COMPARISON OF TILLAGE PRACTICES ON SOIL HEALTH IN THE LOWER COLORADO RIVER BASIN REGION OF THE SONORAN DESERT

by

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ABSTRACT

There is interest in learning how agriculture impacts the greater desert riparian ecosystem. Focus on tillage practices revealed information as to how soil functions on rotation and mono-crop managed systems in comparison to undeveloped land. The purpose was to determine if tillage increased soil health. The secondary question looked at the effect non-tilled soil has on biological activity. Background research studies focused on measuring potential indicators of soil health or quality. Three adjacent fields in the Lower Colorado River Basin in Arizona were used to measure indicators of soil health. Each field differed by tillage and crop management system. Soil health testing methods for biological, chemical and physical indicators were conducted through laboratory analysis and fieldwork. Colony forming units and laboratory soil analysis indicated soil organic matter and soil bacteria were higher as tillage levels increased. Physical indicators of moisture, compaction, and texture showed soil composition of tilled soils was similar to, but not the same in to no-till. Biological indicators showed that except for bacteria colonies, biological activity was highest in reduced and no-till levels. This revealed that conventional tillage is a good habitat for soil bacteria but it potentially does not provide for a diverse number of organisms. The overall assessment showed that each tillage level offered benefits to the soil ecosystem.

INTRODUCTION AND BACKGROUND

Project Background

Researcher's Background

There are some things a person feels they want to accomplish in life. It is usually a challenge, something they need to learn before attempting, and is dependent on will. What prompts the idea to set about on such a goal may relate back to a prior experience, formally or informally learned.

When I began working on my action research project, there surfaced a lingering question and unfulfilled goal in conducting scientific field research. I'd been curious about agriculture in the desert climate. Working with my advisors and learning more about soil helped me pursue this in a manner beneficial to my future science endeavors and teaching.

Research Question

My question sought information as to how soil functions on rotation and mono-crop managed systems in comparison to unmanaged land. Current soil health testing methods for biological, chemical and physical indicators appropriate to the Sonoran Desert region of Arizona were used. Figure 1 shows the location of the Lower Colorado River Basin, one of six subdivisions within the Sonoran Desert (Dimmitt, 2014).

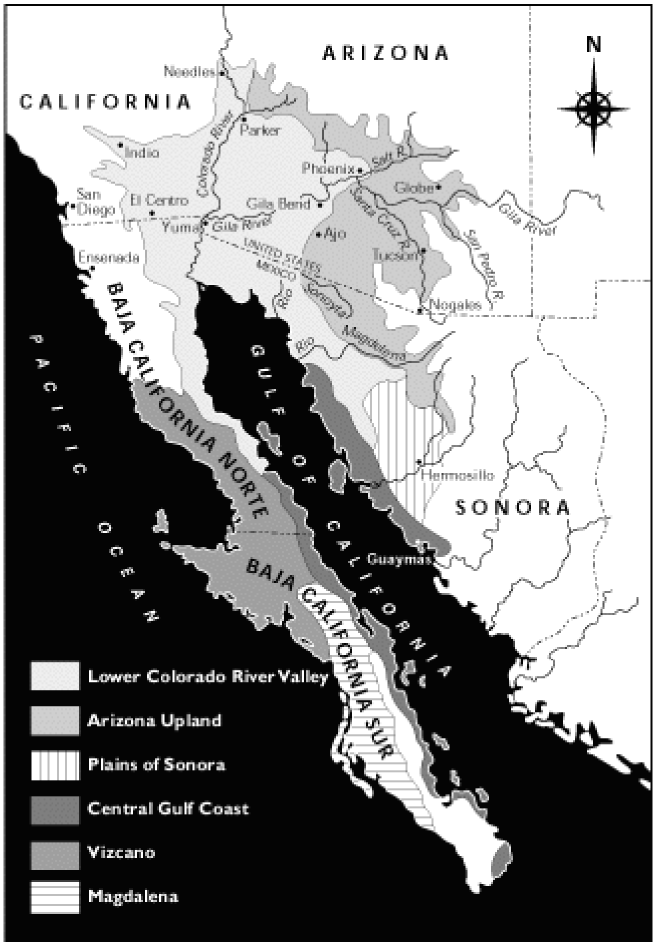


Figure 1. Map of the Sonoran Desert.

The purpose of my study was to determine if agricultural practices in desert landscapes increased soil health. I was interested in learning how agriculture impacts the greater desert riparian ecosystem.

My primary science research question was:

What is the impact of tillage on soil composition around the Lower Colorado River Basin?

My sub research question was: ***What effect does non-tilled soil have on biological activity?***

The dependent variables were the chemical, physical, and microbial soil characteristics. The independent variable was the level of soil tillage. The testable hypothesis was, "Soil composition and structure changes by varying tillage practices."

Support Team

My support team was a combination of people with different experiences. One member has work experience in soil science and education, another in science education, one in education, and a fourth in soil science.

My science chair adviser, Suzanna Soileau, is a soil scientist and educator. She has both experience with field studies and scientific writing. I had the benefit of taking a soils course with her before beginning my research. She was helpful in describing what variables to consider and guiding me throughout the entire action research project.

My education adviser, Walter Woolbaugh, is a professor of science education. He taught me the action research process. His unwavering support of my work was best felt as I changed my project to a science-based focus. As my reader, he gave feedback on multiple facets, including the value of this research to future science education.

Another member, Steve Tourdot, is a teacher and co-worker recently retired from teaching art in public schools. He assisted me in taking field measurements and helped me with concluding questions and interpretation of data. Being raised on a dairy farm in the Midwest, he has an understanding of social issues surrounding agriculture and land management.

My fourth member, Clark Webb, is a crop care specialist. He helped me decide on testing techniques and helped with soil and agriculture questions when I conducted my science research. He is familiar with soil sampling, as he does it on a regular basis for local farms. His help was most valuable when it came to data collection and analysis.

CONCEPTUAL FRAMEWORK

When researching soil, I narrowed down my review to articles focused on the topics of soil health, desert soils, and applicable methodology. This helped me learn about soils and ecosystems based on the soil taxonomy closest to my site.

Soil Health

Soil health is a term used to characterize the integrated functions of soils (Grandy, Billings & Richter, n.d.). As such, soil is viewed as an ecosystem or living community (Haberern, 1992). It is often compared to and used synonymously with soil quality, which is a way of discerning how well soil functions in an ecosystem to sustain plant and animal productivity (Kinyangi, 2007). Thus, soil health takes on a broader scope than soil quality. From scientists to farmers, one term is preferred to another for different reasons.

Soil health can't be assessed directly, but there are many indicators that can be measured to determine the health (Kinyangi, 2007). These indicators can be biological, chemical or physical. Some examples are fungi, soil organic matter (SOM), mineral nutrients, pH, porosity, bulk density, and soil moisture. A more recent approach has been to search for indicator organisms and stress tolerance connected with healthy or deteriorated soil (van Bruggen & Semenov, 2000). Indicators of soil health have stronger correlations depending on the climate, geographic and anthropogenic influences on the soil tested. Climate, parent rock and topology play a part in deciding what the indicators should naturally be for each soil, adding to the complexity. The importance of indicators sometimes varies by constituent like farmers, land use managers, soil conservation organizations, and government agencies. In a survey of the top 50 properties of soil quality, farmers ranked soil organic matter number one and crop appearance number two (Romig, Garlynd, Harris and McSweeney, 1995). Tillage is an anthropogenic influence, and it impacts agricultural soil health. According to Romig et al. (1995), "…Farmer understanding of management effects on soil health appear to warrant scientific investigation to interpret and predict the consequences of management on soil quality" (p. 235). Where farmers tend to use descriptive characteristics to evaluate soil health, scientists use quantitative results (Romig et al., 1995). Assessing soil health is necessary to evaluate levels of degradation and other changes after different land use and management interventions according to Lal (as cited in Kinyangi, 1997).

Researchers have developed tools to make measuring soil health simpler. The National Resources Conservation Service (NRCS) has "Soil Quality Indicator Sheets" on its website that have made selecting appropriate indicators as easy as possible for farmers, researchers, and policy makers (United States Department of Agriculture [USDA], 2009). They developed a matrix showing how each indicator relates to a soil function (USDA, 2009). Making a minimum data set, MDS, of appropriate indicators has also been a way researchers have tried to make soil health easier to measure (Idowa, van Es, Abawi, Wolfe, Schindelbeck, Moebius-Clune & Gugino, 2009; Janvier et al., 2007). A good MDS should include ecosystem processes, be sensitive to climate, be components of existing soil databases and be accessible to many users (Idowa et al., 2009). Still it is a challenge to know what indicators to test (USDA, 2009; Idowa et al., 2009). To simplify the process, Cornell Soil Health developed a set of 15 indicators. (Idowa, et al., 2009). Their "Soil Health Testing" document is useful to interpret measurements (Department of Horticulture, 2009). Streamlined indicators make it easier for farmers and land managers to scientifically assess soil health (Doran & Zeiss, 2000). To track soil health, long-term experiments are emphasized to obtain accurate measurements of indicators (Lal, 1997).

Desert Soils

Historical and recent data has been collected on soil in desert ecosystems. The last published soil survey of the Yuma area, by author Russell Barmore (1980), provided geologic history of the study region. The survey contains climate and soil measurements specific to 1,628 square miles around Yuma, including Yuma Mesa and Yuma Valley. It served as a good resource for historical geology of the area. A graph of salinity trends, wildlife and plant lists were provided for each map symbol, however the map was not available. The NRCS (2012) now has an online soil program that has modernized the older soil surveys like, "Soil Survey of Yuma-Wellton Area" (Barmore, 1980). I used this program to create a map from satellite images of my study sites. The NRCS web soil survey (2012) was useful in providing soil data specific to the coordinates of the study site. Yet, it was limited in retrieving soil data for small, one square meter sampling plots like I used. Data specific to the biological and chemical activity for my study site was not available in these soil surveys.

A variety of biological and chemical indicators have been used to detect soil health in arid climates. In undeveloped desert soil, one study found significant increase in N and P among three woody plant species. It referenced the “islands of fertility” effect, as nutrient levels were greater around plants following mortality or microsite succession (Butterfield & Briggs, 2008). Researchers proposed a correlation of the size of the plant and type of plant to the nutrients available for future plants. For example, succulent species had less growth to trap nutrients from wind and block sunlight. SOM and ammonium were found to have only slight increases overall. The relationship of abiotic and biotic factors added new insight into the function of forbs and shrubs in desert ecosystems. As a biological indicator, plant type could indicate certain chemical properties in desert soils.

A second study compared respiration rates of organisms on bare soil to vegetated soil and course-texture to fine-texture soil (Cable, Ogle, Williams, Weltzin & Huxman, 2008). This study was also conducted in the Sonoran Desert region. They focused testing on precipitation and climate change effects on soil respiration for plots varying in plant coverage. High precipitation rates caused high respiration rates in highly vegetated fine-textured soil, but they had little impact on vegetated and bare coarse-textured soil. These findings indicated that precipitation and irrigation levels would not be needed to measure quantitatively for my purpose, only qualitatively recorded.

In a study of total organic carbon, or TOC, Staben (1997) compared soil biomass and chemical levels of reclaimed and tilled farmlands in Eastern Washington State. pH decreased over time in tilled land, and increased slightly in reclaimed land. The reclaimed land had 100% cover of cryptogamic crust, bunch and wheat grasses. Bacterial biomass was greater in the reclaimed fields; fungal biomass was more common in tilled fields (Staben, 1997). This study provided a good model for assessment of cultivated and uncultivated arid areas.

Recent biological studies have found evidence of higher levels of biomass, or carbon content, in non-cultivated desert soils than had previously been found (Butterfield & Briggs, 2008; Andrew, Fitak, Munguia-Vega, Racolta, Martinson & Dontsova, 2012). Microbial activity in cacti rhizospheres and surrounding soil communities was the subject of study at three different locations in the Sonoran Desert (Andrew et al., 2012). High amounts of bacteria of varying phylums were discovered in the desert soils using a DNA pyrosecquencing technique. Physical and chemical soil properties, including pH, percent carbon, electrical conductivity, and soil particle size distribution had correlation with the differences between locations. Andrew et al (2012) found "… available carbon, not nitrogen, is a limiting factor in driving local microbial diversity in these environments. Interestingly, given the scarcity of water in this desert ecosystem, available water content was not correlated with microbial diversity," (p. 9). Soil characteristic and geographic location were primary factors; rhizosphere secondary in the diversity of microbial communities. Besides ease of sampling, this was a strong reason for choosing sampling locations within close proximity to each other.

Applicable Methodology

The desert soils articles showed what indicators I might include in my MDS. Next, I searched methods to measure indicators specific to the study site conditions. Alternative methods have been proposed using stresses as a way to gage indicators of soil health (Garbisu, Alkortab & Epelde, 2011). Organisms living in the Southwest region of the Sonoran Desert, as evidenced earlier (Andrew et al., 2012), experience high levels of climatic stress (NWS, n.d.). Past research found that, "…Natural stresses (freezing, draught) can temporarily decrease the organismal community by more than 50%…" (Domsch et al., 1983 and Visser & Parkinson, 1992, as cited in Anderson 2003, p. 287). Climate and site conditions on the day of sampling could be useful for triangulating data. A few resources served as a model for surveying site characteristics of slope, climate, and geography (Boone, Grigal, Sollins, Ahrens & Armstrong, 1999; Butterfield & Briggs, 2008; Staben, 1997).

Soil is impacted on different levels by natural and anthropogenic systems. Rotation and tillage are two systems used in crop management. They, too, are indicators of soil health, specifically with diseases. Rotation can be beneficial to soil by avoiding specific plant pathogens unless it's a widespread pathogen (Janvier et al., 2007). Crop rotation is defined as, "A planned sequence of several different crops grown on the same land in successive years or seasons, done to replenish the soil, reduce insect, weed and disease populations, or to provide adequate feedstocks for live- stock operations" (USDA, 2011).

By definition, tillage is the, "Mechanical manipulation of soil performed to nurture crops. Tillage can be performed to accomplish a number of tasks including: seedbed preparation, weed control, and crop chemical incorporation" (United States Environmental Protections Agency [EPA], 2012). There are many tillage systems used in agriculture today. The three systems practiced on the fields in this study were conventional, reduced and no-till.

Conventional tillage involves multiple operations during field preparation and/or cultivation, and it results in little to no crop residue on the soil surface. (USDA, 2011; Nolte, Ottman, Teegerstrom & Wang, 2010). Reduced tillage is a type of conservation tillage that involves two field preparation operations, leaving residue of the previous crop on the surface or partially burying it in the soil (Janvier et al., 2007; Nolte et al., 2010). Meanwhile, no-till crops are planted and harvested without disturbing the soil surface (EPA, 2012).

Besides direct effects on soil preparation, "Tillage is known to decrease soil organic matter, including the active fraction that is largely composed of microbial cells" (Jackson, Ramirez, Morales & Koike, 2002, p.35). Continuous crop rotation systems have shown microbial communities had higher (C_{mic}:C_{org}) ratios and lower community respiration compared to monoculture systems (Anderson, 2003). Microbial biomass (C_{mic}) is a value that measures the weight of organisms per unit area (Brower, Zar & von Ende, 1998). And, soil carbon (C_{org}) is used in testing the level of soil organic matter (SOM), which is from living matter made-up of carbon compounds (Kohnke & Franzmeier, 1995; Ontl & Schulte, 2012). "Recently, reduced or minimum tillage in vegetable crop systems has attracted attention as a possible means of increasing soil organic matter and decreasing labor and production costs" (Jackson et al., 2002, p.35). Leaving the previous crop in or on the soil can increase microbial activity, moisture and temperature.

To consider the greater ecosystem soil health, above ground indicators were often used (Butterfield & Briggs, 2008; Doran & Zeiss, 2000). Plant type and abundance and animal activity are two indicators commonly used by ecologists. For plants, one method that fit my needs was using plot sampling to measure cover. According to University of Idaho (n.d.), "Cover is thought to be more ecologically significant than density or frequency because it is an estimate of how much a plant dominates an ecosystem" (p.2). It is related more to biomass than the alternatives, also. Measured by percent, the types of plant cover I considered were ground cover and foliar cover. Ground cover includes plants, sticks and rocks and is best suited for desert locations, while foliar cover includes the shade of plants covering the soil (University of Idaho, n.d.) To track above ground animal sampling, the point survey method can be used (Brower, Zar & von Ende, 1998). This approach entails an observer recording all animal sightings during a period of 15 to 60 minutes at different waypoints i.e. edges of fields, roads, etc.

The impacts on above ground plant or animal species as a result of an environmental stress may also occur below the soil surface (Anderson, 2003). To measure plant activity below the soil surface, root depth and SOM could be measured. Animal activity presented many conditions to consider.

Biological life in the soil can also be measured with one of many sampling methods. Laboratory investigations make studying and culturing microbes easy (Janvier et al., 2007; Brower et al., 1998). One can study producers (algae), consumers (protoza), and decomposers such as bacteria and fungi (Brower et al., 1998). Commonly, species diversity and species richness, or loss, are measures used to indicate habitat stability or diversity. Yet, it is difficult to quantitatively determine these measures because of difficulties with identification and reliable methods at the species level (Anderson, 2003). For instance, Andrew et al. (2012) presumed the true quantity of soil microbes in desert soils was far greater than what they'd recovered. However, this was met with precaution. Clark Webb (personal communication, June 28, 2013) explained that the quantity of classes not necessarily that of individuals was the key finding in the former report. It raised the question whether a species or class identification of microbial activity was more suitable. Anderson (2003) found that analyzing microbes at the community level was quantifiable. Reportedly traditional microbiological culture methods only expose ~ 5% of the microbes that could be present in a soil community (Anderson, 2003). It is estimated that 1, 530, 000 species of bacteria and fungi remain undiscovered (Anderson, 2003). Both play important roles in building aggregate for soil structure (Rodale Institute, 2011).

Common wet laboratory methods used to measure diversity and/or abundance of bacteria and fungi in soil include microbial biomass, DNA testing and CFU (Colony Forming Units) plate counts (Janvier et al., 2007). DNA testing is being used determine site-specific classes and phylums (Janvier et al., 2007; Andrew et al.

2012). CFUs are a traditional and useful method of assessing microorganisms (Janvier et al., 2007; Staben, 1997; van Bruggen & Semenov, 1999; van Bruggen & Semenov, 2000). I had prior experience with culturing general and E. coli in soil bacteria. Escherichia coli, or *E. coli*, is a species of fecal coliform bacteria (New York State Department of Health, 2011). The equipment and culturing medium were easily accessed, too. Depending on the medium used, different microbes can be cultured and counted. Rose Bengal agar is a medium used for culturing fungi in soil (Bhaduri & Fulekar, 2012). Coliscan Easygel® is a medium used to culture general and coliform bacteria (12 Principles of Soil, 2012; Micrology Laboratories, n.d.). To take a general survey of soil health, I chose to measure the bacteria instead of both.

While independent physical and chemical indicators are studied, “the overall abiotic soil environment should be taken into account” (Janvier et al., 2007 p. 9). The chemical indicators N, K, P, Ca, Mg, electrical conductivity, and pH were used in most MDS (Idowa, et al., 2009; Kinyangi, 2007). They help identify plant available nutrients and biological and chemical activity (Kinyangi, 2007). The correlation between C, N, pH, microbial activity and disease suppression has been documented (Garbisu et al., 2011; van Bruggen & Semenov, 1999 and 2000; Staben, 1997; Anderson, 2003). In other research, measuring effects of N, P, K, soil texture and structure, on macro and microorganisms lead to the conclusion that organic manures and chemical fertilizers were essential for sustained long-term soil fertility and productivity of intensive cropping (Subbian, Lal and Subramanian, 2000). Finally, structural (or aggregate) stability and soil moisture properties have indicated the movement and availability of water and nutrients needed for soil fauna habit (Kinyangi, 2007; Kohnke & Franzmeier, 1995; and Reynolds, Drury, Tan, Fox & Yang, 2009).

Study Area

Yuma is located in the Southwest corner of Arizona, the western edge of the Sonoran Desert, where the Colorado and Gila Rivers meet. The land is relatively flat, with a few low mountains surrounding the area. The most familiar geographic feature is the Colorado River. It divides the farming into districts above and below the river valley, once a flood plain and now part of dam-controlled irrigation network (Barmore, 1980). Russell Barmore (1980) reported that, “The supply of good irrigation water is the main factor limiting the acreage used as cropland” (p.2). Farming continues to be the number one source of employment in Yuma as it has been since the turn of the 19th Century (Barmore, 1980).

The geologic history of the area explains why farmers began cultivating the soil before the days of irrigation canals. Before these rivers were dammed yearly, spring floods were the source of moisture for crops (Barmore, 1980). There are two distinct areas, the Mesa and the Valley, which were both at one time a former valley and delta plain of the rivers (Barmore, 1980). The sedimentation of the river valleys was probably greatest during the Pleistocene Epoch when alluvium from seven states washed down the rivers so much that it filled in part of the Gulf of California (Barmore, 1980). The soil order in this desert region is aridisol (Kohnke & Franzmeier, 1995).

There are high calcium levels for soils in Yuma. And, soil biota is reportedly not high in Yuma (C. Webb, personal communication, June 28, 2013). On pH levels I expected alkaline conditions. Data to support this: "Soils of arid and semi-arid regions tend to be alkaline, because of lack of leaching... dry conditions favor alkaline conditions" (Montana State University, LRES 591, Soil Reaction lecture, 2012). Salt concentration in soil effects pH measurements. The salt levels can change with fertilization and seasons, some labs use a dilute solution to cover the variations due to salts (Walworth, 2011). Free draining soils are low in Si-clay mineral and feldspar. Little precipitation will likely result in accumulation of soluble material: cations and anions (Kohnke & Franzmeier, 1995).

For my research, I focused on the soils in the Valley. Here, the Colorado River formed three levels, referred to as terraces (Barmore, 1980). The study site (N 32 44.436, W 114 32.2198) was located in a group of fields called "Island Farm." The site is approximately 140 acres, consisting of 10 fields. Some fields have date trees. They are managed as a mono-crop, getting tilled about three times a year (J. Jessen, personal communication, October 13, 2013). I labeled these fields *reduced tillage.* The other fields are managed on a crop rotation of spring wheat and vegetable, getting tilled about 10 times a year (J. Jessen, personal communication, October 13, 2013). I labeled these fields *conventional tillage.* The "Island Farm" sits on one side of the Colorado River. All of the fields are irrigated with river water, which is high in phosphorus (C. Webb, personal communication, March 4, 2014). Previously defined, the word *tillage* usually refers to an agricultural field (J. Jessen, personal communication, October 14, 2013). That said, one area in my study, adjacent the "Island Farm" was not being used for agriculture and was labeled *no-till*.

The climate for Yuma in winter ranges from 45°F to 69°F (RSSweather.com, 2012). The warmest month is July when the average high is 108°F. On average three inches of precipitation fall per year, August is the wettest month (RSSweather.com, 2012). There is a bi-seasonal rainfall pattern consisting of cold fronts in the winter and monsoon systems in the summer (Butterfield and Briggs, 2009).

METHODOLOGY

The indicators discussed above were tested to determine how soil health compares by changes in tillage level. Soil health is based on ecological principles. So, my MDS focused on how physical, biological, chemical, climate and geographic indicators would be linked. Methods were chosen to best answer: what impact does heavy tillage have on soil composition around the Lower Colorado River Basin; and what effect does no-till soil have on biological activity?

There were three sites in the study area defined by tillage systems: no-till, reduced and conventional. A site map, Figure 2, displays these areas. They were located very close to each other, separated by a ditch, dirt path or another field. Three composite samples were taken at random locations within the sites, dependent on uniformity.

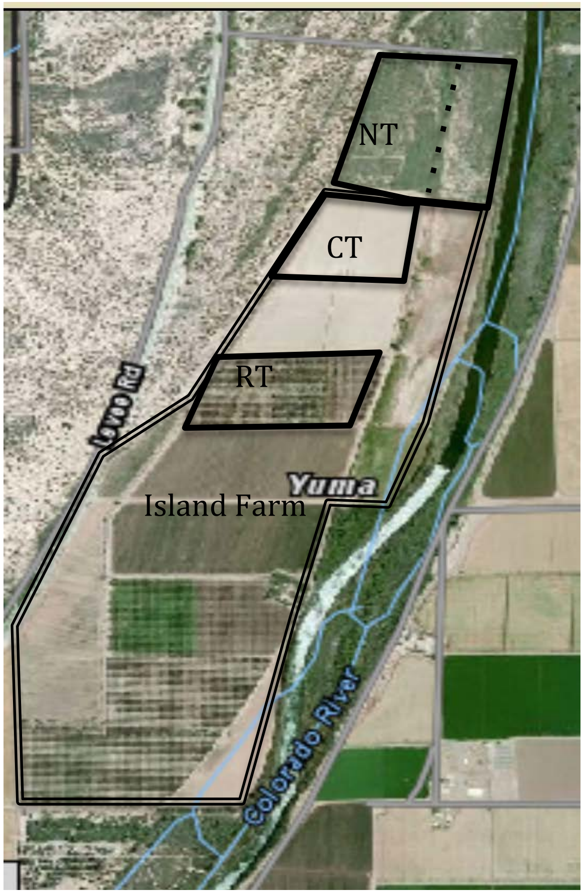


Figure 2. Web Soil Survey Map of Island Farm Study Area Outlined in double Black. Tillage Systems; No-till (NT), Reduced (RT) and Conventional (CT) Outlined in Solid Black. (National Resources Conservation Service, 2012).

There are different methods for obtaining soil samples dependent on factors like time, cost and purpose of the study (Planning and Making a Soil Survey (n.d.), Walworth, 2011). The composite method was the most cost efficient and reliable method (Boone, Grigal, Sollins, Ahrens, & Armstrong, 1999). I chose a fixed-depth sampling of 12 inches (~30 cm) so that I could make cross-site comparisons. Samples taken from 0-20 cm are encouraged as they allow for soil to be sampled below the depth of a plow blade (Boone et al., 1999). Samples bagged for laboratory analysis need to be stored properly and delivered promptly (Walworth, 2011). A local agricultural soil laboratory was contracted to run analysis on soil samples from each plot. This is a common procedure and is done to verify my identification of soil types and obtain the nutrient data that will aid me in identifying the health of the soil.

My goal was to have a total of nine plots to test on adjacent managed and unmanaged fields. The data collection methods were charted according to indicator and type of data. Table 1 illustrates the treatments used and shows how each indicator included multiple methods, each collected two ways.

Table 1
Data Collection Methods for All Sites

Indicators	Methods Qualitative	Quantitative	Indicators	Methods Qualitative	Quantitative
Biological Above Ground			**Physical** *Soil Texture*	Flowchart- by hand	Soil paste- Lab analysis
Animal activity	Point Survey				
Plant growth	Class	Cover			
Below Ground			*Soil moisture*	Feel by hand	Oven drying- Lab analysis
Plant presence		Root Depth			
Microbial life: E. coli, General Bacteria		CFU Count			
Soil Organic Matter (SOM)		Lab analysis			
Chemical *pH*		Home test kit Lab analysis	*Soil Compaction*	Feel by hand/ Digging	
			Site conditions	Coverage from sun, slope	Temperature (°F)
NO_3/K/P Ca, Mg, Na, Electroconductivity (EC)		Home test kit Lab analysis			

The same treatments were used for all plots of all tillage types. Not all of these treatments were tested on the same day. A schedule was followed to organize the presampling, sampling, and testing procedures needed for the study (Appendix A). I also used a texturing flow chart (Appendix B).

Site locations were established by spring 2013, five to six months before testing. The land sites were surveyed for topological differences and closeness to adjacent land type. I chose sites that had convenient access, differed by tillage level, and were geographically close to each other, to increase the chance of having the same soil type. The NRCS Web Soil Survey allowed me mark locations on their mapping system (Appendix C). Pre-testing and testing work occurred over two consecutive weekends in the fall of 2013. The data collection schedule referenced earlier (Appendix A) charts this, showing the sequence of methods tested.

Two samples of each type were taken at each plot, bagged and labeled. One sample was sent to the laboratory for testing. The second sample I took back home to test some chemical and biological indicators. Soil texture, moisture, climate conditions, plant cover, root depth, and animal point surveys were conducted in the field. These tests were described in the Conceptual Framework's under the heading, "Applicable Methodology."

DATA AND ANALYSIS

An assessment of indicators on composite sampled soil from randomly chosen plots within each tillage level was done to determine what impact conventional tillage has on soil composition in the lower Colorado River region. The results allowed answers to the secondary question, what effect does no-till soil have on biological activity.

To get an overview of the soil community composition I began with site observations. The mean air temperature was 74 °F on day of fieldwork (rssWeather, 2013). Any slope in the conventional and reduced tillage fields was not noticeable, a grade of <1%. The no till (NT) field had some, 0-1%, though minimal, changes in slope gradient (NRCS, 2012). The conventional tillage (CT) field had a crop of young celery growing at the time of field sampling. The reduced tillage (RT) field was a grove of mature date palm trees. The date crop had been harvested by the time of field sampling. There were some dates decaying on the soil surface. The NT field was not managed and had no crop. It was a large area and appeared to be divided North to South. The part to the West, appeared to be dense, secondary growth filled-in largely by salt cedar (*Tamarix ramosissima*) a non-native species in the region. The soil in this part was likely disturbed in the past. The East part, adjacent to the Colorado River is where I sampled. It didn't show the same signs of disturbance. There was more bare ground and space between the vegetation. The predominant plants were shrubs, mostly arrowweed (*Pluchea sericea),* and some salt cedar. Also identified in this area were *Populus fremontii ssp. fremontii*, a subspecies of cottonwood trees. Arrowweed and cottonwood are both considered native to the lower Colorado River region (SEINet, 2014).

A combination of biological, chemical and physical assessments of the sites showed the role of biotic and abiotic factors in the soil habitat. Point surveys of visible animal activity and traffic were conducted first at each field site, starting in the southern most site (RT) progressing north (NT). In the RT field, songbirds, hawk and dove were spotted in a 15-minute period. Coyote tracks were found in the Northwest side of the field. Most likely a week or two old, made after the last irrigation or rainfall. In contrast, no animal activity was sighted in the CT field. When entering the NT site, unidentified flying and perched birds were spotted. Dragonflies were sighted further in to the site and birds were heard. Snake tracks were found on a barren section of the soil surface.

Plant cover measurements of ground cover were taken at each of three one-m^2 plots within the fields. All of the plots in the CT and NT fields had at least 35% cover. Plot three in the NT field had the highest cover, 95%. This field had the most variability, 35-95% cover. There was little plant cover within the RT plots, 1-15% was the range. Plant classes were identified as grass and forb. The RT field was almost entirely shaded by 40 year-old date palms with an estimated height 35-45 feet tall (J. Jessen, personal communication, October 13, 2013). The palm frond canopy extended into portions of each plot, but this was not factored in to the cover since the tree trunks were not in the plot quadrants. All CT plots contained forbs and occasionally grass. Shrubs were the only plant class identified in the NT plots. Quite a few dead looking branches and leaves had accumulated at the soil surface of plot NT-C and NT-B. Also, I didn't find any grass or forbs growing in the NT, which are usually seasonal types of plants.

Once soil was extracted from the 12” deep holes, I closely observed for compaction, soil horizons, roots, and moisture. Each field varied. Soil was densely compacted at all of the RT plots. There were sparse roots poked through a single, uniform light brown soil horizon. One hole at plot A had a distinct layer of buried vegetative matter likely from a date palm tree. Patches of clay were found in the profile of a different hole at plot A. Dark streaks also showed inside a hole at plot B.

Figure 3. Photos of Holes from Each Field. Holes were dug to take field observations and measurements of physical and biological indicators, and to take soil samples for additional testing. Shown are of three holes dug at each plot, in order from left to right; RT-B, CT-B, NT-B.

The CT soil was loosely compacted, but still held shape. All had uniform soil horizon and color, again light brown. There were few to no roots visible in the profile. In contrast, roots were present in every hole of the three NT plots. The soil had a uniform horizon, light brown color and was very loosely compacted. The thickness and abundance of roots varied. In each hole, a mat-like layer of thin roots was found 2-7" down the O horizon. Soil moisture was determined on site on a qualitative scale of wet, moist, dry. The RT combined soil samples were all moist/dry. The CT combined soil samples, were on average moist/wet. And, the NT combined soil samples were dry.

Soil tests in the laboratory and home for soil analysis echoed the slight differences shown with the field tests. That is, NT soil showed the most deviation in soil composition. Comparisons of those indicators, listed in Table 1, were made between the different fields. Soil from NT plots had the lowest levels for each chemical and physical indicator. Home nitrogen/phosphorous/potassium (N/P/K) test kit results were recorded from very low to high. There were no significant differences within plots at each field.

The nitrogen (N) levels were low in RT and CT fields, very low in NT soil. Phosphorus (P) was at a medium level in the RT field, and low and very low in CT and NT fields. The potassium (K) tests indicated high levels in all fields, however it was difficult to determine the color of the solutions. The CT field had the most consistent levels of soil organic matter (SOM); all plots had 1.00% SOM. Yet, the RT soil had the highest levels of SOM with an average of 1.27%. Macronutrients were higher in the CT and RT fields. The RT field had on average the highest Mg, P, K, and Na out of all the plots tested. So, the RT soil had the highest levels of soluble salts from those cations magnesium (Mg), sodium (Na), and potassium (K). The electro conductivity (EC) readings were 0.2 ms/cm higher than in CT soil. Levels of calcium (Ca), also a cation, and nitrate (NO_3), an anion, were highest in CT fields. Commonly, there're more macronutrients available in moderately alkaline soil (7.9-8.4 pH) (Walworth, 2011). Levels of pH were similar in all fields with a mean of 8.49 and range of 0.3. The laboratory analysis showed NT and CT soils had at most a 0.2 [H^+] increase compared to RT soils. Home pH test results did not match laboratory results. However, both forms of testing did show RT soil had the lowest pH level. The table below shows the comparison of afore mentioned results.

Table 2.

Average Chemical and Biological Indicator Measurements of Each Treatment by Land Type

	pH (Home)	pH (Lab)	NO3 (ppm)	K (ppm)	P (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	EC (ms/cm)	OM (%)
CT	6.57	8.57	24	168	29	3086	283	155	1.4	1.00
RT	6.53	8.37	15	304	76	2972	354	181	1.6	1.27
NT	7.00	8.53	2	51	3	1406	97	64	0.7	0.27

	N(Home)	P(Home)	K(Home)
CT	low	low	high
RT	low	med.	high
NT	v.low	v.low	high

I was able to validate soil type by comparing data collected on soil with NRCS' Web Soil Survey to my laboratory analysis. The soil paste and texturing tests showed the soil was similar across all fields. Texture test found a higher presence of clay in reduced and conventional tillage fields, where as the soil survey identified more silt. This is possibly due to inaccurate texturing. Of the six CT and RT combined soil samples, five were textured to have some clay. The results of texturing NT soil samples by hand were loamy sand. A comparison of the soil paste and texture are compared to NRCS Web Soil Survey results in Table 3.

Table 3.
Comparison of Soil Paste and Texture Results to NRCS Soil Survey

Field- Plot	SP	Texture	Soil Survey
CT-A	38	clay loam	100% Indio Silt Loam
CT-B	38	sandy clay	
CT-C	38	sandy clay	
RT-A	40	clay loam	76% Indio Silt Loam, 23% Ripley Silt Loam
RT-B	40	sandy clay	
RT-C	40	loamy sand	
NT-A	30	loamy sand	100% Indio-Lagunita-Ripley Complex*
NT-B	30	loamy sand	
NT-C	30	loamy sand	

* Indio-Lagunita-Ripley Complex: 35% (0-6") silt loam, (6-63") sandy loam; 25% loamy sand; 25% (0-6") silt loam, (6-25") sandy loam, (25-60") sand.

CFUs of general and E. Coli bacteria were grown to assess biological activity in the soil. Population counts of colonies per dish were taken. These were multiplied by the ratio of 100 ml of distilled water to soil water. These concentrations were adapted by field type. I assumed the CT to have more bacteria based on feedback (C. Webb, personal communication, June 28, 2013). So, I used 3 ml of soil water for the CT solutions and 5 ml for the RT and NT solutions.

E. coli, colonies were found in RT soil samples. This correlated with the higher level of animal activity in the site. As noted from point survey data, the RT and NT fields had the highest recorded above ground animal activity. In contrast, the CT field had on average the highest recorded below ground animal activity. There was one outlier from plot A in the RT field (RT-A). The total bacteria count in RT-A was 6660, well above the 960 and 620 counts for RT plots B and C. Review of the RT-A photo and data did not reveal similar spikes that might coincide with these differences in numbers.

Therefore, this outlier is most likely because of a sampling error. The chart below shows population counts for each plot.

Table 4
Results of E. coli, General Coliform, Total Bacteria CFUs per 100ml Water

Plot	E. Coli	General	Total
NT-A	0	0	0
NT-B	0	0	0
NT-C	0	40	40
RT-A	1280*	5380*	6660*
RT-B	0	960	960
RT-C	60	560	620
CT-A	533	1167	1700
CT-B	167	3200	3367
CT-C	367	3567	3933

*Indicates outlier soil RT-A

I also examined combinations of treatments to define any trends that would explain soil health of the fields. For example, to assess the biological properties of the soil, I looked at the soil organic matter, plant counts, root depths, amount of plant cover and the total coliform bacteria counts.

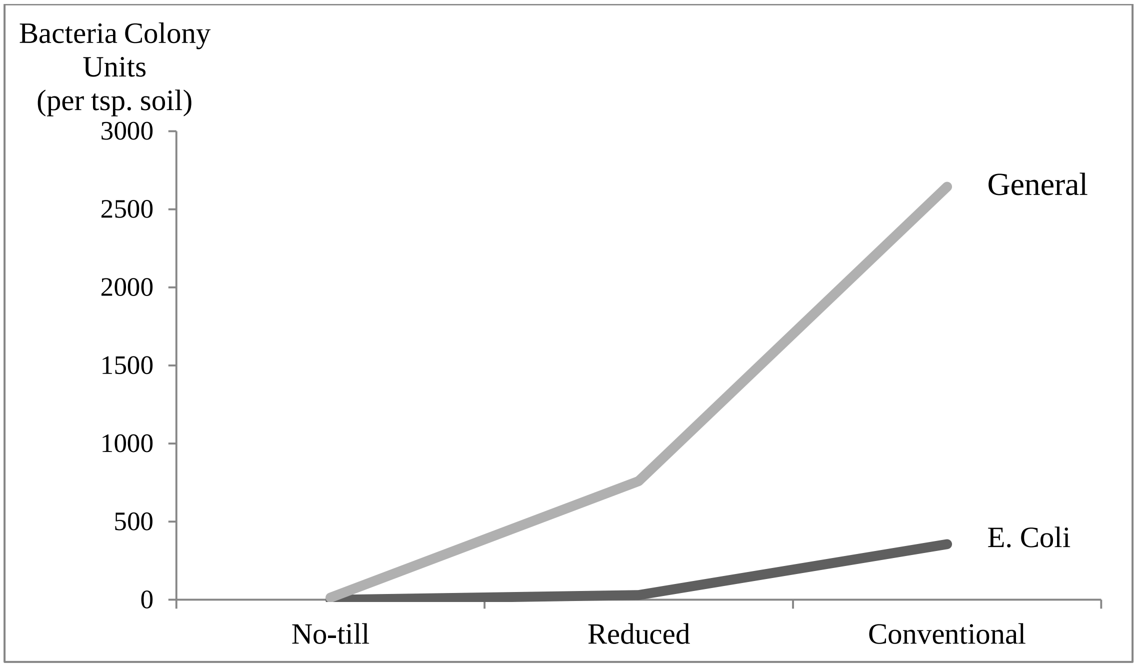


Figure 4. CFUs of Bacteria in Composite Soil Samples by Tillage Type. Excludes outlier soil from RT-A.

Graphing the CFUs by plot within field type I found a positive linear trend in Figure 4. There was an increase in soil bacteria as tillage increased. Also, a positive correlation was found between soil organic matter and soil bacteria in plots (Figure 5).

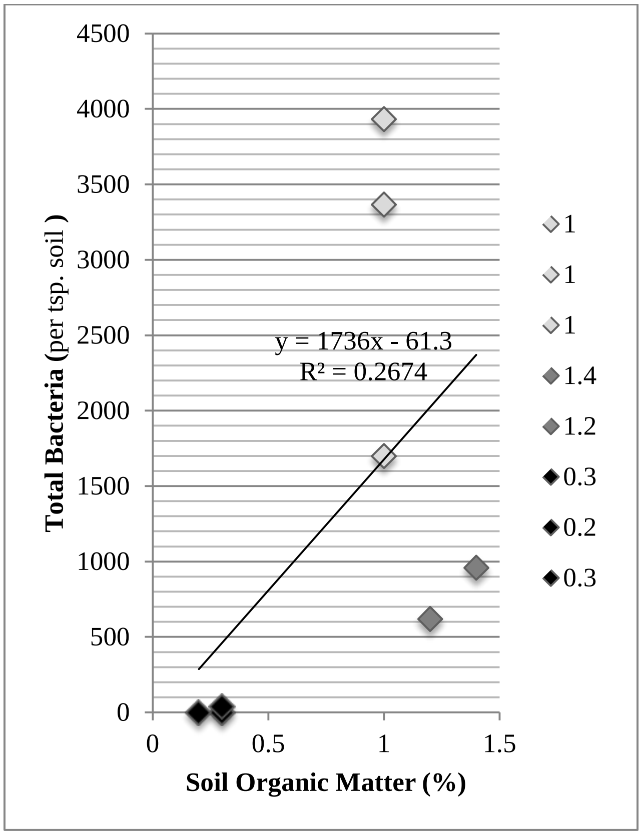


Figure 5. Positive Correlation Between Soil Organic Matter and Soil Bacteria in Plots. Excludes outlier soil from RT-A. Color in key denotes field plots as follows: black- NT, grey- RT, light grey- CT.

A correlation coefficient test showed my results were consistent. The R-value was 0.5171, meaning there was moderate positive correlation. The R^2-value was 0.2674 and is shown above the trend line in Figure 5.

A correlation coefficient test was also run on the percentage of plant cover and SOM in all fields. The results were R= -0.5991, a moderate negative correlation of high plant cover values to low SOM values.

Comparing results of the indicators across field type and against other indicators let me see what differences there were between treatments. Triangulating this information also helped me define the physical health of the soil. Indirectly, I could also see how it impacted soil organisms because soil structure, moisture and available plant nutrients are what provide habitat for living macro and microorganisms.

INTERPRETATION AND CONCLUSION

Healthy soil systems have a wider range of resistance to fluctuations in the external environment and anthropogenic pressures (Kinyangi, 2007). The resistance or resilience of soil depends mainly on land use and management. But how do we know if the current land use and management is hurting, maintaining, or improving soil health? The overall assessment of my data showed that each tillage level offered benefits to the soil ecosystem. In this research study, I asked what impact conventional tillage has on soil composition in the lower Colorado River region. My hypothesis was proven correct to this based on a number of validated and reliability tests. Tillage is potentially correlated to changing the structure and composition of soil. Secondary questioning on the effect of no-till soils have on biological activity was addressed with the same data. A trend in plant and above ground animal data indicated that biological activity increased as tillage decreased. But this trend did not occur in the abundance of soil bacteria.

As soil is considered an ecosystem based on links, so to the MDS used in this study revealed how one indicator links to other indicators. This process helped answer my research questions.

The physical indicators of moisture and texture gave evidence that the soil composition of reduced and conventional tilled fields was similar but not as sandy as no-tilled soil. One clue to proving this was the soil paste numbers. Soil paste (SP) stands for the percent saturation paste. It is measured by finding the percent of water soil can take in 100 grams (G. Jauregui, Personal Communication, January 30, 2014). The lower the number the lighter, or more sandy the soil is. Increases in soil paste numbers and the soil moisture coincided with the hand texturing results. Less sand and more moisture increased as tillage increased. These indicators show that tillage likely attributes to a slight increase in water-holding capacity and nutrient retention.

Results on compaction highlighted the differences in tillage operations. Finding densely compacted soil at all three RT plots coincides with heavy machinery driven over the date fields. However, there were no links from compaction to other indicators, like moisture or texture to show it caused a change in soil composition. Other indicators seemed better at determining if tillage impacted soil composition.

The physical indicators overlapped with chemical indicator findings. Lower soil paste percentages in NT plots indicate it is sandier and thus leaches water quickly. Meanwhile, the high pH level of NT soil shows that the [H^+] are not being leached as quickly as they are in RT and CT fields. When precipitation rates are low in arid regions, like the Lower Colorado River Basin, higher anion and cation levels are typical (Kohnke & Franzmeier, 1995). This was true of the RT and CT, but not so much in the NT soil soil. In the RT and CT fields, cations potassium (K), calcium (Ca), magnesium (Mg), sodium (Na) were found here at much higher levels than the NT field. The cause of these salts could be related to respiration from irrigation water but this possibility wasn't addressed in this study. The RT and CT fields were irrigated with the same Colorado

River water. The results in chemical levels gave evidence of this with the higher phosphorus (P) levels in comparison to NT soil. The pH in RT was on average two times lower than the CT soil. Differences in tillage, fertilization and/or irrigation management could explain the difference in nutrient levels between the two fields.

Soil organic matter (SOM), is one of the key biological indicators of soil health. And, as mentioned, the amount of SOM in even the RT field was very small. Yet, it was interesting to learn what role it did play in these fields.

SOM is used to indicate rates of structure and decomposition. It accumulates differently by region (forests, prairies) according to where the dead OM accumulates (Kohnke & Franzmeier, 1995). The CT field crops got rotated and the plant material left over after harvest time got added to the soil through decomposition, enriching the soil much like grass in a prairie. The celery plants growing in the CT field was an above ground crop. Some of its roots left on or in the soil would be tilled under and left. The same plant parts are left when the wheat is harvested. The NT and RT fields for the most part had only perennial plants (shrubs and trees). In this sense they were more like trees in a forest where dead organic matter settles on top of the soil surface and is not mixed into the soil as with tillage. So, while CT and NT had similarly high percent plant cover and CT had a presumably high decomposition rate, the RT soil had the highest percentage of SOM. Other research also found reduced tillage practices increased SOM (Jackson et al., 2002). But what about animal impact on SOM? Although above ground animal activity was recorded in reduced and no till fields, it appeared to not have a significant influence on the SOM or for that matter on soil composition. And, there seemed little connection between above and below ground biological activity in regards to soil.

Soil organic matter (SOM) quantitatively supported the physical and chemical indicator findings of a change in tilled soil. There was a greater abundance of biological and chemical activity in the RT and CT soils over the other fields. Conventional tillage allowed for the decomposition of more soil organic matter. And, while the percent SOM was low in all fields, CT and RT did have more than NT fields. Colony forming units and laboratory soil analysis provided data to make a positive correlation between microorganisms and organic matter. It proved that SOM and total soil bacteria increased as tillage levels increased. Plant cover revealed how much and what classes of plant matter contributed to biological diversity to the soil, even shading the soil. Yet, plant cover had negative correlation to SOM or soil moisture. As mentioned, the RT plots were shaded by date tree foliage. If trees were in plots, foliar cover measurements could have been included, and this inclusion could potentially alter these outcomes.

Comparing the point survey results to CFU counts, there is no clear understanding why E. Coli counts were nonexistent in NT and RT plots. Indicators showed that except for bacteria colonies, biological activity was highest in reduced and no tillage levels. This revealed that conventional tillage is a good habitat for soil bacteria but it potentially does not provide for a diverse number of organisms. Almost exactly opposite, NT soil provided habitat for different plant and animal species but did not have the best habitat to support soil bacteria. Dead plant material, abundance of roots, and combination of shrubs and trees potentially allow for greater soil stability and less soil loss from wind and water erosion. It is then most beneficial to above ground animals that can travel to where water and food are in greater abundance.

Using a MDS that tested multiple indicators allowed me to see which indicators were more closely linked to answering my questions on tillage and biological activity. Conventional tillage impacts soil composition changing it physically, biologically, chemically, and on a greater ecological level. It has less sand, more soil bacteria, and better water-holding capacity. Yet, it was reduced tillage that had similar chemical and physical properties, and it had the highest amount of SOM. The no till fields in this study offered habitat to animals and conditions for riparian desert plants to grow, but there is much less presence of life below ground.

One modification I considered was lengthening the duration of my testing. There is a strong consensus among soil health researchers that long-term experiments provide the best description of the soil (Doran & Zeiss, 2000 and Kibblewhite et al., 2007). Fertilization and irrigation were factors that were not included in this study, but may prove important to further inquiries on the question of tillage and soil health. Also related to this is the effect of irrigation water. Does it infiltrate the bordering no-till fields and how does this impact plant growth? Future research might include extending this study to other farms with no-till and reduced tillage fields, monitoring the relationship between animal activity and long-term soil health. Research into soil health in reduced tillage by studying the influence of adding ground cover living plants or dead plant material in mature date fields would be beneficial.

VALUE

Researchers have sought out levels of measure to define soil health, and one method is to look at groups of indicators. Kibblewhite et al. (2008) studied soil health of agricultural systems and found the following:

> Variable factors such as pH, bulk density and soil organic matter content, which are influenced by land-use and management [controlling factors for soil health], then determine the prevailing condition of the habitat within the range for a particular soil. These fixed and variable abiotic factors interact with biotic ones to determine the overall condition of the soil system and its associated health (p.690).

In Yuma, as in many other towns across the United States, land use has changed from natural to farmland to housing or business developments. There is a question of land value that many communities are addressing in the form of long-term planning. It seems more and more that we are seeing that each community impacts the global community. Around 12% of the land word-wide is arable. It appears the value of land will be in maintaining as healthy of soil as possible in order to produce food for our ever-increasing human population. This along with the unknown factors tied to climate change place added pressures on local farmland. Time will tell how smart society’s long term planning is and how well it is carried out. Right now some people have decided to assist communities facing these difficult land use decisions with science. According to Grandy et al. (n.d.), “We also need to stimulate technological advances, improve our understanding of how soil responds to ever more extensive and intensive human activities, and revitalize educational curricula in soil science.” This report can be used to inform land managers and students about current state of local agriculture soil health and help them consider and connect human activity with soil ecosystems for best practices of long-term conservation.

When completed in summer 2014, the validation of my study will be best felt by advisors, my readers, peers and myself. It has been a long goal to study science in this nature. The help and support of MSSE and my advisors opened the door for me to take on this challenge. I plan to share my scientific findings to schools and students in Yuma. The field managers of “Island Farm” may be interested in the results of my study, and may wish to have the testing repeated. In the future, I expect I will use modifications of this study in science and environmental studies classes. Work on this project has spurred my own interest in continuing to study and research soil science. I would like to do study more about mediums for culturing other micro bacteria, like fungi, in desert soil.

REFERENCES CITED

Alam, S.M. & Jam, T., (2001). Microorganisms and Soil Fertility. *Root Watch.* Retrieved from http://www.ecat.montana.edu/content/enforced/218115-LRES_591_801881_201270_CL/Week 9 2012/MicroFert.ht...

Anderson, T.-H. (2003). Microbial eco-physiological indicators to assess soil quality Agriculture. *Ecosystems and Environment, 98,* 285–293.

Andrew D.R., Fitak R.R., Munguia-Vega A, Racolta A., Martinson V.G., & Dontsova K. (2012). Abiotic Factors Shape Microbial Diversity in Sonoran Desert Soils. *Applied and Environmental Microbiology. 78(21)* doi:10.1128/AEM.01459-12

Barmore, R.L. (1980). Soil Survey of Yuma-Wellton Area. *U.S. Department of Agriculture Soil Conservation Service.* p. 1-115 Retrieved June 23, 2013, from http://soils.usda.gov/survey/printed_surveys/

Bhaduri A.M. & Fulekar M. H. (2012). Assessment of arbuscular mycorrhizal fungi on the phytoremediation potential of *Ipomoea aquatica* on cadmium uptake. *3 Biotech.* 2(3), 193–198. doi: 10.1007/s13205-012-0046-8

Boone R.D., Grigal D.F., Sollins P., Ahrens R.J., & Armstrong D.E. (1999). Soil Sampling, Preparation, Archiving, and Quality Control. In Robertson, G.P., Coleman, D.C., Bledsoe, C.S., & Sollins, P. (Eds.), *Standard Soil Methods for Long-term Ecological Research* (pp. 3-28). New York, NY: Oxford University Press.

Blecker S.W., Stillings L.L., Amacher M.C., Ippolito J.A., & DeCrappeo N.M. (2012). Development of Vegetation Based Soil Quality Indices for Mineralized Terrane in Arid and Semi-arid regions. *Ecological Indicators, 20,* 65-74.

Butterfield B.J. & Briggs J.M. (2008). Patch Dynamics of Soil Biotic Feedbacks in the Sonoran Desert. *Journal of Arid Environment, 73,* 96-102.

Cable J.M., Ogle K., Williams D.G., Weltzin J.F. & Huxman T.E., (2008). Soil Texture Drives Responses of Soil Respiration to Precipitation Pulses in the Sonoran Desert: Implications for Climate Change. *Ecosystems, 11,* 961-979. doi: 10.1007/s10021-008-9172-x

Department of Horticulture. (2009). Cornell Soil Assessment Training Manual. Soil Health Testing 2nd ed. Retrieved November 27, 2012, from: http://soilhealth.cals.cornell.edu/extension/manual.htm

Dimmit M.A. (2014). Biomes & Communities of the Sonoran Desert Region. Retrieved April 30, 2014, from: https://www.desertmuseum.org/books/nhsd_biomes_.php

Domsch, K.H., Jagnow, G., & Anderson, K.H. (1983). An ecological concept for the assessment of side-effects of agrochemicals on soil microorganisms. *Residue Reviews, 86*, 65–105.

Garbisu. C., Alkortab I. & Epeldea, L. (2011). Assessment of soil quality using microbial properties and attributes of ecological relevance. *Applied Soil Ecology, 49*, 1–4.

Grandy S., Billings S., & Richter D. (n.d.). Saving Our Soils. *Ecological Society of America.* 171.

Haberern, J. (1992). Viewpoint: a soil health index. *Journal of Soil and Water Conservation*. *47*, 6.

Jackson L., Ramirez I.R., Morales L.M. & Koike S. (2002). Minimum tillage practices affect disease and yield of lettuce. *California Agriculture*, *56*, 35-40. doi: 10.3733/ca.v056n01p35.

Janvier, C., Villeneuve F., Alabouvette C., Edel-Hermann V., Mateille T., Steinberg C. (2007). Soil health through soil disease suppression: Which strategy from descriptors to indicators? *Soil Biology & Biochemistry*, *39*, 1–23.

Kinyangi J., (2007). *Soil Health and Soil Quality: A Review*. Retrieved November 27, 2012, from http://worldaginfo.org/files/Soil%20Health%20Review.pdf

Kibblewhite M.G., Ritz K., & Swift M.J. (2008). Soil Health in Agricultural Systems. *Philosophical Transactions of the Royal Society B.* 385-701. doi: 10.1098/rstb.2007.2178

Lal, R. (1997). Degradation and resilience of soils. *Philosophical Transitions of the Royal Society B, 352*, 997–1010.

Micrology Labortories. (n.d.). Coliscan Easygel. Retrieved June 21, 2013, from http://www.micrologylabs.com/page/93/Coliscan-Easygel

Montana State Science Education (2013). Bacteria Testing Using the "Coliscan Easygel" Method. *12 Principles of Soil Science, class notes,* 1-10.

National Resources Conservation Service (2012). Web Soil Survey. Retrieved November 30, 2012 from http://websoilsurvey.sc.egov.usda.gov/App/ WebSoilSurvey.aspx

New York State Department of Health (2011). Coliform Bacteria in Drinking Water Supplies. Retrieved April, 2014, from http://www.health.ny.gov/environmental/ water/ drinking/ coliform_bacteria.htm

Nolte K., Ottman M., Teegerstrom T. & Wang G. (2010). Minimum Tillage for Wheat Following Winter Vegetables. *The University of Arizona Cooperative Extension*, Retrieved May 1, 2014 from https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1523.pdf

Ontl, T. A. & Schulte, L. A. (2012) Soil Carbon Storage. *Nature Education Knowledge*, *3*(10), 35. Retrieved May 2, 2014, from http://www.nature.com/scitable/knowledge/library/soil-carbon-storage-84223790

Planning and Making a Soil Survey. (n.d.) Retrieved November 30, 2012, from ftp://ftp.fao.org/fi/CDrom/FAO_Training/FAO_Training/General/x6706e/x6706e02.htm

Romig D.E., Garylynd J., Harris R.F., & McSweeney K., (1995). How Farmers Assess Soil Health and Quality. *Journal of Soil and Water Conservation*, 50, 229-236.

rssWeather. (2013). Climate in Yuma, Arizona. Retrieved April 11, 2013, from http://www.rssweather.com/climate/Arizona/Yuma/

Sleeter B.M., Sohl T.L., Bouchard M.A., Reker R.R., Soulard C., Acevedo W., Griffith G.E., Sleeter R.R., Auch R. F., Sayler K.L., Prisley S. & Zhu Z. (2012). Scenarios of land use and land cover change in the conterminous United States: Utilizing the special report on emission scenarios at ecoregional scales. *Global Environmental Change*, 896-914.

Staben M.L. (1997). Assessment of Soil Quality in Conservation Reserve Program and Wheat-Fallow Soils. *Soil Science Society of America*, *61*, 124-130.

Southwest Environmental Information Network, SEINet. (2014). Survey Checklist. Retreived on April 30, 2014, from http//:swbiodiversity.org/seinet/index.php.

Subbian P., Lal R., & Subramanian K.S. (2000). Cropping Systems Effects on Soil Quality in Semi-Arid Tropics. *Journal of Sustainable Agriculture. 16*, 7-38.

United States Environmental Protections Agency (2012). Crop Glossary. Retrieved May 1, 2014, from http://www.epa.gov/oecaagct/ag101/cropglossary.html

United States Department of Agriculture (2009). Soil Quality Indicator Sheets. *National Resources Conservation Service.* Retrieved November 27, 2012, from http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/assessment/?cid=stelprdb1237387

United States Department of Agriculture (2011). National Agronomy Manual. Retrieved May 1, 2014, from http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1043210.pdf

University of Idaho (n.d.). Measuring Plant Cover. Retrieved October 2, 2013, from http://www.webpages.uidaho.edu/range357/notes/cover.pdf

van Bruggen, A.H.C., & Semenov, A.M. (2000). In search of biological indicators for soil health and disease suppression. *Applied Soil Ecology, 15*, 13–24.

van Bruggen, A.H.C., & Semenov, A.M. (1999). A new approach to the search for indicators of root disease suppression. *Australian Plant Pathology, 28,* 4-10.

Visser, S., & Parkinson, D. (1992). Soil biological criteria as indicators of soil quality: soil microorganisms, *American Journal Alternative Agriculture, 7,* 33–37.

Walworth, J.L. (October, 2011). Soil Sampling and Analysis. *Arizona Cooperative Extension*. Retrieved November 30, 2012, from http://cals.arizona.edu/pubs/crops/az1412.pdf

APPENDICES

APPENDIX A

DATA COLLECTION SCHEDULE

APPENDIX A

Here is my revised testing schedule. There were three sites: non-tilled, lightly tilled and heavily tilled. They were located very close to each other, separated by a ditch or dirt path wide enough for one vehicle. My plan was to take three composite samples at random locations with in the sites, dependent on uniformity.

Data Collection Revised Schedule for Tests

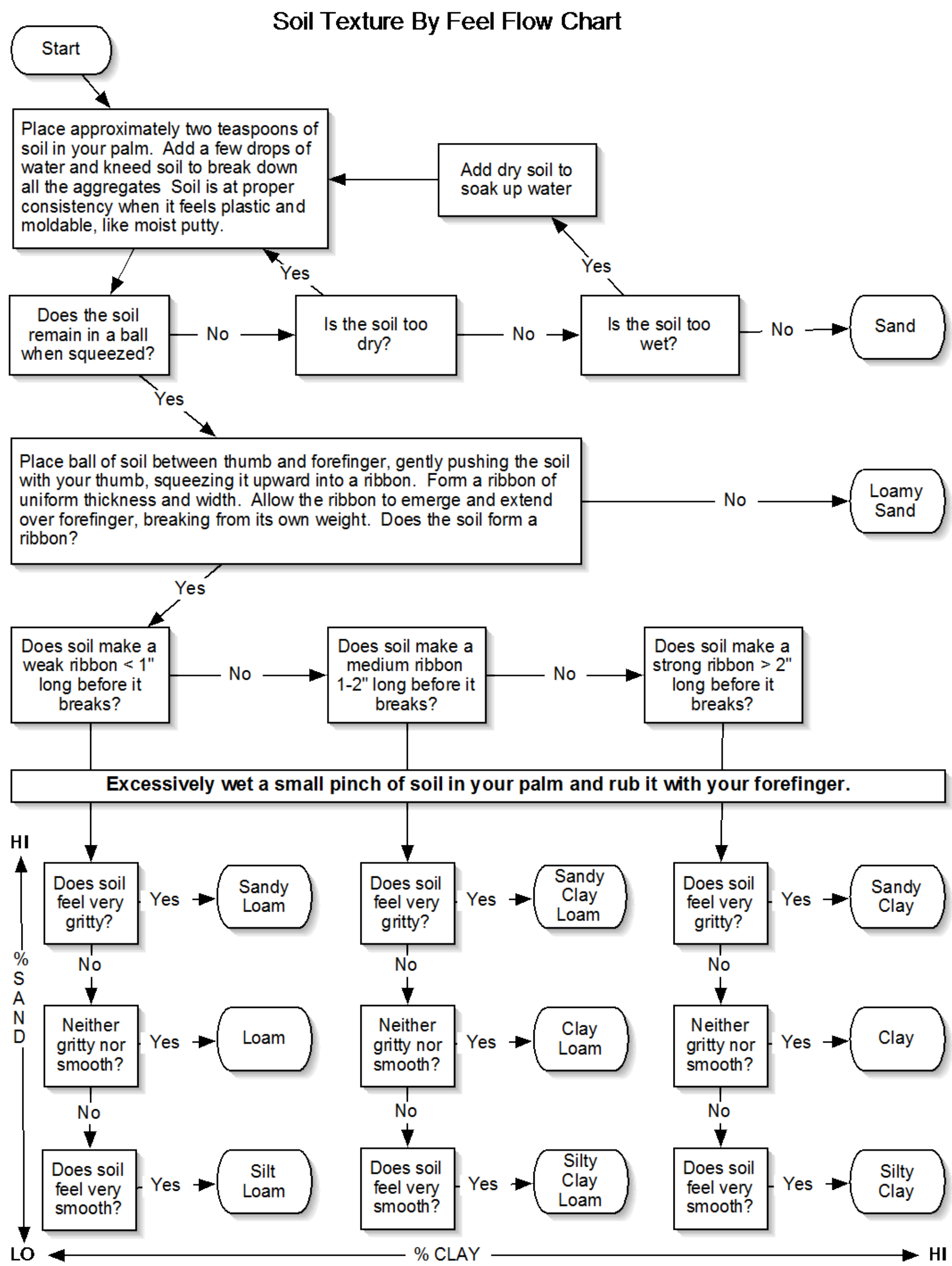
<u>Treatment Cycle</u>	<u>Proposed Dates</u>	<u>Procedures</u>
1- Field and lab material prep.	9/13-9/16/13	Pre-testing: - Preliminary assessment: define areas of division/diversity within site due to slope or succession and map these areas with a GPS device. - Perform an equipment check (incubator needs to be ~90F) and a materials check; prepare materials for use (clean beakers)
	10/14/13	Pre-testing: - Prepare materials for use (culturing solutions, field work materials kit w/ disinfectant supplies and distilled water bottles) Return to study site to review mapped divisions, note any changes in site.
2- Qualitative analysis	10/15/13	Record descriptions of the weather conditions; animal sightings; soil moisture as wet, moist, dry; appearance of vegetation, other observations of events occurring at study site.
3- Physical sampling, Bio./phys./ chem. field measures and tests	10/15/13	Field testing: at all three sites, Non-tilled (NT) Low-tilled (RT) Heavy-tilled (CT) - At each site, randomly choose sampling plots within designated site locations. Mark plot with a flag. - Place a 1m^2 PVC frame to mark a perimeter, near the flag. Measure/record plant coverage, I.D. Photograph plots. - Within 1m of the flag, clear 3-4 areas for digging subsamples. - Fixed depth soil samples. Dig 12” holes. Use shovel method. Take 1” slice from top to bottom of hole, put in sanitized plastic bucket. - Note via field book sketch or with camera the visible soil horizons. - Mix all subsamples in bucket. - Bag composite soil: with replicate volume or weight samples. Label the bags for Lab or Culturing (Lab: Plot A –NT, Culture: Plot A -NT). - Complete a texture, pH and N, P, K test with remaining composite soil. Record data. - Sanitize the shovel and bucket with alcohol and fire b/n sampling plots. ~These measurements will be replicated for all plots in each site~

3- Lab analysis of biological, chemical, and physical indicators	10/15/13	Post Fieldwork: - Bring bags of soil samples labeled “Lab” to soil lab for analysis of OM, pH, soil pasting (texture), macronutrients. - It will take about 10 days to receive results of analysis.
4- Analysis of soil microbe richness	10/15-17/13	Culturing: - Prepare soil bags labeled “culture” for bacteria and, possibly, fungi. - For bacteria, I am using Coliscan Easy gel and following *methods from “ColiscanLab,” <u>Twelve Principles of Soil Science</u>. *attachment - When bacteria culture petri dishes are prepared, put in incubator and record time. They need to incubate for 24-48 hrs. at ~95F - Monitor incubator temperature, every12 hrs. - After 48 hrs. remove dishes from incubator. - Conduct population count of E. coli bacteria. Record data. - Photograph each dish for record. - Clean and store all reusable culture lab materials.

APPENDIX B

TEXTURING FLOW CHART

APPENDIX B

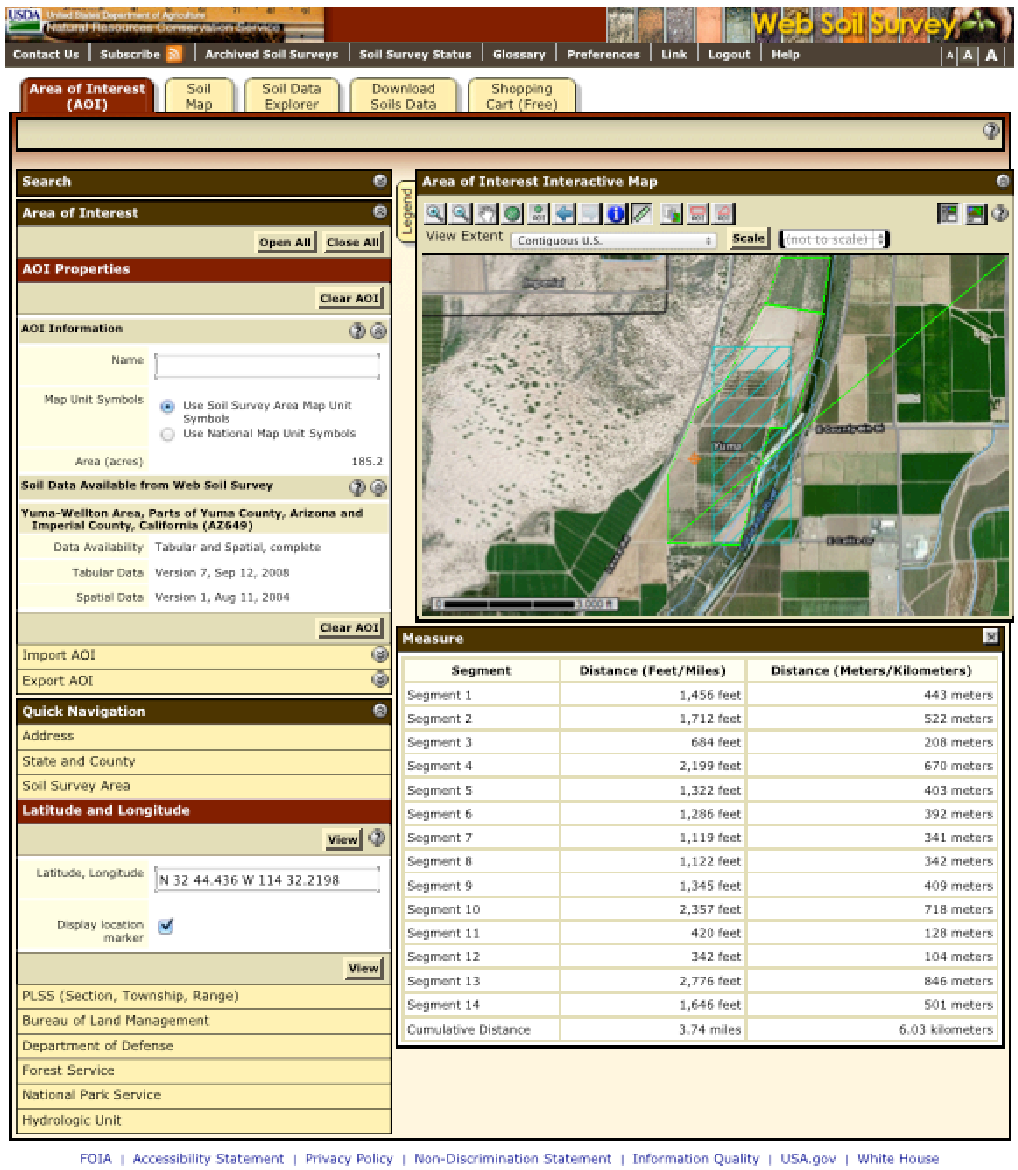

Soil Texture By Feel Flow Chart
Start
Place approximately two teaspoons of soil in your palm. Add a few drops of water and kneed soil to break down all the aggregates Soil is at proper consistency when it feels plastic and moldable, like moist putty.
Add dry soil to soak up water
Yes
Yes
Does the soil remain in a ball when squeezed?
No
Is the soil too dry?
No
Is the soil too wet?
No
Sand
Yes
Place ball of soil between thumb and forefinger, gently pushing the soil with your thumb, squeezing it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow the ribbon to emerge and extend over forefinger, breaking from its own weight. Does the soil form a ribbon?
No
Loamy Sand
Yes
Does soil make a weak ribbon < 1" long before it breaks?
No
Does soil make a medium ribbon 1-2" long before it breaks?
No
Does soil make a strong ribbon > 2" long before it breaks?
Excessively wet a small pinch of soil in your palm and rub it with your forefinger.
HI
Does soil feel very gritty?
Yes
Sandy Loam
Does soil feel very gritty?
Yes
Sandy Clay Loam
Does soil feel very gritty?
Yes
Sandy Clay
No
No
No
Neither gritty nor smooth?
Yes
Loam
Neither gritty nor smooth?
Yes
Clay Loam
Neither gritty nor smooth?
Yes
Clay
No
No
No
Does soil feel very smooth?
Yes
Silt Loam
Does soil feel very smooth?
Yes
Silty Clay Loam
Does soil feel very smooth?
Yes
Silty Clay
% SAND
LO
% CLAY
HI

APPENDIX C

MAP OF RESEARCH AREA

APPENDIX C

Sample of soil map produced using USDA's NRCS online soil mapping program.



APPENDIX D

LAB ANALYSIS REPORT

APPENDIX D

Laboratory analysis of indicators. Note: "HT" represents CT soil, "LT" is the RT soil.

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SOIL ANALYSIS REPORT

DATE: Thursday, October 24, 2013
GROWER: HEIDI JESSEN
ATTN: HEIDI JESSEN

LAB No.	SAMPLE ID	SP	pH	Ece (ms/cm)	% Organic Matter	NO3-N PPM	P PPM	K PPM	Ca PPM	Mg PPM	Na PPM	Fe PPM	Zn PPM	Cu PPM	Mn PPM	B PPM
1135	A - HT	38	8.60	1.70	1.00	23	29	194	3021	286	194	12.4	2.7	1.4	6.4	1.1
1136	A - LT	40	8.50	1.32	1.20	9	83	324	2988	373	161	20.4	4.9	1.7	6.1	1.1
1137	A - NT	30	8.50	0.37	0.30	2	3	48	1412	91	46	6.2	0.4	0.4	4.2	0.3
1138	B - HT	38	8.50	1.26	1.00	23	28	157	3166	290	143	10.8	2.7	1.4	5.4	0.8
1139	B - LT	40	8.30	2.34	1.40	24	83	350	3066	366	238	18.7	5.6	1.6	10.5	1.3
1140	B - NT	30	8.50	0.46	0.20	1	2	40	1176	82	50	7.1	0.3	0.4	4.6	0.2
1141	C - HT	38	8.60	1.24	1.00	25	29	154	3070	274	127	11.3	2.7	1.3	5.4	0.7
1142	C - LT	40	8.30	1.23	1.20	11	62	238	2862	323	143	13.4	4.8	1.3	4.9	0.9
1143	C - NT	30	8.60	1.16	0.30	2	4	66	1629	119	96	7.5	0.5	0.5	4.0	0.6
	suff. Ranges:			1.0-3.0	1.0-5.0	15-20	20-30	250-300	1000-1500	500-1000	200-400	10-15	1.0-3.0	1.0-1.5	10-15	0.5-1.0

CATION EXCHANGE CAPACITY (CEC)

LAB ID No	% Ca	% Mg	% Na	% K	TOTAL
1135	80.2	12.7	4.5	2.6	18.8
1136	76.3	15.9	3.6	4.2	19.6
1137	86.7	9.3	2.5	1.5	8.1
1138	82.1	12.5	3.2	2.1	19.3
1139	75.5	15.0	5.1	4.4	20.3
1140	85.4	9.9	3.2	1.5	6.9
1141	82.6	12.3	3.0	2.1	18.6
1142	78.5	14.8	3.4	3.3	18.2
1143	83.8	10.2	4.3	1.7	9.7