RD
Contractor: Regents, UC Davis
Contract # 08-324

FUNDING FISCAL YEAR	FY 08/09	FY 09/10	FY 10/11	
TERM	06/30/09-06/29/12	06/30/09-06/29/12	06/30/09-06/29/12	
PCA	72360	72360	72360	
LINE ITEM/OBJECT	398	398	398	TOTAL
DESCRIPTION AB32 N_2O study				
Contract $	210,000.00	60,000.00	30,000.00	300,000.00
				-
				-
Total, Contract	210,000.00	60,000.00	30,000.00	300,000.00

Payments to Contractor:

Inv. #	Inv. Date	Ser Per				C/S

Total, Payments	-	-	-	-
Balance Available to Pay Contractor	210,000.00	60,000.00	30,000.00	300,000.00
Balance Must Be Spent By:	*06/30/11*	*06/30/12*	*06/30/13*	

Notes:
Contract Manager: Lei Guo

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11/19/2009

STATE OF CALIFORNIA
STANDARD AGREEMENT
STD 213 (Rev 06/03)

AGREEMENT NUMBER
08-324
REGISTRATION NUMBER

1. This Agreement is entered into between the State Agency and the Contractor named below:

STATE AGENCY'S NAME
Air Resources Board (ARB or State)

CONTRACTOR'S NAME
The Regents of the University of California, Davis (UCD, University, or Contractor)

2. The term of this Agreement is: June 30, 2009 through June 29, 2012

3. The maximum amount of this Agreement is: **$300,000.00** (Three hundred thousand dollars and no cents)

4. The parties agree to comply with the terms and conditions of the following exhibits which are by this reference made a part of the Agreement.

Exhibit A – Scope of Work	1 Page
Exhibit A - Attachment 1	34 Pages
Exhibit B – Budget Detail and Payment Provisions	2 Pages
Exhibit B – Attachment 1	11 Pages
Exhibit C* – General Terms and Conditions	GIA 101
Check mark one item below as Exhibit D:	
☒ Exhibit - D Special Terms and Conditions (Attached hereto as part of this agreement)	1 Page
☐ Exhibit - D* Special Terms and Conditions	
Exhibit E – Additional Provisions	5 Pages
Exhibit F – Research Report Format	6 Pages

Items shown with an Asterisk (*), are hereby incorporated by reference and made part of this agreement as if attached hereto. These documents can be viewed at www.ols.dgs.ca.gov/Standard+Language

IN WITNESS WHEREOF, this Agreement has been executed by the parties hereto.

CONTRACTOR

CONTRACTOR'S NAME *(if other than an individual, state whether a corporation, partnership, etc.)*
The Regents of the University of California, Davis

BY *(Authorized Signature)* [signature]
DATE SIGNED *(Do not type)* JUN 10 2009

PRINTED NAME AND TITLE OF PERSON SIGNING
Ahm ad Hakim-Elahi, Ph.D., JD, Director of Sponsored Programs

ADDRESS
Office of Research, Sponsored Programs
1850 Research Park Drive, #300, Davis, CA 95618

STATE OF CALIFORNIA

AGENCY NAME
Air Resources Board

BY *(Authorized Signature)* [signature]
DATE SIGNED *(Do not type)* 6/17/09

PRINTED NAME AND TITLE OF PERSON SIGNING
~~Socorro Watkins, Chief, Contract Services Section~~

ADDRESS
1001 I Street, 20th Floor, Sacramento, CA 95814

Sharon Simmons
Contract Services Section Manager
Air Resources Board

California Department of General Services Use Only

APPROVED
JUL 31 2009
DEPT OF GENERAL SERVICES

☐ Exempt per:

EXHIBIT A

SCOPE OF WORK

1. The Regents of the University of California, UCD (UCD, University, or Contractor) agrees to provide the following services for the project entitled "Assessment of Baseline Nitrous Oxide Emissions in California Cropping Systems," which is attached hereto as Attachment 1 and made a part of this Agreement.

2. Term: The term of this agreement is June 30, 2009 through June 29, 2012; however no work shall commence until receipt of final approval from the Department of General Services (DGS). Consequently, all dates contained in the Exhibits and Attachments shall be considered revised to conform to the actual term of this agreement, and the schedule shall not begin until Contractor receives written notice from ARB of final approval by DGS.

3. The project representatives during the term of this agreement will be:

Requesting Agency: ARB	**Providing Agency:**
Name: Lei Guo	Name: Prof. William R. Horwath
Research Division	Dept. of Land, Air, and Water Recources
1001 "I" Street	University of California, Davis
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Email: lguo@arb.ca.gov	Email: wrhorwath@ucdavis.edu

The ARB Contract Administrator is: The University's Contract Administrator is:

Requesting Agency: ARB	**Providing Agency:**
Emma Plasencia	May A. Turner
Research Division	Contract & Grants Analyst
Contracts Analyst	Office of Research, University of California
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STATEMENT OF SIGNIFICANCE

The anthropogenically caused increase in atmospheric nitrous oxide (N_2O) is beyond dispute and is significantly related to agricultural activities (IPCC, 2007). Nationally, agricultural soils are estimated to account for 68% of the total U.S. N_2O emissions, equivalent to annual 386.7 Tg CO_2. In California, 55% of all N_2O emissions have been estimated to come from agricultural soil, and N_2O may contribute as much as 50% to the total net agricultural greenhouse gas (GHG) emissions (California Energy Commission, 2005). Therefore, the contribution of N_2O to global radiative forcing out shadows that of methane and carbon dioxide which account for 37.5% and 12.5%, respectively. The California Global Warming Solutions Act of 2006 (AB 32) mandates that the State develops comprehensive strategies to reduce GHG emissions by 2020. Therefore, sustainable agricultural practices that minimize GHG emissions while maintaining optimal production must be developed. For agriculture, the reduction in N_2O emission is key to reducing overall GHG emissions.

Under the statutory authority of AB 32, the California Air Resources Control Board (CARB) has identified collaborative research on how to reduce N_2O emissions from nitrogen (N) land application as one of the early action measures for the overall reduction of GHG emissions. The determination of baseline N_2O emissions from current nitrogen fertilizer application in California is a prerequisite for developing strategies to mitigate N_2O emissions while maintaining agricultural production capacity vital to maintaining the agricultural sector.

A serious problem in estimating N_2O emissions and developing management to reduce emissions is the uncertainty associated with the high temporal and spatial variability of N_2O flux from soils. The uncertainty range for the IPCC default emission factors (tier 1 approach), which are currently used by CARB to derive N_2O emission inventories, ranges from about 10 to 100% for direct emissions. Estimates of N_2O emissions in California derived from modeling suffer from a lack of field measurements needed to calibrate and validate existing models (Li and Salas, 2004). For some of California's most important crops in terms of acreage and economic value, such as alfalfa, tomato, lettuce, vineyards, orchards, and cotton, only few, if any N_2O flux measurements have been reported in the scientific literature. The paucity of California N_2O field measurements is a major obstacle to the estimation of N_2O emissions and development mitigation practices.

In intensively managed cropping systems such as we have in California, there is great potential to mitigate N_2O emissions by optimizing nutrient management while maintaining yield potential. According to the IPCC (2001), a reduction in GHG emissions is most effectively achieved by minimizing N-surpluses. Unfortunately, addition of N beyond crop needs is a typical practice to ensure maximum crop production and to overcome annual changes in crop N demand caused by climate variability. The objectives of this project are to measure N_2O emissions in response to various N application rates in crop systems representative for a large acreage of California's agricultural land and to determine the economic N yield, i.e. the minimum N application necessary to achieve maximum yield in these cropping systems. Studying the relationship between N fertilization rates, environmental factors and N_2O emissions will provide estimates of both annual N_2O emission inventories and potential N_2O emissions reduction through optimizing N input rates.

This project is part of a larger effort by three research groups measuring N_2O emissions in 10 different cropping systems located in the Sacramento Valley, San Joaquin Valley and Central Coast region. The combined efforts of these separate projects will provide scientifically sound results to develop best management practices. The concept of economic N yield serves as a valuable tool for designing N fertilization guidelines for farmers. The concept embodies the notion of optimizing N resource economics. The measurements of N_2O flux and of the physical variables that control N_2O emissions, will serve as basis against which future measurements or the effects of alternative management practices can be compared. The N_2O emission data collected in the proposed research will serve as a data set to validate or revise future measurement activities as farming practices are adjusted and typical California crops and management change.

ABSTRACT

Nitrous oxide (N_2O) is a potent greenhouse gas (GHG), accounting for up to 50% of total agricultural GHG emissions in California. Measuring annual N_2O emissions is laborious because N_2O flux is highly variable and episodic in nature, depending on multiple environmental and agronomic factors, such as fertilization or plant residue management, soil moisture, and soil properties. Only few measurements of these emissions have been made in California, and estimates of N_2O emissions are highly uncertain. The California Global Warming Solutions Act of 2006 (AB 32) mandates that the State develop comprehensive strategies to reduce greenhouse gas emissions (GGE). Nitrous oxide is emitted from soil to the atmosphere as part of the nitrogen (N) cycle, but the addition of reactive nitrogen (N) in the form of fertilizer in intensive crop systems increases N_2O emissions. Therefore, in intensively managed agro-ecosystems, there is great potential to mitigate N_2O emissions, for example by increasing fertilizer N use efficiency. Currently, there is a lack of baseline N_2O emission data for most cropping systems in the State, and the relationship between N fertilization levels and N_2O emission is not well understood at the farming field level. The paucity of N_2O emission data has also hampered biogeochemical modeling, which requires robust data of N_2O emissions to calibrate and validate the models' predictive capability.

The objectives of this project are to (1) measure annual N_2O emissions for five major California crops (tomato,wheat, alfalfa, lettuce, rice) under typical management practices, (2) determine N_2O emission factors for these crop systems at several fertilizer N addition rates, and (3) to characterize the effects of environmental factors on the temporal profile of N_2O emissions. Our collaborators will additionally measure N_2O emissions in corn, cotton, vineyards, walnut and almond orchards during key management events, such as N fertilization and irrigation; in corn and cotton, annual N_2O emissions in response to various fertilizer N rates will also be determined. A system's approach that considers N fertilization, N loss as N_2O, and the soil physical and chemical environment will be employed. Through intensive measurements of N_2O flux in the field

for two consecutive years during periods with high N_2O emission potential, and less frequent, but regular monitoring of N_2O emissions when fluxes are low, total N_2O emissions per year will be estimated for each N addition treatment and crop system. The N_2O emission factors will be determined from the total N_2O emissions due to N fertilizer divided by the amount of fertilizer N applied. Yields in each treatment and crop will be assessed to test the hypothesis that N_2O emissions increase mainly in response to N additions exceeding crop needs. Data of ancillary variables, such as soil moisture, temperature, and soil chemical and physical parameters that are known to affect N_2O emissions will be useful characterize patterns of N_2O emissions in each system.

This research will benefit state agencies (CARB, CDFA-FREP, and CEC) by producing baseline N_2O estimates in response to N fertilization, as well as a comprehensive database that can be used for calibrating and validating biogeochemical models, for modeling N_2O emissions using the emission factors in a tier 2 approach, and for predicting N_2O emission budgets of current and future California cropping systems. The economic N yield, which will be determined for field crop systems, may serve as a valuable tool for designing and optimizing N fertilization guidelines for specific crops.

OBJECTIVES

The overall goal of this collaborative project is to determine N_2O emissions in crop systems representative for a large acreage of California's agricultural land. This project is part of a larger effort by three research groups measuring N_2O emissions in 10 different crop systems located in the Sacramento Valley, San Joaquin Valley and Central Coast region. The N_2O emission data collected by the three research groups will be used to establish baseline N_2O emission estimates in crop systems occupying >5 million acres of California's agricultural land, and to calibrate and validate models. The combined efforts of these separate projects will provide for more robust results and value added outcomes, such as development of best management practices to mitigate California agricultural N_2O emissions.

In this project, we will (1) select representative fields of tomato, wheat, alfalfa, rice, and lettuce crop systems in the Sacramento Valley and Coastal region for N_2O monitoring; (2) set up subplots receiving varied amounts of N fertilizer within each crop system and regularly measure N_2O flux during two consecutive years in each crop system to determine N_2O emissions for each N fertilizer level; (3) estimate annual baseline N_2O emissions for these crop systems, compare these estimates with modeling results generated by our collaborators, and calculate N_2O emission factors (EF) as a fraction of the fertilizer N applied for each crop system to make tier 2 assessments possible; (4) identify key environmental conditions affecting N_2O flux; (5) determine the economic N yield in the field crops in order to evaluate the hypothesis that N_2O emissions increase non-linearly at fertilizer N applications exceeding the amount required to achieve maximum yields, and to estimate and demonstrate the potential reduction in N_2O emissions possible with lower N applications; (6) prepare the final report according to ARB guidelines (Exhibit F).

Nitrogen fertilizer inputs also affect two other gases generated during N transformations in the soil, nitric oxide (NO) and nitrogen dioxide (NO_2). The emissions of these gases control ozone (O_3) production in rural areas, and using measured NO and NO_2 flux data could improve California specific O_3 modeling. The NO and NO_2 flux could be measured in the above experiments if additional funding can be secured.

APPROACH

Task 1: *Site Selection.* Representative soils and crop systems in main production areas will be chosen for N_2O monitoring. On-site characterization of soil parameters will be conducted prior to final selection of monitoring sites. Critical variables to be determined are soil C and N content, soil texture, bulk density, and pH. Soil texture and climate, which differ among regions, influence N_2O emissions mainly through their effects in controlling the duration of water filled pore space after soil wetting events. The management at the selected sites will reflect the "typical" practices for a given crop. Overall, the site selection process will be based on a variety of information, such as management practices, site management histories, soil characteristics and regional climate.

The tomato and wheat systems fertilizer rate experiments will most likely be conducted at the UC Davis Russell Ranch Sustainable Agriculture research site. The tomato/wheat rotation, which has been in place there since 1994, and the soil types (Yolo silt loam and Yolo clay loam) at the site are typical for this region, and yields are comparable to those in the county and adjoining areas (Denison et al., 2004). In addition, previous N_2O measurements by our group in the tomato systems will be useful for designing effective sampling strategies (Burger et al., 2005; Kallenbach, 2008). The alfalfa and lettuce sites will be grower fields in Yolo and Monterey County, respectively. Additionally, fertilizer rate experiments in lettuce systems will be conducted at the Hatnell College East Campus Farm in Salinas CA. For the rice N_2O monitoring, grower fields in Colusa county, where trials involving early season drains and various N fertilizer levels supported by the California Rice Commission are conducted, will be used to supplement our rice crop monitoring efforts at the Cooperative Rice Experiment Station, Biggs, CA, where Dr. Horwath is currently measuring N_2O and CH_4 fluxes.

Task 2: *Nitrogen fertilization and N_2O flux measurements*: For each crop system, microplots will be set up in a randomized complete block design (at least 3 blocks, each with 5 microplots) and N fertilizer will be applied to microplots (typically on the order of 5 x 5 m, depending on bed and furrow configurations) at several rates ranging from 0 to exceeding the highest rate reported for a particular crop. For example, tomato plots will be fertilized at 0, 75, 150, 225, and 300 kg N ha^{-1} (typical rates are 150 to 225 kg N ha^{-1}). For alfalfa, only two levels of N fertilization will be applied since supplemental N additions in alfalfa by farmers are relatively small (<25 kg ac^{-1}). In rice systems, injected aqua-N and surface applied N fertilizer at different rates will be compared in fields with early season drainage.

In each system, data will be collected for two years. We will measure N_2O flux intensively when the potential for N_2O emissions is high, but less frequently when N_2O emissions can be expected to be low. Episodes of high N_2O emissions occur when both soil NO_3^- concentrations and water-filled pore space (WFPS) are high, for example during irrigation or rainfall events following N fertilization (Bronson and Mosier, 1993; Burger et al., 2005; Dobbie et al., 1999; Simojoki and Jaakkola, 2000). The incorporation of residue also stimulates N_2O flux, especially if followed by soil wetting (Baggs et al., 2003; Burger et al., 2005; Kaiser et al., 1998b; Velthof et al., 2002). Emissions of N_2O will also be monitored in the winter because California's mild winter temperatures and seasonal rainfall patterns may be conducive to sporadic high N_2O emissions in the winter (Kallenbach, 2008). Examples of sharp spikes of N_2O fluxes in response to increases in soil moisture and N and carbon inputs in tomato systems in Yolo county are shown in Figure 1. The critical time when substantial N_2O emissions can be expected in rice systems is during spring and early season drainage (March-May) (Linquist et al., 2006), and our intensive sampling efforts will focus on this period.

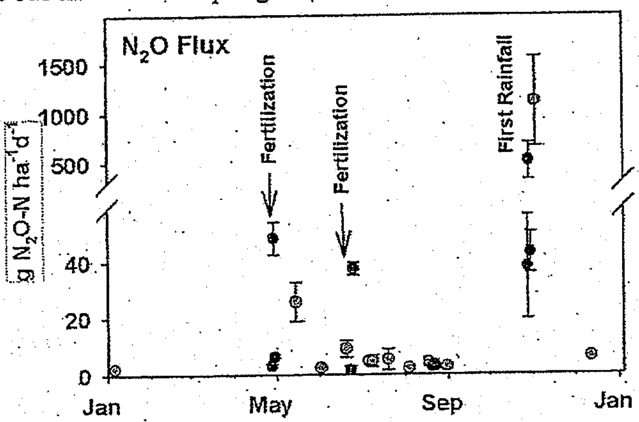


Figure 1. Nitrous oxide flux in response to management events in conventionally managed tomato systems at the UC Davis Russell Ranch Sustainable Agriculture Research site in Yolo County. The red and black symbols represent N_2O flux measurements in different years. Standard errors shown as line bars. n=3.

Frequent N_2O flux sampling will take place immediately before and after N fertilization and irrigation or rainfall events with the goal of capturing the extent of elevated N_2O fluxes until the fluxes subside to background levels. When N_2O flux has receded and soils are relatively dry, measurements will be taken less frequently (e.g. weekly). We will also estimate the magnitude of diurnal fluctuations through short term, detailed time-series measurements of N_2O flux. The information from the diurnal measurements will be useful for choosing the sampling time most representative for the average daily N_2O flux.

Chamber and gas chromatograph (GC) methodology: Nitrous oxide flux will be measured, using a static chamber technique (Hutchinson and Livingston, 1993). Either round chambers or rectangular chambers will be used, depending on field configurations (bed-and-furrow *vs.* flat). By using system-specific chambers that cover an area relating to overall field configuration and that facilitate extrapolation of results, representative sampling can be achieved. In tomato, lettuce, and wheat systems, rectangular stainless chamber bases, 50 x 30 cm and 8 cm deep with a 2 cm-wide horizontal flange at the top end will be inserted into the soil, so that the flange rests on the soil surface. The bases will be left in place unless field operation requires their temporary removal. Thin-wall stainless steel (20 gauge) chamber tops (50 x 30 x 10 cm), with flanges facing down and lined with a rubber gasket, will be placed onto the bases and secured with metal clamps during gas collection. Round, 25.4 cm-diameter PVC chambers will be used to measure N_2O flux in the furrows and in alfalfa and rice systems. The chambers will slide snugly over rings that serve as bases. The rings will be pushed 8 cm deep into the soil and left in place in between samplings. The height of the round chambers will be 10 cm, but 30 cm tall chambers will be used, if necessary, to accommodate alfalfa plants. The chambers will have sampling ports with butyl rubber septa and will be vented (4.8mm dia., 10 cm long tubes), and their outer surfaces will be covered with reflective insulating material.

Chamber gas samples will be collected 0, 30, and 60 min after placing the chamber tops onto the bases. These intervals of sampling collection may be somewhat modified depending on the N_2O fluxes determined in each system during initial analyses. To collect a gas sample from the chamber, headspace air will be removed by inserting the needle of a polypropylene syringe (Monoject) through the septum of the sampling port and by slowly withdrawing 12 mL gas. The gas in the syringes will immediately be transferred into evacuated 12-mL glass vials with grey butyl rubber septa (Exetainer, Labco Ltd., Buckinghamsire, UK), and then another 12 mL gas will be withdrawn from the chamber and stored in the same glass vial. Thus, the air in the glass vial will be pressurized. Having 24-mL gas per sample allows two analyses (see below) of one sample, if necessary. The air temperature inside the chambers will be recorded, along with other environmental variables (see Tasks 3 and 4).

The gas samples will be analyzed by a Shimadzu gas chromatograph (Model GC-2014) with a ^{63}Ni electron capture detector (ECD) linked to a Shimadzu auto sampler (Model AOC-5000). The autosampler uses a gas-tight syringe to remove 5 mL gas from a sample vial and inject it into the GC port. Subsequently, the autosampler's syringe and the GC's sample loop are purged with helium. The GC uses as carrier gas P5 (mixture of 95% argon and 5% methane). The carbon dioxide and N_2O are separated by a Haysep Q column at 80° C. The ECD is at 320° C and the pressure of the carrier gas at the ECD is 60 kPa. The minimum quantity of N_2O detected by this GC system is 0.1 pg s^{-1}. The system will be calibrated daily using analytical grade N_2O standards (Airgas Inc., Sacramento CA). Quality assurance of the N_2O values generated by the GC and its software is obtained by processing N_2O standards in exetainers after taking them to the field and treating them the same way as field samples. The number of daily samples generated at two sites during an intensive sampling period can be processed in a 24-hour period on one of the two gas chromatographs (Dr. Horwath and Dr. Six) available at UCD. Should backlogs occur, samples can be stored for up to two weeks and their quality assurance insured using N_2O standards treated (age and storage conditions) as field samples would be. With few exceptions (e.g. first rainfall), the times when the greatest number of samples is generated vary among the crop systems being monitored. Sample collection in the field and analysis of samples by GC will be according to clearly established protocols. The overall quality control of the gas collection and N_2O analyses is the responsibility of the Project Manager.

Task 3: *Annual N_2O emissions.* Gas fluxes will be calculated from the rate of change in chamber concentration, chamber volume, and soil surface area (Hutchinson and Mosier, 1981). If the rate of change of headspace trace gas concentration is not constant, then an algorithm appropriate for curvilinear concentration data with time will be used to calculate this rate (Hutchinson and Mosier, 1981). Chamber gas concentrations determined by GC (volumetric parts per million) will be converted to mass per volume units assuming ideal gas relations using the measured air temperature values in the chamber during sampling. The annual N_2O emissions will be calculated by assuming that the measured fluxes represent mean daily fluxes, and that mean daily fluxes change linearly between measurements. Differences between N fertilization treatments will be assessed using one-way ANOVA and standard mean separation procedures. Transformation of the N_2O emission data will be carried out for the statistical analysis if the data will not be normally distributed. The N_2O flux data generated in the proposed research and the ancillary variables measured during gas sampling (see Task 4) will also be used to calibrate and validate modeling of N_2O emissions by our collaborators.

The emission factors (EF) will be estimated by the difference in total N_2O-N emissions between fertilized treatments and the control (0 N fertilizer applied) divided by the amount of fertilizer N applied. This analysis also allows for calculation of EF per growing season, rainy season, all year, and for a specific event or fertilizer N level, i.e. a range of crop specific EFs will be determined. The N_2O emission data generated by our collaborators will also be used to calculate N_2O emission factors.

The IPCC (tier 1) approach uses an emission factor (EF) of 1%, i.e. the fraction of the applied fertilizer N lost as N_2O to the atmosphere. This is a statistically derived value based on a meta-analysis of available data (Bouwman et al., 2002). Estimates of EFs reported in the literature range from 0.2 (Dobbie et al., 1999) to 15.5% (Jungkunst et al., 2006). Some studies found EFs <1% from small-grain cereal systems and relatively higher EFs (2.6-5.7%) in broccoli, potato, and sugar beet systems (Dobbie and Smith, 2003; Kaiser et al., 1998a). In St. Barbara county, CA, EFs in vegetable systems (lettuce, broccoli, cauliflower, artichokes), which received 290-665 kg N ha^{-1}, ranged from 4.0 to 9.3% (Ryden and Lund, 1980). In addition to NO_3^- levels and soil moisture, local factors relating to soil conditions and weather patterns seem to influence N_2O emissions. For example, Ruser et al. (2001) reported that up to 58% of annual emissions in wheat, potato, and corn systems occurred outside the cropping period, and that high N_2O losses in a particular system were mainly due to high losses from the inter-row area during the cropping season.

A non-linear increase in N_2O emissions may occur when N fertilizer inputs are in excess of crop N need. Meta-analyses based on over 1000 studies found that increasing fertilizer N application rates significantly increase N_2O emissions, (Bouwman et al., 2002; Eichner, 1990; Stehfest and Bouwman, 2006), and this trend is more pronounced at the high end of N application rates (>200 kg ha^{-1}). However, several studies have shown that N_2O emissions increased sharply in response to N inputs that exceeded crop N requirements or economic N yield (Edis et al., 2008; McSwiney and Robertson, 2005). Fertilizer N inputs greater than at levels where yield is maximized, seem prone to result in drastic increases of N_2O emissions. For example, N_2O flux increased from 20 to 50 g N_2O-N ha^{-1} d^{-1} with an increase in N fertilizer of only 33 kg N ha^{-1} above the economic N yield (McSwiney and Robertson, 2005). In a modeling study, Grant (2006) reported a non-linear rise in N_2O emissions where mineral N availability exceeded crop N demand. The difference between the mineral available N and crop N uptake seems to have a greater influence on N_2O emissions than the absolute amount of fertilizer applied. Sehy et al. reported a 34% decrease in N_2O emissions over a 10-month period with a 17% decrease in N fertilizer input at a low-yielding site in a maize field, whereas an increase in 17% N fertilizer at a high-yielding site had no effect on N_2O emissions (2003). Other studies showed that the residual N not taken up by a crop lead to higher N_2O emissions than those in crop systems with lower post-harvest NO_3^- levels (Ruser et al., 2001; Smith et al., 1998).

Task 4: *Effects of environmental variables on N_2O emissions*. Soil moisture and soil N availability, in addition to carbon availability, largely control the magnitude of N_2O emissions. Denitrification occurs under oxygen (O_2) limitation, typically when diffusion of O_2 from the atmosphere into the soil is limited at high soil water content, for most soils at a water-filled pore space (WFPS) >60% (Linn and Doran, 1984). Heterotrophic bacteria use NO_3^- instead of O_2 as an electron acceptor, thereby reducing NO_3^- to N_2 via the obligate intermediates nitrite (NO_2^-), nitric oxide (NO) and N_2O. The proportion of N_2O that is not consumed and escapes to the atmosphere is regulated by O_2 via WFPS, and the concentration of NO_3^-, i.e. the N_2O/N_2 ratio decreases with a water content near saturation (WFPS >90%) and increases with increasing NO_3^- concentrations in the soil (Firestone et al., 1982). The highest N_2O fluxes occur at WFPS 60-90% (Davidson, 1992; Dobbie et al., 1999; Linn and Doran, 1984; Simojoki and Jaakkola, 2000). The availability of carbon (C) stimulates microbial activity, thereby decreasing the available O_2 in the soil and increasing NO_3^- demand and N_2O production (Weier et al., 1993). Nitrous oxide is also produced during nitrification although the exact mechanisms and environmental conditions are not as well understood as those of denitrification. Nitrification, the conversion of NH_4^+ to NO_3^- via the intermediate NO_2^- is carried out by autotrophs and occurs mostly under aerobic conditions, i.e. at lower WFPS, but there is evidence of denitrification by nitrifiers under O_2 limitation (Wrage et al., 2001). The main driver of nitrification is NH_4^+ availability. Low pH may stimulate N_2O production under aerobic conditions (Venterea and Rolston, 2000).

Soil temperature in addition to air temperature, and soil moisture will be recorded during each gas sampling. Periodically, inorganic N to a depth of 15 cm will be determined in soil extracts, and pH will be measured in soil slurries. Bulk density in the 0-15 cm layer will be determined to calculate the soil water-filled pore space, a useful predictor for N_2O flux, from soil moisture values. The quantity and C/N ratio of incorporated crop residues will be recorded because both C and N inputs potentially stimulate N_2O production. Soil temperature will be measured using soil temperature probes inserted to 5-cm depth. Air temperature will be measured by thermocouples. Air temperature measurements will also be compared to temperature available from local weather stations. Soil moisture in the 0-15 cm layer of soil will be determined via TDR (time domain reflectometry) probes. The TDR-based measurements of soil moisture will be calibrated by periodic determination of gravimetric soil moisture and soil bulk density. Gravimetric soil moisture will be calculated from wet and oven-dry (105°C) mass of soil collected in the 0-15cm layer using a 1.83-cm steel corer. The bulk density will be measured by collecting 10 cm dia. x 10 cm long cores in the 5-15 cm layer of soil, followed by drying to 105°C. Soil cores to 15 cm depth will be collected in each microplot of each crop system. These soil samples will be extracted with 2 M potassium chloride (KCl) at a liquid to soil ratio of 5, and the extracts will be analyzed colorimetrically for ammonium (NH_4^+) and nitrate (NO_3^-) by a Shimadzu spectrophotometer (Model UV-Mini 1240) in Dr. Horwath's laboratory. For determining NH_4^+, the phenate (indophenol blue) method will be employed (Forster, 1995). Nitrate will be reduced to nitrite (NO_2^-) with vanadium chloride, and NO_2^- will be analyzed by diazotizing with sulfanilamide followed by coupling with N-(1-naphthyl) ethylenediamine-dihydrochloride (Doane and Horwáth, 2003). The pH will be measured in supernatant of soil slurries of 1M KCl and an equal mass of soil by a pH meter (Model 220, Denver Instrument Co., Arvada, CO) in Dr. Horwath's laboratory (Venterea and Rolston, 2000).

The ancillary data will be used to characterize the environmental factors that, in addition to N fertilizer application, control N_2O emissions. Measurements of the above variables will contribute to better understanding how environmental factors affect N_2O emissions under California specific conditions, such as the most common irrigation techniques or specific N fertilizer types used in each of the crop systems. These ancillary variables will also be used as inputs for modeling by our collaborators.

Task 5: *Economic N yield.* Yield will be assessed using hand harvest in each microplot. The least amount of fertilizer N needed to achieve maximum yield, i.e. the economic N yield, will be inferred from the N application rates and yield data. The economic N yield and N_2O emission data determined for corn and cotton by our collaborators will also be considered in our analyses. The economic N yield and N_2O flux data in each system will be used to evaluate the hypothesis that N_2O emissions increase non-linearly at N fertilizer levels exceeding crop N demand. We will be able to calculate emission factors at each N fertilizer level for the different cropping systems (see task 2). By determining the least amount of N fertilizer needed to achieve maximum yield, the potential reduction in N_2O emissions from a decrease in fertilizer N additions can be estimated as well as demonstrated. Farmers may be able to reduce fertilizer N applications without yield penalty by avoiding excessive N applications. The practice of over-fertilization is common. For example, University of California research has shown that maximum yields of processing tomatoes can be obtained with about 115-175 kg N ha^{-1}, yet typical seasonal N application rates are 140 to 300 kg ac^{-1} (Hartz et al., 1996).

In irrigated systems, the economic N yield, which can only be determined in hindsight, can be more reliably predicted than in rain fed systems. Therefore, using less N fertilizer is less risky for farmers in California, than, for example, in the Midwest where climatic influences can dramatically change economic N yield annually. The information generated in our research can be used to develop sensible best management practices for growers.

Task 6: *Reports*. Quarterly progress reports will be submitted to ARB. The draft final report will be submitted 3 months prior to the expiration of the grant according to ARB Research Final Report Format (Exhibit F). We request this change of the draft submission date because N_2O monitoring in some of the systems (e.g. wheat) will extend until late summer 2011. Our monitoring plans are determined by logistics tied to the cropping cycles. The final report will be submitted within 45 days of receipt of ARB's comments on the draft Final Report.

2. PROJECT SCHEDULE

Task 1: Select sites, build flux chambers
Task 2: Set up N fertilization plots & measure N_2O flux
Task 3: Calculate annual N_2O emissions, emission factors
Task 4: Measure factors that control N_2O emissions
Task 5: Measure economic N yield
Task 6: Prepare final report

2009	MONTH	1	2	3	4	5	6	7	8	9	10	11	12
TASK													
1		■	■	■						■			
2					■	■	■	■	■	■	■	■	■
3													
4					■	■	■	■	■	■	■	■	■
5									■				
6													
		i		p	q		p	q		p	q		p

2010	MONTH	1	2	3	4	5	6	7	8	9	10	11	12
TASK													
1													
2		■	■	■	■	■	■	■	■	■	■	■	■
3					■	■	■			■	■	■	
4		■	■	■	■	■	■	■	■	■	■	■	■
5							■		■				
6													
		q		p	q		p	q		p	q		p

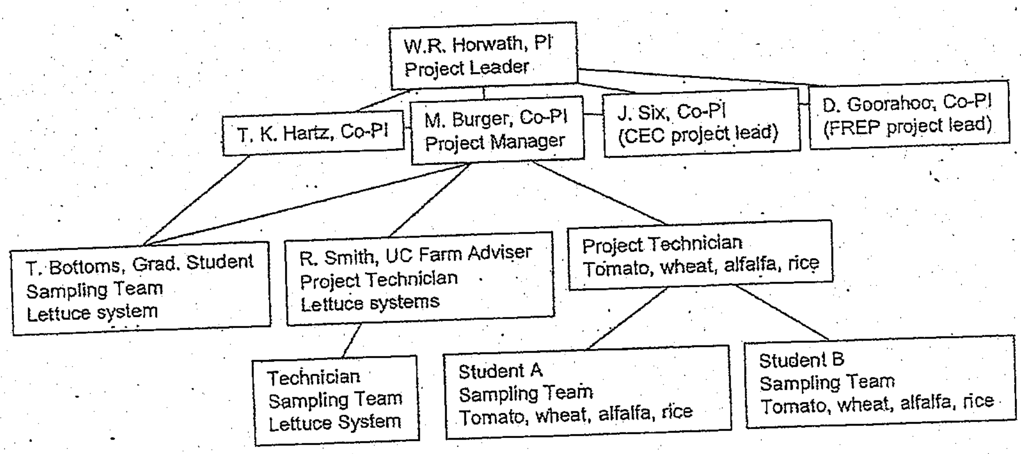
2011	MONTH	1	2	3	4	5	6	7	8	9	10	11	12
TASK													
1													
2		■	■	■	■	■	■	■	■				
3					■	■	■	■	■	■	■		
4		■	■	■	■	■	■	■	■				
5							■						
6					■	■	■	■	■	■	■	■	■
		q		p	q		p	q		dp	q	f	q

i=initial meeting; p= progress review meeting; q=quarterly progress report; d=draft final report; f=final report

In general, the cropping cycles of each crop system will determine the timeline of the experiments to measure economic N yield and annual N_2O emissions.
Tomato: Planting and N fertilization starts in April/May 2009, harvest takes place in August/September. Monitoring of N_2O emissions will start in March 2009 and it will end in March 2011.
Wheat: N fertilization and planting takes place in the fall (October) 2009, harvest is in June. N_2O flux monitoring will start in October 2009, and it will end in September 2011.
Lettuce: Usually two crops between May and September. N_2O flux monitoring will start in April 2009 and it will end in March 2011.
Alfalfa: Harvests take place from April to November, and in addition, N fertilization is sometimes undertaken in December/January. Monitoring N_2O will take place between spring 2009 and spring 2011.
Rice: Research, including our preliminary studies at the Biggs Experiment Station, has shown that N_2O emissions are below detection when rice fields are flooded. Critical periods during which N_2O emissions may be substantial are during spring dry down (April/May) and during early-season and mid-season drainage (May/June).

3. PROJECT MANAGEMENT PLAN

a) Organizational Chart



b) Responsibilities of Personnel

The Project Leader and Manager provide project oversight. The Project Manager is responsible for convening monthly meetings with the PIs and the Project Technicians. The Project Manager and the PIs make the final decisions on site selections, N fertilizer treatments, and overall sampling strategy. The PIs, Project Manager and Project Technicians evaluate data interpretation. The Project Manager is responsible for flux chamber design, establishing sampling protocols, data quality control, calculating annual N_2O emissions and emission factors, writing quarterly reports, the draft final report and the final report.

The Project Technicians will lead the Sampling Team. The Project Technicians will be responsible for the N_2O flux measurements by collecting air samples and ancillary data in the field, analyzing air samples by GC, measuring yield, processing soil samples collected in the field, and recording data.

The Sampling Team, which will include student assistants, will be responsible for carrying out the above tasks under the supervision of the Project Technicians according to protocols established by the Project Manager. Safety decisions will be made by the Project Manager and the Project Technicians.

c) Management and Coordination

The Project Manager will hold monthly meetings with the PIs and the Project Technicians to plan future activities, discuss results and resolve potential difficulties. The timelines of the tasks will be decided on at the monthly meetings. Because of the physical distance between sampling locations, some of these meetings may take place via conference call. The Project Manager ensures that the tasks outlined in this work plan are carried out in a timely manner and that the budget is adhered to. The Project Manager will work closely with the Project Technicians, especially in setting up the N fertilization plots and in establishing sampling routines in the field. The Project Manager will confer with the Project Technicians at a minimum on a weekly basis to discuss progress, plans, and difficulties in adhering to established sampling protocols and timelines.

d) Curricula vitae

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EDUCATION
1993 Ph.D.s Soil Science, College of Agriculture, Depart. of Crop and Soil Sciences & Forest Ecology, Depart. of Forestry, Michigan State Univ., E. Lansing, MI.

1979 BS. Forestry Environmental Impact Assessment, College of Agriculture, Department of Forestry, Southern Illinois University, Carbondale, IL.

Positions Held:
Professor of Soil Biogeochemistry, University of California, Davis, CA. 7/04 to present
Assoc. Professor of Soil Biogeochemistry, University of California, Davis, CA.7/00 to 6/04
Assist. Professor of Soil Biogeochemistry, University of California, Davis, CA.7/96 to 6/00
Graduate Faculty, Oregon State University, Corvallis, OR. 1/95 to present
Research Soil Microbiologist, USDA ARS, Corvallis, OR.10/94 to 5/96
Faculty Research Associate, Oregon State University, Corvallis, OR. 11/92 to 9/94
Graduate Research Assistant, Michigan State University, E. Lansing, MI. 9/88 to 10/92
Research Specialist, Michigan State University. 11/85 to 9/88
Staff Research Associate, University of California at Berkeley, CA 4/83 to 10/85
Forestry Apprentice, German Academic Exchange Service, Munich, Germany. 6/79 to 6/80

Publications (Selected since 2003)

1. Dahlgren, R.A., W.R. Horwath, K.W. Tate, and T.J. Camping. 2003. Blue oak enhance soil quality in California oak woodlands. California Agriculture 57(2):42-47. 714 p.
2. Yu, Z., T.E.C. Kraus, R.A. Dahlgren, W.R. Horwath, and R.J. Zasoski. 2003. Mineral and dissolved organic nitrogen dynamics along a soil acidity-fertility gradient. Soil Sci. Soc. Am. J. 67:878-888.
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4. Bird, J.A., C. van Kessel, and W.R. Horwath. 2003. Stabilization and ^{13}C-Carbon and immobilization of 15N-Nitrogen from rice straw in humic fractions. Soil Sci. Soc. Am. J. 67:806-816.
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6. Doane, T.A., O.C. Devêvre, and W.R. Horwáth. 2003. Short-term soil carbon dynamics of humic fractions in low-input and organic cropping systems. Geoderma 114:319-331.
7. Horwath, W.R. 2003. Microbial Biomass in Soils. In: Encyclopedia of Agrochemicals. Academic Press, New York. In Press.
8. Doane, T.A. and W. R. Horwath. 2003. Spectrophotometric Determination of Nitrate with a Single Reagent. Analytical Letters: ANALYTICAL LETTERS 36,: 2713–2722.
9. Koivunen, M. E., C. Morisseau, J. W. Newman, W. R. Horwath and B. D. Hammock. 2003. Purification and characterization of a methylene urea-hydrolyzing enzyme from *Rhizobium radiobacter* (*Agrobacterium tumefaciens*). Soil Biol. And Biochem.: In Press.
10. Kraus T. E. C., R. J. Zasoski, R.A. Dahlgren, W.R. Horwath and C.M. Preston. 2004. Carbon and nitrogen dynamics in a forest soil amended with purified tannins from different plant species. Soil Biology and Biochemistry 36 (2): 309-321.
11. Koivunen M. E. and W. R. Horwath. 2004. Effect of management history and temperature on the mineralization of methylene urea in soil. Nutrient Cycling in Agroecosystems 68: 25-35.
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13. Garcia-G. R., Gomez A., Lopez-U. J., Vargas-H. J., W.R. Horwath. 2004. Tree growth and delta C-13 among populations of Pinus greggii Engelm. at two contrasting sites in central Mexico. Forest Ecology and Management 198: 237-247.
14. Koivunen M. E. and W. R. Horwath. 2005. Methylene urea as a slow-release nitrogen source for processing tomatoes. NUTRIENT CYCLING IN AGROECOSYSTEMS 71 (2): 177-190.
15. Onsoy YS, Harter T, Ginn TR, Horwath WR. 2005. Spatial variability and transport of nitrate in a deep alluvial vadose zone. VADOSE ZONE JOURNAL 4 (1): 41-54.
16. Doane TA, Horwath WR 2004. Annual dynamics of soil organic matter in the context of long-term trends. GLOBAL BIOGEOCHEMICAL CYCLES 18 (3): Art. No. GB3008 AUG 6 2004
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23. Moran, K.K., Six, J., Horwath, W.R., and C. van Kessel. 2005. Role of mineral-nitrogen in residue decomposition and stable soil organic matter formation. Soil Science Society of America Journal.
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36. Davis JH, Griffith SM, Horwath WR, Steiner JJ, Myrold DD. 2007. Mitigation of shallow groundwater nitrate in a poorly drained riparian area and adjacent cropland. Journal of Environemtal Quality 36: 628-637.

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EDUCATION

2002	Ph.D., Ecology (Area of Emphasis Agroecology); University of California, Davis. Dissertation: Soil Nitrogen Transformations in Response to Farming Practices and the Presence of Roots
1996	B.S., International Agricultural Development, Highest Honors; University of California, Davis.

PROFESSIONAL EXPERIENCE

2008-	Research Manager, Sustainable Agriculture Farming Systems project, University of California, Davis, CA
2004-2007	Postdoctoral Scholar Dept. of Plant Sciences, University of California, Davis, CA
2003-2004	Postdoctoral Research Associate USDA-ARS, Soil and Water Management Unit, Dept. of Soil, Water and Climate, University of Minnesota, St. Paul, MN
1996-2002	Research Assistant Dept. of Vegetable Crops, University of California, Davis, CA

RESEARCH INTERESTS

Carbon and nitrogen cycling in crop systems; Rhizosphere ecology; Soil fertility and mineral nutrition of plants; Plant nitrogen use under elevated atmospheric carbon dioxide concentrations; Nitrous oxide emissions from agricultural soil.

PUBLICATIONS

Burger M., Venterea R.T. Nitrogen immobilization and mineralization kinetics of cattle, hog and turkey manure applied to soil. Soil Science Society of America Journal (in press).

Jackson L.E., Burger M., Cavagnaro T.R. 2008. Roots, nitrogen transformations and ecosystem services. Annual Review of Plant Biology, 59: 341-363.

Gentile R., Burger M., Pierce D., Smart D.R. 2006. Impacts of Climate Change on Crop and Animal Physiology in California Agriculture. In Cavagnaro T.R., Jackson L.E., Scow K.M. (eds.) Climate Change: Challenges and Solutions for California Agricultural Landscapes. California Climate Change Center. http://www.energy.ca.gov/2005publications/CEC-500-2005-189/CEC-500-2005-189-SF.PDF.

Venterea R.T., Burger M., Spokas K.A. 2005. Nitrogen oxide and methane emissions under varying tillage and fertilizer management. Journal of Environmental Quality, 34: 1467-1477.

Burger M., Jackson L.E., Louie D.T., Lundquist E.J., Miller R.L., Rolston D.E., Scow K.M. 2005. Microbial responses and nitrous oxide emissions during wetting and drying of organically and conventionally managed soil under tomatoes. Biology and Fertility of Soils. 42: 109-118.

Burger M. and Jackson L.E. 2004. Plant and microbial nitrogen use and turnover: Rapid conversion of nitrate to ammonium in soil with roots. Plant and Soil, 266:289-301.

Burger M. and Jackson L.E. 2003. Microbial immobilization of ammonium and nitrate in relation to ammonification and nitrification rates in organic and conventional cropping systems. Soil Biology and Biochemistry, 35: 29-37.

PROFESSIONAL AFFILIATIONS

ASA-CSSA-SSSA (Agronomy, Crop Science, and Soil Science Societies of America).

Journal article reviewer for Global Change Biology, Soil Science Society of America Journal, Journal of Environmental Quality, Plant and Soil, Journal of Agricultural and Food Chemistry, Waste Management, Soil Ecology.

JOHAN SIX

EDUCATION

1998 Ph.D., Soil Science, Colorado State University, Fort Collins, Colorado. Dissertation: 'Aggregate and Soil Organic Matter Fraction Dynamics in Agroecosystems'

1995 M.Sc. Bio-Engineering, Katholieke Universiteit Leuven, Belgium. Major: Soil Science; Minor: Tropical Agriculture. Thesis: 'Soils and Land Use in the Eastern Region of South Vietnam and Lam Dong Province'

RESEARCH EXPERIENCE

2006- present *Assistant Professor*
Department of Plant Sciences, University of California, Davis, CA.

2005-2006 *Full Professional Researcher*
Department of Plant Sciences, University of California, Davis, CA.

2003-2005 *Associate Professional Researcher*
Department of Plant Sciences, University of California, Davis, CA.

2002-2003 *Assistant Professional Researcher*
Department of Agronomy and Range Science, University of California, Davis, CA.

2001- present *Research Scientist*
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2000 *Visiting Scientist*
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1999-present *Affiliated Professor*
Department of Soil and Crop Sciences, Colorado State University.
Regular Faculty Member
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1999-2001 *Scientist*
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1999 *Research Associate*
Natural Resource Ecology Laboratory, Colorado State University, Ft. Collins, CO.

FUNDED FEDERAL RESEARCH PROPOSALS (SELECTED 2004-2008)

Effect of climate change on crop production in the Central Valley of California. **J. Six**, P.I. and S. De Gryze. California Energy Commission. Funded for $60.000. (10/07-10/08)

Physicochemical and biochemical controls on soil C saturation behavior. **J. Six**., P.I. and A.F. Plante. *Department of Energy*. Funded for $374,991. (09/07-08/10)

Sustainable, environmentally friendly, and cost-effective production of biomass for energy efficient biofuels in California. **J. Six**, P.I., and S. De Gryze, S. Kaffka, B. Linquist, J. Mitchell, M. Ruark, C. van Kessel, M. Delucchi, M. Melaina, R. Howitt. Chevron. Funded for $890,907. (09/07-08/10)

Incorporating physically defined SOM pools into EPIC. **J. Six**, P.I.. *Oak Ridge National Laboratory, Department of Energy*. Funded for $165,333. (09/07 - 08/10)

Collaborative research on feedbacks between microbial community composition, soil structure, plant growth and nitrogen cycling in ecosystems exposed to elevated CO_2 and O_3. **J. Six**, P.I., H. Chung, K.M. Scow, and C. van Kessel. *National Science Foundation*. Funded for $672,000. (07/06- 06/09)

The interaction between resource quality and aggregate turnover controls ecosystem nitrogen and carbon cycling. **J. Six**, PI., and C. van Kessel. *National Science Foundation*. Funded for $620,000. (05/04 - 04/07)

Control of vertical soil variation on temporal variation of soil CO2 production and emissions. **J. Six**, and S. De Gryze. *Kearney Foundation*. Funded for $86,000. (01/07-12/08)

An integrated assessment of the biophysical and economic potential for greenhouse gas mitigation in California agricultural soils. **J. Six**, PI., R.E. Howitt, D.E. Rolston, R. Plant, J. Mitchell, C. van Kessel, and J.W. Hopmans. *California Energy Commission/ Kearney Foundation*. Funded for $332,945. (11/04 - 10/07).

Enhancing COMET-VR system: Uncertainty estimation and expanded management options. K. Paustian, PI., and **J. Six**. *United States Department of Agriculture/Natural Resource Conservation Service*. Funded for $251,000. (09/07-08/08)

PUBLICATIONS (SELECTED 2005-2008)

Gulde, S., H. Chung, W. Amelung, C. Chang, and **J. Six**. 2008. Soil carbon saturation controls labile and stable carbon pool dynamics. Soil Sci. Soc. Am. J., 72:605-612.

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Van Oost, K., T. A. Quine, G. Govers, S. De Gryze, **J. Six**, J.W. Harden, J.C. Ritchie, G.W. McCarty, G. Heckrath, K. Cosmas, J.V. Giraldez, J.R. Marques da Silva, R. Merck. 2007. The impact of agricultural soil erosion on the global carbon cycle. Science, 318:626-629.

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Chivenge, P.P., H. K. Murwira, K. E. Giller, P. Mapfumo and **J. Six**. 2007. Long-term impact of tillage and residue management on soil carbon stabilization: Implications for conservation agriculture on contrasting soils. Soil Till. Res., 94:328-337.

Denef, K., L. Zotarelli, R.M. Boddey, and **J. Six**. 2007. Microaggregate-associated C as a diagnostic fraction for management-induced changes in soil organic carbon in two Oxisols. Soil Biol. Biochem., 39:1165-1172.

Fonte, S.J., A.Y.Y. Kong, C. van Kessel, P. F. Hendrix, and **J. Six**. 2007. Influence of earthworm activity on aggregate-associated carbon and nitrogen dynamics differs with agroecosystem management. Soil Biol. Biochem., 39:1014-1022.

De Graaff, M.A., K.J. van Groenigen, **J. Six**, B.A. Hungate, and C. van Kessel. Interactions between plant growth and soil nutrient cycling under elevated CO_2: a meta-analysis. Global Change Biol., 12:2077-2091.

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Moran, K.K., J. Six, W.R. Horwath, and C. van Kessel. 2005. Role of mineral-nitrogen in residue decomposition and stable soil organic matter formation. Soil Sci. Soc. Am. J., 69:1730-1736.

Kong, A.Y., J. Six, D.C. Bryant, R. F. Denison, and C. van Kessel. 2005. The relationship between carbon input, aggregation, and soil organic carbon stabilization in sustainable cropping systems. Soil Sci. Soc. Am. J., 69:1078-1085.

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EDUCATION:

B.S. Biology, Chemistry, Bowling Green State University, Ohio, 1973
M.S. Horticulture, Colorado State University, 1977
Ph.D. Horticulture, Virginia Polytechnic Institute and State University, 1980

PROFESSIONAL EXPERIENCE:

1989-Present
Extension Specialist, University of California

Support the statewide vegetable industry through applied research and education programs. Areas of emphasis include: drip irrigation and fertigation management, soil fertility, soil organic matter management, and non-point source pollution abatement.

1987-1989
Assistant General Manager, Chiquita Melon Packers (a subsidiary of Chiquita Brands).

Directed field production and postharvest handling for melon operations in Texas, California, and Mexico. Served as technical consultant for related Chiquita subsidiaries in Honduras, Guatemala and the Dominican Republic.

1981-1987
Extension Specialist, Texas A&M University

Provided technical support to the vegetable industry of the Rio Grande Valley through research and education programs. Areas of emphasis included: drip irrigation management, plasticulture techniques, and alternative pest control.

RECENT PUBLICATIONS:

Hartz, T.K., P.R. Johnstone, R.F. Smith and M.D. Cahn. 2007. Soil calcium status unrelated to tipburn in romaine lettuce. HortScience 42:1681-1684.

Hartz, T.K., P.R. Johnstone, E. Williams and R.F. Smith. 2007. Establishing lettuce leaf nutrient optimum ranges through DRIS analysis. HortScience 42:143-146.

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Hartz, T.K., P.R. Johnstone and J.J. Nunez. 2004. Production environment and nitrogen fertility affect carrot cracking. HortScience 40:611-615.

Hartz, T.K. 2003. The assessment of soil and crop nutrient status in the development of efficient fertilizer recommendations. Acta Hort. 627:231-240.

Martini, E.A., J.S. Buyer, D.C. Bryant, T.K. Hartz, and R.F. Dension. 2003. Yield increases during organic transition: improving soil quality or increasing experience? Field Crops Research.

Hartz, T.K. 2002. Sustainable vegetable production in California: current status and future prospects. HortScience 37:1015-1022.

Hartz, T.K., C. Giannini, R.O. Miller and E.M. Miyao. 2002. Estimating soil K availability for processing tomato production. Commun. Soil Sci. Plant Anal. 33:1389-1400.

Breschini, S.J. and T.K. Hartz. 2002. Drip irrigation management affects celery yield and quality. HortScience 37:894-897.

Breschini, S.J. and T.K. Hartz. 2002. Presidedress soil nitrate testing reduces nitrogen fertilizer use and nitrate leaching hazard in lettuce production. HortScience 37:1061-1064.

Andrews, S.S., J.P. Mitchell, R. Mancinelli, D.L. Karlen, T.K. Hartz, W.R. Horwath, S. Pettygrove, K.M. Scow, and D.S. Munk. 2002. On-farm assessment of soil quality in California's Central Valley. Agron J. 94:12-23.

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EDUCATION
Master of Science, Agronomy, 1985, U.C. Davis
Bachelor of Arts, Biology, 1977, Sonoma State University

EXPERIENCE
1985-present University of California, Cooperative Extension
1981-1985 University of California, Davis, Dept of Agronomy

CURRENT POSITION
Farm Advisor, Vegetable Crops and Weed Science, University of California Cooperative Extension Monterey County

Responsible for conducting a research and education program in vegetable crop production and weed science. Crops include cool season vegetables such as lettuce, cole crops, celery, onions and spinach as well as warm season crops such as peppers, squash. Establish research and educational programs to meet the needs of growers and the allied agricultural industry. Conduct research on cultural practices, weed science, soil fertility and new crop development. Primary area of expertise includes weed science, soil fertility and plant nutrition. Conduct educational programs through newsletters, field days, meetings and farm calls. December, 1985 to present.

PROFESSIONAL ORGANIZATIONS

Weed Science Society
American Society for Horticultural Science
American Society of Agronomy and
California Chapter of the American Society of Agronomy

AWARDS AND HONORS

California Weed Science Society Award of Excellence 2004
2003 Oscar Lorenz Award
Pedro Ilic Award 1996

RECENT PUBLICATIONS

Tourte, L., R. Smith, L. Bettiga, T. Bensen, J. Smith and D. Salm. 2008. Post emergence herbicides are cost effective for vineyard floor management on the Central Coast. California Agriculture 62(1): 19-23.

Daugovish, O., S.A. Fennimore and R.F. Smith. 2007. Herbicide evaluation for fresh market celery. Weed Technology 21:719-723.

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Gaskell, M. and R.F. Smith. 2007. Nitrogen sources for organic vegetable production. HortTechnology 17(4):431-441.

Davis, R.M., J.J. Hao, M.K. Romberg, J.J. Nunez and R.F. Smith. 2007. Efficacy of germination stimulants of Sclerotium cepivorum for management of white rot of garlic. Plant Disease 91(2): 204-208.

Smith, R.F., S. Fennimore and E. Brennan. 2007. Weed management for organic vegetable production on 80-inch beds. *CAPCA Advisor* Vol. 10, No. 1.

Smith, R.F. and M. LeStrange. 2007. Preemergence weed control trials in peppers. *Pepper News*, May 2007, p-1-2.

Cahn, M., R.F. Smith and A. Young. 2007. Controlling storm run-off in vegetable fields. Vegetables West 11(2): 8-9.

Smith, R.F. 2007. High-denisty plantings on 80-inch beds: a challenge for weed control. *Coastal Grower*, Winter, pages 32-33.

Smith, R.F., S.A. Fennimore and L. Tourte. 2007. Precision guided cultivation improves weed control in broccoli and lettuce production. Proceedings of the European Weed Research Society workshop on Physical and Cultural Weed Control. Salem, Germany, p. 50. Abstract.

DiTomaso, J.M., G.B. Kyser, J.R. Miller, S. Garcia, R.F.Smith, G. Nader, J.M. Connor, and S.B. Orloff. 2006. Integrating prescribed burning and clopyralid for the management of yellow starthistle (*Centaurea solstitialis*). Weed Science 54:757-767.

Smith, R.F., L. Bettiga, T. Bensen and L. Tourte. 2006. Effects of vineyard floor management practices on the development of distinct weed communities in a California vineyars. Proceeding of the California Weed Science Society annual meeting, Ventura, pp 112-117.

Baumgartner, K., R.F. Smith, and L. Bettiga. 2005. Weed control practices and cover crop management affect mycorrhizal colonization of grapevine roots and arbuscular mycorrhizal fungal spore populations in a California vineyard. Mycorrhiza 15:111-119.

Brennan, E.B. and R.F. Smith. 2005. Winter cover crop growth and weed suppression on the Central Coast of California. Weed Technology 19:1017-1024.

Smith, R.F. and T. Bensen. 2006. Precision cultivation evaluations. *Vegetables West* 10 (6): 16-17.

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EDUCATION

1999	PhD	Soil Science, University of Guelph, Ontario, Canada
1993	M.Sc.	Soil Science, University of Guelph, Ontario, Canada
1990	B.Sc.	Agriculture, University of the West Indies, Trinidad

PROFESSIONAL EXPERIENCE

- Aug. 2006- Present: Assistant Professor – Vegetable Crops Production in Plant Science Dept., & Soil Scientist at Center for Irrigation Technology (CIT),College of Agricultural Science and Technology (CAST), California State University, Fresno.
- Dec. 1999 – Aug. 2006: Research Soil Scientist at Center for Irrigation Technology,

California State University, Fresno.

- Jul. 1999 - Dec. 1999: Post-doctoral Fellowship, Soil Science Department, University of Saskatchewan, Canada
- Jul. 1998 – Jun. 1999: Visiting scholar, Soil Science Department, University of Saskatchewan, Canada.
- Jun. 1998: Graduate research assistantship. University of Guelph, Canada.

MAJOR TEACHING & RESEARCH INTERESTS

- "Ag Environ" Research aimed at evaluating the impact of agricultural practices on our air, soil and water resources.
- Interaction of nutrient cycling and transport of water and chemicals within the Soil-Plant-Air-Water Continuum.
- Organic farming
- Warm and cool season vegetable production
- Impact of air injection into root zone and CO_2 enrichment around crop canopy on crop production and water use efficiency
- Efficacy of manure based Nitrogen fixing fertilizer on yield and quality of vegetables
- Spatial and temporal variability of soil salinity and nitrogen loading for irrigated fields
- Real time ammonia and methane emissions from dairy and agricultural operations
- Nitrogen budgets for cropping systems typical of California

FUNDED RESEARCH GRANTS (selected)

- California State University/Agricultural Research Initiative (CSU/ARI): The impact of air injected into water delivered through subsurface drip irrigation (SDI) tape on the growth and yield of vegetables and fruits. $51,200. D. Goorahoo, D. Zoldoske, E. Norum and A Mazzei.
- California Department of Food and Agriculture Crop Specialty Program - Agricultural Research Initiative Program (CSU/CDFA). The impact of air injected into water delivered through subsurface drip irrigation (SDI) tape on the growth and yield of Melons. $51,200. D. Goorahoo, D. Zoldoske, E. Norum and A. Mazzei
- California Department of Food and Agriculture Crop Specialty Program - Agricultural Research Initiative Program (CSU/CDFA). The impact of air injected into water delivered through subsurface drip irrigation (SDI) tape on the growth and yield of Tomatoes. $51,200. D. Goorahoo, D. Zoldoske, E. Norum and A Mazzei.
- CK life Sciences and Biomatrix™ of Hong Kong. Efficacy of manure based N fixing fertilizing system on broccoli and peppers grown in California. $31,246. D. Goorahoo and F. Cassel.
- California Department of Food and Agriculture Crop Specialty Program - Agricultural Research Initiative Program: *Open-Field CO_2 Enrichment Using Drip Irrigation Systems*. $77,000 (2004-2006). F. Cassel S., D.Goorahoo, and S. Ashkan.
- Mazzei and Toro Ag. Industry Support: *Air Injection in subsurface drip irrigation for increasing crop yields.* $5,000 (2000). D. Zoldoske, E. Norum, G. Carstensen and D.Goorahoo.

PUBLICATIONS, REPORTS, AND PRESENTATIONS (SELECTED)

- Cassel S., F., D. Goorahoo, D. Adhikari, and S. Ashkan. 2007. Photosynthesis response curves for strawberries subjected to elevated CO_2 levels. 6th North American Strawberry Symposium, Ventura, CA.
- Goorahoo, D, S.E.. Benes and C. Krauter. 2007. Soil water and plant relations. Chapter 3 in the Irrigation 6th Edition (in progress)
- Goorahoo, D., D. Adhikari, D. Zoldoske, F. Cassel S., A. Mazzei, and R. Fanucchi. 2007. Potential for AirJection® Irrigation in Strawberry Production. 6th North Am. Strawberry Symposium, Ventura, CA.
- Cassel S., F., D. Goorahoo, M. Rothberg, and D. Adhikari. 2005. Benefits of a new forage grass for controlling nutrient levels in effluent-irrigated soils. Proc, 26th Annual Central CA Res. Symp, Fresno, CA. p. 100.
- Cassel F., D. Goorahoo, D. Adhikari and M.Rothberg 2005. Potential Use of a New Forage Grass for BMP Involving Irrigation with Dairy Wastewaters. Presented at the CA Chapter of ASA, Feb 2005.
- Adhikari D., F Cassel, D. Goorahoo, A. Shrestha and S. Ashkan 2005. Impact of Open Field Carbon-Dioxide Enrichment on Growth and Yield of Strawberry. Proceedings of the 26th Annual Central California Research Symposium, CSU-Fresno.
- D. Goorahoo, F. Cassel S and D. Adhikari. 2004. Efficacy of Manure Based Fertilizer System on Broccoli. Final Report- Submitted to CK Life Sciences International Inc. HK.
- Adhikari D., F Cassel S, D. Goorahoo, A Shrestha and S Ashkan., 2004.Photosynthesis Response to Enriched Atmospheric Carbon Dioxide in Strawberry Leaves. ASA-CSSA-SSSA-CSSS Annual Meetings, Seattle, WA.
- Ng J., A. Chu, D. Goorahoo, F Cassel, D. Adhikari 2004. Growing Broccoli with a Sustainable Manure-Based Fertilizing System (MBFS). ASA-CSSA-SSSA-CSSS Annual Meetings in Seattle, WA.
- Fandino C., S. Benes, D. May, J.P. Mitchell and D. Goorahoo. 2003. Use of Sudan grass and early soil testing as a means to optimize nitrogen management for processing tomatoes. CA Plant and Soil Conference, Modesto, CA.
- Goorahoo D., G. Carstensen and D. Zoldoske, S Kostka, K. Mauser and M. Franklin 2002. Addition of Surfactants to improve irrigation efficiency in turf systems. Annual Crops, Soils and Agronomy Societies of America meeting, Indianapolis, IN.

4. RELATED RESEARCH

a. Currently, N_2O and CH_4 emissions are being monitored at the Rice Experiment Station, Biggs, CA, by Dr. Horwath and technician Jakov Assam. The study includes a comparison of N_2O and CH_4 emissions from a conventional wet-seeded rice systems, a wet-seeded rice with early season drainage system, and a drill-seeded rice with early season drainage system. Additionally, each management practice is associated with various N fertilizer levels. This project, entitled "Evaluation of best management practices for irrigation and nitrogen fertilizer application to mitigate greenhouse gas emissions from rice cropping," is funded by California Rice Commission ($45,000).

b. Emissions of N_2O were assessed by Dr. Horwath and graduate student C. Kallenbach in processing tomato systems that were either furrow-irrigated or subsurface drip-irrigated at the UC Davis Russell Ranch Sustainable Agriculture Research site from 2005 to 2006 during the tomato growing season, as well as in winter after rainfall events. Additional treatments in this project were the presence or absence of a winter legume cover crop and two tillage practices (standard and reduced tillage). A manuscript of a journal article of this investigation, entitled "Nitrous oxide emission in sub surface drip and furrow irrigation systems" is in internal review. The study was funded by the Kearney Foundation of Soil Science ($90,000).

c. Emissions of CH_4 and N_2O were assessed by Dr. Horwath and post doctorate Urszula Norton in various chaparral systems with different fire histories form 2005 to 2007. A manuscript of a journal article of this investigation, entitled "Chaparral fire history influence on methane and nitrous oxide emissions" is in internal review. The study was funded by Kearney Foundation of Soil Science ($90,000).

d. An integrated assessment of the biophysical and economic potential for greenhouse gas mitigation in California agricultural soils under the lead of Dr. Six, with co-investigators R.E. Howitt, D.E. Rolston, R. Plant, J. Mitchell, C. van Kessel, and J.W. Hopmans, funded by the California Energy Commission/Kearny Foundation ($334,945), was completed in July 2008. This assessment was accomplished by directly linking an ecosystem model calibrated for California conditions with an economic model that has been extensively used to assess sustainable agricultural practices. The ecosystem model provides greenhouse gas mitigation supply curves based on estimates of changes in soil C, trace gas fluxes, and productivity (yield) based on soil, climate and management data. The ecosystem model outputs serve as input into the economic model. This decision-support assessment tool provides an accounting structure for land use and management impacts on C stocks and associated CO_2, N_2O and CH_4 fluxes.

e. A project with a focus on efficiently managing nutrient inputs in drip-irrigated high-yield processing tomato production by Dr. Hartz from 2007-2009 is funded by CDFA Fertilizer Research and Education Program ($84,264).

f. A project with a focus on improving fertilizer and drip irrigation management for coastal lettuce production by Dr. Hartz from 2006-2008 is funded by the Community Foundation for Monterey County ($37,030). Some preliminary N_2O flux measurements in grower fields by Dr. Hartz and graduate student T. Bottoms are currently made in Salinas, CA.

g. Detailed time series of N_2O emissions after irrigation and after first rainfall after harvest were conducted at the UC Davis Russell Ranch Sustainable Agriculture Research site by Dr. Burger and co-workers in organically and conventionally managed tomato systems (Burger et al, 2005). This research was funded by a LTRAS Seed Grant from the Agronomy Department, UC Davis.

h. Flux measurements of N_2O and CH_4 were conducted by Dr. Burger in corn systems with long term tillage treatments and applications of different fertilizer types during 2003 and 2004 in Minnesota (Venterea et al., 2005). Funding for this study was by USDA-ARS.

i. The following projects, funded by the California Lettuce Research Board, were conducted by Dr. Hartz: Efficient N and irrigation management for lettuce production, 2000-2001 ($ 19,000); Efficient N use in lettuce production, 1999-2000 ($ 12,200); Efficient N use in lettuce production, 1998-1999 ($11,000).

5. PUBLICATIONS LIST

Davis J.H., S.M. Griffith, **W.R. Horwath**, J.J. Steiner, D.D. Myrold. 2007. Mitigation of shallow groundwater nitrate in a poorly drained riparian area and adjacent cropland. Journal of Environmental Quality 36: 628-637.

Hartz, T.K. 2006. Vegetable production best management practices to minimize nutrient loss. HortTechnology 16:398-403.

Lee, J., **J. Six**, A.P. King, C. van Kessel, and D.E. Rolston. 2006. Tillage and field-scale controls on greenhouse gas emissions Journal of Environmental Quality 35: 714-725.

Burger M., L.E. Jackson, D.T. Louie, E.J. Lundquist, R.L. Miller, D.E. Rolston, K.M. Scow. 2005. Microbial responses and nitrous oxide emissions during wetting and drying of organically and conventionally managed soil under tomatoes. Biology and Fertility of Soils 42: 109-118.

Ladha, J.K., H. Pathak, T.J. Krupnik, **J. Six**, and C. van Kessel. 2005. Efficiency of fertilizer nitrogen in cereal production: Retrospects and prospects. Advances in Agronomy 87:85-156.

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Six, J., S.M. Ogle, F.J. Breidt, R.T. Conant, A.R. Mosier, and K. Paustian. 2004. The potential to mitigate global warming with no-tillage management is only realized when practised in the long term. Global Change Biology 10:155-160.

Doane, T.A. and **W. R. Horwath**. 2003. Spectrophotometric Determination of Nitrate with a Single Reagent. Analytical Letters:. 36: 2713-2722

Breschini, S.J. and **T.K. Hartz**. 2002. Presidedress soil nitrate testing reduces nitrogen fertilizer use and nitrate leaching hazard in lettuce production. HortScience 37:1061-1064.

Bossio, D.A., **W.R. Horwath**, R.G. Mutters, and C. van Kessel. 1999. Methane pool and flux dynamics in a rice field following straw incorporation. Soil Biology & Biochemistry 31:1313-1322.

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Bouwman, A.F., L.J.M. Boumans, and N.H. Batjes. 2002. Emissions of N2O and NO from fertilized fields: Summary of available measurement data. Global Biogeochemical Cycles 16.

Bronson, K.F., and A.R. Mosier. 1993. Nitrous oxide emissions and methane consumption in wheat and corn-cropped systems in northeastern Colorado, p. 133-144, *In* G. A. Peterson, ed. Agricultural Ecosystem Effects on Trace Gases and Global Climate Change. ASA Special Publication no. 55, Madison, WI.

Burger, M., L.E. Jackson, E.J. Lundquist, D.T. Louie, R.L. Miller, D.E. Rolston, and K.M. Scow. 2005. Microbial responses and nitrous oxide emissions during wetting and drying of organically and conventionally managed soil under tomatoes. Biology and Fertility of Soils 42:109-118.

Davidson, E.A. 1992. Sources of nitric oxide and nitrous oxide following wetting of dry soil. Soil Science Society of America Journal 56:95-102.

Denison, R.F., D.C. Bryant, and T.E. Kearney. 2004. Crop yields over the first nine years of LTRAS, a long-term comparison of field crop systems in a Mediterranean climate. Field Crops Research 86:267-277.

Doane, T.A., and W.R. Horwáth. 2003. Spectrophotometric determination of nitrate with a single reagent. Analytical Letters 36:2713-2722.

Dobbie, K.E., and K.A. Smith. 2003. Nitrous oxide emission factors for agricultural soils in Great Britain: the impact of soil water-filled pore space and other controlling variables. Global Change Biology 9:204-218.

Dobbie, K.E., I.P. McTaggart, and K.A. Smith. 1999. Nitrous oxide emissions from intensive agricultural systems: Variations between crops and seasons, key driving variables, and mean emission factors. Journal of Geophysical Research-Atmospheres 104:26891-26899.

Edis, R.B., D. Chen, G. Wang, D.A. Turner, K. Park, M. Meyer, and C. Kirkby. 2008. Soil nitrogen dynamics in irrigated maize systems as impacted on by nitrogen and stubble management. Australian Journal of Experimental Agriculture 48:382-386.

Eichner, M.J. 1990. Nitrous oxide emissions from fertilized soils: Summary of available data. Journal of Environmental Quality 19:272-280.

Firestone, M.K., R.B. Firestone, and J.M. Tiedje. 1982. Nitrous oxide from soil denitrification: Factors controlling its biological production. Science 208:749-751.

Forster, J.C. 1995. Soil nitrogen, p. 79-87, *In* A. K. and N. P, eds. Methods in Applied Soil Microbiology and Biochemistry. Academic Press, San Diego.

Grant, R.F., E. Pattey, T.W. Goddard, L.M. Kryzanowski, and H. Puurveen. 2006. Modeling the effects of fertilizer application rate on nitrous oxide emissions. Soil Science Society of America Journal 70:235-248.

Hartz, T., E. Miyao, J. Mickler, M. Lestrange, S. Stoddard, J. Nuñez, and B. Aegerter. 1996. Processing tomato production in California Vegetable Production Series, Vol. 7228. University of California ANR.

Hutchinson, G.L., and A.R. Mosier. 1981. Improved soil cover method for field measurement of nitrous oxide fluxes. Soil Science Society of America Journal 45:311-316.

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Kaiser, E.A., K. Kohrs, M. Kucke, E. Schnug, O. Heinemeyer, and J.C. Munch. 1998a. Nitrous oxide release from arable soil: Importance of N-fertilization, crops and temporal variation. Soil Biology & Biochemistry 30:1553-1563.

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Kallenbach, C.M. 2008. The use of subsurface drip irrigation, cover crops, and conservation tillage in reducing soil CO_2 and N_2O emissions from irrigated row-crop system. MS Thesis. University of California Davis.

Linn, D.M., and J.W. Doran. 1984. Effect of water-filled pore space on carbon dioxide and nitrous oxide production in tilled and nontilled soils. Soil Science Society of America Journal 48:1267-1272.

Linquist, B.A., S.M. Brouder, and J.E. Hill. 2006. Winter straw and water management effects on soil nitrogen dynamics in California rice systems. Agronomy Journal 98:1050-1059.

McSwiney, C.P., and G.P. Robertson. 2005. Nonlinear response of N2O flux to incremental fertilizer addition in a continuous maize (Zea mays L.) cropping system. Global Change Biology 11:1712-1719.

Ruser, R., H. Flessa, R. Schilling, F. Beese, and J.C. Munch. 2001. Effect of crop-specific field management and N fertilization on N2O emissions from a fine-loamy soil. Nutrient Cycling in Agroecosystems 59:177-191.

Ryden, J.C., and L.J. Lund. 1980. Nature and extent of directly measured denitrification losses from some irrigated vegetable crop production units. Soil Science Society of America Journal 44:505-511.

Sehy, U., R. Ruser, and J.C. Munch. 2003. Nitrous oxide fluxes from maize fields: relationship to yield, site-specific fertilization, and soil conditions. Agriculture Ecosystems & Environment 99:97-111.

Simojoki, A., and A. Jaakkola. 2000. Effect of nitrogen fertilization, cropping and irrigation on soil air composition and nitrous oxide emission in a loamy clay. European Journal of Soil Science 51:413-424.

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Wrage, N., G.L. Velthof, M.L. van Beusichem, and O. Oenema. 2001. Role of nitrifier denitrification in the production of nitrous oxide. Soil Biology & Biochemistry 33:1723-1732.

EXHIBIT B

BUDGET DETAIL AND PAYMENT PROVISIONS

1. Invoicing

A. For services satisf actorily rendered in accordance with this agreement and upon receipt and approval of the invoices which properly detail all charges the Air Resources Board agrees to compensate the Regents of the University of California, Davis for actual expenditures incurred in accordance with the rates specified herein or attached hereto.

B. Invoices shall inclu de the Agreement Number and shall be submitted in triplicate not more frequently than quarterly in arrears to Ms. Emma Plasencia at the address stated in Exhibit A, Article 3.

C. Budget Flexibility: Subject to the prior review and approval of the contract manager, line item shifts of up to $25,000 or ten percent of the annual contract total, whichever is less, may be made up to a cumulative maximum of $25,000 or 10%, whichever is less, for all line item shifts over the life of the contract. There must be a substantial business justification for any shifts made. Fund shifts which increase Indirect, Overhead or General Expense line items are prohibited. Line item shifts may be proposed/requested by either the State or the University in writing and must not increase or decrease the total contract amount allocated. Any line item shifts must be approved in writing by the Division Chief of the Research Division, or his or her designee, and must be sent to the Contracts Section within 10 days of approval for inclusion in the contract folder. If the contract is formally amended, any line item shifts agreed to by the parties must be included in the amendment.

2. Budget Contingency Clause

A. It is m utually agreed that if the Budget Act of the current year and/or any subsequent years covered under this Agreement does not appropriate sufficient funds for the program, this Agreement shall be of no further force and effect. In this event, the State shall have no liability to pay any funds whatsoever to Contractor or to furnish any other considerations under this Agreement and Contractor shall not be obligated to perform any provisions of this Agreement.

B. If funding for any fiscal year is reduced or deleted by the Budget Act for purposes of this program, the State shall have the option to either cancel this Agreement with no liability occurring to the State, or offer an agreement amendment to Contractor to reflect the reduced amount.

3. Payment

A. Costs for this Agreement shall be computed in accordance with State Administrative Manual Sections 8752 and 8752.1.

B. Nothing herei n contained shall preclude advance payments pursuant to Article 1, Chapter 3, Part 1, Division 3, Title 2 of the Government Code of the State of California.

C. ARB shall withhold payment equal to ten percent of the total Agreement cost until completion of all work and submission to ARB by University of a final report (including computer diskette copy) approved in accordance with Exhibit F, by ARB. It is University's responsibility to submit an invoice in triplicate with the revised final report for ten percent withheld.

D. University will be paid for the payment period completed upon receipt, by ARB, of an invoice and progress report satisfying the requirements of this Agreement. The invoice and progress report must be deemed by ARB to reflect reasonable work performed in accordance with the Agreement.

E. Th e amount to be paid to University under this Agreement includes all sales and use taxes incurred pursuant to this Agreement. University shall not receive additional compensation for reimbursement of such taxes and shall not decrease work to compensate therefore.

Budget Submittal Form

This form is supplied for presenting budget detail to the Air Resources Board.

PLEASE TYPE OR PRINT:

Title of Proposal: Assessment of Baseline Nitrous Oxide Emissions in California Cropping Systems Application and Nitrous Oxide Emissions

Total Budget Requested: $300,000

Period Covered (months): 36 months

University: University of California Davis

Address: One Shields Ave, Davis CA 95616

Name of person authorized to bind this bid: May Turner

Title: Contract and Grants Analyst

Phone: 530-754-8112

Signature of person authorized to bind this bid: ______________________

Budget Summary

Budget details must be supplied on pages 3-11 and on additional pages if necessary.
Instructions and definitions of terms are provided in Attachment 1 of the Guidelines for Proposals.

NOTE: Totals in categories in this summary are automatically updated from pages 3-11 when using Excel file.

Direct Costs		
1.	Labor & Employee Fringe Benefits	$213,884
2.	Subcontractor(s)/Consultant(s)	$0
3.	Equipment	$0
4.	Travel & Subsistence	$25,644
5.	Electronic Data Processing	$0
6.	Photocopying & Printing	$298
7.	Mail, Telephone, and Fax	$1,052
8.	Materials & Supplies	$27,204
9.	Analyses	$0
10.	Miscellaneous	$4,645
	Total Direct Cost	$272,727

Indirect Costs		
11.	Overhead	$27,273
	Total Indirect Cost	$27,273

Total Direct and Indirect Cost:	$300,000

Budget Detail
I. Direct Costs

1a. Labor Charges for Universities and Other State Agencies
Note: Total Salary Requested cells automatically calculate when using Excel file.

	Individual's Name	Work Title	Mo. Salary	Est. Months	% of Effort or % of Salary	Total Salary Requested
A.	Martin Burger	Project Manager	$4,550.00	36.00	40.00%	$65,520.00
B.		Project Technician A	$2,917.00	24.00	90.00%	$63,007.20
C.		Project Technician B	$2,917.00	24.00	30.00%	$21,002.40
D.		Student Assistant A	$375.00	20.00	100.00%	$7,500.00
E.		Student Assistant B	$375.00	20.00	100.00%	$7,500.00
F.						$0.00
G.						$0.00
H.						$0.00
I.						$0.00

(use additional page if necessary)

Subtotal: $164,529.60

Cost justifications. Describe exactly why each individual listed in the Budget Detail is needed in this project (i.e., their role in the project), why this particular person was chosen for this role, and why their proposed level of effort is necessary. Describe, for each position listed, why the specified rate is reasonable or competitive. (Use additional page if necessary).

1. Labor
a) Martin Burger, Project Scientist. Dr. Burger has a background in soil science and plant physiology. He has conducted numerous field projects with a focus on N2O flux measurements, on assessment of soil nitrogen dynamics, and on plant nitrogen uptake. In his role as Research Manager of the Sustainable Agriculture Farming Systems project he is used to managing multi-year, extensive field projects. In addition, he is familiar with the proposed experimental sites in Yolo county and in Monterey counties. It is expected that considerable amount of his time is required for setting up the experiments, leading and coordinating sampling efforts, conducting quality control, data analysis and preparing the final report and research publications. The specified rate is in accordance with the policy of the University of California. A 3% increase per year is computed and listed under (10) Miscellaneous.

b) Project Technician A. The Project Technician will be responsible for the bulk of the data collection in the field, analysis of the air samples by GC, routine data calculations, maintenance of the GC, supervision of student assistants, analysis of soil samples. This position is for the duration of two years when most of the data are being collected. The specified rate is in accordance with the policy of the University of California. A 3% increase per year is computed and listed under (10) Miscellaneous.

c) Project Technician B. The Project Technician will be responsible for the bulk of the collection of air and soil samples, and yield measurements in lettuce systems in Monterey county. This is a 30% position for the duration of two years when most of the data are being collected. The specified rate is in accordance with the policy of the University of California. A 3% increase per year is computed and listed under (10) Miscellaneous.

d and e) Several student assistants: The undergraduate student assistant carries out air and soil sampling according to protocols, assists with yield measurements, and carries out routine analyses of soil samples. The student assistants are indispensable for the success of the project. Their pay rate is competitive being only $ 0.50 above the California minimum wage. A 3% increase per year is computed and listed under (10) Miscellaneous.

1

	Individual's Name	BASE ($)	RATE (%)	COST
A.	Martin Burger	$65,520.00	34.00%	$22,276.80
B.	Project Technician A	$63,007.00	32.00%	$20,162.24
C.	Project Technician B	$21,002.00	32.00%	$6,720.64
D.	Student Assistant A	$7,500.00	1.30%	$97.50
E.	Student Assistant B	$7,500.00	1.30%	$97.50
F.				$0
G.				$0
H.				$0
I.				$0
(use additional page if necessary)				

Subtotal: $49,354.68

Cost justifications. Provide the Basis for the Fringe Benefit Rates. (Use additional page if necessary).

The benefit rate for the Project Manager is 34% and for the Project Technician is 32%. The benefit rate for student workers at UC Davis is 1.3% when working at <46% time in accordance with the policy of the Department of Land, Air and Water Resources.

2. Subcontractors & Consultants

List all subcontractors and consultants. **Also submit separate Budget Submittal Form for each subcontractor and consultant.**

Subcontractor or consultant	Cost
A.	
B.	
C.	
D.	

(use additional page if necessary)

Subtotal:	**$0**

Cost justifications. Describe exactly why each subcontractor is needed in this project (i.e., their role in the project). Describe, for each subcontractor, why the specified rate is reasonable or competitive. (Use additional page if necessary).

3. Equipment (Itemize)

Item	Cost
A.	
B.	
C.	
D.	

Subtotal:	**$0**

Cost justifications. Describe exactly why each listed equipment item is needed in this project, and why the cost is reasonable. (Use additional page if necessary).

(Refer to Exhibit E, page 19)

4. Travel and Subsistence (Itemize). Use State Rates (Appendix IV). NO FOREIGN TRAVEL ALLOWED.

	Description	Cost
A.	Air transportation	$500
B.	Ground transportation	$24,644
C.	Per diem or subsistence	$120
D.	Other (Lodging & Parking)	$380

Subtotal: $25,644

Cost justifications. Describe the purpose and duration of each trip and explain why the travel is necessary. (Use additional page if necessary).

The travel expenses are required to collect air samples and soil samples. During irrigation and rainfall events, daily trips to the experimental sites are required. The site in Salinas, Monterey county, and at the Rice Experiment Station in Biggs, Colusa county, are 160 miles and 80 miles from Davis, respectively. In Salinas, most of the samples will be collected by researchers living in the area. One trip to a professional conference is requested. The UC mileage reimbursement rate is currently 58.5c.
90 trips @ $ 33.-
60 trips @ $ 93.-
6 trips @ $ 187.-
80 trips @ $ 20.-
70 trips @ 15.-
Total per year 12,322.-
One conference total $ 1000.-
Travel expense will occur during two years in each system.

5. Electronic Data Processing (Itemize)

	Description	Cost
A.		
B.		
C.		
D.		

Subtotal: $0

Cost justifications. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

6. Photocopying & Printing (Itemize)

Description of product	Cost
	$298
A.	
B.	
Subtotal:	**$298**

Cost justifications. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

The costs include copies for the proposal, final report, and for publications from libraries. The cost basis is 10c page.

7. Mail, Telephone & Fax (Itemize)

Item	Cost
	$927
A.	$125
B.	
C.	
Subtotal:	**$1,052**

Cost justifications. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

The air samples from Salinas will be shipped regularly by Fedex. The Fedex rate is $ 12.30 per package. An additional $ 125.- is budgeted for phone and mail costs.

8. Materials & Supplies (Itemize)

	Item	Cost
		$8,354
A.	Chambers	$6,250
B.	Carrier gas	$5,200
C.	Vials and caps	$900
D.	Standards	$5,000
E.	Supplies for soil N analysis	$300
F.	Supplies for C & N analyzer	$1,050
G.	TDR moisture probes	$150
H.	Thermocouples, temperature probes	
I:		

Subtotal: $27,204

Cost justifications. Describe exactly why each item listed above is needed in this project. Explain why the proposed cost is reasonable. (Use additional page if necessary).

We will manufacture 42 insulated, thin gauge stainless steel chambers for $ 69.- each, 72 stainless steel bases for $48.- each, 80 PVC chambers at $ 15.- each, 80 PVC bases at $10.- each to collect air samples for N2O flux measurements in the five cropping systems.

The required carrier gases for the gas chromatograph are hydrogen, air, helium, and P5 for continuous operation of the gas chromatograph at a cost of $ 2500.- per year. We calculated these expenses for 2.5 years because during the first 3 months and during the last three months of the project, the GC will not be used.

A minimum of 5000 glass vials and10,000 caps for storage and transport of the gas samples form the field to the laboratory are required at a cost of $ 2600 (includes shipping from Great Britain) per year.

Three N2O standards @ $ 300.- each.

Supplies for Inorganic N analyses (including reagents, microcuvettes and caps, pipette tips) will cost $ 2500 per year. The expenses will occur during two years.

Supplies for the dry combustion C/N analyzer (Costech) to analyze plant tissue will cost $ 300.

To simplify soil moisture measurements, we request 3 TDR soil moisture sensors including rods for $ 350.- each.

For thermocouples and soil temperature probes $ 150.- are requested.

9. Analyses (Itemize)

	Description	Cost
A.		
B.		
C.		
D.		
E.		
F.		
G.		
H.		
I.		

Subtotal:	**$0**

Cost justifications. Describe the purpose of each different analysis and explain why it is needed in this project. Explain why the proposed rate is reasonable. (Use additional page if necessary).

10. Miscellaneous (Itemize)

	Item	Cost
A.	Salary increases (+benefits) 3% per yr Project Manager	$2,660
B.	Salary increase (+benefits) 3% per yr Project Technicians	$1,660
C.	Salaray increase (+benefits) 3% per yr Student Assistants	$325
D.		

Subtotal: $4,645

Cost justifications. Justify all costs not included in the categories above. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

Salary increases of 3% for the Project Manager are calculated for year 2 and year 3 of the project according to the guidelines of UC Davis, Dept. of Land, Air, and Water Resources.
One salary increase of 3% is calculated for the Project Technicians and Student Assistants according to the guidelines of UC Davis, Dept. of Land, Air, and Water Resources.

Total Direct Costs (add subtotals for categories 1-10): $272,727

II. Indirect Costs

11. Overhead and Other Indirect Costs

	Base (Salaries, total direct costs, etc.) ($)	Rate (%)	Cost
A.	$272,727.00	10.00%	$27,273
B.			$0
C.			$0

Subtotal: $27,273

Total Indirect Cost: $27,273

Total Project Cost: $300,000

EXHIBIT D

SPECIAL TERMS AND CONDITIONS

1. **Termination**

A. This Agreement may be canceled at any time by either party, upon thirty (30) days written notice to the other party.

B. In the case of early termination, the performing agency will submit an invoice in triplicate and a report in triplicate covering services to termination date, following the invoice and progress report requirements of this Agreement. A copy and description of any data collected up to termination date will also be provided to ARB.

C. Upon receipt of the invoice, progress report, and data, a final payment will be made to the performing agency. This payment shall be for all ARB-approved, actually incurred costs in accordance with Exhibits A and B, and shall include labor, and materials purchased or utilized (including all noncancellable commitments) to termination date, and pro rata indirect costs as specified in the proposal budget.

2. **Disputes**

A. ARB reserves the right to issue an order to stop work in the event that a dispute should arise, or in the event that the ARB gives the performing agency a notice that this Agreement will be terminated. The stop-work order will be in effect until the dispute has been resolved or this Agreement has been terminated.

B. Any dispute concerning a question of fact arising under the terms of this Agreement which is not disposed of within a reasonable period of time by agency employees normally responsible for the administration of this agreement, shall be brought to the attention of the Executive Officer or designated representative of each agency for joint resolution.

3. **Amendments**

ARB reserves the right to amend this agreement for additional time and/or additional funding.

EXHIBIT E

ADDITIONAL PROVISIONS

1. Equipment Provisions

A. Equipment is defined as movable articles of nonexpendable property that meet the following requirements:

1. have a normal useful life (including extended life due to repairs) of at least one year;
2. have a unit acquisition cost of at least $5,000 for other than land and structures (for example, identical assets costing $3,000 each for a $12,000 total would not meet the requirements); and
3. be used to conduct work under this contract, and/or
4. any and all EDP equipment used to conduct work under this contract.

B. The cost of equipment includes the purchase price plus all costs to acquire, install, and prepare equipment for its intended use.

C. The ARB reserves the right to purchase total equipment whose cost is greater than $25,000 and any and all EDP equipment for this contract, through the State procurement process. Contractor's proposed cost of this equipment will be deducted from the total amount payable to the Contractor. The equipment provided by ARB will be equivalent to Contractor's specifications, as described in Contractor's proposal.

D. In the event Contractor purchases with ARB funds, procures, uses, or otherwise takes possession of equipment owned by ARB to perform work under this contract, title to such equipment shall remain with ARB and such equipment shall become ARB's equipment upon delivery thereof into the Contractor's control or possession.

E. Contractor shall obtain written approval from ARB prior to the purchase of equipment that is not specifically identified and listed in the approved budget and which is valued at more than $5,000. The contract funding shall be adjusted for any equipment or supplies furnished by ARB.

F. ARB reserves the right to full and adequate access to ARB equipment.

G. Contractor shall maintain and administer a program for the utilization, maintenance, repair, protection, and preservation of ARB equipment, whether acquired from the ARB or purchased with ARB funds from a third party, so as to assure its full availability and usefulness for performance of this contract or as long as this equipment remains in the control or possession of the Contractor.

The Contractor will install upon each item of equipment a tag identifying the equipment as belonging to the ARB and will maintain location records of all equipment. The Contractor shall take steps to comply with all appropriate directions or instructions that the ARB may prescribe for the protection of ARB equipment.

H. Contractor shall provide to ARB, with the final invoice, a final equipment inventory. The final invoice shall contain an itemization of equipment purchased with ARB funds or procured through the State procurement process, including the type of equipment, manufacturer, serial number, and cost. All ARB equipment shall be returned to the ARB at ARB's expense in full operating condition upon termination of this contract, unless ARB approves a different disposition in writing. Disposition of the equipment shall be in accordance with the instructions from ARB, to be issued after receipt of the final inventory.

2. Reports and Data Compilations

A. ***With respect to each invoice period, University shall forward to the ARB Contract Administrator, one (1) electronic copy of the progress report and mail one (1) copy of the progress report along with each invoice. (Do not use Express Mail). When emailing the progress report, the "subject line" should state the contract number and the billing period. Each progress report will begin with the following disclaimer:***

> *The statements and conclusions in this report are those of the University and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.*

B. Each progress report will also include:

1. A brief narrative account of project tasks completed or partially completed since the last progress report;

2. A brief discussion of problems encountered during the reporting period and how they were or are proposed to be resolved;

3. A brief discussion of work planned, by project task, before the next progress report; and

4. A graph or table showing allocation of the budget and amount used to date.

5. A graph or table showing percent of work completion for each task.

C. If the project is behind schedule, the progress report must contain an explanation of reasons and how the University plans to resume the schedule.

D. Six months prior to Agreement termination date, University will deliver to ARB twenty (20) bound copies of a draft final report. The reports may be stapled or spiral bound, depending on size. The draft final report will conform to Exhibit F.

E. Within forty-five (45) days of receipt of ARB's comments on the draft Final Report (Exhibit F), University will deliver to ARB's Contract Manager two (2) copies of the Final Report incorporating all reasonable alterations and additions requested by ARB. Upon approval of the amended final report approved by ARB in accordance to Exhibit F, University will within two (2) weeks, deliver to ARB two (2) camera ready UNBOUND originals of a Final Report incorporating all final alterations and additions. The final report will conform to the Contract Final Report Format, Exhibit F.

F. Together with the final report, University will deliver a copy of the report on diskette/CD, using any common word processing software (please specify the software used) and a set of all data compilations as specified by the ARB Contract Manager.

G. University's obligation under this Agreement shall be deemed discharged only upon submittal to ARB of an acceptable final report in accordance to Exhibit F, report diskette/CD, all required data compilations, and any other project deliverables.

H. Prior to completion of this Agreement, University shall be entitled to release or make available reports, information, or other data prepared or assembled by it pursuant to this Agreement, in scientific journals and other publications and at scientific meetings, provided however, that a copy of the publication be submitted to ARB for review and comment 45 days prior to such publication. Further, University shall place the disclaimer statement in a conspicuous place on all such reports or publications. Health related reports should include an acknowledgment to the late Dr. Friedman. Nothing in this provision shall be construed to limit the right of State to release information obtained from the University or to publish reports, information, or data in State publications.

3. **Copyrightable Materials**

In recognition of the policy of ARB and University to promote and safeguard free and open inquiry by faculty, students and the members of the public and in furtherance of such policy, both parties agree to the following with respect to rights in data and copyrights under this Agreement:

A. The term "Subject Data" shall mean all original and raw research data, notes, computer programs, writings, sound recordings, pictorial reproductions, drawings or other graphical representations, and works of any similar nature, produced by University in performance of this Agreement, but specifically excluding "Reports," as defined in this Agreement. Subject Data also excludes financial reports, cost analyses, and similar information incidental to contract administration.

B. The term "Reports" shall have the meaning assigned to it in this Exhibit F of this Agreement.

C. Ownership of all Subject Data and copyrights arising from Subject Data shall be vested in University while ownership of all Reports and copyrights arising from the Reports delivered under this Agreement shall be vested in ARB. University agrees to make available to the public for public benefit, to the extent the University shall have the legal right to do so, without license or fee, any scholarly articles which are published from the Subject Data.

D. Nothing in this exhibit or Agreement shall be construed to limit the right of University faculty, students or staff to publish the Subject Data in the form of scholarly articles in academic journals nor to affect, abrogate or limit the right of University faculty, staff or students to make use of the Subject Data.

4. **Travel & Per Diem**

A. Any reimbursement for necessary travel and per diem shall be at the University's approved travel rates.

B. No foreign travel shall be reimbursed unless prior written authorization is obtained from ARB.

5. **Meetings**

A. Initial meeting. Before work on the contract begins, the Principal Investigator and key personnel will meet with the ARB Contract Manager and other staff to discuss the overall plan, details of performing the tasks, the project schedule, items related to personnel or changes in personnel, and any issues that may need to be resolved before work can begin.

B. Progress review meetings. The Principal Investigator and appropriate members of his or her staff will meet with ARB's Contract Manager at quarterly intervals to discuss the progress of the project. This meeting may be conducted by phone.

C. Technical Seminar. The Contractor will present the results of the project to ARB staff and a possible webcast at a seminar at ARB facilities in Sacramento or El Monte.

6. Confidentiality

A. It is understood that in the course of carrying out this Agreement, State may wish to provide University with proprietary or confidential information of State (Proprietary Information). University agrees to use its best efforts to hold proprietary information in confidence and shall return it to State upon the completion of the project.

B. This obligation shall apply only to proprietary information that is designated or identified as such in writing by State prior to the disclosure thereof. All proprietary information shall be sent only to the Principal Investigator. Moreover, this obligation shall not apply to any proprietary information which: a) is or becomes publicly known through no wrongful or negligent act on the part of University; b) is already known to University at the time of disclosure; c) independently developed by University without breach of this agreement; or d) is generally disclosed to third parties by State without similar restrictions on such third parties.

7. Studies Involving Human or Animal Subjects

A copy of the Institutional Review Board (IRB) approval must be submitted to ARB upon receipt by the investigator.

EXHIBIT F

RESEARCH FINAL REPORT FORMAT

The research contract Final Report (Report) is as important to the contract as the research itself. The Report is a record of the project and its results, and is used in several ways. Therefore, the Report must be well organized and contain certain specific information. The ARB's Research Screening Committee (RSC) reviews all draft Final Reports, paying special attention to the Abstract and Executive Summary. If the RSC finds that the Report does not fulfill the requirements stated in this Appendix, the document will not be approved for release, and final payment for the work completed may be withheld. This Appendix outlines the requirements that must be met when producing the Report.

Note: In partial fulfillment of the Final Report requirements, the Contractor shall submit a copy of the Report on a CD in PDF format and in a word-processing format, preferably in Word - Version 6.0 or later. This is in addition to the submission of any paper copies required. The diskette shall be clearly labeled with the contract title, ARB contract number, the words "Final Report", and the date the report was submitted.

Legibility. Each page of the approved Final Report must be legible and camera-ready.

Binding. The draft Report, including its appendices, must be either spiral bound or stapled, depending on size. The revised Report and its appendices should be spiral bound, except for two unbound, camera-ready originals.

Cover. Do not supply a cover for the Report. The ARB will provide its standard cover.

One-sided vs. two-sided. To conserve paper, both the draft Report and the revised Report, except for the unbound camera-ready copies, should be printed on both sides of the page. The unbound camera-ready copies must be printed on only one side of the page.

Title. The title of the Report should exactly duplicate the title of the contract unless a change is approved in writing by the contract manager.

Spacing. In order to conserve paper, copying costs, and postage, please use single or one-line (1) spacing.

Page size. All pages should be of standard size (8 ½" x 11") to allow for photo-reproduction.

Large tables or figures. Foldout or photo-reduced tables or figures are not acceptable because they cannot be readily reproduced. Large tables and figures should be presented on consecutive
8 ½" x 11" pages, each page containing one portion of the larger chart.

Color. Color presentations are not acceptable; printing shall be black on white only.

Corporate identification. Do not include corporate identification on any page of the Final Report, except the title page.

Unit notation. Measurements in the Reports should be expressed in metric units. However, for the convenience of engineers and other scientists accustomed to using the British system, values may be given in British units as well in parentheses after the value in metric units. The expression of measurements in both systems is especially encouraged for engineering reports.

Section order. The Report should contain the following sections, in the order listed below:

Title page
Disclaimer
Acknowledgment (1)
Acknowledgment (2)
Table of Contents
List of Figures
List of Tables
Abstract
Executive Summary
Body of Report
References
List of inventions reported and copyrighted materials produced
Glossary of Terms, Abbreviations, and Symbols
Appendices

Page numbering. Beginning with the body of the Report, pages shall be numbered consecutively beginning with "1", including all appendices and attachments. Pages preceding the body of the Report shall be numbered consecutively, in ascending order, with small Roman numerals.

Title page. The title page should include, at a minimum, the contract number, contract title, name of the principal investigator, contractor organization, date, and this statement: "Prepared for the California Air Resources Board and the California Environmental Protection Agency"

Disclaimer. A page dedicated to this statement must follow the Title Page:

The statements and conclusions in this Report are those of the contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

Acknowledgment (1). Only this section should contain acknowledgments of key personnel and organizations who were associated with the project. The last paragraph of the acknowledgments must read as follows:

This Report was submitted in fulfillment of [ARB contract number and project title] by [contractor organization] under the [partial] sponsorship of the California Air Resources Board. Work was completed as of [date].

Acknowledgment (2). Health reports should include an acknowledgment to the late Dr. Friedman. Reports should include the following paragraph:

This project is funded under the ARB's Dr. William F. Friedman Health Research Program. During Dr. Friedman's tenure on the Board, he played a major role in guiding ARB's health research program. His commitment to the citizens of California was evident through his personal and professional interest in the Board's health research, especially in studies related to children's health. The Board is sincerely grateful for all of Dr. Friedman's personal and professional contributions to the State of California.

Table of Contents. This should list all the sections, chapters, and appendices, together with their page numbers. Check for completeness and correct reference to pages in the Report.

List of Figures. This list is optional if there are fewer than five illustrations.

List of Tables. This list is optional if there are fewer than five tables.

Abstract. The abstract should tell the reader, in nontechnical terms, the purpose and scope of the work undertaken, describe the work performed, and present the results obtained and conclusions. The purpose of the abstract is to provide the reader with useful information and a means of determining whether the complete document should be obtained for study. The length of the abstract should be no more than about 200 words. Only those concepts that are addressed in the executive summary should be included in the abstract.

Example of an abstract:

A recently developed ground-based instrument, employing light detecting and ranging (lidar) technology, was evaluated and found to accurately measure ozone concentrations at altitudes of up to 3,000 meters. The novel approach used in this study provides true vertical distributions of ozone concentrations aloft and better temporal coverage of these distributions than other, more common methods, such as those using aircraft and ozonesonde (balloon) techniques. The ozone and aerosol measurements from this study, in conjunction with temperature and wind measurements, will provide a better characterization of atmospheric conditions aloft and the processes involved in the formation of unhealthful ozone concentrations than can be achieved with traditional ground-based monitors.

Executive Summary. The function of the executive summary is to inform the reader about the important aspects of the work that was done, permitting the reader to understand the research without reading the entire Report. It should state the objectives of the research and briefly describe the experimental methodology[ies] used, results, conclusions, and recommendations for further study. All of the concepts brought out in the abstract should be expanded upon in the Executive Summary. Conversely, the Executive Summary should not contain concepts that are not expanded upon in the body of the Report.

The Executive Summary will be used in several applications as written; therefore, please observe the style considerations discussed below.

Limit the Executive Summary to two pages, single spaced.

Use narrative form. Use a style and vocabulary level comparable to that in Scientific American or the New York Times.

Do not list contract tasks in lieu of discussing the methodology.

Discuss the results rather than listing them.

Avoid jargon.

Define technical terms.

Use passive voice if active voice is awkward.

Avoid the temptation to lump separate topics together in one sentence to cut down on length.

The Executive Summary should contain four sections: Background, Methods, Results, and Conclusions, described below.

THE BACKGROUND SECTION. For the Background, provide a one-paragraph discussion of the reasons the research was needed. Relate the research to the Board's regulatory functions, such as establishing ambient air quality standards for the protection of human health, crops, and ecosystems; the improvement and updating of emissions inventories; and the development of air pollution control strategies.

THE METHODS SECTION. At the beginning of the Methods section, state what was done in general, in one or two sentences.

The methodology should be described in general, nontechnical terms, unless the purpose of the research was to develop a new methodology or demonstrate a new apparatus or technique. Even in those cases, technical aspects of the methodology should be kept to the minimum necessary for understanding the project. Use terminology with which the reader is likely to be familiar. If it is necessary to use technical terms, define them. Details, such as names of manufacturers and statistical analysis techniques, should be omitted.

Specify when and where the study was performed, if it is important in interpreting the results.

The findings should not be mentioned in the Methods section.

THE RESULTS SECTION. The Results section should be a single paragraph in which the main findings are cited and their significance briefly discussed. The results should be presented as a narrative, not a list. This section must include a discussion of the implications of the work for the Board's relevant regulatory programs.

THE CONCLUSIONS SECTION. The Conclusions section should be a single short paragraph in which the results are related to the background, objectives, and methods. Again, this should be presented as a narrative rather than a list. Include a short discussion of recommendations for further study, adhering to the guidelines for the Recommendations section in the body of the Report.

Body of Report. The body of the Report should contain the details of the research, divided into the following sections:

INTRODUCTION. Clearly identify the scope and purpose of the project. Provide a general background of the project. Explicitly state the assumptions of the study.

Clearly describe the hypothesis or problem the research was designed to address. Discuss previous related work and provide a brief review of the relevant literature on the topic.

MATERIALS AND METHODS. Describe the various phases of the project, the theoretical approach to the solution of the problem being addressed, and limitations to the work. Describe the design and construction phases of the project, materials, equipment, instrumentation, and methodology. Describe quality assurance and quality control procedures used. Describe the experimental or evaluation phase of the project

RESULTS. Present the results in an orderly and coherent sequence. Describe statistical procedures used and their assumptions. Discuss information presented in tables, figures and graphs. The titles and heading of tables, graphs, and figures, should be understandable without reference to the text. Include all necessary explanatory footnotes. Clearly indicate the measurement units used.

DISCUSSION. Interpret the data in the context of the original hypothesis or problem. Does the data support the hypothesis or provide solutions to the research problem? If appropriate, discuss how the results compare to data from similar or related studies. What are the implications of the findings? Identify innovations or development of new techniques or processes. If appropriate, discuss cost projections and economic analyses.

SUMMARY AND CONCLUSIONS. This is the most important part of the Report because it is the section that will probably be read most frequently. This section should begin with a clear, concise statement of what, why, and how the project was done. Major results and conclusions of the study should then be presented, using clear, concise statements. Make sure the conclusions reached are fully supported by the results of the study. Do not overstate or overinterpret the results. It may be useful to itemize primary results and conclusions. A simple table or graph may be used to illustrate.

RECOMMENDATIONS. Use clear, concise statements to recommend (if appropriate) future research that is a reasonable progression of the study and can be supported by the results and discussion.

References. Use a consistent style to fully cite work referenced throughout the Report and references to closely related work, background material, and publications that offer additional information on aspects of the work.. Please list these together in a separate section, following the body of the Report. If the Report is lengthy, you may list the references at the end of each chapter.

List of inventions reported and publications produced. If any inventions have been reported, or publications or pending publications have been produced as a result of the project, the titles, authors, journals or magazines, and identifying numbers that will assist in locating such information should be included in this section.

Glossary of terms, abbreviations, and symbols. When more than five of these items are used in the text of the Report, prepare a complete listing with explanations and definitions. It is expected that every abbreviation and symbol will be written out at its first appearance in the Report, with the abbreviation or symbol following in parentheses [i.e., carbon dioxide (CO_2)]. Symbols listed in table and figure legends need not be listed in the Glossary.

Appendices. Related or additional material that is too bulky or detailed to include within the discussion portion of the Report shall be placed in appendices. If a Report has only one appendix, it should be entitled "APPENDIX". If a Report has more than one appendix, each should be designated with a capital letter (APPENDIX A, APPENDIX B). If the appendices are too large for inclusion in the Report, they should be collated, following the binding requirements for the Report, as a separate document. The contract manager will determine whether appendices are to be included in the Report or treated separately. Page numbers of appendices included in the Report should continue the page numbering of the Report body. Pages of separated appendices should be numbered consecutively, beginning at “1”.