Long-term Research in Irrigated and Dry Land Agriculture: Crop Yields and Soil Properties

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ASI RUSSELL RANCH SUSTAINABLE AGRICULTURE FACILITY

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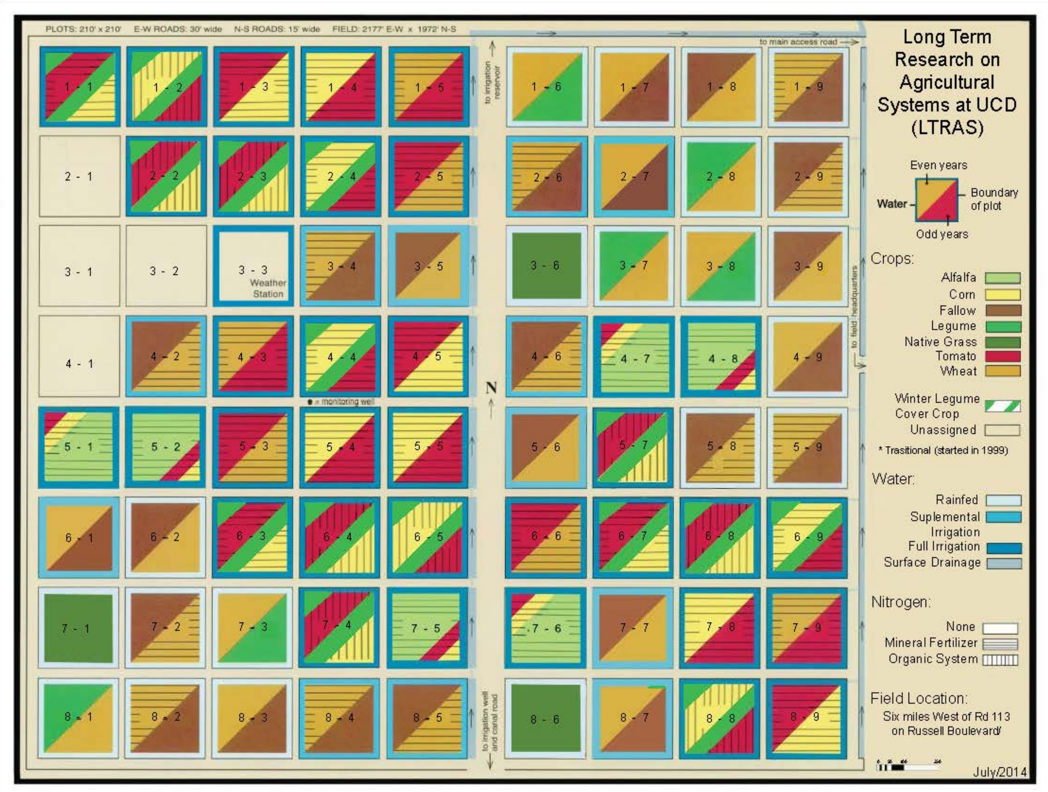
Russell Ranch: The Century Experiment

The Russell Ranch Sustainable Agriculture Facility is a unique 300-acre facility near the UC Davis campus dedicated to investigating irrigated and dry-land agriculture in a Mediterranean climate. Our flagship experiment, the Century Experiment (formerly known as the LTRAS - Long Term Research on Agricultural Sustainability), is a 100-year study located on the main plots at Russell Ranch.

In 12 replicated systems encompassing 72 acres, the Century Experiment measures the long-term impacts of crop rotation, farming systems (conventional, organic and mixed) and inputs of water, nitrogen, carbon and other elements on agricultural sustainability. Sustainability is indicated by long-term trends in yield, profitability, resource-use efficiency (such as water or energy) and environmental impacts. The Century Experiment has monitored changes in crop and soil properties, soil biology, weed ecology and economic indicators since 1993. Each plot is one-acre, which allows the use of commercial scale farming equipment.



Figures 1 and 2: Aerial view of Russell Ranch and plot map for the Century experiment cropping systems.

Current cropping systems

The original cropping systems in the Century Experiment were updated in 2012 to include a native grassland system and a six-year alfalfa-corn-tomato rotation. The energy, water and carbon inputs, as well as crop yields, are measured each year. Two proposed systems are highlighted in Figure 3 below: a one year, reduced tillage wheat-corn rotation and a four year “Super Bio” system with reduced fallow time, high carbon inputs and increased reliance on legumes for fertilization.

System	Symbol	Irrigation	N Source	Pesticides
Organic Tomato/corn	OMT	Irrigated	Manure + WLCC	Organic
Transitional Tomato/corn	TR	Irrigated	Manure + WLCC	Organic
Mixed (Legume Tomato/corn)	LMT	Irrigated	Fertilizer + WLCC	As needed
Conventional Tomato/corn	CMT	Irrigated	Fertilizer	As needed
Conventional Wheat/tomato	CWT	Irrigated	Fertilizer	As needed
Alfalfa/ Tomato/corn	AMT	Irrigated	P fertilizer	As needed
Wheat/fallow	IWF	Irrigated	Fertilizer	As needed
Wheat/fallow	IWC	Irrigated	None	As needed
Wheat/fallow	RWF	Dry land	Fertilizer	As needed
Wheat/legume	RWL	Dry land	WLCC	As needed
Wheat/fallow	RWC	Dry land	None	As needed
Native grass	NG	Dry land	None	None

Table 1: Current cropping systems for the Century Experiment.

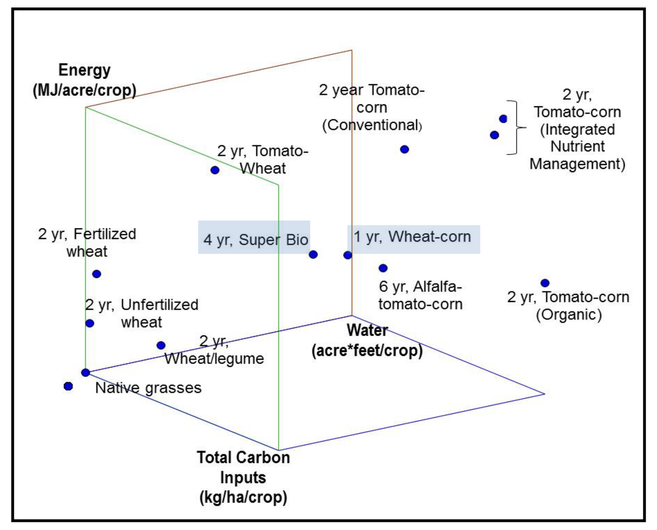
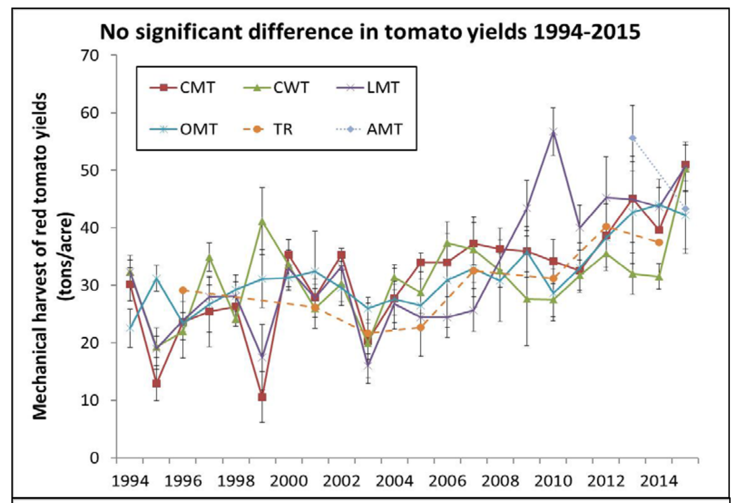
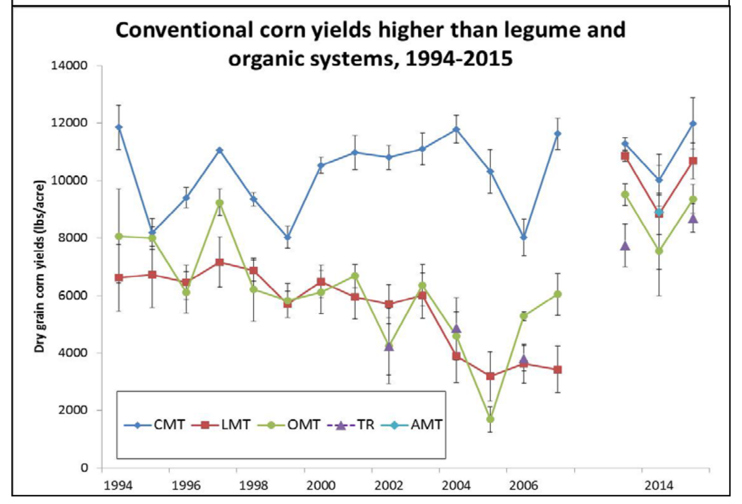


Figure 3: Three-dimensional representation of the energy, water and soil inputs to Century Experiment cropping systems.

Long-term Trends in Crop Yields

Tomato yields in conventional, mixed and organic systems were not significantly different during the first 22 years of data. Conventional tomato yields were also more variable than organic tomato yields. Higher fertilization in the mixed system—a legume/maize/tomato system (LMT)-- resulted in significantly higher yields from 2009-2015.



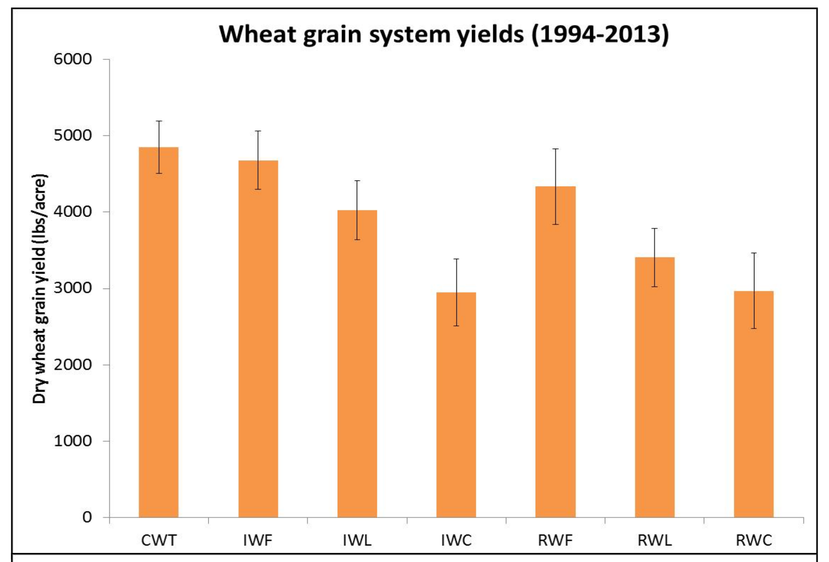


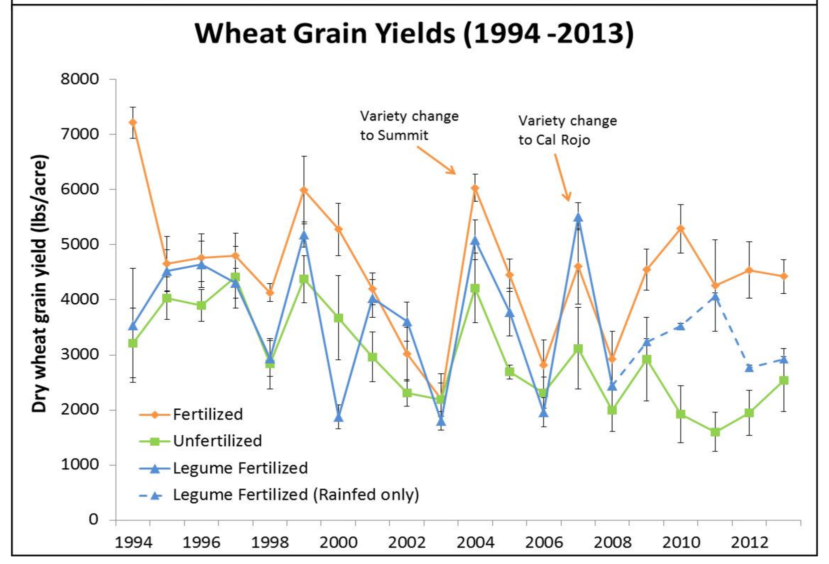
Figures 4 and 5: Corn and tomato yields from 1994-2015. Error bars represent standard deviations from three plots.

Corn yields, however, were significantly lower in the mixed (LMT) and organic (OMT) systems. Corn in the conventional corn-tomato (CMT) system is planted earlier than in the OMT and LMT systems, due to winter cover crop incorporation. Up until 2002, shorter season corn varieties were grown in these systems as well. Grain yields have declined, but not biomass yields, which suggests that insufficient N is available to corn crops during the grain-filling stage in these systems.

Wheat yields were higher in the fertilized systems than unfertilized and legume rotations in both the irrigated and rainfed plots. The irrigated wheat/tomato (CWT) rotation had similar wheat yields to the irrigated wheat/fallow system (IWF).

Year-to-year variation is quite high in the wheat system. Fertilized, legume-fertilized and unfertilized systems had similar yearly yield variations, although fertilized yields were higher. From 2001 to 2003, wheat yields declined in all systems, but a switch in 2004 to a single resistant wheat variety in both rain-fed and irrigated plots resulted in a return to average or higher wheat yields for all systems.





Figures 6 and 7: Wheat yields from 1994-2013

Soil Properties

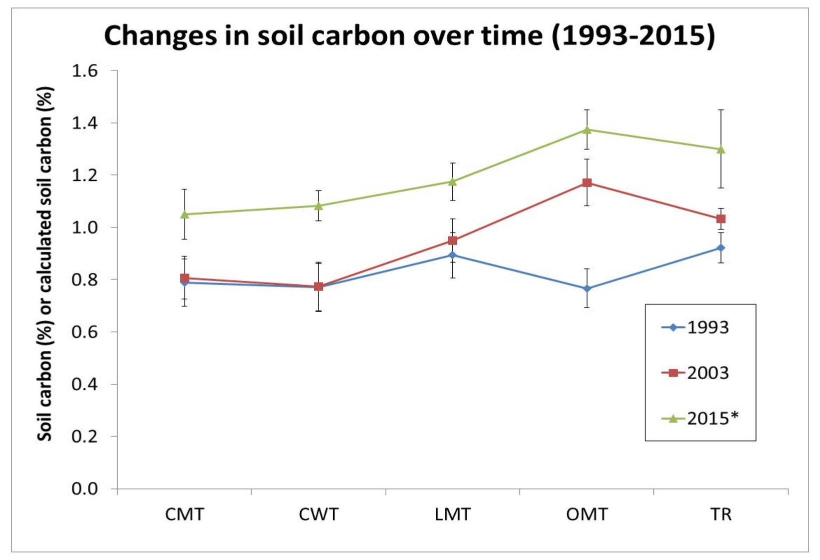


Figure 8: Total soil carbon (%) from 0-30 cm. Total C measured in 1993 and 2003 by dynamic flash combustion and 2015 values calculated as 0.50 * Organic Matter (measured as loss by ignition).

The 12 cropping systems receive different amounts of carbon input in the form of crop residues, manures and cover crops. The organic corn/tomato rotation (OMT) receives the most carbon inputs and the unfertilized, rainfed wheat/fallow (RWC) received the least. Changes in the amount of carbon accumulated or lost on average over the ten-year period from 1993 to 2015 are represented in Figure 8 for the tomato cropping systems.

The OMT system had the largest increase in soil organic carbon (SOC), which developed in the 1993-2003 period. The absolute values for the 2015 samples can not be compared to the other years, as this was calculated by a different methodology (organic matter, loss upon ignition). These measurements are currently underway. Data on long-term changes in soil carbon are important for assessing the potential for carbon sequestration in California soils.

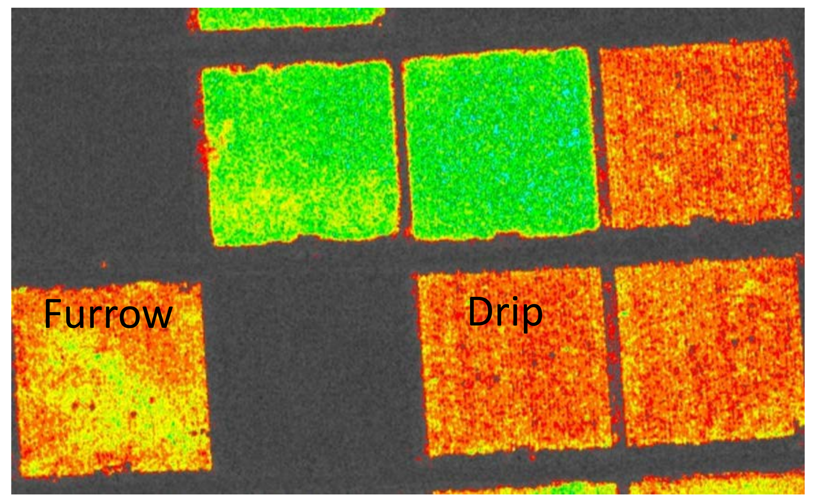
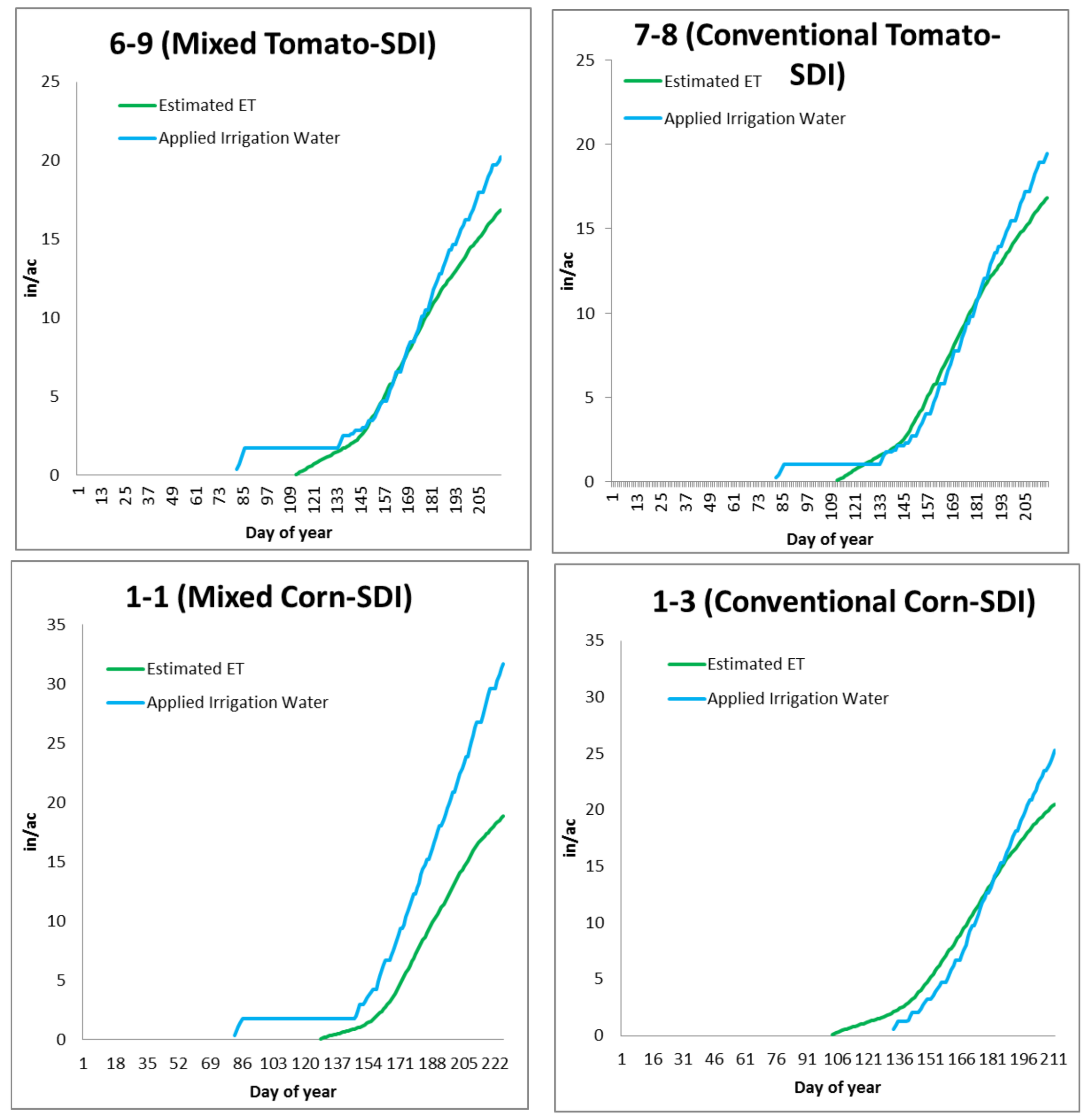


Figure 9: Weekly aerial flights image the plots at the Century Experiment and the Normalized Difference Vegetation Index (NDVI) of the crops is calculated (TerrAvion, 2015).

Irrigation application and Et_c for 2015



Water stress was observed in the Mixed Corn system (1-1) at day 155 and additional irrigation water was added to reduce water stress.

Figures 10-14: Irrigation applied to tomato and corn crops in 2015. The reference ETc curve for each crop (as well as Tule technology) was used to calculate the quantity of irrigation water to apply.

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