve individual profiles morphological descriptions by compiling current and past data, showing mostly Ultisols at higher elevations and soils with Inceptisol (likely Dystrudepts) characteristics along the valley. Future work should focus on collecting data required for accurate taxonomic classification, surveying erosion rates and abundance, and creating a comprehensive soil management plan for the FCRE. Questions regarding general ecological management and research plans for FRCE are also raised in an effort to promote increase sustainability and more clarity for researchers. This research project can serve as a basis of current knowledge to be used for future soil research and for students at FCRE.

Introduction

Soil is the basis of terrestrial life. Most terrestrial ecosystems rely on soil for plant growth and as a source of storage. Soil and associated microorganisms fix atmospheric elements such as nitrogen and carbon, and act as storage for inorganic nutrients. Plant and leaf litter, once decomposed, is converted to soil, thus returning organic matter to the soil ecosystem for future plant growth (Lavelle and Spain, 2005). Soil ecology and soil science are complex and fascinating fields, which have only recently gained mainstream scientific acknowledgement due to the vitality of soil for ecosystem success. In addition to supporting the majority of terrestrial plant growth and providing habitat for animals, fungi, and microorganisms like bacteria, soils provide a variety of ecosystem services. Soils filter water and are also the basis of our agricultural system, feeding 7 billion people annually. Soils are closely related to anthropogenic climate change, and land use changes are a significant source of releases of greenhouse gasses such as CO_2, which is stored in soil (Soil Science Society of America, 2013). It would be difficult to overstate the importance of soil to human existence.

Why is it important to know soil properties and taxonomy? Differences in climate, organisms, relief, parent material, time, and human activity all influence soil genesis. Variation in these factors results in observable differences in soil characteristics. Soil taxonomy is a system that names and classifies soils based on these variations in physical and chemical characteristics (Brady and Weil, 2008). Due to the dynamic nature of soil, “the information that best captures the full picture of depth, horizon structure, minerology, and chemistry is a soil’s taxonomic name” (Schimel and Chadwick, 1999). By studying soil and classifying it taxonomically, we can learn about land use history, soil quality, effective land management, and the function of a given soil within its ecosystem. For instance, environmental management tools such as identifying soil loss tolerance limits rely on accurate analysis of soil qualities (Pretorius and Cooks, 1989). Physical soil properties such as soil texture can be used to help determine post disturbance succession and biomass accumulation for secondary forests (Johnson et al., 2012). A soil's taxonomy and properties can have implications for erosion rates and management of erosion. Soils are palimpsests, showing observable traces of past conditions yet are constantly changing. Studying land history and soil quality has meaningful implications for conservation work, ecological understanding, and environmental management (Foster et al., 2003).

Costa Rica has a diverse variety of soil types, with ten out of twelve soil orders represented. The two most common soil orders are Inceptisols and Ultisols (Henríquez et al., 2013). Geologically, the country used to be sub oceanic, and was formed by the compression of tectonic plates, resulting in uprising and volcanic activity. Costa Rica hosts a variety of ecosystem types including tropical rainforest, and has primarily Udic and Perudic soil moisture regimes (NRCS, 1997). Much of the country has been deforested and converted to pasture and agricultural land since the early-mid 1900's. For decades of Costa Rica's history, estimated soil losses due to land use changes, pollution, and erosion amounted to over 4.5 million US dollars annually (Solorzano et al., 1991). Soil health and quality have been proposed as ideal indicators for sustainable land use (Doran, 2002) (Herrick, 2000), and Costa Rica's soil and land use history diversity make it a dynamic location for soil research.

The Firestone Center for Restoration Ecology (FCRE) is located in Barú, within the Puntarenas province of Costa Rica. The land is owned and managed by Pitzer College (Claremont, CA, USA). FCRE was previously a working farm with expanses of pasture land in cleared forest area. However, due to conservation and restoration efforts, it currently hosts primary tropical forest and naturally regenerating secondary tropical forest, as well as riparian zones, recovering pasture, replanted hardwood forest, and planted bamboo habitat. As seen in Appendix 1, for undisturbed soils, the region surrounding the FCRE has been mapped generally as Ultisols (somewhat acidic soils often associated with tropical forest). Two projects had been previously conducted at FCRE relating to soil. Chen & Mahlab (2008) conducted surveying across multiple ecological types, collecting a variety of chemical concentration data. In 2013, research was conducted by James Gordon, assisted by Keck professor Colin Robins, as part of the Melon Project. This work consisted of sampling 9 plots across FCRE and creating soil profile morphology descriptions for each site (see Appendix 2). From this work, it was hypothesized that the property likely contains primarily Ultisols, but also Inceptisols, Oxisols, and perhaps Alfisols. In terms of geology, some work was conducted at FCRE by Rick Hazlett in mapping rock types. The uphill, western half of the property is rounded and coarsely crystalline igneous rocks, which transition to dipping, tabular-bedded sedimentary rocks starting about halfway down the slope.

Based on previous research, there were clearly gaps in knowledge regarding the soils of FCRE. One such gap was the Inceptisols near the Quebrada Cacua river on the eastern edge of the property. There was only one profile described that seemed to be an Inceptisol. I hypothesized that there would be an observable transition from Inceptisol to Ultisol when elevation and distance from the river increased. This hypothesis would be supported if plots at higher elevation along an east to west transect starting at the river contained characteristics consistent with Ultisols, and those a lower elevation were Inceptisols. In addition to investigating this hypothesis, there were two research goals; describing more soil profiles at FCRE, and creating a map of newly and previously described sites with tentative taxonomic classifications.

Though such classifications may require further research for accuracy, they can be helpful nonetheless as a starting point for taxonomic classification and management of soils at FCRE.

Methods

After reviewing soil data from previous research at FCRE, the river valley region along the eastern edge of the property showed some evidence of having soil properties not found elsewhere at FCRE. Thus, it was selected for further research. Initially, Farm Supervisor and Caretaker, Greddy Arias Rojas, was interviewed regarding land use and soil variations on the property. With his assistance, three sites were selected for analysis with the goal of having an East-West transect in an area hypothesized to be a transition zone between soil types. These sites were at varying elevations in secondary forest near the Quebrada Cacua river, the lowest portion of FCRE (see Figure 1). This area is within an unnamed watershed lying between the Upper North Creek and Terciopelo Creek watersheds, within the greater Quebrada Cacua river watershed.

At each of the three selected sites, the same procedure was followed. First, with the assistance of Greddy, and sometimes Farm Worker Carlos Antonio Mora Ureña, a pit was dug in order to view a clear soil profile. These pits were one meter wide and were dug to the depth of bedrock. The uphill wall of each pit was cut cleanly. After excavation, each individual horizon of the soil profile was identified. This involved visual observation of color and morphology differences, followed by physical textural analyses. Once identified, the boundaries between horizons were marked. Using the methodology and terminology criteria described in Schoeneberger et al. 2013, about twenty pieces of data were collected for each horizon. Depth of the horizon was measured from ground level in centimeters, and horizon boundary distinctness and topography was recorded. Though a Munsell soil color chart was unavailable, color was visually assessed and recorded for moist soils (all sampling occurred soon after/during rain events). Using a soil texture chart, texture was classified. Percent gravel composition was visually estimated, and gravel size was measured. Soil structure type, grade, and size were determined. Using hand tests for soil consistence, clod/ped rupture resistance, soil stickiness, and plasticity were classified. Size, quantity, and location was determined for both roots and pores. Redoximorphic features were also recorded. A sample of each horizon's soil was taken in a zippered plastic bag, with cobbles and roots removed. These samples were labeled then later dried and stored in the humidity controlled storage room at the ecology center of FCRE.

Following the data collection described above for each distinct horizon (excluding Oi and Cr horizons) the Schoeneberger et al. 2013 guide for horizon criteria was used to designate a classification name for each identified horizon. Before leaving each site, photographs of the profile were taken. A written description of each site was made, and elevation and slope were recorded using a smartphone application. Aspect of the profile was determined with a compass, and location was marked on a map. GPS location was also recorded, but satellite connection was poor so exact location is not certain.

After all soil sampling had been conducted, field notes were transcribed into full soil descriptions for each of the three profiles. These results and the United States Department of Agriculture Natural Resources Conservation Service's 2014 Keys to Soil Taxonomy were consulted to roughly classify the observed soils. Lastly, the soil plots were mapped along with 2013 soil profiles to visualize taxonomy estimates.

Results

The following are soil morphological profile descriptions for the three sites studied (pit 10, 11, and 12). The goal of this results section is to present accurate horizon descriptions and to justify horizon designations. All colors are for moist soils. All Bw horizon designations (as opposed to B, Bt, Bw, Bo, Bs) were determined partially based on lack of observable waxy clay coatings on peds and in pores. These horizons also lacked identifiable redoximorphic features. However, there were textural and other physical changes compared to the A horizons, such as increased plasticity or stickiness, indicating a degree of clayeyness, albeit somewhat weak. Color changes were observable between A and Bw horizons, but a Munsell soil color chart was unavailable for classification of these differences.

<u>FCRE Pit 10</u>

Described 4/28/2017 by Jack Halsey

Coordinates: 09° 16’ 51.79” N, 83° 51’ 43.66” W

Pit dug on slope between Waterfall Trail and creek running along Eastern edge of property; area had multiple patches of exposed sedimentary bedrock; pit dug between 2 converging creeks; west aspect; elevation 45 m; slope 35°; secondary forest vegetation; backslope profile position.

Oi – 0-5 cm; Mostly leaves, with some decomposition and small twig pieces.

A – 0-7 cm; brown; sandy loam; fine subangular blocky structure; friable, slightly sticky, moderately plastic; many medium roots throughout; medium tubular pores; clear smooth boundary.

Bw1 – 7-37 cm; reddish brown; sandy clay loam; fine subangular blocky structure; friable, moderately sticky, moderately plastic; common medium to very course roots throughout; interstitial pores only; 20% cobbles; clear smooth boundary.

Bw2 – 37-60 cm; reddish brown; sandy loam; fine subangular blocky structure; friable, moderately sticky, slightly plastic; few medium roots throughout; interstitial pores only; 5 % fine gravel; clear wavy boundary.

Cr – 60+ cm; dipping, tabular-bedded sedimentary rock, possibly shale.

Notes:
Munsell soil color chart not available for color analysis. Color difference between A and Bw1 was very slight, but observable. Gravel and cobbles were very different between Bw1 and Bw2.

FCRE Pit 11

Described 5/2/2017 by Jack Halsey

Coordinates: 9° 16' 51.837" N, -83° 51' 39.42"W

Pit dug slightly downhill from South Trail; west aspect; elevation ~90 m; slope 25°; secondary forest vegetation; backslope profile position.

Oi – 0-4 cm; Mostly leaves, with some decomposition and small twig pieces.

A – 0-10 cm; brown; clay loam; fine subangular blocky structure; friable, slightly sticky, slightly plastic; common fine roots throughout; few vesicular pores throughout; abrupt smooth boundary.

Bw – 10-33 cm; reddish brown; clay loam; fine subangular blocky structure; friable, moderately sticky, slightly plastic; few course roots throughout; few vesicular pores throughout; clear wavy boundary.

B/C – 33-80 cm; reddish brown; sandy clay loam; medium subangular blocky structure; friable, moderately sticky, slightly plastic; few moderately fine roots around rock fragments; few vesicular pores throughout; gradual irregular boundary.

Cr – 80+ cm; dipping, tabular-bedded sedimentary rock; weathered and crumbling.

Notes: B/C horizon was ~ 50% unconsolidated bedrock, with pockets of soil. B/C horizon had some rock material (slightly reddish, possibly sandstone based on texture) that was different than bedrock, perhaps deposited runoff from an uphill location.

FCRE Pit 12

Described 5/3/2017 by Jack Halsey

Coordinates: 9° 16' 51.898" N, -83° 51' 45.813" W

Pit dug on slope west of Waterfall Trail and about 5 m south of a dry creek bed of exposed sedimentary bedrock; west aspect; elevation ~65 m; slope 29°; secondary forest vegetation.

Oi – 0-5 cm; Mostly leaves, with some decomposition and small twig pieces.

A – 0-17 cm; brown; sandy loam; very fine subangular blocky structure; friable, slightly sticky, moderately plastic; common medium roots throughout; few fine tubular pores throughout; clear wavy boundary.

B– 17-49 cm; reddish brown; sandy clay loam; very fine subangular blocky structure; friable, moderately sticky, moderately plastic; very few coarse roots throughout; few fine tubular pores throughout; few, coarse, distinct, yellowish red iron-magnese or ironstone nodules, dry, spherical, in the matrix, weakly cemented, clear (Redoximorphic feature); gradual wavy boundary.

Cr – 49+ cm; dipping, tabular-bedded sedimentary rock, possibly shale.

Notes:
Munsell soil color chart not available for color analysis.

Discussion

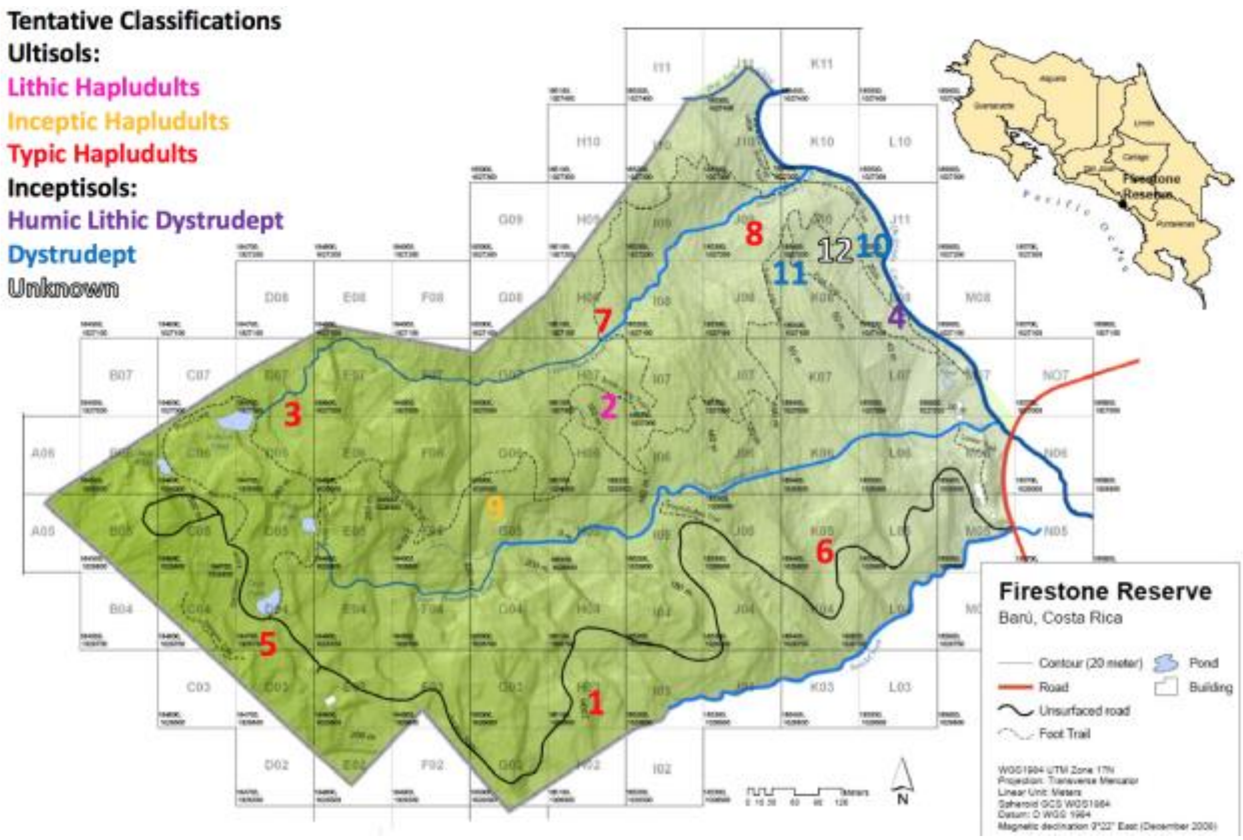
Due to lack of a Munsell color chart and chemical data (base saturation, sodium, bulk density, etc.), it's not possible to accurately classify the taxonomy of the 3 soil profiles observed for this study. However, it is possible to provide a tentative classification based on the soil profile descriptions in the results section. All three soil pits (10, 11, and 12) had observable O and A horizons. No profiles had strongly red soils, the reddest color observed was a reddish brown. Based on lack of redoximorphic features and no observable waxy clay coatings, pits 10 and 11 had Bw horizon classifications due to their relatively weak development. Based on observable characteristics, these profiles are best classified as Inceptisols, most likely a type of Dystrudept. There is currently not sufficient information to more accurately taxonomically classify these profiles further. Given the steep slope of this area, Inceptisol classification is intuitive, with topography making longer term weathering unlikely.

Pit 12 did have a few ironstone or iron-magnese nodules, leading to a B horizon classification, indicating redox. However, based on proximity to a creek, it's possible that this was deposited from uphill. Another possibility with this profile, as well as perhaps other profiles, is that these are polygenetic profiles, meaning they were developed from multiple sources. This land was once primary forest, which could have led to the development of Ultisols. Following deforestation for pasture grazing land, erosion of the top section of an existing Ultisol could have occurred. As reforestation and succession happened, a current Inceptisol could have formed, overprinting the existing Ultisol. This polygenetic theory is possible, but further research would be necessary to determine if this may have occurred or not. Given available data, it's not possible to make an accurate classification for pit 12, though there are several possibilities. This soil could be an Inceptisol, perhaps a Humic Lithic Dystrudept, or some type of Ultisol (Soil Survey Staff, 2014)

Of the nine pits (seen in Appendix 2) described by Gordon and Robins in 2013, the majority had characteristics of Ultisols. Though exact classification is not possible due to lack of mineralogical and chemical data, it's possible to conservatively estimate these soil's taxonomies. Assuming an argillic and not kandic horizon (which laboratory testing could determine), pits 1-3 and 5-9 could be classified as Ultisols, specifically, Hapludults (Robins, 2013). The shallowest pit, 2, with bedrock less than 50 cm from the surface, could be tentatively classified as a Lithic Hadipult (Soil Survey Staff, 2014). Pit 9, with its clay rich horizon less than 25 cm thick, could be considered an Inceptic Hadipult. Based on their soil profile descriptions, sites 1,3,5,6,7, and 8 could all be considered Typic Hadipults based on the keys to taxonomy guidelines (Soil Survey Staff, 2014). For all potential Ultisol classifications, low organic matter content for subsurface horizons is assumed. These areas were all at one point primary tropical forest, though land use has changed over time in some areas to pasture, secondary forest, and bamboo plantations. Still, current soil is typical of being formed in an udic or perudic moisture regime with tropical forest. The last soil pit sampled, pit 4, can be classified as a likely Humic Lithic Dystrudept, an Inceptisol, based on the shallow depth to bedrock and the accumulation of organic matter. It's located near a river in an area that sometimes experiences flooding. Ongoing erosion and sediment deposition are likely explanations for the apparent young age and shallowness of this soil profile.

The higher elevation, western part of FCRE has been mapped as primarily Ultisols based on available data (this area covers most of the property). At elevations under 100 meters near the eastern valley, soils appear to transition to primarily Inceptisols, especially at the lowest elevations (Pits 4 and 10) nearest the river. The available data do support the stated hypothesis of this project that there would be an observable transition zone between the two soil orders, though a specific association with elevation was not apparent. While the taxonomy of these sites is tentative and requires further data for accurate classification, Figure 1 can serve as a helpful general guide for future research and environmental management efforts.

Figure 1. Map of Firestone Center for Restoration Ecology soils (adapted from Roberts 2009). The approximate location for each pit for soil profile evaluation is marked with its respective number. The color of each number corresponds to a tentative soil taxonomic classification, but definitive taxonomy has not yet been determined.



There were a variety of shortcomings associated with conducting this project. Firstly, no Munsell color chart was available for accurately identifying soil color (hue, value, and chroma). This was a major limiting factor in accurately classifying surveyed soils taxonomically. The lack of a Munsell color chart also diminished the accuracy of redoximorphic feature descriptions. For future soil research at FCRE, having access to this chart is vital for determining color accurately.

The second major shortcoming of this project, and Gordon and Robins' work in 2013, was chemical and mineralogical analysis not being conducted due to equipment constraints. For future work, some chemical analysis such as CEC, organic matter, pH, and base saturation, could be conducted at the University of Costa Rica's soil laboratory (Centro de Investigaciones Agronómicas) in San Jose. It should be kept in mind that this testing can take several weeks. For fully accurate taxonomic classification of soils at FCRE, "analysis of percent soil organic matter content, percent organic carbon content, bulk mineralogy, percent clay content, clay mineralogy, cation exchange capacity, and percent base saturation" is required for samples from every horizon (Robins, 2013). These data could be collected at the Claremont Colleges, but unfortunately a USDA foreign soil lab certification would be necessary, as foreign soil import autoclaving would compromise soil analysis. These processes could take a significant amount of time to complete. Thus, it would be ideal if equipment necessary for some analysis could be purchased and used at FCRE during future research (Robins, 2013). Such equipment might also be useful in testing soils from farms, pastures, or forests owned by other individuals or organizations in the region. Such research could be conducted by Claremont Consortium students and faculty, or even individuals with different university affiliations.

In addition to chemical and mineralogical analyses to determine soil taxonomy at FCRE, there are many research opportunities relating to researching additional soil types within FCRE. According to observations by Robins (2013), there are likely Oxisols with accumulations of bauxite north of the field station at FCRE. Additionally, there are possible Alfisols located near the drainage at the southern edge of FCRE. Future studies could be done to describe and analyze profiles in these areas to better understand the diversity of soil orders on site. Further studies relating to previously unstudied regions will also help to aggregate data for more detailed mapping efforts in the future.

With more data available to begin classifying soil taxonomy at FCRE, at some point in the near future it will be important to create management goals and plans relating to soil. By combining soil knowledge with existing ecological management tools and establishing goals for sustainability, soil quality information can help drive land management decisions (Doran, 2002). Conversely, effective land management goals must include addressing the maintenance and restoration of health soils. Soil quality acts as the ideal indicator for sustainable land management, and its assessment and the results of such assessment should be holistically incorporated into strategic ecological planning (Herrick, 2000). Herrick (2000) and Doran (2002) elaborate significantly on these ideas, emphasizing that soil quality can be used as a tool for monitoring the success of such ecological management efforts.

What are important aspects of a land management strategy for FCRE relating to soil? Firstly, research on erosion should be conducted, and goals created regarding research priorities. This could include evaluating taxonomic differences in erosion, measuring erosion rates, analyzing plant cover across the land use types, and other erosion related research. From this, better management decisions and strategies can be made based off more holistic data. Moving past erosion studies, there’s a general advantage to identifying what’s know about local soil taxonomy, and what needs to be learned/studied further. It’s important to determine goals for future soil research, which at some point can expand past implications for FCRE and delve into more widespread soil science/ land management understanding. For a US educational institution, Pitzer College is unique in having private ownership and established study abroad program with incorporated research projects in Costa Rica. This can (and will) continue to provide an invaluable research experience for students and professors alike. Environmental analysis students can incorporate their own field with soil science, ecology, and/or land management to craft innovative research projects. Examples of previous Costa Rica based research in these fields include studies into the relation of leaf litter nutrients to precipitation levels in tropical forests (Wood et al., 2005) and investigations of post disturbance soil carbon accumulations (Foote and Grogan, 2010). Shifts in bacterial community structure between pasture and forest vegetation have been studied in tropical soils (Nüsslein and Tiedje, 1999) and could be used for inspiration at FCRE, where natural secondary forest succession into previous pasture land can be observed in real time by students.

When thinking about sustainable land management and research at FCRE, several questions came to mind regarding Pitzer College's involvement. What are institutional and faculty goals for specific research, and broader goals for development of research at FCRE? To what degree will faculty lead the development of sustainable management goals, and how much will students be involved in such processes? What does the future of research at the FCRE look like in terms of infrastructure and laboratory equipment? What might sources of funding (grants private donors, annual college budget) be for such research endeavors? As the managing body of a restoration ecology site, Pitzer College might gain from developing both short and long term plans for FCRE more concretely to ensure sustainable land management.

Conclusion

Through field descriptions of soil at FCRE, it was possible to provide tentative soil taxonomic classifications. These classifications help to further our understanding of tropical soils at FCRE. Additionally, a basic map of soil types was created, combining past and current research. This project can be used as a general basis of knowledge for education and soil science at FCRE. Still, there is a great need for additional future research, especially research addressing accurate taxonomic classification through chemical and mineralogical testing, as well as erosion studies. Such soil research can be combined with land management planning to help ensure healthy ecosystems at FCRE. Additionally, soil research can be conducted that has scientific implications beyond FCRE. Pitzer College has a unique opportunity with its land and field station, and planning efforts should aim to maximize future research and educational opportunities.

Acknowledgements

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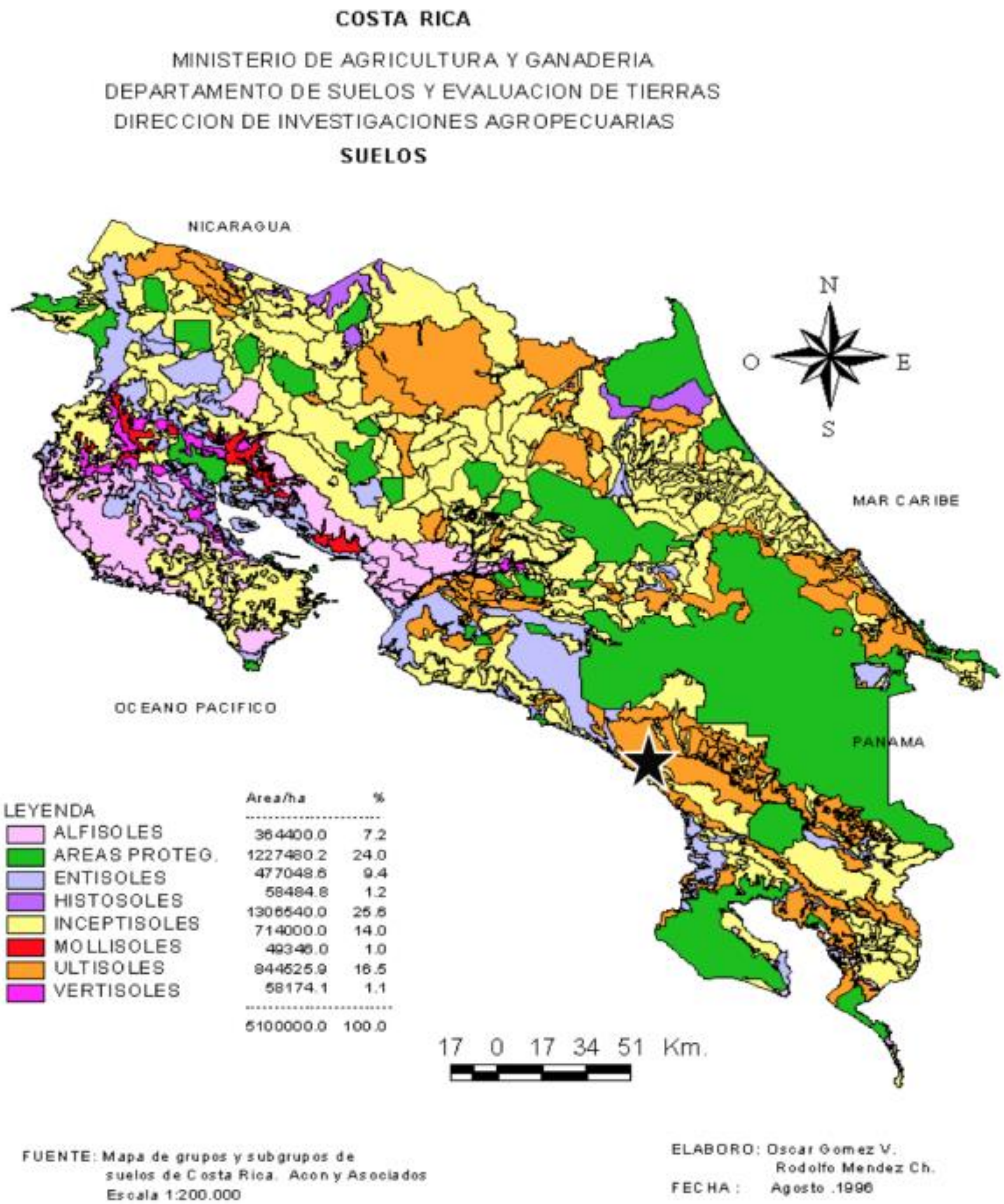
Appendices

Appendix 1: Map of Costa Rica's Soil orders (Gomez and Mendez, 1996). Black star indicates approximate location of Firestone Center for Restoration Ecology.



Appendix 2: Unpublished data primarily collected by James Gordon for the Mellon Project in 2013. Similar methods were used as in Gordon's study and this 2017 study (a continuation of sorts). All colors are for moist soils.

FCRE Pit 1

Described 5/28/13 by J. Gordon and C. Robins

Coordinates: 09 16' 31.314" N, 083 51' 57.570" W

Exposure in a roadcut along the FCRE access road, near the FCRE's bamboo hut. Rounded granodiorite boulders seen throughout the profile; south aspect; 292.39 m elevation; 15-20 degree slope.

Oi- 0-7 cm; abrupt smooth contact.

A- 0-12 cm; dark reddish brown (7.5YR 4/6); silty clay loam; fine to medium subangular blocky structure; friable, slightly sticky, moderately plastic; many fine to medium roots throughout; very fine to fine dentritic tubular pores; iron masses (redoximorphic feature, or RMF) seen in up to 2% of peds and faint clay linings seen in pores and ped surfaces; abrupt smooth boundary.

Bo – 12-58 cm; reddish brown (7.5YR 3/4); clay loam; medium to fine subangular blocky structure; friable, slightly sticky, moderately plastic; many fine to medium roots throughout; very fine to fine dentritic tubular pores; iron masses (RMF) seen in 40% of peds and faint clay linings seen in some pores and ped surfaces; abrupt smooth boundary.

Bo – 58-117 cm; light reddish brown (5YR 4/6); clay loam to silty clay loam; medium subangular blocky structure; friable, moderately sticky, moderately plastic; some fine to medium roots throughout; very fine to fine dentritic tubular pores; iron masses seen in 10% of peds with some very faint clay surface coating; gradual smooth boundary.

Bo – 117-190+ cm; light reddish brown (5YR 4/6); clay loam to silty clay loam; fine to medium subangular blocky structure; friable, moderately sticky, very plastic; some fine to medium roots throughout; very fine to fine tubular and irregular pores with some fines dendritic tubular pores throughout; iron masses seen in 10% of peds with some very faint clay surface coating; boundary not observed.

Notes: Becomes increasingly redder, more plastic.

FCRE Pit 2

Described 5/29/13 by J. Gordon and C. Robins

Coordinates: 185123 1026961 UTM Zone 17N, 09 16’ 44.154” N, 083 51’ 56.795”W

Hole excavated near South Loop Trail; very close to granodiorite-sedimentary rock geology contact; east aspect; elevation 197.8 m; slope 20 degrees; backslope profile position.

A – 0-10 cm; light reddish brown (5YR 4/6); silty clay loam; medium subangular blocky structure; friable, moderately sticky, very plastic; many fine to medium roots throughout; many very fine tubular pores throughout; clear smooth boundary.

BA – 11-23; very light reddish brown (2.5YR 4/8); silty clay loam; coarse subangular blocky structure; friable, moderately sticky, moderately plastic; some fine to medium roots throughout; fine to very fine tubular pores; gradual smooth boundary.

Bo – 23-51 cm; reddish brown (5YR 5/8); silty clay loam; coarse subangular blocky structure; friable, moderately sticky, moderately plastic; few roots; very fine tubular pores; clear irregular boundary.

BCr – 51-63+; extensively weathered and oxidized siltstone. Has bright red (2.5YR 4/8) iron stained matrix and black (2.5YR 2.5/1) manganese stains with gray depletions (2.5YR 7/1). These features are pervasive and prominent with fairly abrupt boundaries, and original rock structure is preservered.

Notes: Looks like red soil with diffuse, faint organic stains; “boxwork” structure of red clay throughout peds. Becomes increasingly red, then less red as soil hits bedrock.

FCRE Pit 3

Described 6/2/13 by J. Gordon

Coordinate: 09 16’ 44.448” N, 083 52’ 10.158” W

Exposure next to Basilisk Pond, near trailhead. west aspect; rounded granodiorite boulders throughout profile; 5 degree slope; elevation 285.89 m; bamboo vegetation.

Oi – 0-5 cm

A – 0-14 cm; dark reddish brown (10YR 3/6); silty clay loam; fine subangular blocky structure; friable, moderately sticky, moderately plastic; many roots throughout; dendritic tubular and tubular pores; waxy clay coats throughout peds; clear wavy boundary.

Bo – 15-43 cm; light reddish brown (5YR 4/6); clay loam; fine subangular blocky structure; friable, moderately sticky, moderately plastic; some roots throughout; very fine tubular pores; waxy clay coats throughout peds; gradual smooth boundary.

Bo – 44-75 cm; light reddish brown (5YR 5/8); silty clay loam; fine subangular blocky structure; friable, moderately sticky, moderately plastic; some roots throughout; very fine tubular pores; waxy clay coats throughout peds; clear smooth boundary.

Bo – 76-110 cm; *same as above*: light reddish brown (5YR 5/8); silty clay loam; fine subangular blocky structure; friable, moderately sticky, moderately plastic; some roots throughout; very fine tubular pores; waxy clay coats throughout peds; clear smooth boundary.

Cr – 110-160+; rounded granodiorite boulders.

Notes: In first B horizon, some weathered rong with manganese stains. In third B horizon, some sparkly, sugary grains visible in peds – sand coat? Similar reddish brown soils to Pit 1 (which was roughly the same elevation on the property).

<u>FCRE Pit 4</u>

Described 6/4/13 by J. Gordon

Coordinates: 09 16’ 49.272” N, 083 51’ 42.966” W

Pit near student dorms, along waterfall trail and the lower side of the FCRE property; sedimentary rocks; east aspect; elevation 46.70 m; footslope profile position; 10 degree slope.

A – 0-15 cm; reddish brown (7.5YR 3/3), sandy clay loam; fine to medium subangular blocky structure; friable, slightly sticky, moderately plastic; many roots; irregular pores; very faint, if any, iron concentrations; some red-brown throughout the dominant gray-brown matrix; clear smooth boundary.

B – 15-38 cm; reddish brown (7.5YR 3/4); sandy clay loam; fine subangular blocky structure; friable, slightly sticky, moderately plastic; some roots; irregular pores; waxy (red) clay exteriors throughout; clear smooth boundary.

Cr – 38-45+ cm; very weathered sandstone bedrock.

Notes: Relatively brown soils compared to higher up on the property. This area regularly floods during rainstorms.

<u>FCRE Pit 5</u>

Described 6/6/13 by J. Gordon

Coordinates: 09 16’ 34.481” N, 083 52’ 10. 860” W

Pit on the summit of property along border w/ Hacienda Baru and near Banana Trail. Rounded granodiorite boulders; elevation 337.2 m; west aspect; ~15 degree slope; shoulder profile position.

A – 0-18 cm; reddish brown (7.5YR 3/4); clay loam; fine to medium subangular blocky structure; friable, slightly sticky, moderately sticky; some roots; tubular pores; waxy clay exteriors throughout; clear smooth boundary.

Bo – 18-36 cm; light reddish brown 5YR 4/6; clay loam; fine to medium subangular blocky structure; friable, slightly sticky, moderately plastic; some roots; tubular pores; waxy clay exteriors throughout; clear smooth boundary.

Bo – 37-61+; light reddish brown 5YR 4/6; clay loam; fine to medium subangular blocky structure; friable, slightly sticky, moderately plastic; some roots; tubular pores; waxy clay exteriors throughout; boundary not observed.

Notes: Relatively easy digging – soil was soft red clay – but area had a ton of ant nests. Accidentally dug into one of the wide holes apparently being used by the ants. I eventually had to stop digging at ~50 cm or risk getting eaten alive. Still, bright red soils apparent, clear differences between soils downslope (the soils more prone to weathering from rainwater).

<u>FCRE Pit 6</u>

Described 6/8/13 by J. Gordon

Coordinates: 09 16’ 37.728” N, 083 51’ 46.901” W

Exposure along access road (eastern side, near FCRE program house); sedimentary rocks; elevation 163.19 m; north aspect; backslope profile position.

A – 0-30 cm; dark reddish brown (10YR 3/4); sandy clay loam; fine to very fine subangular blocky structure; friable, moderately sticky, moderately plastic; some roots; tubular pores; iron concentrations (or clay depletions – red areas surrounded by gray-brown); some waxy clay exterior; abrupt smooth boundary.

Bo – 30-56 cm; reddish brown (10YR 3/4); sandy clay loam; fine to medium subangular blocky structure; friable, slightly sticky, moderately plastic; some roots; tubular pores; iron concentrations (or clay depletions – red areas surrounded by gray-brown); some waxy clay exterior; gradual smooth boundary.

Bo – 58-87 cm; reddish brown (7.5YR 4/6); clay loam; fine to medium subangular blocky structure; friable, slightly sticky, very plastic; some roots; tubular pores; waxy clay exterior; clear wavy boundary.

BC/C – 87-121+ cm; reddish brown (7.5YR 4/6); clay loam; fine to medium subangular blocky structure; friable, slightly sticky, very plastic; some roots; tubular pores; waxy clay exterior; boundary not observed.

Notes: Darker soils on the top horizons than the access road exposure farther up (see pit 1). Becomes reddish soils abruptly between A horizon and first B horizon. Last two B horizons have similar features, but there is clearly more bedrock in the lower horizon.

FCRE Pit 7

Described 6/10/13 by J. Gordon

Pit in the primary forest, near intersection of stream and FCRE N. Loop Trail; east aspect; steep (slope ~30 degrees); backslope profile position.

Oi – 0-5 cm

A – 0-20 cm; dark reddish brown (10YR 3/4); clay loam; fine to very fine subangular blocky structure; friable, slightly sticky, moderately plastic; many fine roots throughout, some coarse roots throughout; few fine dentritic tubular pores; few faint iron concentrations; clear smooth boundary.

B – 21-50 cm; dark reddish brown (10YR 4/6); clay loam; fine to medium subangular blocky structure; friable, slightly sticky, moderately plastic; few faint clay depletions; some waxy clay exterior throughout; clear smooth boundary.

B - 21-58+ cm; reddish brown (7.5YR 4/6); clay loam, fine to medium subangular blocky structure; friable, slightly sticky, moderately plastic; few fine roots throughout; waxy clay exteriors throughout; boundary not observed.

FCRE Pit 8

Pit described 6/12/13 by J. Gordon

Coordinates: 09 16’ 53.123” N, 083 51’ 47.837” W

Pit along lower portion of FCRE S. Loop Trail; sedimentary rocks; steep (slope ~25 degrees); elevation 102.5 m; backslope profile position.

Oi not visible

A – 0-11 cm; reddish brown (7.5YR 4/6); clay loam; fine to medium subangular blocky structure; friable, slightly sticky, moderately plastic; many fine roots throughout; fine to very fine tubular pores; streaks of clay depletion in 10% of peds; very waxy clay exterior throughout; clear smooth boundary.

Bo – 11-49 cm; light reddish brown (5YR 4/6); silty clay loam; fine to medium subangular blocky structure; friable, slightly sticky, moderately plastic; many fine, some coarse roots throughout; very fine tubular pores and fine dentritic tubular pores; very waxy clay exterior throughout; clear irregular boundary.

Cr – 50-60+ cm; loose, weathered sandstone

Notes: steep backslope

<u>FCRE Pit 9</u>

Pit described 6/13/13 by J. Gordon

Coordinates: 09 16’ 40.842” N, 083 52’ 2.748” W

Pit near the Terciopelo Stream, Upper Loop Trail; rounded granodiorite boulders seen around pit site; very steep slope (~30 degrees); elevation 252.89 m; backslope profile position.

Oi not visible

A/B – 0-14 cm; reddish brown (5YR 3/4); sandy clay loam; fine to medium subangular blocky structure; friable, slightly sticky, moderately plastic; few very coarse roots and many fine roots; fine dentritic tubular pores and fine tubular pores; waxy clay exterior throughout; gradual irregular boundary.

Cr- 15-38+; highly weathered volcanic rock; manganese and iron oxide stains prominent.

Notes: Very steep slope. Almost immediately started hitting weathered bedrock with my shovel and could barely dig after 25 cm or so.