Soil Health Based on Organic Matter.

Abstract: This story concerns soil organic matter as an indicator of soil health under differing management regimes. Introduced with soil comparisons on arable land, the story moves to the effect of grazing, first in the Intermountain West of the United States and later to Ecuador, Morocco and East Africa Argentina, England and Mexico. I started with farming's affect on soil health and later this narrowed to the affect of grazing on soil health. The time span is open-ended and covers research design that has been adjusted and modified over time. Additions to this ongoing paper will be made as additional countries are visited. It is hoped that Internet coverage will encourage comments from readers on e-mail. Richard Strong's E-mail address is: voiceofthesoil@juno.com

My Background and Methodology

After college I served as a soil scientist with the Soil Conservation Service for three years. The next 31 years I worked with livestock and agriculture in the western U.S. but I was always interested in soil health. Reports saying we have lost a third of our arable soils through erosion and degradation never seemed real to me. In 1993 I went to Peru to work on a salinity problem and began using a soil auger again. On returning from Peru I equipped a small soil laboratory and started a consulting company called The Voice of the Soil. When asked what the voice says, I reply, "The voice is that of millions of microorganisms and what they say is, 'If we don't eat, nobody eats'".

Those who are familiar with soil metabolism and the carbon cycle know that bacteria, fungi, protozoa, invertebrates, nematodes, worms and others are an interrelated complex food web dependent on a supply of organic matter from above ground. Decaying plant matter and detritus is broken down to become humus, the foundation of the food chain. Humus is the stabilized end product of complete decomposition. It is 58% carbon. Carbon moves from the soil up to plants, flesh and bone, brain cells, and back to the soil in the carbon cycle. This circular loop is related to other cycles: nitrogen, phosphorus, and hydrology etc. Carbon, or soil organic matter is a benchmark indicator. It is a key to understanding whether a particular landscape is "sustainable".

There is no established level of organic matter that spells out a "healthy soil". The amount of organic matter that sustains a plant community varies with latitude, elevation, soil texture and climate. Plant communities will thrive if organic matter can be maintained between a few tenths of a percent, (Sahara desert) to nine percent, (English countryside). To find this amount, I take a spoonful of dry soil, weigh it into a furnace and take it up to 400 degrees centigrade for two hours and weigh it out again. The procedure, known as "loss-on-ignition", yields the percentage by weight of organic matter in the soil, nothing short of the basic building blocks of life on earth.

When I first began my own soils research, I wanted to try my new instruments on something simple. The problem with a single sample is that it only gives current data, a snap shot in time. Ideally one should sample a field over a hundred year period as at Rothemstead, England where organic matter trajectories have been mapped since the early 1800's. To get around this problem I sought out protected areas with the relic of the original soil across the fence from soil farmed for many years. These matched pairs of samples give a comparison of organic matter after years of change. For the last nine years I have observed balances between plant communities and the results of their exploitation by man and his animals. Observations included organic farming in Cuba, French and Spanish grain farming, Eucalyptus vs. native prairie, goat fuel load control vs. brush, and selected examples described below. Results demonstrated the principle that sustainability is dependent on not reducing carbon from the system.

Farming vs. Non Farming. The first experiment was in the Palouse Hills of Whitman County, Washington, which had a uniform silt loam. This lovely soil originated from glacial till. Till is rock flour resulting from the grinding action of glaciers. It was first carried by water and later re-deposited by wind. This soil, known as lloess, lies some thirty feet deep. Immigrant farming families came in the 1880's, plowed up the prairies and raised heavy yields of soft white winter wheat. They buried their dead in isolated cemeteries in

the original prairie soil. Many of the cemeteries had never been tended, mowed or fertilized. I took samples on both sides of the fence. The resulting matched pairs from 22 cemeteries showed that erosion and mining the soil by farming had reduced organic matter by 24%, from 5.2 to 3.96%. The shortfall had been made up with chemical fertilizer and multiple tillage passes to create the desired soil structure.

Irrigated vs. Non Irrigated.

The next experiment was to compare irrigation with dry farming. This would test the effect of "artificial climate change" resulting from the introduction of center pivot irrigation sprinklers to the sandy soils of Nebraska in 1965. These semi- arid, porous soils had lower organic matter and had traditionally been dry farmed, even though they overlay the great Ogallala Aquifer. With ground water tapped by wells and with water sprinkled on the land, the increased biomass meant an accelerated carbon cycle. I sampled thirty pairs of soils at the edge of center pivots where, under the sprinkler, the crop reflected greater biomass than under rainfed grain on the outside. This increase in crop meant an increase in material to decompose, hence, more organic matter. These center pivots, averaging 23 years from installation, boosted organic matter 18% from 1.2 to 1.5%.

Organic vs. Conventional.

The next collection of samples from farmed soil compared the soil health of organic farmers with that of the conventionally farmed soils of their neighbors. Conventional has come to mean farmers bypass natural soil processes and feed plants with readily soluble chemical fertilizers. This practice results in reduced return of organic matter, affects soil structure, moisture holding capacity, and resilience. I first chose farms of friends I had met while working for the California Farm Bureau where my job involved working with pest management practices. Some pioneer organic farmers not only eschewed chemicals but also were composting and cover cropping. These practices send down a fine feast to the food web hungrily waiting below ground. As paired samples from adjacent conventional and organic fields went across the scales, the early results were decisive. In four farms in the sandy soils of the San Joaquin Valley, the organic grower's soils had 31% more humus than their neighbors; 0.80 vs. 0.55%. (It should be noted that irrigated soils of the hot central valley mimic tropical forests where organic matter oxidizes before it can accumulate. A similar moisture regime in northern Canada produces a peat soil because the cold prevents decomposition.) In Sonoma County, California seven tested organic farms were split, five pairs favoring organics by 45%, while the remaining two showed 20% higher organic matter for conventional farming. The reason for this disparity was that those two growers who were "organic" by virtue of not applying chemicals were coasting on the existing fertility rather than augmenting the carbon cycle by composting and cover cropping. High yield conventional farming will sometimes produce more organic matter in root mass as well as turned under more aftermath than that of more casually farmed organic crops across the fence.

Dry Farmed vs. Grazed Only.

In the Dunnigan Hills of California, the soils are mapped as severely eroded after nearly a century of dry farming on 10% slopes. The disked ground has a distinct line where it becomes too steep for tillage. I took five paired samples on both sides of that line where the tilled soil had 29% less organic matter than the native soil which had only been grazed, (2.4% vs. 1.7%). In another set of tests in Southern France, four woodlots had only 9% more organic matter than neighboring grain fields, (3.4% vs. 3.1%). However, I had no way of knowing if wood lots were rotated with tilled ground over several centuries.

Grazing vs. Protected.

At this point in my research, on the trip to Nebraska, I stopped in Laramie, Wyoming where I met Bill Laycock, then the chair of the Range Management Department of the University of Wyoming. He figures prominently in Deborah Donahue's recent book: The Western Range Revisited. She advocates getting livestock off the public ranges in areas of less than 12 inches of rainfall. She provides a shaded map that covers vast areas of public lands of the Intermountain West from which domestic livestock would be excluded. Donahue worked for the BLM before becoming a lawyer and teaching on the same campus with Laycock. It was Laycock who initially got me interested in range exclosures. These are experimental areas

fenced off for the purpose of studying the contrast between grazing and protected ground. After leaving Laycock's office, walking back across campus to my car, I noticed a quote inscribed on the building: "The Foundation of Agriculture is not Rooted in the Soil, but Rather in the Vision and Attainment of Men", (O.A. Beath). It reminded me of a similar inscription on Hilgard Hall on the U.C.Berkeley campus: "To Rescue for Human Society the Native Values of Rural Life". Both the vision and the native values have led to over exploiting the resource base. I had raised cattle and studied soil in the western range and decided to try my tools out on range exclosures to test the thesis that excessive removal of organic matter depletes soil health.

At the 1977 Nairobi conference on desertification, the idea that man's agricultural activities of grazing and farming were causing an irreversible advance of deserts became fashionable. An atlas of world desertification was published in 1992. I had raised cattle at under 150 mm of rainfall just north of Death Valley and had worked on ranches in Montana, Nevada and Eastern Oregon. I was suspicious of gloomy estimates of range condition and trend for the Intermountain West. Studies were based on plant species composition and range management principles mostly derived from temperate climates. If changes in soil organic matter occurred more slowly than changes in species composition above ground, then research on organic matter could contribute to the understanding of soil health and the effect of grazing.

Worldwide, domestic livestock accounts for 30 to 40% of the global agricultural output and uses 2/3 of all agricultural land. Much of this occurs on land that appears barren or empty when viewed from the air. In fact a quarter of the earth's land surface is devoted to domestic animal grazing. Agro-pastoralists now account for 54% of the world livestock management. Earlier the inclusion of livestock with crops was a large part of the sustainability of agriculture in temperate Europe and in the first world before artificial fertilizer and specialization. Between 1961 and 2000, however, livestock numbers have increased dramatically: cattle by 41%; sheep only by 7%; but goats by 105%. Much of this increase is absorbed by the tropics and sub humid areas as a result of forest conversion or land use choices by large landowners. Buried in these figures are portions of livestock now kept in confined "factory farms". Half of the world's livestock is on the original, natural grazing range and the other half is now on converted forests. This further breaks down to roughly 30% temperate forest and 70% tropical forests. Arid and semi arid land based livestock numbers are stagnate or declining as stocking rates are at capacity or because the land is degraded. Some authors claim that a fifth of the world's rangeland has been degraded since 1950 by overgrazing. Great changes are currently taking place with respect to both increased grazing pressure and the spread of exotic plant species around the world. My interest has been to ask what this means for the micro population of the soil, particularly in arid and semi-arid ranges.

For five years I have hunted up exclosures using published inventories furnished by Laycock and exclosures located by asking at offices of the BLM, Forest Service, and the Natural Resource Conservation Service. At each site I sampled both the protected inside and the grazed outside. The effort covered nine states running from the Mexican border nearly to Montana and between the Rockies and the Sierras. Over time the database contained 185 sites. Where exclosures were scarce or non-existent, I made do with cemeteries, (9), railroad or highway right-of-ways, (18), and odd boundaries of parks, military bases or natural reserves.

The study of the effect of grazing on soil organic matter proved to be much more complex than with soil used for growing crops. The great rape of these virgin western rangelands was concentrated between 1880 and 1920 when competitive, communal grazing often resulted in overuse. Approximately the same thing happened in Australia and Argentina where the degree of grazing was tripled by domestic livestock on arid land. As early as 1895 the Botanical Survey was reporting overgrazing. The Forest Service was started in 1905 and the first exclosures were built in 1912 in Las Cruces, New Mexico and Ephraim, Utah. By the mid thirties the Taylor Grazing Act created grazing allotments. The Soil Conservation Service was started on the impetus of the Dust Bowl. By 1960 allotments were being adjudicated and rest-rotation, and deferred grazing schemes were becoming popular. Although the western rangelands today are a mosaic patchwork of poor to excellent conditions, the overall fact is one of destocking from around 1920. In grazing exclosures, the organic matter may be increasing on both sides of the fence as both sides recover from earlier grazing levels.

I guessed that my samples, representing a snap shot in time, would show that any grazing would cause a

decrease in soil organic matter. This was not always the case, in fact a third of the samples indicate greater organic matter outside the exclosure under light to moderate grazing.

Light grazing takes off a portion of the plant, keeping it in a younger growth stage. Younger plants have more nitrogen and higher rates of carbon gain than mature or senescent older growth. Old growth becomes blanketed with dead stalks, lowering photosynthesis. Some grasses are stimulated by grazing which encourages tillering, (growth at the base of the plant).

Worldwide research is inconsistent in regard to the effect of grazing on soil organic matter and, in fact, I found little literature specifically on grazing and organic matter. Most evidence is based on changes in species composition. Where this may make sense from the standpoint of livestock, for soil microbes, they will take carbon from whatever can manage up there above ground. The invaders and increaser plants, that substitute for preferred palatable and nutritious grasses, also contribute to the carbon cycle. There is, however, agreement that consistent heavy grazing can reduce any plants' ability to store adequate carbohydrates, causing a drop in vigor, failure to reproduce and a slowdown of the carbon cycle. At below 15 Cm of rainfall consistent heavy grazing is actually economically difficult to maintain.

Arguments involving a universal negative effect of trampling on the soil surface are being contested. There is an assumption that large animals compact the soil causing inevitable damage. In semi arid areas the coarse sandy soil is less affected by compaction than clayey soils. Matched pair organic matter samples failed to demonstrate adverse compaction from trampling on sandy desert soils.

Paired samples taken along fence lines were at first simple. I began with the open areas between the sagebrush. I took multiple samples and commingled them to avoid "hot spots". Later I compared the "resource island" under the shrub canopy with the interspace sample. Organic matter in the island is 20% greater than the interspace by virtue of leaf fall, wind delivered debris and nutrients harvested by rodents and other small creatures. The height of the island is usually 15 to 50 Cm. above the surrounding level. Most islands have old burrows from kangaroo rats or squirrels. On 67 sites, ungrazed shrub soils had 52% more O.M. than outside the fence, (1.83% vs. .88%). On the other hand 25 sites indicated grazed shrubs had 45% more O.M. than under the protected side, (1.81 vs. .83%). For the interspace, 24 sites showed 79% more O.M. under protection, (1.76% vs. .76%). Another 27 sites had 48% more O.M. under grazing compared to inside the exclosure, (1.93% vs. 1.60%). But for many matched pairs, particularly in more arid areas, there were no significant changes in O.M. In 1967 I had built 3 exclosures on a ranch I was running that had 15 Cm of rainfall. The soil O.M. did not change in 30 years. I avoided exclosures constructed in less than 15 years and specially valued older ones kept in good repair. I had read of experiments on individual exclosures in New Mexico, Arizona and Colorado where detailed soil and plant composition were done, all detailing bad effects of grazing. These were hand picked exclosures and, although they showed correlation of negative effects of heavy grazing, they left out a broader picture of a range of differing grazing intensities and climates.

Nearly all exclosures are built on public land by agencies charged with the stewardship of public resources. Both the agency regulators and the ranchers were aware of the land use conflict. My travels around the West exposed me to demographic and social changes that were also effecting the soil indirectly. (My Berkeley degree was in Anthropology and Philosophy and only later did I study soil at U.C. Davis.)

The increase of recreation and a return-to-nature movement in the west has pitted urbanites against the more conservative rural gentry. This is at the heart of the grazing conflict, to graze or not to graze. Donahue wrote about this in The Western Range Revisited. She described the attitudes of cattlemen who are the local elites who, by way of their wealth, are isolated from progressive social and environmental thought. These men are leaders in their communities thus contributing to the schism between grazers and the public. The rural West, over time, has developed a finely stratified class structure. The advent of increasing tourism, second home sprawl, and the invasion of urban culture via TV, computers, and the youth-drug-music culture is creating a much more complex society than the popular notion of the old wild west.

Range conflict can be better understood as a part of the background of changes taking place in society at

large. Economically the agricultural predominance is being diluted with recreation, retirees, and urban refugees. The livestock industry is also suffering from a variety of structural re-alignments: *Dietary switch from red meat to pork, poultry and fish because of health and price concerns. *Fabrics switch from natural to synthetic fiber plus the loss of the wool program. *Pork and poultry, the early innovators of factory farming and vertical integration, have been able to capture a larger portion of the producer's share of the consumer dollar without passing the cost on at the checkout stand, thereby displacing beef in the market basket. *Like"Big Oil" or "Big Tobacco", there is a growing "Big Agriculture" which increases the roll of the middleman at the expense of the producer, in our case, the range livestock operator.

These realignments make range grazing less viable and more difficult for marginal operators to survive. There is a temptation to exploit forage more aggressively. The loss of economic viability makes it particularly difficult for public agencies to enforce stewardship of the resource base. Both agency people and ranchers live in the same town and shop at the same stores. Agency employees are generally well educated, live in the confines of towns hemmed in by public land, and are often looked down on as second-class citizens by the gentry. I know this from my experience, initially as a ranch hand, latter as a "government man" and finally as a hired ranch manager and a Director in the Nevada Cattle Association. I saw it from both sides.

As the rancher's economic position weakens, opportunities for "off farm income" increase and more small scale permittees using public grazing land are finding that livestock is becoming a smaller part of their income. This can mean less pressure to stock as heavily. This is truer in lower rainfall areas that are marginal at best. There is a level of 115 to 200 mm, (6 to 8 inches) of precipitation below which a year round supply of forage is hard to maintain. Droughts are becoming more common and this may be due to global warming. Although more year-long permits are written for deserts, in practice they are often used seasonally or stocked at below the permitted number. This substantiates the destocking trend.

The mixed results of paired samples support a complex story of a mosaic of differing range conditions. Progressive ranchers practice techniques such as rest rotation, rotation deferred, or even opportunism including draught year sanctuaries and those who forego the exceptional years and stock more lightly. These operators should be encouraged and supported. Although some progressive ranchers have alliances with range conservationists, more often there are conflicted relationships. That is why the consensus oriented stakeholder meetings are so popular, particularly with public servants and environmentalists caught in the crossfire. Increasingly, at urban and rural environmental conferences, there are workshops featuring success stories on restoration of riparian areas, citing increased diversity, biomass and wildlife. The education goes both ways. Urban people are learning of the role of ruminants in the carbon cycle and ranchers are coming to appreciate concept of sustainability, soil food webs, and seedling recruitment.

The impact of grazing by domestic livestock in the Western United States is mostly condensed into the last century and a half. I concluded that grazing related soil erosion and degradation are highly exaggerated. My next thought was to look at other countries that had experienced domesticated livestock grazing over several centuries.

ECUADOR

In the summer of 2001, in an effort to assess soil health under centuries of grazing, I spent a month sampling soils of small-scale agro-pastoralists in the Ecuadorian Andes. The Spanish had brought livestock to Ecuador four centuries ago. I thought surely there had been enough time for range sites to stabilize under grazing. The colonialists and the wealthy "ganaderos" who succeeded them forced indigenous people away from the valley floors and up on the mountain sides. A rich mix of crops and eight kinds of livestock were raised at from 8,000 to 12,00 feet of elevation for up to three centuries.

I had designed a research trip around the amount of soil samples that could be returned to my lab in California in a single backpack. This amounted to a months stay in a country that was divided up into four "work stations". I would headquarter in a village, walking out by day, seeking measurable contrasts in soil health and looking at how plant litter, crop residue and manure were decomposing. In the valley floors and along the coastal plains the wealthier landowners were running commercial dairies with fenced pastures that could more easily manage the balance of organic matter. I am interested in the more complex farming

system, which integrates animals, farming and family labor. In Ecuador this includes daily green chop of selected plants for guinea pigs inside the house, staked pigs for household scrapes, staked cows for once-a-day milking, free roaming chickens, staked goats, sheep, donkeys and horses for transport, and subsistence and cash crops.

This was my first venture into a country where livestock were under constant daily care. They were staked in order to graze a circle of forage to the length of their tether or were day herded and returned each evening to a pen. Fenced pastures existed on the valley floors and were part of "high tech" grazing which could include modern conservation management. I chose to sample what was happening with the intense intercropping, multi harvesting, and seasonal crop rotations of a combination of cash cropping and subsistence farming and gardening on the uplands.

Southern Ecuadorian soils are derived from metamorphic rock, are more susceptible to erosion and less fertile than high volcanic Andes further north. There is greater poverty in the south, more out migration and a breakdown in the complex labor allocation of agro- pastoralism. I was struck by the labor required in staking cows and sheep. The animals can be micro controlled to graze paths, roadsides, fallow fields and crop aftermath. The natural forests were either converted to fast growing exotic trees or gradually converted to crops.

Organic matter in the higher elevation no-tilled original forest and pasture was comparable with the volcanic soils of the north at 17% for six samples. This level declines with tillage and intense grazing to 6.8% for eight samples with typical matched pairs of tilled vs. non-tilled dropping half of the organic matter due to tillage.

In Northern Ecuador, among the volcanoes, the indigenous people farm slopes up to 50%! (The principal cause of death for cattle are falling while staked). These deep volcanic ash soils at from 8,000 to 12,000 feet of elevation on the equator had ample gentle rainfall. Volcanic ash, with a high angle of repose, like silt, resists erosion. Cold, high altitude temperatures mean that roots and plant litter decompose slowly. These humus rich soils handle like potting mix and are nearly black in color. The organic matter levels are the highest I had tested after the peat soils of the Sacramento River delta.

Although rich, resilient and forgiving, these soils do migrate down slope with constant tillage. The time frame of farming on these steep slopes may be five centuries. The Inca conquest moved north from Peru only a century prior to the advent of Europeans. In Peru the Incas and their predecessors developed terraced, irrigated farming that was sustainable. In the volcanic ash of Ecuador there are no stones with which to build terraces. The rainfall is sufficient for to grow a variety of crops. Closer to the equator the rains are gentle, which reduces erosion. Day after day, as I walked the trails and fields I noticed erosion and differences in crop yields. Slowly, with constant cropping, the dark color changes to white ash and crop yields drop. There is a growing dependence on artificial fertilizer for the principal crop, potatoes. In Ecuador, as elsewhere in the third world, multinational chemical companies and agricultural extension personnel from the cities are pushing green revolution fertilizers and pesticides. Growers are attracted by the prospect of high yields and overcoming crop pests and diseases even at the great expense of imported chemicals. This transfer from natural to artificial nutrient paths masks a general downward trend in soil health. Soil organic matter comparisons between native prairie, darker new ground and light colored, depleted soil suggests that the time left before abandonment is only in the nature of generations not centuries. There isn't a sense of urgency due to soil resiliency and the high starting point of organic matter at initiation of farming at this elevation on the equator.

The short frost free growing season above 12,000 feet provides a ceiling for farming. Above the cropland there are high pastures of perennial grasses. Here mixed herds of cattle, sheep, goats, and lamas are herded during the day. If they are not penned in the high country they are returned to fallow ground and held in portable pens that are moved to distribute the manure for future crops. In England this practice is known as "folding". The animals carry the nutrients daily from the high elevation pastures down onto soils that are arable by virtue of a longer growing period. This works as a translocation of nutrients, in the manure, from higher grasslands down to the zone of longer growing seasons. With global warming the frost free season is moving higher. The original high prairie is being broken up for crops as farmers move up the mountains. This makes a climate change frontier that provides relief from a very slowly deteriorating level

of soil health under constant cropping downslope and near the more settled areas.

The non-tilled forest had12.4% organic matter and the high grass pasture, called the paramo, had 16.8%. Fields under cultivation had dropped down to 1.49%. This was indicated by a dramatic soil color change. Four of the lightest soils ranged from 0.10 to .79% where four, nearby dark colored cropped soils, averaged 5.8%.

Around Ecuadorian cities close to the Pan American Highway I found fields abandoned due to erosion and depleted nutrients. This use pattern of exploiting steeper slopes and higher elevations over time gives a sense of the impact of development. This was also impacted by the historic role of the hacienda system and church lands that superimposed hacienda agricultural relations on traditional small farming and trading. The result has been a patchwork of land use practices in which the soil organic matter decline isn't obvious, particularly with such an inheritance of initial high organic matter.

Selecting matched pairs of soils to demonstrate the effect of grazing in the Andes proved nearly impossible. The overlap in agro-pastoralism is so integrated that my results were a combination of tillage and grazing. This might not be the case in a more arid country like Morocco, where farming is mostly restricted by the need for irrigation.

MOROCCO

North Africa received a cattle culture from the east with the influx of Berbers prior to 2500 BC, which marked the end of the Saharan wet phase. The Moroccan landscape is a gradation from a mesic, California-like Mediterranean climate in the north to the hyper arid Sahara Desert. Morocco would be an opportunity for me to find out what two millennia of grazing would do to soil health. In the spring of 2002 my first work station was in eastern Morocco at a rainfall barely supporting dryland grain, (300 mm). I stayed with Peace Corps volunteers in two villages: Fri Tessa and Toachorte; one consisting of "motor pump farms" and the second an example of irrigated fields on the flood plain with the grazing on the uplands. This part of Morocco had, until 1940, supported a "transhument" grazing pattern wherein Berber herders moved camels and small stock, (sheep and goats), in a elliptical circle a hundred miles long. First the French and later, the Moroccan government discouraged migratory nomadic pastoralism. Nomads are hard to count, tax, educate and govern. Sedentarization concentrated year-long grazing within eight kilometers of the villages.

Morocco, being close to Europe and having a well developed export and market oriented agriculture in the north, is further along than Ecuador in the penetration of specialized, green- revolution farming. At the margin of Moroccan dryland farming, tractors are being used to plant rainfed grain on semi-arid uplands. These fields are widely spotted across the plains in areas of wind deposited soils and in depressions with run-on moisture. They seem to be exploited on a one time only basis and compete with grazing for available land. The tillage increases wind and water erosion by breaking up the surface.

Ongoing grazing in Morocco falls into two categories. In general, the serious flocks of over a dozen small stock are herded by youths or mature men who leave at 8 A.M. and return at 5 P.M. after having moved out as far as eight kilometers. The herders take only a liter of water and no book or transistor radio. I was impressed. It seems everywhere in the third world livestock are subject to theft and are loose herded by day, everyday! I also found a second grazing category, smaller flocks of five to a dozen or so animals that I called "household flocks" which were watched by children, young boys, women or elders. They ventured out at odd hours and are found within three kilometers of the village. Elsewhere in Morocco I found an additional pattern involving milk cows. Families would keep cows for milk and they had to chop and haul fresh forage for the cows daily. There was a pattern for women to take cows out for grazing along byways, streams and on harvested stubble. The cows got some exercises and the women had an occasion to socialize. In semi arid Morocco I found no cows grazing away from arable land. In the short time I was there, it seemed that grazing close in to villages is becoming more intense while outlying forage is less utilized both because of sedentarization's affect on nomadism. and competition for the labor required for serious, day-long herding trips. My thought was that changes in the last century might be affecting the soil organic matter.

My problem was how to find grazing contrasts that would accurately demonstrate affects on soil health? In developed countries, highways, rail lines, airports and power stations are fenced off providing historic contrasts between grazing and protected botanical sanctuaries. In a land of day herding there is no need for those fences. Everywhere any forage that grows is grazed at the first opportunity. Everywhere that is, except in graveyards. Even if they are not fenced, the local custom is to not let animals forage among the gravestones. After lengthy negotiations with village elders, I was able to sample five such sites and photographed others. The results were a 36 % increase in O.M. under the canopy of shrubs protected from grazing in four pairs and a 16% increase in O.M. in the interspace in five pairs. This indicates that grazing did alter the organic matter content but I felt that this was true only up to a point. After millennia of domestic livestock grazing the plant community and soil surface has changed and conditioned to exploitation. The tall, seed bearing grasses have retreated to a few outlying north slopes, what remains is a sort of desert pavement with forbs, thorns and succulents and a few low growing annual grasses.

Besides cemeteries, I tried sampling along transects out from water point were stock could drink. Unfortunately, the five transects where I sampled failed to demonstrate diminishing grazing pressure further from water. Although the soil appears to be the same, the sample might measure effective precipitation, parent material, slope or local hydrology. In transects south of the Atlas Mountains, it was hard to tell distance to water because of new motor pump farms along old grazing routes. I conclude that soil organic matter testing is of little use for evaluating transects of several kilometers.

Given the constraint of labor intensive day herding livestock on low producing landscapes, there seems to be a balance between grazing and the regenerative capacity of the soil. Another way of evaluating this standoff is to imagine trying to eliminate all plant growth by the use of domestic herbivores. I was in Morocco in the springtime of a wet year when the soil was warming up. On what looked like barren ground, goats and sheep were taking small bites of green growth as quickly as it grew up past pebbles and stones. In the semi arid part of the country, cattle have ceased to graze outside of irrigated ground for centuries. South of the Atlas Mountains, in the direction of the Sahara Desert, sheep are grazed to their ecological limit beyond which only goats survive and even goats have a limit, the edge of the "hyper arid" zone in which only camels can live. Beyond that, the primary herbivores are gerbles, then termites, ants and beetles.

In Southern Morocco I found a German woman doing a doctorate on the demise of nomadism. Her informants felt that the range condition status was currently a function of climate change rather than overgrazing. Range condition ideally translates to soil health. That idea seems to support the notion of a balance arrived at by grazing intensity largely governed by the labor requirement. There have always been droughts but the droughts of 1972,1984 and 1998 were of greater scope and intensity than earlier. The intensity of grazing had not increased during the same period. Currently the border with Algeria is closed because of civil war. The traditional grazing routes permitted grazing in Morocco when Algeria was dry or grazing in Algeria when it was dry in Morocco.

KENYA AND TANZANIA.

In East Africa, with a monsoonal climate and close to the equator, an undisturbed soil-plant community will produce greater bio mass and higher organic matter content than a site disturbed by man. Human impact with domestic grazing is greater than the impact of wild, naturally migratory animals whose numbers are controlled by predators. Brush control by elephants and frequent cold fires maintained a more constant grass-savannah landscape which may have more fully utilized the photo synthetic potential. The starting point of organic matter in this semi arid area of Africa varied from a high of 8.5% in an irrigated banana field on volcanic ash soil on the rainy side of Mt. Meru to two maize and one millet field in the granite/gneiss soils of Singida and Dodoma which had two 0.04's and a 0.40 %. The only other .04 percentage soil I had found was a gravel wash at Brazinsky Point in Death Valley, in California.

In Kenya, where land privatization and fencing were more common, I tested fence lines with fifty years of history of differing levels of grazing and tillage. On managed private or cooperatively managed ranches organic matter was elevated 29.2% over communal grazing on three locations with eight pairs. In Tanzania, on the other hand, fences were practically non existent accept for one government ranch and a government brewery.

I could test reduced grazing or grazed old fallow land compared to currently tilled and planted ground. On seven pairs the most recently tilled and planted sites had 9% less organic matter then fallowed and grazed matches. On two sites I compared untilled bush to fields that had been part of a largely failed Canadian wheat scheme. Soil under the original bush had 30 and 38% more organic matter. What happens when virgin soil is first tilled is long sequestered organic matter is released on a one time basis. This reserve is mined by the decomposers and the plant community resulting in an entirely new equilibrium. Growers know this and will plant either new ground or that which has enjoyed the longest fallow period.

One military base, with no grazing since WW II, had 26% more organic matter than communal grazing across the road. Under agro-pastoralism not only the pastures suffer from year round grazing but grazing effects the restorative function of fallow periods as stubble and regrowth are both grazed. On virgin pasture shrub and tree "resource islands" are indicative of the effect of both grazing and fuel wood gathering. Twelve pairs showed that the island had a third more organic matter than the interspace, the average being 3.7% vs. 2.5%.

ARGENTINA

The spread of domesticated European livestock to the new world was relatively recent and also sudden. It came at a time when large scale commercialization of hides and tallow was made possible by expanding sea transport. This was the early justification for cattle in Patagonia and California. Before there was an export market for meat, livestock were raised mainly for subsistence and closely herded by their owners.

In Patagonia, when a supply of salt became available, it was possible to export salt beef to support cheap or slave labor for plantation agriculture in the Caribbean. The situation in the temperate Pampas was such that animal numbers grew both from feral cattle and owned animals. The indigenous people rounded up wild cattle and stole from the settlers and drove herds of thousands over the Andes to Chile. The Araquenos Indians acted as middle men and sold the cattle to the Chilenos miners. Livestock numbers in the drier, south end of Argentina did not increase until the 1850's. Patagonia, like the western U.S. did not have large numbers of livestock until the last century and a half.

In 2004 I spent some weeks hunting for sites that would show the effect of commercial grazing on soil health. The Atlas of Desertification indicated that Patagonia suffered from overgrazing and accelerated wind erosion. Like the United States the pastures are fenced. This was encouraging because fences provide grazing contrasts, a means to demonstrate the effect of grazing on soil health.

Argentinian buses are often double deckers. I would try for an upper level window seat and kept a running log of type and number of livestock and any differences in the vegetation on both sides of the fence. I did this for weeks and discovered that dramatic cases of damage from over grazing are rare, not common. Around the historic settlements and towns, particularly where horses are allowed free grazing there is concentrated grazing. This was truer in the north were the holdings are smaller and less so as estancias became larger further south. Another factor is that for the last ten years the world market for wool had collapsed and the pastures may have been experiencing a recovery due to destocking. I sampled highway fences, cross fences, airports, two organic farms, a cemetery, radio relay station and one range experiment exclosure.

I did find fifteen sites in which the average soil organic matter on the protected side of the fence was 14.7% greater than the grazed side. The difference ranged from 3% to 27%, the latter being on an experimental station with pasture protected for 25 years. There were three sites without significant differences. With one exception the weaker contrasting sites overlapped with sites indicating greater O.M. on the grazed side of the fence. Four sites showed significant differences ranging from 1.3 to 25.1% more O.M. under the grazed side. Three sites were too marginal to count. Even though I was making a prolonged search for across-the-fence contrasts nearly half of the pairs tested failed to demonstrate grazing was harming soil health.

With regard to wind erosion, the role of domestic grazing as a cause gets confused with natural, background aeolian soil movement. Loess is the term for wind borne soils. These are silts, silt loams or fine sandy loams depending on wind speed. There must be a source for material sufficient to produce the

classically deep soils such as in China or the wheat country of Eastern Washington State. There were many loess deposits in Patagonia that predated domestic grazing. Under normal conditions wind born dust makes a hazy sky. This means a constant deposition is going on. It is subtle enough so that the extension people I interviewed did not recognize what I called mini loess deposits.

In 1993 a volcano in the Andes had an eruption which laid down a blanket of ash in a plume that extended across Argentina from the Andes to the Atlantic Ocean. The ash fell on fresh snow resulting in a frozen crust which kept the sheep from reaching forage buried beneath. Three quarters of the sheep died in the area covered by the ash plume. I took micro samples of the amount organic matter which had developed in the new thirteen year old eaolian soil, 1.5%, and comparing it with the deposited ash, .45%, and finally with the original surface soil, 1.3%. The older original soil had the greatest organic matter reflecting development over time, the new soil was catching up and the ash layer had by far the least amount. The volcanic eruption also gave me a chance to tell how old moss patches were where they occurred above the ash layer. Moss developing over 13 years had increased the organic matter by 40% over the interspace soil, 0.5%, deposited by wind. Lichen and moss have been used as indicators of overgrazing. These biological soil crusts were developed during a known grazing period.

ENGLAND

In late May of 2004 I went on a walking vacation with friends in the Lake District in the Cumbrian Mountains up next to the Scottish border. The first domestic grazing was started by people from the Middle East and later from Ireland. They put up stone circles where they worshipped and had fairs. The grazing was only in the valleys. The Romans came through in 79 AD but didn't change the grazing much, they were mostly building roads to Scotland and Ireland. They left in the 4 th. century. It wasn't until the 6 th. century that Anglian people from Germany arrived and it was these farming people that forced the locals to begin grazing on the uplands. Two hundred years later Vikings who had been in Ireland came crossed the Irish sea and moved both cattle and sheep up into the mountains and began true transhument grazing. They ran pigs in the woods.

This part of England, warmed by the gulf stream and saturated by moist winds from the sea has organic matter that reflects the rise and distance from the sea and the rain shadow on the lee side of the mountains. Rainfall is 40 inches on the coast, 80 seven miles inland and 110 inches on the highest sheep pastures, but falls off to the east in the grain growing areas. Soil organic matter on permanent pastures ran 5%, 11% under forest canopy and 16% on the high mountains which also had peat bogs where drainage was restricted. In the rain shadow the pasture soils had 6% organic matter. The stocking rate is set by the National Park. Excessive grazing simply doesn't exist by ordinary standards. The concern is over maintaining the heather for the birds and color for the walking public. Great efforts are being made to reduce erosion caused by some of the steep walking paths. Sheep raising is subsidized partially for aesthetic reasons.

MEXICO

In April 2005 I went to the Chihuahua Desert in N.E. Mexico entering at Juarez. I was looking for termites in the cow pats which is a marker for this desert. The old Camino Real came through Chihuahua in order to support the outposts of the Spanish Empire in Santa Fe and Taos in 1747AD but there was no real market for cattle until the late19th century. This isolation from markets was similar to Argentina. There was a large number of feral cattle just as in Texas to the east but no particular evidence of over grazing. It was not until the California Gold rush that a market developed towards the north. My wanting something to compare with Tanzania with over a thousand years of grazing was not to be! Mexico's economic development reflects less subsistence grazing and fuel wood gathering than in Tanzania. The large ranches largely survived land reform on the 1910 revolution and there were relatively few ejidos. After 14 years of drought plus low prices, there has been a destocking of cattle. The drought and NAFTA prices have caused abandonment of fields and towns. The country is all fenced and there has been considerable work on new wells and plastic pipes to provide water points in little used pastures. No day herding and very little small stock.

I ran into difficulties with Homeland Security on recrossing the border and lost all my soil samples so that

there is no data on the highway fence line matched pairs that I had collected.

TENTATIVE CONCLUSIONS.

Climate change, stocking rates and cropping patterns are seldom going to be gathered in a reliable data base. Farmers work the land down to a level below which yields no longer justify the effort. Likewise livestock people, with the constraints of day herding, (for security), and mobility, (to overcome variations in forage and water), keep at it until the return is no longer justified. My intuitive feeling is that the resource base, in general, is on a downward trend. Particular ecosystems differ in relationship to type change and approach to equilibrium states. For some ecosystems the rate of degradation slow and subtle, for others, particularly those exposed to domestic livestock for less than 150 years, the degradation is more rapid and obvious. I think damage by grazing has been exaggerated and although grazing needs reform, damage due to grazing is not as catastrophic as often presented.

"Experts" competing with other experts often predict ecological collapse. Exaggeration may creep in to get the attention of a jaded public. The distortion of reality can result in livestock bans in places like Tunisia and Tanzania. Livestock bans have resulted in hunger and have had to be withdrawn. The Sierra Club proposes a ban on grazing on public land in the Western U.S. under 12 inches of rainfall, (300 mm). If this were to be extended to the world it would affect 900 million people. The history of government livestock bans have mostly been a history of failures.

A second cause for anti livestock feeling is erroneous interpretations of landsat photos that have yet to be ground-truthed. As I traveled I carried maps from the Atlas on Desertification. The fact that one had to search hard for outstanding examples of anthropogenic gullying or wind blowouts and other indicators of disaster means that they may not be the normal landscape as interpreted from the landsat maps.

My interest in grazing has been on the marginal, arid areas where soil failure under overgrazing should occur first. Below certain minimum rainfall thresholds perennial grasses cannot compete with annuals and forbs. These range site evaluation scores are sometimes inaccurately penalized for bare ground that may be the normal interspace condition between shrubs so that these sites are also penalized for the lack of perennials themselves. Western range scientists can underestimate the resiliency of an annual plant community adapted to a long dry season. My feeling is that an organic matter reserve in arid soils functions to buffer rainfall variation. The difference between a heavily grazed soil and one that is protected still leaves a common level of organic matter on both sides of the fence. The question is, can this amount serve as an index of resiliency? Most range condition and trend studies measure the site on the potential natural plant community using plant species composition, maturity and recruitment.

By these criteria many third world arid range sites score badly. One thing missing might be resiliency and resistance to grazing. Could it be that, although a site might be below it's potential natural plant community; it might be on a new, sustainable equilibrium? This equilibrium might be at the end of a long downward spiral of overgrazing. It might be at the point at which grazing is matched by resilience simply because further herding doesn't justify the effort.

I found an example of resiliency in the literature of nomadism. Nomads, besides being popular and intriguing, have evolved an economic adaptation to extreme aridity that is dependent on plant resiliency. In the ergs of the "empty quarter" in Saudi Arabia there is a bush called the abal which can remain green for four years after a single rain. Camels can exist on the least amount of water of any mammal. Some local Bedouin graze only camels which can utilize a greater variety of forage than other herbivores. These pure pastoralists whose caloric intake is dominated by milk and dates have mastered a complex grazing management system that has been sustainable for centuries. It is based on the sustainability of a soil-plant community in which recruitment of some species will only occur decades apart. The closest I have seen of this is Indian rice grass and creosote brush in the Mojave Desert of eastern California. I believe that some of the common perennial grasses in arid areas enjoy reproduction only in infrequent good years.

FUTURE STUDIES. I plan on visiting Mongolia to compare long term grazing in a cold, dry climate to the grazing Patagonia that has had relatively recent grazing. Another comparison would be between four hundred years of grazing in the Mexican Chihuahua Desert with Tanzania, particularly with regards to the

role of termites.

I would appreciate comments, design suggestions, and advice on this work as I increase the data base. Data are available on request. My e-mail is: voiceofthesoil@juno.com

Richard Strong, 8 La Madronal, Orinda, CA 94563 USA