

# Effects of Keyline Soil Conditioning on Pasture Soils & Production

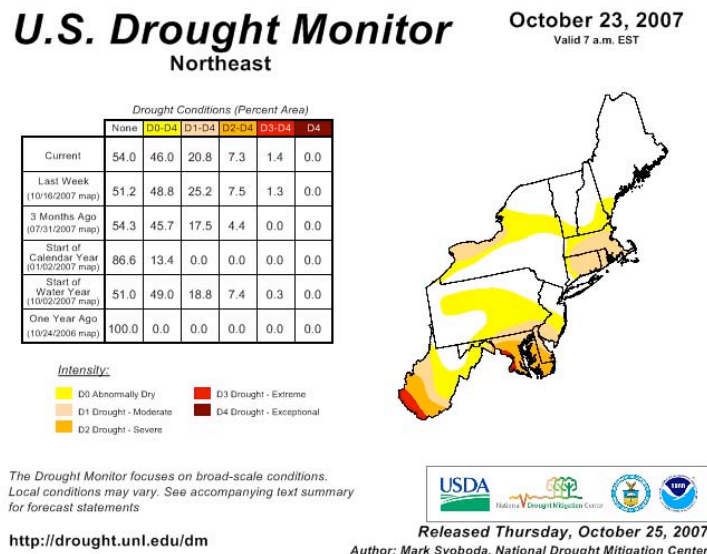
NE-SARE Partnership Grant Proposal

*DRAFT Version 10, November 28, 2007*  
 Prepared by Mark Krawczyk and Ethan Roland

## 1. What is the problem and why is it important?

Several interconnected problems are addressed. Our primary issue is the overall health of pasture and cropping soils in northeastern North America. Throughout the past century, agricultural soils throughout the country have been subject to heavy abuse due to the widespread effects of machinery, livestock, tillage and chemicals. As such, many of these soils suffer severe compaction, low organic matter and soil life, and compromised moisture-holding capacity. As the health and fertility of our soils ultimately determines its productivity as well as the health of the food it in turn produces, we need to develop land management practices that act to restore the structure and fertility of our soils and thereafter work continually to improve them.

On a wider scale, erratic weather patterns and rapidly growing levels of atmospheric CO<sub>2</sub> are combining to compromise the relative climatic stability we have come to know in the northeast. This season, extended drought conditions have affected significant parts of the northeast (see figure 1 below), while the nation’s southeast and southwest zones are currently suffering greatly due to extreme drought. These conditions not only affect localized agricultural productivity but also threaten the economic feasibility of agricultural livelihoods in these regions. Farmers throughout the country need to explore and adopt management practices that catch and store water in their agricultural landscapes – especially in soil, which offers the most effective means for on-site moisture retention.



**Figure 1.** Northeast Drought Conditions, October 2007

Increases in atmospheric CO<sub>2</sub> concentrations are believed to be one of the primary causes of growing climatic instability and rising global temperatures. Professor of Soil Science at Ohio State University Dr. Rattan Lal has calculated that 476 Gigatons (Gt) of carbon have been emitted from farmland soils due to inappropriate farming and grazing practices (Christine Jones, PhD, [www.amazingcarbon.com](http://www.amazingcarbon.com)). In contrast, 270 Gt have been emitted over the past 150 years of fossil fuel burning (Jones, [www.amazingcarbon.com](http://www.amazingcarbon.com)). In their study, “Carbon Sequestration Potential Estimates with Changes in Land Use and Tillage Practices in Ohio, USA,” Zhengxi Tan and Rattan Lal explain that the conversion of natural ecosystems to those managed agriculturally can reduce the soil organic carbon pool by up to 50% in the top 20 cm of the soil and 25-30% in the top 100 cm depth after 30-50 years of cultivation (Tan, Lal, 2005). There is currently a significant need to reduce the release of carbon into the atmosphere while at the same time, instituting large-scale initiatives to sequester the excessive carbon that has already accumulated.

## **2. What is your proposed solution?**

Our proposed solution is careful and well-timed repetitive subsoiling using the Yeomans Keyline plow, coupled with appropriately timed and managed grazing practices. The keyline system of whole-farm planning was developed in Australia in the 1950s by P.A. Yeomans and his sons to provide multiple benefits to agricultural landscapes:

- Drought-proofing, water storage, and water distribution through the construction of earth ponds and gravity-fed irrigation systems
- Rapid development of biologically active, fertile soil through repeated subsoiling using the Yeomans plow
- A perennially abundant landscape that functionally connects farm infrastructure, holistic pasture management, and diversified tree-crop agriculture

P.A. Yeomans was a mining ecologist with an uncanny ability to read landscapes. In drought-prone dryland Australia during the post war period, poor land management had led to the abuse and erosion of the scant topsoil cover throughout the country. In response to the dominant emerging land use ethic of conservation, Yeomans developed his Keyline design system. Yeomans strongly believed that it was not enough to simply work to conserve the already abused landscape; the need was instead to work to develop managed systems that act to regenerate it. In 1953, he published his first book, entitled The Keyline Plan in which he first began to unveil his theories on soil rehabilitation through water harvesting and non-inversion (subsoiling) tillage. Early in his work, Yeomans and his sons used a conventional chisel plow to do their subsoiling, later developing their own specialized design in 1974. Over the past thirty+ years, the design for this plow has been repeatedly modified and refined.

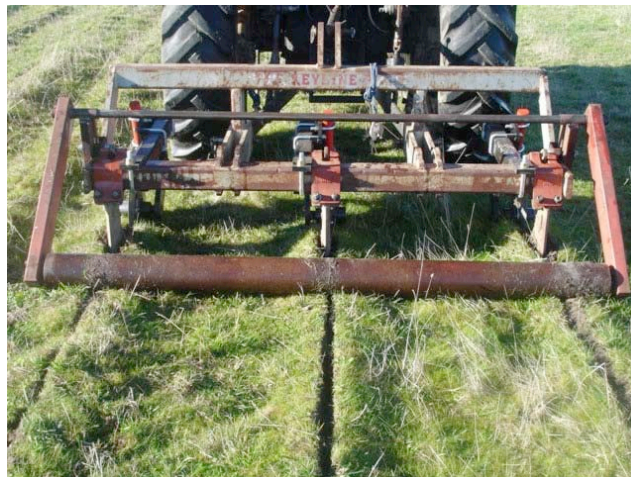
A series of rigid shanks (typically three to five) mounted on a heavy steel frame comprise the bulk of the implement. Typically a coulter disc precedes the shanks, slicing open the upper soil layer, helping to minimize soil disturbance. The keyline plow differs significantly from traditional sub-soiling implements in two main ways:

1. The plow shanks' thin profile and knife-like edge combined with the sod-cutting action of the coulter are engineered to smoothly decompact and aerate subsoil with minimum effects on the pasture surface.
2. Soil layers are not disturbed or mixed by the plow because the angle of action on the foot of the shanks is very slight – only 8%. Most subsoilers or chisel plows have steeper angles closer to 25%, which causes disturbance as well as lifting and mixing of subsoil into topsoil layers. When using the keyline plow, little to no inversion is observed.



**Figure 2.** Yeomans Keyline plow shank with attached coulter.

Behind the coulter and shanks, a roller bar can be mounted to the rear of the plow, acting to lightly compress the de-compacted soil, helping again to minimize the surface disturbance. (Please see the attached diagrams/images to help illustrate the action of the Yeomans plow.)



**Figure 3.** Yeomans Keyline plow in operation. Note the lack of disturbance on the soil surface.

The enhanced soil conditions that result from cultivation with a subsoiling plow (decompaction, aeration, improved water infiltration), provide the potential for significant regrowth of just-grazed pasture plants. These plants are then allowed to reach full vegetative maturity (early boot stage) before they are again grazed by livestock. It is this grazing of the plants' aerial parts and the subsequent root die-back, that makes considerable quantities of once-living organic matter available to soil life. The consumption and conversion of this organic matter by soil microorganisms has been observed to enhance soil fertility, forage production, soil water-holding capacity as well as the cultivation of a rich and healthy soil ecosystem. Additionally, the development of soil organic matter helps to provide a significant means by which to sequester excess atmospheric carbon, helping mitigate the effects of global warming and climate change.

Our cooperative farm-based research project scientifically explores the keyline design system through monitoring of soil conditions as farmers apply Yeomans keyline plow subsoiling coupled with well-timed and managed grazing practices. It is our hypothesis that together, these two land use strategies will work to rapidly transform and enrich soil, improving its structure, organic content and moisture-holding capability. These enhanced soil qualities would act to remedy several of the problems we seek to address in our study.

The Carbon Farmers of America report that studies have shown 12% increases in agricultural productivity resulting from a 1% increase in organic matter to six inches of soil depth. Additionally, "Enhancing SOC sequestration with changes in land use and management practice has been recognized as one of the important strategies for reducing atmospheric CO<sub>2</sub> level." (Tan, Lal, 2005) In 1999, Lal, et al. estimated that improvements in the management of US cropland could potentially sequester between 75 and 208 Tg C year<sup>-1</sup> (83-230 million tons of Carbon) for several decades.

Though keyline practices have been adopted throughout Australia, there is a lack of well-documented studies that actually quantify the effects of keyline cultivation, especially in cool temperate climates with 30+ inches of annual rainfall.

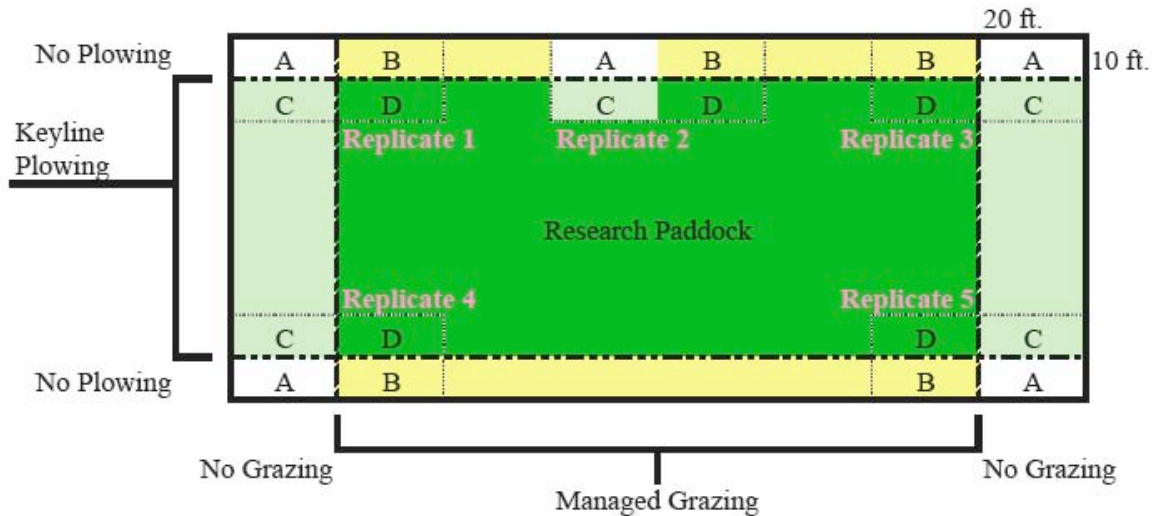
### **3. What are your project methods?**

Our project records key pasture production parameters over a two-year period as farmers apply keyline soil conditioning strategies. On four working livestock farms across 3 states (MA, NY, VT), we will implement 4 treatments with 2 variables to study the effects of keyline plowing + managed grazing techniques on soil compaction, organic matter, nutrients + availability, temperature and moisture, and lower-than-optimal forage production. The proposed treatments (A-D) are:

	<b>Control – No Grazing</b>	<b>Experiemental – Grazing</b>
<b>Control – No Plowing</b>	A. (NP/NG) No Plowing / No Grazing	B. (NP/G) No Plowing / Grazing
<b>Experimental – Keyline Plowing</b>	C. (P/NG) Plowing / No Grazing	D. (P/G) Plowing / Grazing

**Table 1.** Proposed treatments (A-D) with control and experimental variables.

Each farm will choose paddocks of uniform slope and soil type and delineate areas for each experimental variable. In the paddock, we will mark out 5 replicate areas containing 10x20ft plots for each of the 4 treatments (a total of 20 plots). The following diagram (not to scale) illustrates the conceptual layout of the research paddock:



**Figure 4.** Research paddock layout with experimental variables, replicates areas, and testing plots.

Soil conditioning will occur 3 times over the project timeline, with 4 data collections:

<b>Timeline</b>	<b>Soil Sample</b>	<b>Keyline conditioning</b>
May 2008	1 <sup>st</sup> Soil sample - baseline	-
Jun 2008	-	1 <sup>st</sup> Soil conditioning with Keyline plow
Aug 2008	2 <sup>nd</sup> Soil sample	-
Sep 2008	-	2 <sup>nd</sup> Soil conditioning
Apr 2009	3 <sup>rd</sup> Soil sample	-
May 2009	-	3 <sup>rd</sup> Soil conditioning
Aug 2009	4 <sup>th</sup> Soil sample - final	-

**Table 2.** Soil conditioning and data collection timeline.

Each data collection includes 7 parameters:

Number	Parameter	Units	Assay
1	Soil organic matter	(%, tons/ac)	Soil Nutrient Analysis
2	Soil cation exchange capacity (CEC)	Meq	Soil Nutrient Analysis
3	Soil nutrient levels	Ppm	Soil Nutrient Analysis
4	Soil temperature	degrees	Thermometer
5	Soil moisture	%	Soil Drying
6	Soil compaction	Psi	Penetrometer
7	Dry forage production	tons/ac	Pasture Plate

**Table 3.** Parameter descriptions, units, and proposed assays.

Soil nutrient analysis (1-3) will be conducted by the University of Vermont Agricultural and Environmental Testing Laboratory. We will collect and record data for parameters 4-7 in the field with the appropriate protocols and calibrated instruments.

Our intent is to develop these studies up so that they have a practical value to farmers. Our long-term goal is to collect information to answer the questions most farmers are interested in:

1. *What will this do for my soils?*
2. *How much extra feed will I get?*
3. *What increases in feed value will I get?*
4. *What is the overall cost benefit?*

In this pilot project, we are focusing almost exclusively on the first question, with a small bit of data for the second. In the future, we also intend to expand this pilot study to a larger SARE Research & Education project in order to more completely address each question.

#### **4. What is the project timetable?**

Our study runs from spring 2008 until fall 2009 (See also table 2 above). Depending on soil moisture conditions, we will begin the study sometime in May 2008, collecting soil data for each of the test plots on each of the four participating farms. After allowing stock to graze the designated test plots, we will immediately make the first ripping pass with the keyline subsoiling plow on all the appropriate plots at each farm.

When pasture plants have reached the early boot stage of their growth cycle, farmers will turn stock onto the fields to graze once again. This will then be followed by another round of soil and forage data collection during the month of August 2008. Immediately following this grazing we will again subsoil our test plots.

We will reconvene our study in early 2009 with our third series of soil and forage data collection. Pasture plants will be allowed to again reach early boot stage before another round of grazing, to be followed by a late spring rip (May 2009). This will be followed

by one more succession of pasture regrowth, upon which we will collect our final data sample in August. With trials complete, we will collate results and draw conclusions, completing our final report by the end of 2009.

## **5. How will you disseminate your project results?**

We plan to share and distribute the results of our study collaboratively with our farm partners via three primary avenues:

- Presentations, workshops and speaking engagements
- Digital photographic & video media through the internet
- Printed 3-fold pamphlets

Our most direct and effective efforts will be through lectures, workshops and pasture walks. We will present our results at the winter NOFA conference as well as local agriculture related conferences and events. We will also be offering pasture walks during the prime pasture subsoiling seasons (late spring/fall) in our respective regions while also demonstrating these subsoiling techniques so as to more effectively transmit the theory and practice behind our endeavors.

Using simple digital video, photographs, and audio recordings, we will produce a concise 5-minute piece of electronic media explaining the basics of keyline design and the results of our experiment. This media will accompany our conference and workshop presentations, and be made freely available on the internet.

Additionally, we will produce a pamphlet explaining the process of keyline pasture management as well as the results of our study and subsequent recommendations. This pamphlet will be simple and informative and it will be made available through NOFA and local agricultural extension services.

## **6. What are your qualifications?**

**Mark Krawczyk** has worked in a range of agricultural settings since receiving his B.S. in Environmental Studies from the University of Vermont in 2001. His thesis focused on the development of a directory of useful plants for use in integrated perennial agricultural systems in climate zones 5 and below. He spent a season working on a 10-acre vegetable CSA, Urban Roots, at Burlington, VT's Intervale farm complex in 2001. Thereafter he has spent time working as an intern/employee for tree crop and greenhouse specialist Jerome Osentowski, Basalt, CO 2001/3/4/7; a coppice forester, apprenticing with woodsman and author Ben Law at his woodland in West Sussex, England 2003/4; and as an intern for Dan Hemenway, traditional agricultural specialist in Sparr, FL 2002. Additionally he maintains his own traditional woodworking business, RivenWoodCrafts ([www.rivenwoodcrafts.com](http://www.rivenwoodcrafts.com)), and is a builder and educator, working as a member of Seven Generations Natural Builders ([www.sgnb.com](http://www.sgnb.com)). He completed a six and two day Keyline Design Course with instructors Darren Doherty and Abe Collins in 2007. He is the director and founder of Keyline Vermont – a farm design/consulting business

specializing in the development and implementation of soil building and water harvesting techniques.

**Ethan Roland** [Please See Attached Resume for more information]

- M.S. Associate: Integrative eco-social design, Gaia University 2007-2008.
- B.S. Biology, Minor Mathematics, Haverford College 2004. Undergraduate thesis won Ariel G. Lowey award for best original research.
- Founder and principal, AppleSeed Permaculture.  
([www.appleseedpermaculture.com](http://www.appleseedpermaculture.com)) Design, research, and teaching firm focusing on the design and maintenance of agriculturally productive ecosystems that integrate humans and landscape to sustainably produce food, water, energy, and shelter.
- Educator – over 30 national and international invited lectures on sustainable agriculture and orchard management.
- Keyline Design Course graduate, 6- and 2-day intensives with Darren Doherty and Abe Collins in 2007.

**7. Who are the project’s cooperating farmers?**

Farm	Description	Location	Contact Person	Phone	Email
Stony Pond Farm	Og beef and milking cows	Fairfield, VT	Tyler Webb	802-827-3693	stonypondfarm@verizon.net
Doe's Leap Farm	Organic Goat Dairy	Bakersfield, VT	Kristen Doolan	802-827-3046	doesleap@pshift.com
Threshold Farm	Organic cattle	Philmont, NY	Hugh Williams	518-672-5509	threshold@taconic.net
Blue Hill Farm	Organic cattle & chickens	Great Barrington, MA	Sean Stanton	413-528-2092	seanstanton@hotmail.com

Advisors	Specialty	Entity	Location	Phone	Email
Keith Ryan	Yeomans Keyline Plow	Yeomans Plow Company	Australia	-	-
Royal Purdy	Keyline Design	A. H. Tuttle and Company	NY	315-986-7007	rapurdy@ahtuttle.com
Karen Hoffman-Sullivan	Dairy nutritionist	USDA-NRCS	NY	607-334-4632	karen.sullivan@ny.usda.gov
Darren Doherty	Keyline Design + Planning	Australia Felix Permaculture	Australia	+0418 254 605	darren@permaculture.biz
Abe Collins	Northeast Keyline Design	Carbon Farmers of America, Cimarron Dairy Farm	VT	802-527-2913	abe@carbonfarmersofamerica.com
Stephen Herbet	Soil Science + Pasture Research	UMass Amherst	MA	413-545-2250	sherbert@pssci.umass.edu
Rachel Gilker & Jennifer Colby	Soil Science, Pasture Management	VT Pasture Network @ UVM Ctr of Sustainable Ag	VT	802-656-3834	rgilker@uvm.edu, jcolby@uvm.edu