These notes include the reflections of the CIFS executive committee following the November 2005 assessment and planning meeting. They include a summary of the discussions taking place in response to suggestions created in a group process at the meeting itself. A series of consensus about changes to the project evolved. These include:

1. **The project must retain its long-term character,**
2. **increasing rotation length to three years from two,**
3. **using tomatoes, wheat and corn as the core crops to maintain continuity of inference,**
4. **adding a fourth (horticultural) crop to the system, likely following wheat, to increase the number of crops around which research can be carried out, and to better reflect farm practice,**
5. **dropping irrigated wheat/fallow plots to create opportunities for other cropping systems that do not need to conform to the design requirement of the core experiment, but which are related to the core issues assessed on the effects of C, N and irrigation water inputs on sustainability,**
6. **Modify the organic and intermediate systems to improve their performance and strengthen the core research capacity of the experiment. These may include systems focusing on biofuels and on the perennial forages.**

Ideas and input about how to modify the management of the organic and intermediate systems and about what kinds of non-conforming systems could be added are being solicited from interested participants.

CIFS executive committee

November 17, 2005 committee meeting

At the CIFS committee meeting held on November 17, 2005, there was discussion about the Assessment and Planning meeting from November 3/4, 2005. The list of tasks discussed at the planning meeting was transcribed from the meeting notes.

These tasks were:

1. *Define how long the project should last*

2. *Define principles for selecting improved experimental and treatment designs*

3. *Develop experimental and treatment designs*

4. *Establish principles for resource allocation*

5. *Create a list of stakeholders*

6. Elicit additional support from the dean

In addition, concerns raised at the SAFS pow-wow the following week were communicated. In particular, there was a request for the CIFS committee to create a formal production committee and define its area of competence**. It was agreed that a production committee would be useful but that its role would follow naturally from the needs of the project in the future, which must first be determined.**

Following discussion, the CIFS executive committee agreed that:

1. The project was /is a long term project. Its long term character is essential and distinguishes it from other research in California.

2. Because it is long term, there must be continuity between data collected in the past and data that will be collected in the future. Care must be taken in modifying the project's experimental design to preserve the ability to make clear inferences about cause and effect in and between the differing cropping systems, to evaluate trends, and to maintain the usefulness of both the project's data base and archives.

3. A longer crop rotation would be desirable; minimally three years, possibly four years, depending on the outcome of careful consideration of the dual needs for continuity and for evolution.

4. The long-term research project should remain "hypothesis" driven. The core hypotheses should/do concern basic processes in cropping systems: responses of systems to irrigation and inputs (particularly C and N).

5. There should be better treatment design that can more effectively evaluate response to these fundamental types of inputs in Mediterranean systems. There should be improvement in the ability to test the fundamental hypotheses.

6. The core experiment should evolve to more effectively test these responses. Currently, there are too many treatments and plots allocated to the lower input end of the range of comparisons. Some of the wheat/ follow plots could be used for new treatments.

7. In addition to the changes in treatment design in the core experiment, new treatments should be introduced that are less constrained by the core experiment's design requirements and which reflect interesting and innovative examples of input intensification. These treatments can be analyzed in combination with plots from the core experiment if some crops overlap, but primarily as part of a regression analysis approach to assessment of inputs and soil and crop responses. Such treatments might include grain only (very high input treatments), or biomass production treatments, or others that involve innovative cropping system combinations.

8. The relevancy of new treatments to a future agriculture should be given a high priority.

9. The outcome should be to create a more effective long-term experiment, one that allows greater flexibility in some of the plots in the trial, and that is as rich as possible in potential hypotheses across as many disciplines as possible.

Attending:

Steve Kaffka
Will Horwath
Howard Ferris
Chris van Kessel

December 6, 2005 committee meeting

At a meeting on December 6, 2005, the CIFS committee discussed some issues of experimental design. The hypothesis driven character of the core experiment was reaffirmed following discussion. WH reported that total carbon levels seemed to reach a peak in the current management systems within the first four years (by 1997). Discussion followed about the utility of continuing to use carbon as one of the focal points for research and one of the factors (inputs) being evaluated. The committee concluded:

- **that a long term experiment requires a more basic focus as its organizing principle**
- **that the long-term effects of N and water on soil quality, production, environmental quality, and other factors should remain the basic focus of the experiment,**
- **that carbon was a fundamental factor influencing crop response to N and water, and other important cropping system properties and that more still could be learned about these interactions.**

Crop rotation length was discussed. SK provided a table indicating the number of irrigated plots needed for the current two year comparisons (corn/tomato), for a three year rotation comparison, for a four year rotation comparison, and for a four year rotation, but reduced to two replications from three.

Table 1. Comparisons of differing crop rotations. More detailed assessment of degrees of freedom for data analysis are included in a companion document on the design of the LTRAS experiment.

factor	**current 2-yr rotation**	**3-yr rotation**	**4-yr rotation**	**4 yr rotation with 2 reps**
blocks or reps	**3**	**3**	**3**	**2**
systems	**3**	**3**	**3**	**3**
crops	**2**	**3**	**4**	**4**
# of irrigated plots needed	**18**	**27**	**36**	**24**

Currently, there are 45 irrigated plots used in cropping systems comparisons at LTRAS. Eighteen are used in the C/T comparisons. There are 6 used for the wheat/tomato rotation, and three are left over from the organic transition experiment (Martini et al., 2005). In addition, there are 18 irrigated plots used for the wheat/fallow systems comparisons. By using the six wheat/tomato plots and the three organic transition plots, a smooth and simple transition to a three year crop rotation can be carried out, especially if wheat, tomatoes and corn are used. The three transition plots are already fully organic. They have been managed similarly to other organic plots for six years and are in most ways similar to the others in the C/T organic plots. They would provide the three additional plots needed for the organic comparisons. The wheat/tomato plots are managed conventionally. Three of them would easily become conventional three year plots through, for example, the addition of a corn crop. The other three would require some time to become functionally equivalent to intermediate systems, but perhaps not more than two crop cycles. There would be no additional costs for this change, since it reflects a simple reorganization of current plots and crops.

A four year rotation was disfavored because it would be more expensive to implement in terms of staff and operational budgets, more complex to manage to the level of quality practiced at LTRAS. Most importantly, it would be very different from the current combinations of two year systems, raising more problems with continuity of the long-term experiment and interpretation of results over time. A four year rotation with only two reps was disfavored because some compromise is needed to allow graduate students to carry out research in two or three year periods and having three reps increases the discriminatory power of comparisons in the short term compared to two reps.

- **The committee decided to emphasize the three year rotation in the next 12 year period**.

Further discussion of the three year rotation focused on crops. **It was agreed that *wheat* should be one of the crops**. Including wheat allows for comparison across all the cropping systems: from wheat/fallow to organic, using wheat as the common element in all rotations. It is widely grown in California, is a winter crop important for agronomic reasons, and is the world's most

important food crop.

Tomatoes were discussed. They are by far the most expensive part of the project, and the one with the most difficulty in reaching county yield averages or better. They may not have a long-term future in the Yolo county region. Nonetheless, they remain one of the most important annual crops in California, are a C3 dicot, spring-summer annual and an important horticultural food crop, allowing for direct connection to the consumer public in the arena of food quality. Also, they are part of a newer research effort involving faculty from Food Science and Plant Sciences that focuses on food quality (tomatoes). Plots will be needed in the future that are managed sufficiently similarly to past plots for this work.

- **The committee decided that wheat and tomatoes should be part of the three year rotation.**

SK suggested keeping *corn* in the system as well. The advantages of doing so are the importance of corn in California and worldwide. In California, a large amount of corn is grown to feed cattle and this preserves a link to livestock-based systems. It is a C4 grass, adding a different but important type of organic matter to the systems; it is easy to manage and a good test species for N response work. Most importantly, keeping corn in the systems' comparisons provides for continuity with the data previously collected and with archived samples from the first 12 years of the project. Indeed, its loss may create potentially severe difficulties in interpreting results over time.

There were comments in favor and comments against the continued use of corn. Comments against were essentially comments in favor of thinking about and including other types of crops, especially horticultural ones, that reflect the current trend in California's central valley and the Yolo region in particular towards farmers including more horticultural crops on farms. In discussion, the use of a horticultural crop as a fourth crop in the late summer following wheat or tomatoes was made. A brassica like *kale or broccoli* was suggested because it could be grown as a short crop after wheat (July to October) or tomatoes (September to February). It is N responsive and provides an alternative, high value species. They are similar in many ways to mustard or other brassica catch crops and may have interesting phytopatholgy properties. They would allow for interesting insect management investigations within the main cropping systems.

- **The committee decided to continue further discussion of a possible fourth (and fifth?) crop in the core three-year systems**.

Improvements to the current organic (OCT) and intermediate (LCT) systems were discussed. The organic system is likely being over-fertilized, and the LCT one is not very interesting. Most think it is not intensive enough. There is room to change some of the cover crops to ones which increase C but do not fix N and rely more on fertilizer for N inputs in this system. Other ideas were discussed.

- **Once the three year rotation is settled, the committee will address the management of individual cropping systems.**

Discussion turned to the *wheat-fallow systems*. There was discussion about the number of replications needed. SK suggested that if the complete set of treatments was kept, that only two replications be considered. Since there are now 12 years of data from these systems, the number of replications is becoming less important statistically. This would free up six irrigated plots for alternative, non-conforming cropping systems. Others suggested eliminating all irrigated wheat/fallow treatments and preserving three replications of the non-irrigated wheat/fallow treatments. Eliminating irrigated wheat/fallow treatments would free up 18 irrigated plots for alternative treatments. Most attending favored eliminating the irrigated wheat/fallow treatments.

- **The committee decided to continue discussion of the number of replications and of possibly eliminating the irrigated wheat fallow systems at the next meeting.**

At the November3/4 assessment meeting, *alternative (non-conforming) cropping systems* were proposed that would provide a wider range of cropping systems and be useful for purposes of evaluating different combinations of N and C inputs. Most of these systems would tend to be more intensive than many current ones and most would require irrigation. One idea was to double crop wheat and corn, continuously. This would be a high N input system. Using corn and wheat in a double crop system would allow comparison with the core cropping systems that also had wheat and corn. There was also interest in having perennials like biomass crops or perhaps alfalfa in a set of plots to compare with purely annual systems. The idea of having some non-conforming treatments with more horticultural crops was also raised. In particular, there was a comment that some cropping systems might be organized with the idea of the total food system in mind, particularly emphasizing food quality.

Lastly, Steve Kaffka distributed a Powerpoint presentation made at the last American Society of Agronomy meeting in Salt Lake City by a statistician from Kansas State (Loughlin) made during a session on the analysis of long-term experiments. It is distributed with this email. The main point made was that even with the used of mixed models for the analysis of LTEs, some confounding of random and fixed effects still occurs at the plot level. He suggested that the way to be able to separate these two effects at the plot level is use a “staggered start.” That means beginning each replication on a successive year. At LTRAS for a three year rotation, one rep would be converted from two to three years each year fro three years. Loughlin presented some simulations indicating that a *staggered start* substantially improves the likelihood of detecting true trends, and once the transition was complete, that trends could be detected in a shorter time. If this is so, we have a chance now to adopt a staggered start during this transition period. If true, this would be an important and substantial legacy to leave future researchers, and favor the outcome of research conducted over shorter periods of time, especially by graduate students. In the short run, as the transition occurred there would be some continuity with current systems, and a number of interesting questions to ask about non-conforming systems and transitional effects.

- **Further discussion of transition strategies would be continued at future meetings.**

Steve Kaffka

Chris vanKessel
Ed Depeters
Bruce Lampinen
Karen Klonsky
Will Horwath

December 21, 2005 Committee Meeting

Discussion resumed about the core experiment. It was agreed that a three year crop rotation was the most prudent choice, because it allowed for greater crop diversity, but did not require the commitment of a larger number of plots to the core arable crop rotation. Previous discussions about including wheat and tomatoes were affirmed. Corn was discussed again as the third crop. There are many advantages associated with corn, including its ease of cultivation, responsiveness to N, that it is a C4 cereal and one of the three most important crops produced world wide, that is relevant to dairy systems and continues to hold a place in arable crop rotations in California, though diminishing. It has an important role in ethanol production. Using corn will allow for much greater continuity with previous work on the project, while removing it would make inference from the previous 12 years cropping systems more difficult or in some cases impossible. The primary disadvantage associated with corn is its declining importance currently in crop rotations, especially in the southern Sacramento Valley, where more horticultural crops are being used by growers.

The addition of a fourth crop to the three year rotation was discussed. The use of a brassica crop like kale, collards or broccoli in late summer following wheat or at some other point in the rotation as a catch crop was discussed. The brassica crop would provide an additional species in the rotation, be responsive to residual N, especially in the organic and organic matter intensive plots, and provide additional interesting research opportunities in entomology and plant pathology, and add another horticultural crop to the core system. The idea of a fifth crop (another short season catch crop was raised, but left for future discussion). The disadvantage would be added work and expense from the field to the archive.

There was general agreement that a core three year rotation would use wheat, tomatoes and corn, but a fourth (brassica or other short term horticultural) crop would be added to all systems. This was considered the option with sufficient improvement to add biological diversity and relevance to current farming trends while maintaining sufficient continuity with past treatments to allow for clear inference from past results.

The wheat systems were discussed. The issue of dropping the irrigated wheat fallow treatments was raised again. Arguments in favor of keeping some irrigated wheat-fallow plots were that the irrigated wheat-fallow plots are the only “intermediate” irrigation treatments in the irrigation comparison. That is, they are the only plots to receive irrigation every other year. So the yields of wheat can be compared from plots that are never irrigated, irrigated every other year, or irrigated every year (wheat-tomato plots). This is the only comparison possible currently in the experiment using the complete irrigation gradient. Additional arguments in favor of retaining the range of wheat-fallow treatments were the importance of wheat-fallow systems in Mediterranean

and semi-arid regions of the world, and the likelihood that low input systems may at some point in time be more widely used in California as a land management strategy for retired farm land, hence their relevance.

Alternatively, irrigated wheat plots provide a large number of plots (18) that could be used for alternative, non-conforming systems without much additional investment in water supply and equipment.

Table 2. Wheat yields over the 1995-2006 period in the LTRAS experiment. Irrigated and fertilized crops had approximately 600 kg ha larger yields over this period than non-irrigated crops.

Treatment	n	mean	sd	se	CV
CWT	30	5575	1340	245	24.0
IWC	30	3730	1015	185	27.2
IWF	30	5360	1460	270	27.3
IWL	30	4500	1620	300	36.0
RWC	30	3880	1100	200	28.4
RWF	30	4770	1380	250	29.0
RWL	30	3910	1200	220	30.8

CWT: Conventional wheat/tomato (fully irrigated), IWC: Irrigated Wheat Control (no fertilizer), IWF: Irrigated wheat + fertilizer, IWL: Irrigated wheat/legume; RWC: Rain fed wheat control; RWF: rain fed wheat + fertilizer; RWL: Rain fed wheat/legume.

Discussion turned to new systems. WH had proposed previously an intensive wheat-corn single year systems, managed continuously with a high level of conventional inputs. This system would be intended to provide a highly intensive comparison with core, three-year plots which also include wheat and corn in the rotation, but only one crop per year and add a system that was intentionally managed with high fertilizer levels in a single year. Since these plots would be continuous wheat-corn, there would only need to be three reps for a total of three plots. This system could be viewed as part of a biofuels research program. The idea of adding plots with a perennial biomass crop was discussed. If a grass like *Miscanthus*, for example, were grown, it would be low input (fertilizer), high irrigation, and generate large amounts of carbon as part of a perennial root system. Again, only three replications would be needed.

The value of adding alfalfa was raised. This would introduce the most important forage crop in California into the system, and add relevance to the experiment. If a single system were compared, then three replications would be needed. The replications would need to be either three year or four year series, with two or three for alfalfa and one year for a rotated crop, possibly corn. This would require up to 12 plots. The start of the alfalfa series would be staggered to allow for at least two replications in every year. The fourth crop could be compared directly to the corresponding plots in the core experiment if one of the core crops, corn for example, were used.

If all three of these non-conforming systems were added to the experiment, all the plots with irrigation capacity would be used, but no significant investment would be required to do so. The

capacity of the irrigation systems may need to be increased and additional gated pipe purchased.

There was consensus that the irrigated wheat plots should be eliminated in favor of adding additional, alternative systems for comparison. The alternative systems discussed would be revisited at the next meeting and wider input sought.

SK discussed the potential value of a staggered start for the transition to a three year rotation. Tom Loughlin in a presentation at the last American Society of Agronomy meeting (circulated to the committee) has argued that staggering the start of crop rotation would increase significantly the ability of a long-term experiment to detect trends in properties of interest. Staggering the start would allow for the separation of fixed and random effects at the plot level. To do this would require one replication being converted from a two year to a three year system each of the next three years. In three years, all the systems would be operating as a three-year rotation and in six years all the systems would have cycled twice. The disadvantage in the short run would be having some two and some three year systems at the same time. This would reduce the number of reps available during the transition period. Advantages would be sufficient plots for continuity in the recently submitted tomato fruit quality experiment if it is funded, and a number of interesting questions to ask as the systems' shift from two to three years.

The committee decided to invite Tom Loughlin to come to Davis in the near future to present his ideas and discuss this issue with committee.

Attending: Steve Kaffka, Will Horwath, Karen Klonsky, Chris van Kessel

January 19, 2006 meeting

The group reviewed the results from previous discussions. There was continued agreement that a three year crop rotation using current crops should be adopted in place of the current two-year cropping systems, and that a horticultural crop should be added. Discussion about using a horticultural crop like broccoli followed. It was suggested that having a brassica crop would provide additional opportunities for entomologists and pathologists within the experiment. Several alternatives in the brassica family were discussed as well as the potential for interactions with root knot nematodes which are present on some plots. There was concern about whether farmers would think growing a broccoli crop would be a reasonable high value alternative. It was suggested that SK and any others interested in doing so with him seek out some growers who are familiar with the project and solicit their views about the inclusion of a horticultural crop, and which ones should be considered.

Discussion shifted to implementation of the proposed changes and how to widen participation in the planning process. SK suggested that changes could begin this summer with the planting of a brassica or some other horticultural crop. In the fall, when wheat planting starts, the transition to a three year system would begin in some of the plots (those corn/tomato plots having wheat for the first time) and that next spring (2007) more plots would be converted (for example, some wheat/tomato plots growing corn for the first time).

The idea of a staggered start for the transition from two to three year crop rotations was discussed further. The idea may have merit and should be evaluated by inviting Thomas Loughlin, a statistician favoring this approach, to speak at Davis. CvK suggested that if Loughlin were willing, he could be the first speaker in the spring (April) Plant Sciences seminar series and that we could ask to him work on an LTRAS data set for that purpose. The CIFS committee then would have a day to interact with him to discuss issues of experimental design and data management. There was general agreement that should be done.

Discussion turned to the idea of adding additional systems**. It was agreed again that the irrigated wheat/fallow plots should be made available for new systems.** CvK raised the issue of developing a basis or set of principles for decisions about including or rejecting ideas for new systems. SK commented that ***previously the committee had agreed that one criteria for the addition of new systems should be to strengthen the capacity to address the fundamental concern of the project for the effects of irrigation, N and C inputs on sustainability over time.*** Systems in the core experiment as currently managed do not provide a sufficient gradient of treatments. Modification of the core experiment to include three year rotations together with improved management of the three comparison systems (conventional, organic and intermediate) are also part of the effort to improve the effectiveness of the core experiment. For example, intensifying the intermediate systems would help in this regard. (Fig.1, created by Johan Six and Chris van Kessel is included below for conceptual purposes.)

But additional treatments that emphasize more extreme or unconventional types of inputs have been suggested as well. One is a one-year, conventional, continuous corn-wheat system originally suggested by WH. This would be a very high input, conventional system, presumably

managed no-till or reduced till. Another would be a biomass treatment with something like *Miscanthus* (or another cellulosic biomass crop to be determined) which would be perennial, likely a grass, require little N, but that would create a lot of C. This would be an irrigated crop.

It was agreed that adding energy–related cropping systems was seen as a desirable direction in its own right and consistent with the fundamental concern of the project for sustainability. The goal would be to create a number of interesting treatments that would diversify both quantitatively and qualitatively the treatments available for research across a three way response surface with irrigation, N and C as the axes. To assess the suitability of new systems for evaluation, estimations of their potential C/N use and contribution should be made together with their water use. Different possible treatments can be compared in this way and evaluated based on what they could contribute to the overall experiment.

Increased relevancy and wider experimental use was agreed upon as a second principle or reason to include new treatments. For example, an alfalfa rotation (conventional, 4 year: a-a-a-c) would allow for a different type of perennial than *Micanthus*, create opportunities for experiments relevant to the alfalfa producers and the dairy industry, and introduce a legume intensive treatment to contrast with annual crops and a perennial biomass grass crop.

It was decided that that the process of soliciting ideas for new systems should be publicized and opened up to anyone with an idea about interesting systems that could contribute to the larger experimental purpose and framework. **It was also decided to post notes about the discussion about the experiment's evolution together with supporting material on the website.**

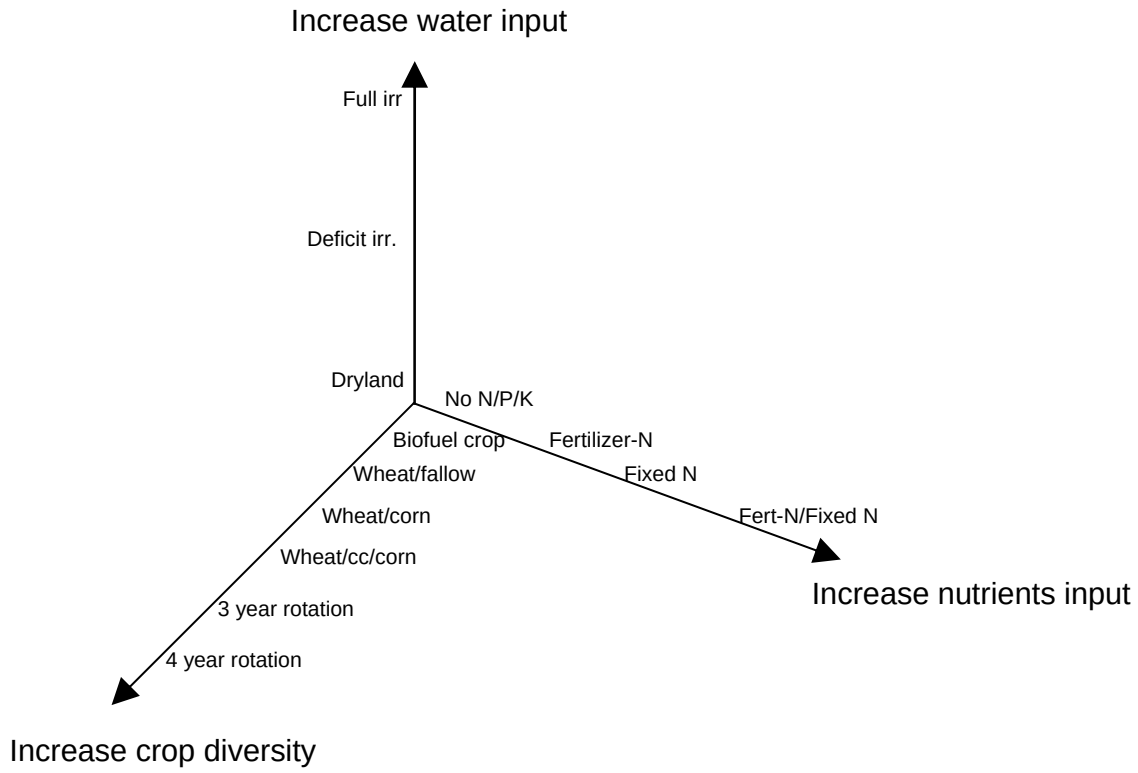

Fig. 1. Conceptual framework of rotations with various levels of nutrient and water input and cropping system diversity. (Johan Six, Chris van Kessel)

Present: Howard Ferris, Karen Klonsky, Bruce Lampinen, Chris van Kessel, Frank Zalom

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