The LTRAS Century

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LTRAS Objectives in Focus

The overall objectives of the Long Term Research on Agricultural Systems project (LTRAS) are concisely stated on a sign marking the entrance to the site -- "a *facility* to study *sustainability* of agricultural systems and their impact on the *environment* [emphases added]."

Most of the current effort at LTRAS is on the first long-term experiment -- a 100 year study of annual field crop systems. However, this 72-acre experiment still leaves much of the 300- acre site available for additional experiments on the sustainability and environmental impact of agriculture. Thus LTRAS is a *facility*, not just a single experiment. Each experiment at the site is also expected to serve as a multipurpose facility so long as that does not conflict with its specific goals. For example, atmospheric dust from field operations was not considered in the design of the first experiment, but a proposal to monitor dust (respirable silica) production at the site, in response to cropping system and implement speed, is now being reviewed by the EPA. Similarly, LTRAS is expected to contribute to teaching and extension as well as research.

The word *sustainability* applied to agriculture is subject to at least two distinct types of controversy. People may disagree on the *criteria* that define sustainability as well as on which agricultural practices best meet their preferred criteria. LTRAS may not contribute much to settling the first type of controversy, but should help with the second.

A cropping system is sustainable in an agronomic sense if long-term yield trends increase or remain constant, unless maintaining yields requires ever increasing levels of inputs. However, economic and social sustainability also depend on market conditions (consumer preferences, trade barriers, etc.) and responses of the political system to actual or perceived problems of environmental quality or social and economic equity.

Because certain types of environmental impacts may be of considerable public concern without directly affecting the agronomic sustainability of a particular agricultural system, *environmental impact* was explicitly included in the research mission of LTRAS. For example, low levels of nitrate in groundwater or surface waters may have little direct adverse effect on agriculture, but nitrate contamination of drinking water could indirectly affect agricultural sustainability by leading to new restrictions on the use of synthetic nitrogen fertilizers or animal manure.

PI Profile -- Graham Fogg

LTRAS is a multidisciplinary collaboration involving Principal Investigators from at least six UCD departments. The extent of involvement varies from occasional advice to active on-site research.

Graham Fogg and members of his groundwater research team are among the more active of those currently working at the LTRAS site. The proximity of the LTRAS site to Putah Creek has been a plus for M.S. candidate Anne Benjamin's work on hydrologic interactions between irrigation, groundwater, and stream flow. This work has required installation of monitoring wells (with screens at different depths) both within LTRAS plots, adjacent to the creek, and in the creek bed itself, as well as monitoring of stream levels in response to irrigation and pump activity. After supervising construction of the new irrigation well in 1992, Anne conducted a 7-day pumping test of the well in Spring 1993 to determine the degree of interaction between Putah Creek and the aquifer system. Preliminary results demonstrate no

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hydrologic interconnection between the creek and aquifers tapped by the irrigation well. Shallow aquifers (<200 ft) however, show a response to irrigation events and exhibit a certain amount of interconnection with the creek.

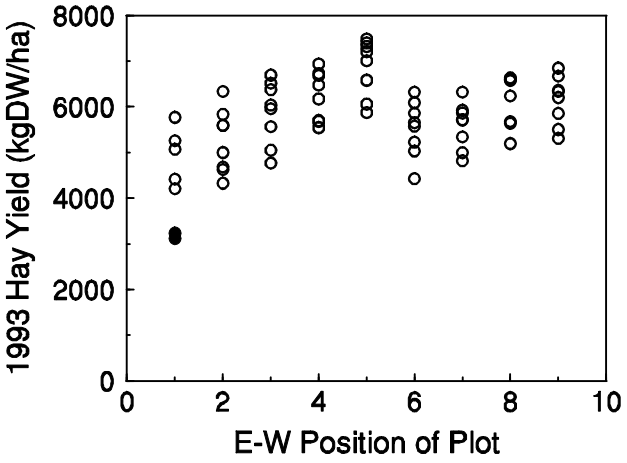
Nitrate pollution of groundwater is also a central concern of Fogg's group. David Decker and Jim MacIntyre have been working on methods of identifying the source of nitrate in groundwater, based in part on differences in isotopic composition of nitrate from fertilizer, animal waste, or soil organic matter. Five deep cores (surface to groundwater) collected at the LTRAS site, which received nitrogen fertilizer before the alfalfa rotation that preceded LTRAS, will be compared to similar cores collected at sites containing animal waste sources (manure or septic tanks) and soil organic matter sources. Nitrate can take decades to move from surface to groundwater, so possible changes in isotopic composition during downward migration (e.g., due to denitrification) are being investigated. Groundwater issues are of considerable current concern because of dwindling quantity and quality of groundwater in agricultural regions worldwide.

Spatial Trends Revealed in "Time Zero" Data Sets

Trends over time (in yield, soil organic matter, irrigation requirements, disease incidence, etc.) are a principal focus of LTRAS. To detect and quantify such changes over time, we need a "time zero" data set characterizing the initial conditions before beginning the rotations. Sampling for this data set should be complete by mid-October.

After laboratory analyses this winter, our time zero soils data set will include information (for each of 72 plots) on the depth of soil horizons and on soil texture and soil chemistry (pH, total N, total organic C, P, K, Na, and B) at five depths. Archival soil samples (720 composite samples plus 288 intact cores) will allow additional analyses to be performed in the future. The soils archive will also include five cores extending from surface to groundwater (see *PI Profile*).

Sudangrass hay crops were grown over the entire plot area, without nitrogen fertilizer, in 1992 and 1993. Yield data for each plot and aerial photos of the entire area are also included in our time zero data set. Hay yields in 1993 tended to increase from west to east across the field, with a discontinuity corresponding to the main N-S road (see figure). This pattern was much less apparent in 1992. Image analysis of 1993 aerial photos found that low-yielding plots also had a lower ratio of infrared to red reflectance, characteristic of less plant cover. (The aerial photos, with a resolution of better than one meter, also reveal some spatial patterns within individual plots.)



During initial land leveling, more topsoil (and presumably more organic matter) was removed from the western part of each half of the field, and this may explain the spatial patterns in yield and aerial photos. Residual nitrogen may have been sufficient to maintain relatively uniform yields in 1992; nitrogen analysis of hay samples from the two years is planned. If N supply is responsible for much of the variability shown in the figure, then variability among replicates should be less in the future, at least for those plots with an adequate supply of N (from fertilizer, manure, or legume cover crops).

Three plots at the west edge of the field (solid circles in graph) had substantially lower hay yields than the others each year and also had the lowest IR:red ratio in aerial photos. At a recent meeting of the LTRAS Statistics Subcommittee, it was decided to randomly reallocate to two nearby plots the treatments (not yet started) originally planned for two of these plots. (The third plot was already unassigned.) This change reduced

differences in mean hay yield among planned treatments, thereby reducing the chance of incorrectly concluding that there are differences due to treatment when differences actually result from initial differences in yield potential (Type I errors). Variability among replicates (*within* two of the planned treatments) also decreased, reducing the probability of missing actual differences due to treatment (Type II errors) in future comparisons.

LTRAS Update

R. Ford Denison, the first "permanent Director" of LTRAS arrived in May. (In the context of a 100-year experiment, perhaps this title is a bit optimistic!) Thanks to former Directors Ken Cassman and Montague Demment, and their many collaborators, for a massive effort in planning, site selection and preparation, and fundraising (see *A Brief History of LTRAS*).

Completion of the LTRAS "time zero" data set within the next two months will roughly coincide with planting of wheat and leguminous winter cover crops to begin the first rotations. Installation of an automated weather station and some improvements to the LTRAS field headquarters and will also be completed this fall.

Clarification of the organizational structure of LTRAS is also underway. The LTRAS Charter, approved unanimously by attendees at a well-publicized recent meeting, gives overall authority to determine LTRAS policy to an explicitly defined LTRAS General Committee, and delegates administrative authority to the Director and a newly formed Executive Committee. It is expected that most decisions will continue to be made by near-consensus. However, given the planned duration of LTRAS, it was decided that some mechanism was needed to deal with possible future disagreements.

To decrease the chances of mistakes made due to haste, it was decided that any major changes (e.g., a switch to genetically engineered nitrogen-fixing corn, if it ever becomes available) would have to be approved at two successive meetings of the LTRAS General Committee. This approach is consistent with the well-known statement by an early agricultural researcher, Thomas Jefferson, that systems long-established should not be changed for "light and transient" reasons. On the other hand, previous long-term projects have had to respond to changes in available technology (e.g., the introduction of dwarf wheat varieties). The LTRAS Charter is intended to provide an appropriate mechanism to make such changes when necessary.

Holocene Park?

"Which lambsquarter genes were involved in the evolution of glyphosate resistance?"

"Did the decrease in severity of *Fusarium* correspond to any changes in soil populations of pseudomonads?"

"Did current differences in nematode populations among plots precede the start of the rotations?"

These are the kinds of questions that may someday be answered using the LTRAS Soil Biology Archive, now under development. We plan to preserve weed seeds and samples containing representative populations of soil microorganisms, under cryogenic conditions suitable for long-term preservation of DNA. Part of this archive will be kept in reserve in anticipation of future technological developments that, we hope, will someday allow nearly complete recovery, quantification, and sequencing of the DNA in a very small sample. This would allow us to track changes in soil biology (abundance and genetic composition) as a function of cropping system and time. Participants in the design of the LTRAS Soil Biology Archive include weed scientist Robert Norris, soil microbiologist Kate Scow, plant pathologist Dave Gilchrist, microbiologist Linda Smith, nematologist Howard Ferris, and molecular biologist Thea Wilkins.

A Little Help from Our Friends

Core operations at LTRAS are made possible by funding from the UC Davis College of Agriculture and Environmental Sciences, and by special appropriations from the Division of Agriculture and Natural Resources. This support,

in times of sharply curtailed budgets, clearly indicates the commitment of the University of California to solving issues of agricultural sustainability and environmental impact. A generous startup grant from the Sustainable Agriculture Research and Education Program was critical to the initial establishment of LTRAS. Gifts from individuals and organizations have also greatly assisted LTRAS. In particular, we appreciate recent donations of seed or equipment from the UCD Foundation Seed and Plant Materials Service, Cal/West Seeds, Bernie Gorman, Barrios Farms, and the UCD Grounds Division. Dave Klippert, of UCD Agricultural Services, has been especially helpful in helping to get the LTRAS site and field headquarters ready for operations.

Our most colorful donation to date is Phil Mainwaring's map of LTRAS, which is included as an insert in this issue. Plot colors indicate the crops in each two-year rotation, shading represents external inputs of N, and border color indicates extent of irrigation. Thanks for your support of LTRAS!

A Brief History of LTRAS

In 1988 Dean Hess approved a proposal from the Agronomy and Range Science Department to establish a college program in Sustainable Agriculture (UCDSAP) directed by Montague Demment. This program spawned the LTRAS project. UCDSAP was developed to initiate actions within the college that focused on the interaction of agriculture and the environment. Because so many of the critical processes determining sustainability and agriculture/environment interactions occur slowly, the development of long-term experiments was a critical component of the college's capacity to fulfill its mission.

There were three critical ingredients required for this long-term research to succeed. First, a considerable amount of funding would be required for initial establishment of the facility. Second, the campus would have to supply the land. Third, the College, Campus, and Division would have to establish a partnership to ensure a long-term financial commitment.

The first ingredient came in the form of a competitive grants program from SAREP that specifically identified long-term site research as a funding category. Long-term research was one of the responsibilities identified for SAREP in the original Senate bill that created the program. The proposal from Davis was headed by Ken Cassman and included two farm advisors and 15 faculty from eight departments. On March 28, 1990 SAREP announced that Davis won the competition and awarded $150,000 start-up funding.

The next two years were a period of slow but steady progress for LTRAS. Land allocation was critical to the project. Negotiations between UCD and the Ham family for the purchase were completed in the summer of 1990. LTRAS was cited by Chancellor Hullar as one of the prime justifications for the purchase. Surveys of the ranch followed and the site for the first experiment was chosen and allocated to the project in the summer of 1991.

The arrival of Dean Kinsella in the fall of 1990 and impending budgetary constraints required a renewed discussion of the resource committments of the three partners in the project. Spurred on by the award from SAREP, the partners were able to find the funding to establish the facility and made a long-term commitment to a permanent operating budget to support the core project. In the spring of 1992 construction began. The 300 acre site on the Russell Ranch saw the completion of a 1500 gal/min well, a 15 acre-ft reservoir, underground supply pipes and water meters for each irrigated plot, plot leveling, and road construction in the fall of 1992.

Montague Demment became interim Director of LTRAS in 1991 after the departure of Ken Cassman, to head the agronomy unit of the International Rice Research Institute.

The LTRAS Century is an occasional publication of the Long Term Research on Agricultural Systems project at the University of California, Davis. To subscribe, please contact:

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