CALIFORNIA WHEAT COMMISSION
Interim Progress Report Prior to Major Initiation of Project
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Project Title: **Optimizing efficiencies and economics of solid-set subsurface drip and overhead mechanized irrigation systems with flat-planted wheat and acotton cropping systems**

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Progress Made on Project Objectives to Date:

Our research team is grateful to the California Wheat Commission for your initial sponsorship of this work. To date, we have quite successfully established the experimental field in Five Points, CA and have begun the first rotation crop, cotton, in 2011. This cotton crop will be harvested on October 31, and soon thereafter, we will no-till flat-plant our first experimental wheat crop using a John Deere 1560 no-till drill. The following data sets will be collected for this wheat crop: soil water storage using a neutron hydroprobe, emergence and stand counts, applied water volumes for both the subsurface drip and overhead irrigation systems, crop growth and development by non-destructive canopy cover determinations using a red/near infrared band ratioing camera, crop biomass accumulation using twice-weekly harvesting, and final crop growth next spring. The 2011 cotton crop was intensively monitored in terms of applied water, soil water storage using neutron probe, and also the following measurements have been made by a graduate student at CSU Fresno under the guidance of Jeff Mitchell, Anil Shrestha, and Dan Munk: crop growth and development, insect and pest incidence, soil temperature, plant mapping, canopy cover, plant height, and weed infestations. The thesis supervisory committee for the CSUF student recently met to iron out her thesis plans.

Our hypothesis that no-till established wheat and cotton approaches under solid-set subsurface drip and overhead mechanized irrigation can yield commercially strong production will be tested through two cycles of the cotton/wheat rotation that was initiated in 2011. In this start-up year, we were grateful to the CWC for allowing us to add a pressurized pump and filter station to this study that has now been installed and that provided pressurized water for both the drip and overhead systems in 2011. I will send a photograph of this station to CWC Executive Director, Janice Cooper, on October 25, and ask that it be forwarded to Commission members. We are still very much in the ‘data collection’ mode with respect to the wheat component of this study.

Within two weeks, we will have our first experimental wheat crop and will begin in earnest to collect information on it.

On September 8, 2011 we held a very successful public field day that was attended by Executive Director Cooper (right to the bitter end at 8:30 PM that night!). This event highlighted work that we have begun in this CWC-sponsored field. A write-up on this educational event is available at http://ucanr.org/sites/ct/?blogpost=5760&blogasset=14128

Photos of the 2011 'set up' year are attached below along with our original proposal to provide a more in-depth of where we are trying to go with this CWC work. To date, everything is in place to continue to profitably conduct the work. Our team is excited and committed about this work and will do its best to implement it in a careful, solid manner. I do apologize to members of the California Wheat Commission for the lateness of this interim report. I spoke with Janice Cooper regarding this and do apologize for it. Henceforth, we'll get reports in on time.

Photo 1. Condition of soil in experimental field following installation of subsurface drip tape.

Photo 2. Initial overhead irrigation of no-till seeded cotton in April 2011

Photo 3. Participants in 2011 Twilight Overhead Irrigation and Conservation Tillage Field Tour and Barbeque with CWC study field on right side.

Summary:

Improved practices and better information have led to widespread adoption of more efficient irrigation technologies in California during the past several decades. Subsurface drip irrigation, for example, has been shown to increase productivity and profitability, reduce subsurface drainage, and improve weed control. A recent survey of UC Cooperative Extension Advisors and San Joaquin Valley (SJV) West Side farmers indicated that over 85% of processing tomato acreage and an increasing percentage of cotton acreage in the Central SJV is now produced using permanent bed subsurface drip irrigation. When subsurface drip is used, however, as it is commonly used with SJV tomatoes, farmers tend to be limited to tomatoes followed by tomatoes due to the placement, spacing and configuration of the buried tape. Rotating to other crops becomes more difficult and costly, and as a result, continuous monocultures often result with corresponding risks for pathogen build-up in the soil. When growers use more temporary types of drip irrigation such as surface or near-surface installations, additional initial setup and retrieval costs add to production costs on a recurring basis.

Similar surveys of irrigation technology adoption from the High Plains Aquifer of the Midwestern United States, the largest freshwater aquifer in the world, over the past fifteen years indicate a steep decline of more than 50% in the use of surface (flood or furrow) irrigation and a corresponding increase in the use of overhead mechanized irrigation systems that employ low-pressure, "dropped" nozzle packages that suspend sprinkler heads just above the canopy of the crop, increasing application efficiency by decreasing the amount of water lost to evaporation and drift, particularly in hot and windy areas. It is currently estimated that in several other regions of the US and the world, overhead center pivot systems are the dominant irrigation method. Somewhat conservative estimates indicate that there are between 175,000 – 200,000 center pivot and linear move overhead systems currently in use in the US covering 22,000,000 to 26,000,000 acres of automated irrigation, or approximately 40% of all irrigated acres in the country. These numbers are rapidly changing in many areas as flood or surface irrigation is being converted to overhead. Similar trends in increased adoption of overhead mechanized irrigation have been documented worldwide.

Overhead irrigation is currently estimated to be used on less than 1% of California's crop acreage. Very recently, however, within the past five years, there has been a dramatic increase in the number of overhead irrigation systems that have been introduced into the Central SJV. Overhead mechanized irrigations systems have been generally shown to have higher application uniformities and efficiencies than surface systems. Higher application efficiencies can lead to reduced water requirements. In irrigated areas such as the Ogallala Aquifer or the south-central region of Brazil, where overhead irrigation has rapidly expanded, its use is often coupled with various sorts of conservation tillage (CT) practices because furrows that permit surface water movement and that require considerable intercrop tillage, are no longer required. Direct-seeding or no-till planting is thus enabled in overhead systems. After sustained CT production, soils may store more water than conventionally tilled soils due to the maintenance of macropores. In addition, soils with stubble cover also reduce wind velocities and temperatures at the surface, which may reduce evaporation from the soil. Coupling no-till and surface residue preservation with overhead, low-pressure irrigation may thus be a means for conserving water and improving the production efficiencies in SJV cropping systems, and also for providing greater cropping

flexibility to rotations, however both the production mechanics and related research base are currently lacking that might substantiate this claim.

Conservation tillage provides significant means for reducing costs, dust emissions, and fuel use in many crop production systems. We recently demonstrated that costs can be reduced by 14 – 18% when using CT cotton planting and postharvest stalk management systems, while yields were maintained. No-till and strip-till crops are successfully produced in the South, the Midwest and in Brazil. No-till, flat-planted late-season cotton has been produced profitably for several years in AZ. No-till and strip-till forage production has been successful in some SJV dairies. These experiences indicate that no-till production is feasible and could ultimately become a viable option for the SJV if focused and intensified research is dedicated to it.

In order to effectively "couple" highly efficient irrigation systems such as drip and overhead with the use of cost-cutting CT practices, however, new production paradigms are needed to optimize the performance of the merged technologies. Traditional raised planting beds, - we propose, - will no longer be required and indeed, would present unneeded complications and expense to producers. In diverse crop rotations, for example, that include traditionally bedded crops such as tomatoes and cotton as well as broadcast-seeded field crops such as wheat or triticale, having beds may be desirable for the row crops in such a rotation under surface or furrow irrigation, but raised beds under sustained CT cropping may become a problem due to residues accumulating in furrows and causing seeding difficulties for drill-seeded crops.

To overcome such problems and to develop what may become truly "next generation" precision irrigation and conservation tillage systems, we propose to evaluate overhead mechanized and solid-set subsurface drip irrigation systems with flat-planted cropping systems as a means to optimize irrigation and cropping efficiencies and to also increase the overall precision and flexibility of cotton-containing crop sequences. This cropping, irrigation, and tillage systems integration recognizes that it may be via the coupling or merging of these technologies that a higher level of production efficiencies will be achieved and it anticipates what very well may be the eventual inevitability of such precision farming systems in the SJV.

The work proposed here will therefore develop information on the relative performance of overhead and solid-set drip irrigation under minimum and no-tillage management on productivity, profitability, water use efficiency, salinity, and vertebrate pest pressure in a large-scale, replicated study to be conducted at the University of California West Side Research Center in Five Points, CA. Our initial, working hypothesis will be that both the solid set subsurface drip and the overhead, automated precision irrigation systems will provide cheaper cropping options that surface flood or furrow irrigation, or current subsurface drip systems. This proposed work will be very visibly disseminated throughout the SJV via our very successful CT Workgroup's extension education programs and will provide training to a CSU Fresno student.

Objectives of the Proposed Research:

The goals of this proposed project are:

1. To compare flat-planted minimum tillage cotton cropping systems under overhead mechanized irrigation and solid-set subsurface drip irrigation in terms of water use efficiency, profitability, soil salinity, and drainage volumes,
2. To develop cost studies for these irrigation and cropping systems, and
3. To extend information developed by this project widely throughout California's production regions

Significance of Research:

Improved practices (Schwankl and Frate, 2004) and better information (Hanson and May, 2006; Hanson et al., 2009) have led to widespread adoption of more efficient irrigation technologies in California during the past several decades. Subsurface drip irrigation, for example, has been shown to increase productivity and profitability ard reduce subsurface drainage (Hanson and May, 2003), provide salinity control (Hanson et al., 2009), and improve weed control (Shrestha et al., 2007; Sutton et al., 2006). A recent survey of UC Cooperative Extension Advisors and San Joaquin Valley (SJV) West Side farmers (Turini, Munk and May, 2009) indicated that over 85% of processing tomato acreage in the Central SJV is now produced using permanent bed subsurface drip irrigation. When subsurface drip is used, however, as it is commonly used with SJV tomatoes, farmers tend to be limited to tomatoes followed by tomatoes due to the placement, spacing and configuration of the buried tape. Rotating to other crops becomes more difficult and as a result, continuous monocultures often result with corresponding risks for pathogen build-up in the soil (Atherton and Rudich, 1986).

Similar surveys of irrigation technology adoption from the High Plains Aquifer of the Midwestern United States, the largest freshwater aquifer in the world, over the past fifteen years indicate a steep decline of more than 50% in the use of surface (flood or furrow) irrigation and a corresponding increase in the use of overhead mechanized irrigation systems that employ low-pressure, "dropped" nozzle packages that suspend sprinkler heads just above the canopy of the corp, increasing application efficiency by decreasing the amount of water lost to evaporation and drift, particularly in hot and windy areas (Pfeiffer and Lin, 2009). It is currently estimated that in several other regions of the US and the world, overhead center pivot systems are the dominant irrigation method. Somewhat conservative estimates indicate that there are between 175,000 – 200,000 center pivot and linear move overhead systems currently in use in the US covering 22,000,000 to 26,000,000 acres of automated irrigation, or approximately 40% of all irrigated acres in the country (W. Dorsett, Personal communication). These numbers are rapidly changing in many areas as flood or surface irrigation is being converted to overhead. Similar trends in increased adoption of overhead mechanized irrigation have been documented worldwide (R. Batten, Personal communication).

Overhead irrigation is currently estimated to be used on less than 1% of California's crop acreage. Very recently, however, within the past five years, there has been a dramatic increase in the number of overhead irrigation systems that have been introduced into the Central SJV (Cline, 2009). Overhead mechanized irrigations systems have been generally shown to have higher application uniformities and efficiencies than surface systems (Letey, 2007). Higher application efficiencies can lead to reduced water requirements. An increase in application efficiency from 65% to 85%, for instance, has been shown to lower the water requirement by

24%, or 26”/year for alfalfa in the low desert region of AZ where the annual ET demand is 72” (Brown, Personal communication). In irrigated areas such as the Ogallala Aquifer or the south central region of Brazil, where overhead irrigation has rapidly expanded, the use of overhead irrigation is often coupled with CT practices because furrows that permit surface water movement and that require considerable intercrop tillage, are no longer required; direct seed, or no-till planting is thus enabled in overhead systems. After sustained CT production, soils may store more water than conventionally tilled soils due to the maintenance of macropores (Beck, 2002; Tanaka and Aase, 1987). In addition, soils with stubble cover also reduce wind velocities and temperatures at the surface, which reduces evaporation from the soil surface. In addition, soils with stubble cover reduce wind velocities and temperatures at the surface, which reduces evaporation from the soil surface. Coupling no-till and surface residue preservation with overhead, low-pressure irrigation may thus be a means for conserving water and improving the production efficiencies in SJV cropping systems, and also for providing greater cropping flexibility to rotations, however both the production mechanics and related research base are currently lacking that might substantiate this claim.

There is now a growing research and experience base in the SJV on CT. Conservation tillage provides significant means for reducing costs (Mitchell et al., 2008; Mitchell et al., 2009), dust emissions (Baker et al., 2005; Madden et al., 2008), and fuel use (Mitchell et al., 2009) in many crop production systems. We recently demonstrated that costs can be reduced by 14 – 18% when using conservation tillage (CT) cotton planting and postharvest stalk management systems, while yields were maintained (Mitchell et al., 2006). No-till and strip-till crops are successfully produced in the South, the Midwest and in Brazil. No-till, flat-planted late-season cotton has been produced profitably for several years by Ron and Robert Rayner in Goodyear, AZ. No-till and strip-till forage production has been successful in some CV dairies. These experiences indicate that no-till forage and cotton production is feasible and could ultimately become a viable option for the SJV if focused and intensified research and “adoption-aimed” outreach are dedicated to it.

Tillage systems in agronomic crop production in the SJV were generally developed more than six decades ago and changes have largely been incremental in nature, with only modest reductions in tillage practices on most farms (Personal communication, J. Stone, J. Woolf and A. Ruozi). Although there has been some movement toward “minimum” (reduced pass) tillage in recent years, San Joaquin Valley production systems remain relatively tillage intensive. Recent changes in tomato production toward semi-permanent beds and drip irrigation and minimum till approaches, and in dairy forage production systems toward no-till and strip-till planting have been undertaken by some producers, however, for various reasons, more classic forms of conservation tillage such as no-till or strip-till, have not rapidly expanded in this region.

Our recent research with CT systems in California has suggested slightly higher soil water content in the surface 240 cm of soil in CT systems in the fall when the soil in these systems is not disturbed as is done in conventional tillage systems (Unpublished data). Additional work by Czyz and Dexter (2008) has revealed that tillage systems significantly affect soil physical properties, and especially soil water content. In two soil types, a loamy sand and a silty loam, available soil water content averaged annually was greater in a no-till system than in the conventional system at almost all depths. Preliminary work conducted by USDA researchers, Faircloth, Sorensen and Lamb with cotton and peanut in the southeast has demonstrated lower seasonal water use by strip-tilled crops relative to conventional tillage of 19% for peanut and 42% for cotton (Personal communication, D. Rowland).

In order to effectively "couple" highly efficient irrigation systems such as drip and overhead with the use of cost-cutting conservation tillage practices, however, new production paradigms are needed to optimize the performance of the merged technologies. Traditional raised planting beds, - we propose, - will no longer be required and indeed, would present unneeded complications and expense to producers. In diverse crop rotations, for example, that include traditionally bedded crops such as tomatoes and cotton as well as broadcast seeded field crops such as wheat or triticale, having beds may be desirable for the row crops in such a rotation under surface or furrow irrigation, but raised beds under sustained CT cropping may become a problem due to residues accumulating in furrows and causing seeding difficulties for drill-seeded crops (Photo 1).

Photo 1. Wheat crop drill-seeded on 60" no-till beds. Note uneven emergence in furrow bottoms where crop residues accumulate

To overcome such problems and to develop what may become truly "next generation" precision irrigation and conservation tillage systems, we propose to evaluate overhead mechanized and solid-set subsurface drip irrigation systems with flat-planted cropping systems as a means to optimize irrigation and cropping efficiencies and to also increase the overall precision and flexibility of crop sequences. This cropping, irrigation, and tillage systems integration recognizes that it may be via the coupling or merging of these technologies that a higher level of production efficiencies will be achieved and it anticipates what very well may be the eventual inevitability of such precision farming systems in the SJV.

In anticipation of potential vertebrate pest problems such as gophers, that may increase under sustained CT production, we also propose to evaluate minimum tillage versus no-tillage practices for both irrigation systems. The work proposed here will therefore develop information on the relative performance of overhead and solid-set drip irrigation under minimum and no-tillage management on productivity, profitability, water use efficiency, salinity, and vertebrate pest pressure in a large-scale, replicated study to be conducted at the University of California West Side Research Center in Five Points, CA.

Prior and Current Research

In a recently-completed project, *Coupling automated overhead, low-pressure irrigation systems with conservation tillage: A new irrigation, crop and drainage management paradigm for the Central San Joaquin Valley*?, we compared surface and overhead irrigation under conventional and conservation tillage through two cycles of a wheat/corn rotation. Major outcomes and findings of this work include the following:

1) 93% CU (Christiansen Coefficient of Uniformity) achieved with "spinner" overhead nozzle package (Figure 1)
2) both 2008 and 2009 overhead wheat crops were irrigated with about 65% of the total water applied to the furrow systems with similar yields
3) estimated deep percolation from the furrow system was considerably higher and more variable than under the overhead system
4) corn yields between systems in both years were similar except in the 2009 season under the standard tillage overhead system due to a breakdown of the Field Station's pressure system during a peak ET period
5) more frequent irrigations were applied in smaller amounts under the overhead systems relative to the furrow systems (Figure 2)

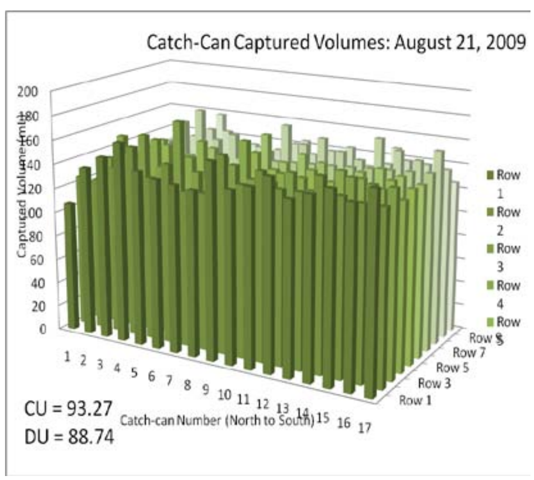

Figure 1. Catch-can Christiansen Coefficient of Uniformity for overhead irrigation system, University of California West Side Research and Extension Center, Five Points, CA, August 21, 2009 using "spinner" nozzles at 48" above the soil surface

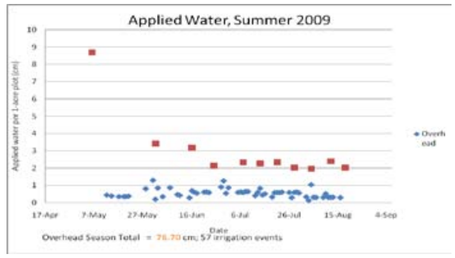

Figure 2. Applied irrigation water for furrow and overhead systems at the University of California West Side Research and Extension Center, Five Points, CA 2009

In conjunction with this Research Center work, we also determined CU's for 135-ac center pivot corn and tomato fields at Red Rock Ranch in Five Points, CA. These efforts demonstrated CU's in the mid-80%'s and higher values under "spinner" nozzles than "rotator" packages.

In a broader context, our ongoing CT research has demonstrated the potential to produce a variety of crops including tomatoes, cotton, corn and wheat using no-tillage practices that reduce production costs (Mitchell et al., 2008, 2009), dust emissions, (Baker et al., 2005; Madden et al., 2008), and increase soil carbon (Manuscript for Agronomy Journal now in preparation). We have demonstrated experience and equipment now to produce a variety of crops including cotton using no-tillage (Photo 2). In a longstanding cotton/tomato rotation study in Five Points, CA, CT cotton yields have matched yields under standard tillage for the past several years following a period of a "learning curve" experiences during which we gained proficiency in crop establishment under no-tillage. We believe that we can successfully establish no-till cotton in the proposed wheat/cotton rotation with very good likelihood.

Photo 2. No-till seeded Acala cotton at the University of California West Side Research and Extension Center, Five Points, CA 2006

Our understanding of CT has relied largely on experiences derived from the Midwest and the Southeast US. Less than 2% of Central Valley row crop acreage currently uses any form of CT (Mitchell et al., 2007). Locally-based knowledge is needed for better understanding of the potential for CT in California to be a viable water and crop management option. This project would expand understanding of CT and how CT might impact water management throughout the region by evaluating CT production systems that use center pivot or linear move overhead, low-pressure irrigation and solid-set subsurface drip irrigation as a new "systems" paradigm for water and crop management in the Central SJV, and by facilitating understanding of high residue CT systems as a means to better manage local water resources. The farmer partners we propose to work with on this project have recently installed over fifteen 135-ac center pivot systems themselves and are quite active with our team in terms of planning, discussing priorities and monitoring project progress. Studies by Goldhamer (1984) and Phene (Personal communication) in the early 1980's compared linear move systems with surface irrigation and did not find the linear systems to be superior given the technologies that existed at that time. We postulate, however, that given improvements in overheard system technologies and in light of today's labor situation and the recent advent of CT capabilities in California, that the "systems level" production economies and potential benefits of the approaches we propose to evaluate here will indeed be compelling and quite worthy of investigation. We further believe that the management lessons we have recently learned with respect to overhead irrigation and our ability to establish no-till cotton will enable us to cheaply produce cotton in the SJV with both cost and water savings.

Plan of Work:

Funds are requested of the California Wheat Commission to conduct a multidisciplinary project in Five Points, CA aimed at developing information on alternative irrigation and crop management systems that may have considerable future relevance for California's SJV. The synthesis or integration of these systems components, as outlined in this proposal, is completely new and untested in California. The proposed work will compare flat-planted no-till and minimum tillage crop production under solid-set (30" tape spacing at 12" depth) subsurface drip (0.45 gallons / 100 ft / minute) with overhead mechanized irrigation (Figure 1). The work will be conducted at the University of California West Side Research and Extension Center in Five Points, CA. A core data set consisting of the following system performance attributes will be collected at both sites: yield and product quality, fixed and variable inputs, tractor operations, labor requirements, irrigation water timing and amounts, soil salinity (0 – 30 and 30 – 60 cm), % and weight of crop residues, soil bulk density (0 – 10, 10 - 20 and 20 – 30 cm), soil penetration resistance (0 – 45 cm), gopher infestations, crop growth and water status and diesel fuel use of the irrigation systems.

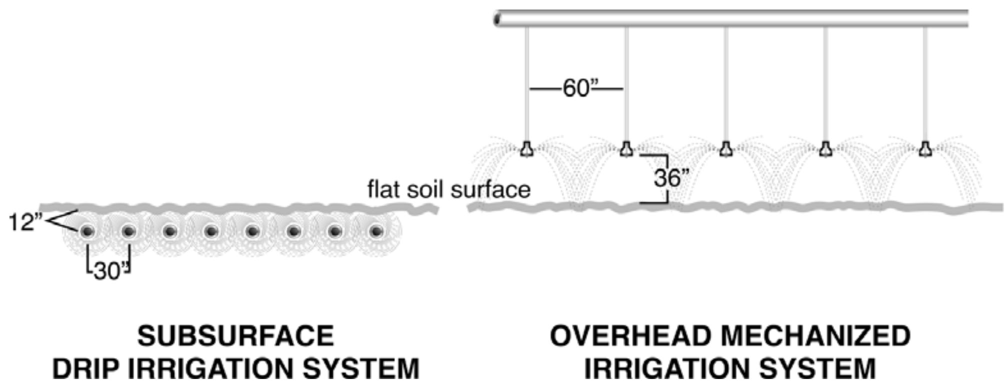

Figure 1. Schematic description of solid-set subsurface drip and overhead mechanized irrigation systems with emitter and nozzle spacings

A research team led by Jeff Mitchell,Wes Wallender, Karen Klonsky, Anil Shrestha, Dan Munk, and Willi Horwath, in conjunction with farmer cooperators, John Diener and Scott Schmidt, and private sector partners, Monte Bottens of Ag Spectrum, and John Bliss, Pat Murray and Ray Batten of Valmont, Irrigation Company, will carry out the work for the project. Each will be involved according to his or her respective area of expertise in the collection and analysis of data, the evaluation of cropping system performance and the presentation of findings. Each UC researcher on the project will be charged with collecting and summarizing information related to his or her area of expertise and periodic planning meetings will be held to coordinate research responsibilities and timing. Because the work proposed is completely new and as yet undeveloped, we expect to have routine project team meetings that will involve all PI's, the team's farmer members, NRCS conservationists, and other interested CT Workgroup members.

We will compare four irrigation / tillage systems: solid-set drip and overhead irrigation will be main plots and minimum tillage and no-tillage will be subplots, each replicated four times (Figure 2). Each system will be laid out in 75 ft X 300 ft plots in a Panoche clay loam soil type at the study site (fine-loamy, mixed superactive, thermic Typic Haplocambids). The overhead irrigation systems will be irrigated using a hose-fed, eight-span lateral-move irrigation system (Model 6000, Valmont Irrigation, Valley, NE). This system has a diesel-electric power plant with a CAMS control panel for speed control. Irrigation amounts for the overhead systems will be determined by various combinations of the lateral-move system movement speed and application nozzles, and application water volumes will be determined using in-line flow meters. The four 1-acre overhead plots will typically be irrigated with 450 gpm (entire span) nozzle package to allow full daily ET depletion replenishment during peak demand periods within the 8-hour work days at the Research Center. Run-time and personnel constraints at the Center require us to irrigate in this manner. The drip irrigation system will use high flow T-TAPE (0.45 gallons / 100 ft. / minute) buried 12 inches deep with 30 inch tape-to-tape spacing. A 4 inch main line will supply water the entire field length with lateral manifolds coming off according to the experimental plot randomization so as to provide uniform pressures to each drip plot. We propose to use requested CI State Support funding to help us acquire a Grundfos pump and to install an underground water pipeline to our experimental field from the power and pump location at the Field Station.

A water budget approach will be used to determine irrigation and crop production system performance. For the water budget, applied water, soil water, weather data, canopy cover, estimated actual evapotranspiration, and water table depth will be monitored, and deep percolation will be calculated. Standard atmosphere-driven evapotranspiration calculation methods will give water removed by evaporation and transpiration. Change in soil water storage will be measured using four neutron probe access tubes that will be installed along a diagonal transect 20m apart in each plot and monitored twice weekly during each cropping season and weekly during the winter to determine soil water content to 2.7m. This instrument will be calibrated for the experimental field soil. Applied irrigation water will be compared with the change in soil water caused by irrigation. From measurements of applied water, evapotranspiration and changes in soil water storage, the closure term in the water budget, deep percolation, will be calculated. Wallender and Mitchell will supervise the student who will work on these field data-derived and modeled outputs, Mitchell and Munk will coordinate the field monitoring work, and Klonsky and Mitchell will collaborate on the economic analysis associated with the study.

A salt budget will parallel the water budget. Soil salinity (EC) will be determined in the spring and fall of each year by collecting composited soil samples in each plot (0 – 30 cm and 30 – 60 cm) at 8 sites in a 10m X 23m grid in each plot. Soil penetration resistance will be measured using a portable penetrometer (0 – 45 cm) (Spectrum Technologies) to determine soil compaction at eight sites in each plot. Soil bulk density will be determined for the 0 – 10, 10 – 20 and 20 – 30 cm depths using the compliant cavity method. The electrical conductivity of the irrigation water will be measured monthly using a portable EC meter. Irrigation water applications to each system will be monitored using flow meters and by determinations of application times to maintain annual water applications between the systems relatively similar.

Two cycles of a cotton/wheat sequence will be pursued. GPS-tractor guidance will be used in the establishment of each crop. Having a flat planting surface should, we postulate, not only reduce tillage costs typically associated with intercrop bed preparation, but also, facilitate more uniform wheat establishment in what would be furrow bottom areas where high residue levels might accumulate. “No-tillage” treatments will involve zero tillage other than a very shallow (4 inch deep) in-season cultivation in each tomato crop. “Minimum tillage” will involve two shallow diskings and a clod-busting roller operation following each crop’s harvest and before establishment of the next crop. Weed management will include “over-the-top” spray applications of glyphosate for cotton. Weed pressure assessments will be made by counting and identifying weeds in $1m^2$ quadrats during the first quarter of the growing season for each crop. Gopher infestations will be determined in each plot at one month after each crop is established by counting the number of burrows per plot and by estimating the time required for pesticide bait treatment.

A calendar of operations will be maintained for each of the systems and the equipment used and materials applied will be recorded. The cost of each operation for each system will be estimated using a model of a hypothetical farm under each of the four systems. The time required for each operation, fuel, lube, and repairs will be generated using agricultural engineering equations. The input costs for seed, transplants, fertilizer and pesticides will be obtained from local input suppliers and entered into the model. The water use for each system will be measured as part of the experiment and input into the model. Water costs per acre foot will reflect local irrigation district charges. The cost or production and resource use for each of the systems will be compared. In particular, the model will summarize the labor requirements for both tractor operators and irrigation labor as well as fuel use. Finally, the yield data will be used to calculate the expected gross returns using local market information. From this, the economic feasibility of each system will be estimated and the relative profitability determined.

To test the hypothesis that tillage results in losses of surface soil layer water and to determine the extent of such losses, we will intensively monitor surface soil water content using volumetric soil water content sampling and time domain reflectometry (TDR) before and after each tillage operation at 0 – 12 cm and 0 – 20 cm depths in the experimental field at the WSREC in Five Points, CA. To compensate for anticipated changes in bulk density caused by tillage and effects of bulk density changes on TDR-measured soil water content, soil bulk density will be determined using the compliant cavity method (Soil Survey Laboratory Methods Manual Report 42, 2004) in each plot before and after tillage operations in the tilled systems at 0 – 12 cm and 0 – 20 cm depths and in the no-tillage systems at the start of the study. A calibration relationship between soil volumetric water content and raw TDR readings will be made. Soil gravimetric water content will also be determined before and after each tillage event at 0 – 12 cm and 0 – 20 cm depths.

To determine whether surface residues reduce soil evaporation relative to bare soil, a study in a field adjacent to the main experimental field will be conducted in which three % residue cover treatments (0, 50% and 100%) replicated four times in ≈ 30 ft X 75 ft plots will be used to monitor the water content in surface 0 – 12 cm and 0 – 20 cm depths using TDR and gravimetric water content sampling, as well as in the surface residue mulch during a two-week drying period following a uniform overhead irrigation that will be applied so as to fill the surface 0 – 20 cm without allowing deep percolation. By determining application volumes and the amount of water stored in the surface soil and aboveground residue, we will estimate evaporation under the % cover treatments for a period of 14 days following a water event.

Soil temperature will be determined in the residue / evaporation study using HOBO U23-004 External Temperature Data Loggers at 10 cm depths and air temperature will be determined at 1m above the soil surface. One soil and one air temperature sensor will be placed in each of the three 0, 50 and 100% residue plots.

Statistical analyses will be conducted with SAS (SAS Institute Inc., 1990) using the general linear model (GLM) procedure for analysis of variance. The data set will be analyzed as a split plot design with irrigation treatment as the main factor and tillage as the subfactor. Observations such as soil moisture and water budgets will be analyzed as a factor within irrigation or tillage treatment. The assumptions needed to meet the requirement of the statistical models will be tested for all data sets. Normality of the residuals will be evaluated graphically and with Shapiro Wilk test. Homogeneity of variances will be tested by plotting the residuals vs the predicted values and with Levene’s test. If necessary, the data will be transformed. Mean comparisons will be performed using the Tukey test, which controls the experiment-wise type I error rate α (SAS Institute, 1990). Irrigation and tillage effects or their interactions will be considered significant at $P < 0.05$.

Anticipated Results:

We expect that through the field studies outlined in this proposal 1) both the subsurface solid-set drip and the overhead mechanized irrigation and no-tillage systems will provide crop yields comparable or better than current standards or the standard "control" minimum tillage system, 2) soil salinity will be lower and less variable under the overhead system relative to the drip system, 3) soil water content will be measurably higher in the no-tillage and surface residue systems and 4) that overall fuel and labor costs will be lower for the overhead no-tillage system relative to other irrigation and tillage systems. We believe that the flat-planted alternative systems have the potential to significantly reduce production costs and to improve irrigation management and cropping flexibility in this region. We will develop information on irrigation water use efficiencies of the two irrigation systems, crop productivity and profitability, and soil water storage and salinity patterns under the two systems. In sum, we believe that the information, - both field monitoring–derived, and modeled, - will lead to important findings related to the current and future potential of irrigation and crop management systems that integrate CT and overhead irrigation technologies.

Qualifications of Research Investigators and Cooperators:

Jeff Mitchell is a Cooperative Extension Specialist in the Department of Plant Sciences at the University of California, Davis and for the past eight years he has served as Chair of UC's Conservation Tillage Workgroup. In this capacity, he oversees a variety of CT research and demonstration evaluations in conjunction with Workgroup partners. Wes Wallender is Professor of Hydrology at the University of California, Davis. He conducts research on the physical, biological and economic performance of surface as well as pressurized irrigation systems. Karen Klonsky is an agricultural economist in the Department of Agricultural and Resource Economics at the University of California, Davis. She has conducted extensive production cost and economic analyses of cropping systems throughout California and has collaborated with this WSREC team on several other economic studies in the past. Dan Munk is the Fresno County UCCE Farm Advisor for cotton and water. His research focuses on irrigation management. Anil Shrestha is a Professor of Weed Sciences at CSU Fresno. He has considerable experience with weed management and herbicide resistance management strategies in CT systems. John Diener is a farmer and landowner in Five Points, CA. He is also a recipient of UC Davis' Distinguished Service Award and the 2009 Leopold Conservation Award for his wide-ranging innovations in agricultural production systems. Scott Schmidt is the farm manager for Farming 'D' in Five Points. William Horwath is Professor in the Department of Soils and Biogeochemistry at the University of California, Davis.

Investigators' Overall Research:

This project that is proposed to the California Wheat Commission represents **the** most significant research effort and opportunity that PI Mitchell has been involved with to date. It integrates not only state-of-the-art conservation tillage systems that he has been working to develop for more than ten years, with overhead irrigation technologies that were tried previously in California, but that did not expand much due to early difficulties. The opportunity to work on this project with a strong UC team that is also keenly interested in this work and two San Joaquin Valley farmers who have gone to Washington State to talk with overhead irrigation system farmers, and recently bought fifteen 135-acre center pivots, further strengthens the importance of this proposed project as part of PI Mitchell's current work.

Wallender is also a member of the UC Conservation Tillage Workgroup and has collaborated closely with Mitchell in the past on a variety of studies including a major experiment also in Five Points, CA that compared water balance implications of integrating winter cover crops into San Joaquin Valley cropping systems. Wallender has both professional and practical experience with overhead systems and is very interested in developing information on the integration of CT and overhead irrigation for California.

Klonsky and Horwath are also long-standing project team members and CT Workgroup members.

Dan Munk, UCCE Soils, Water and Cotton Farm Advisor in Fresno County, has taken on Co-PI status for a number of our team projects at the UC West Side Research and Extension Center in Five Points. He has assumed a primary and direct role for the project's conduct with Mitchell at this UC facility and is committed to working collaboratively with our entire research team to make it successful.

The integrated work described here that couples irrigation systems with flat-planting cropping is new. We have secured an initial allocation of $30,000 to initiate this work, however, this amount does not cover installation of the Grundfos pump which we now recognize as essential to the conduct of this work. In ongoing work we have recently been doing at the Field Station, it has become necessary for us to seek means to augment the flexibility and capability of bringing pressurized water on demand to our experimental field sites. The WSREC currently does not have the capability to do this and thus, we seek assistance with this from CI.

NOTE: We wish to clarify our budget request to the CWC. We are seeking exclusively support to help us install a drip booster pump and to offset anticipated annual fees of the West Side Field Station. However, we wish to make clear to the Commission that we will have all other project infrastructure, equipment and instrumentation covered by existing supporters. Valmont Industries has loaned us the 8-span overhead system. They are partners on this proposed work. We have been in communication with Netafim Irrigation Company regarding support of the drip system tape and mainline. Mitchell will provide flow meters, soil sampling equipment and a neutron hydroprobe. The wheat silage chopping will be done by the Field Station's relationship with a local commercial chopping service which allows us to use their field-scale weighing equipment. All needed CT equipment, - no-till seeder, no-till drill and cultivator, - is available through the CT Workgroup.

Budget Request:

	Year 1	Year 2

Installation and operation of Grundfos pump for drip Irrigation system at WSREC	$6,000	
Payment of WSREC labor Fees 2011 for conduct of project		$6,000
Total	**$6,000**	**$6,000**

Budget Narrative:

Jeff Mitchell will act as P.I. and will contribute 5% effort at no cost to the project. The bulk of funding requested for this proposed project in Year 1 will be used for installation of the drip system pump and for payment of WSREC research fees at the Field Station

Student Training:

We have hired a CSU Fresno student who will conduct the field data collection, data analysis and compilation responsibilities outlined here under the field supervision of Mitchell and Shrestha at CSU Fresno.

Project Dissemination Plan:

The goals, findings and conclusions of this project will be very intensively and widely disseminated via a variety of means and will involve the participation of all PI's. We expect that due to the "newness" of the systems we propose here, and the interest that this work may present to very wide audiences, that there will be considerable opportunities to extend information related to this project through field demonstrations, our CT conferences, our CT website, a new CT newsletter that we are producing, DVD videos we plan to develop related to this work and our other, ongoing work, and also more formal publications. We anticipate having opportunities also for each PI to conduct tours of the study sites for his respective clientele groups. Specific groups that will be targeted for project outreach will include, but not be limited to: California Wheat Commission, California Cotton Growers and Ginners Associations, the California Tomato Research Institute, the California Tomato Commissions, the California Dairy Campaign, California Dairymen's Association, private sector equipment and ag support companies, PCA's CCA's, the San Joaquin Valley Air Pollution Control District, the California Department of Water Resources, and the USDA Natural Resources Conservation Service.

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