A. Cover page
1. Project Title: Evaluation of certified organic fertilizers for long-term nutrient planning

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5. CDFA Funding Request Amount/Other Funding
CDFA Funding Request
Year 1 $56,418
Year 2 $91,354
Year 3 $76,999
Total (CDFA) $224,771

In kind Funds
Year 1 $8,544
Year 2 $8,544
Year 3 $8,544
Total (UCDAVIS) $25,632.

Total request $250,403

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B. Executive Summary

The use of organic fertilizer materials with a certified nutrient analysis for crop production is problematic due to inconsistencies in nutrient availability, especially nitrogen (N). Knowledge of nutrient values of these organic soil amendments is limited because the nutrients from these sources are gradually released into soils in plant available forms and may be temporally tied up in soil microorganisms or organic matter. The consistency of some of the organic based fertilizer varies annually depending on the quality and availability of fertilizer materials, such as manures, fish by-products, food processing waste, etc. Therefore, predicting nutrient release from organic based fertilizers is challenging resulting in a dearth of information available to make consistent informed nutrient management decisions. Organic based fertilizers, with lower carbon to nitrogen ratios, likely have higher nutrient value than high C to N materials, such as greenwaste composts. However, relying on C to N ratio alone has shown inconsistent result. Composts for example have low C to N ratios but low N availability. There is a general lack of reliable predictions of nutrient release from organic sources in California’s soils and climate.

The nutrient value of annually applied organic fertilizer amendments likely provides a more consistent nitrogen mineralization response than sporadic applications. However, running field experiments to determine the accumulative nitrogen mineralization response from annual application of organic soil amendments across different cropping systems and soils is impractical without a large study that first incorporates the response of organic fertilizer amendments and soils from various regions of California’s diverse agriculture systems. This project proposes to combine lab incubation with predictive modeling to evaluate the use of organic fertilizer amendments applied on an annual basis to provide guidelines for reassessing nitrogen fertilizer inputs across a variety of crops. The information is necessary to avoid over loading of N that can lead to N losses through greenhouse gas emissions and leaching to groundwater. The uses of organic fertilizer amendments also add to potential soil carbon sequestration and thereby likely improve soil productivity and healthy soil. Therefore, this project is important to informing policies and management guidelines that promote and embody the intent of the Healthy Soils Initiative.

Objectives. The overarching objective is to provide baseline data to inform nitrogen management plans specific to CA where organic fertilizer amendments are used in agricultural production areas. Specific project objectives are: 1) Conduct an extensive literature review on soil N and organic N fertilizers; 2) characterize the temperature response of N mineralization of organic based fertilizers in soils of the major agriculture production areas in CA; 3) incorporate temperature response and N mineralization kinetics and turnover rates in the the DayCent model to predict long-term N availability; 4) Conduct field trials to confirm lab and DayCent model results and to inform the Comet–Farm modeling tools; and 5) conduct extensive engagement and outreach to inform the value and to reassess organic fertilizer amendment rates to avoid N loss and promote healthy soils.

General Research Approach. We propose a combination of literature values and lab incubations to calibrate the DayCent model to better predict the seasonal and long-term nutrient value of organic fertilizer amendments for soil productivity improvement and nutrient management. We will specifically determine nitrogen mineralization responses to predict the long-term effects of repeated annual applications of organic fertilizers on soil N availability. Key to effectively use the information on nitrogen mineralization generated in this research is the parameterization of the DayCent model, so that the model can accurately predict nitrogen
mineralization rates at different soil temperatures under soil conditions in CA throughout the year. Most models use default values resulting in poor prediction outcomes. We will develop $Q_{10}$ temperature coefficients for microbial nitrogen and carbon mineralization in a temperature range from 10 to 30°C across a range of soils (3 - 4 major agricultural soil series) and various types of organic fertilizer amendments. Because the DayCent model includes crop nitrogen uptake and yield, it can be used to reassess fertilizer nitrogen inputs. We will initially use the FREP fertilizer guidelines and other sources for crop nitrogen requirements to run the model. Our results will provide for adjustments of nutrient management guidelines depending on organic fertilizer sources, soil type, and climate data. The information generated in this research will be used by UC Extension, CCAs and farmers to reassess nitrogen management across a variety of crops. The DayCent model is also the basis of COMET-Farm, a tool being considered by CDFA to assist farmers in engaging in California’s climate action planning. We will conduct on-farm field trials to validate the predictive value of lab and modeling results. The three-year project will be conducted in a staged approach with results from early stages informing the research plan for later stages. This approach will allow for adjustments of nutrient management plans to maintain and increase crop productivity, reduce the potential for N loss to groundwater, and minimize greenhouse gas emissions.

**Audience.** The proposed research addresses 2 of the 3 priority research areas in CDFA/FREP. We will address the “Improving Input Management” priority area by developing guidelines for nutrient availability from certified organic fertilizer amendments. Within this priority area, we address education and outreach through the development of educational and/or certification materials and methods to increase awareness and implementation of agronomically sound use of fertilizer materials, trainings for a graduate student and technology transfer that combine training topics including nitrogen management for growers located outside of the Central Valley. Also within this priority area, we will promote adoption of knowledge and practices to optimize the use of organic fertilizer amendments by peer-to-peer farmer interaction and field demonstrations. In the second research priority “Understanding Soil-Plant Processes” we address vegetable cropping systems in the Salinas Valley through field demonstration and training. Within this priority research area, we address the “Role of Soil Organic Matter and Organic Fertilizing Materials on Nutrient Management in Soil.” This research will provide much needed information to a growing number of stakeholders who are in need of guidelines and recommendations regarding the use of organic fertilizer amendments as nutrient sources in CA agriculture. The targeted audience includes growers, fertilizer producers, compost and digestate producers, farm advisors, NGOs and a number of state offices and agencies (i.e., ORP, CDFA, ARB, CalEPA, Calrecycle, DWR, State Water Resources Control Board). Our proposed project will engage with a number of these key stakeholder groups throughout the duration of the project.
C. Justification

1. Problem.

California agriculture is highly productive contributing $55.7 billion gross value production in 2012 to California’s economy (CDFA, 2014). The high yield potential of California crops is due to favorable climate, availability of water and fertilizer inputs, in particularly N. This intensive management has lead to increases in soil carbon and N over the period from 1945 to 2001 (Declerk and Singer 2003). The increase in soil C and N is likely due to increasing productivity of crops through water and N inputs that lead to increased C (crop residue) inputs over time. However, the intensive fertilizer N inputs have lead to large losses of N to the groundwater as nitrates (Harter et al., 2012) and to the atmosphere as nitrous oxide (Xiang et al., 2013). These reactive N sources degrade water quality and contribute to climate change, both critical issues confronting California’s path to a sustainable society.

Nitrogen management, and predicting soil nitrogen availability through mineralization of soil N and organic fertilizer amendments is a challenge in cropping systems due to the complexities and interacting forces of weather, soil biology and physical properties, organic input quality and chemistry, and intensive management practices (Cabrera et al., 2005; Schomberg et al., 2009). The value of organic fertilizer N amendments cannot be overstated. In general, using organic fertilizer N sources increases N use efficiency. Combined with conventional mineral fertilizers, organic fertility sources can achieve equivalent or larger yields and often provide for greater yield stability than conventional mineral fertilizers alone (Poudel et al., 2001). One of the reasons for higher yield potential is that soils amended with organic nutrient sources, often increase the mineralization of native soil N compared to those receiving only mineral fertilizers (Doane et al., 2009; Moreno-Cornejo et al., 2015).

In a research setting, soil nitrogen mineralization potential, i.e. the availability of plant-available N over a given time, is often assessed with laboratory incubations of soil and or mixtures of soil and amendments (Stanford and Smith 1972). The method is extremely accurate in predicting the N mineralization potential of different amendments and soil N. For example, Heinrich and Pettygrove (2012) demonstrated that about 48% of N mineralized from a range of dairy manures after 63 days of incubation in a class 1 fine sandy loam soil. However, the time and costs associated with such analyses has limited their adoption into most standard commercial soil testing laboratories. The lack of information on the N mineralization kinetics of organic fertility sources has hampered our ability to effectively use organic fertilizers in crop management to increase the efficacy of nutrient plans.

The inclusion of mineralized N from soil and organic sources of N into fertilizer recommendations is essential to improving nitrogen use efficiency in agronomic systems. Underestimation of the contribution of organic soil amendments and fertilizers to plant-available N can result in excess reactive nitrogen being released into the environment. Over fertilization has been shown to result in increased N$_2$O emissions (Stehfest & Bouwman, 2006) and the pollution of groundwater with nitrate (Harter et al., 2012). To avoid such serious consequences of over-fertilization, it is necessary to accurately predict N release from organic N sources and sync N supply with crop N demand.

2. FREP Mission and Research Priorities.

The proposed research addresses 2 of the 3 priority research areas in CDFA/FREP. This project addresses the “Improving Input Management” priority area by developing guidelines for nutrient availability from organic fertilizer amendments. Within this priority area, we address education
and outreach through the development of educational and/or certification materials and methods to increase awareness and implementation of agronomically sound use of fertilizing materials, trainings for a graduate student and technology transfer that combines training topics including nitrogen management training for growers located outside of the Central Valley. Also within this priority area, we will promote adoption of knowledge and practices to optimize the use of organic fertilizer amendments by peer-to-peer farmer interaction and field demonstrations. In the second research priority “Understanding Soil-Plant Processes” we address vegetable cropping systems in the Salinas Valley through field demonstration and training. Within this priority research area, we address the “Role of Soil Organic Matter and Organic Fertilizing Materials on Nutrient Management in Soil.”

The goal of this project is to develop guidelines for the efficient use of organic fertilizer sources by demonstrating general nitrogen mineralization patterns and combine the findings with modeling exercises to extend the results to predict long term responses to repeated organic fertilizer applications and C sequestration in many soil types. These efforts also address the Healthy Soils Initiative through the increase of crop productivity and resilience that can be achieved with regular additions of organic amendments. Furthermore, the research contributes to climate change mitigation through soil carbon sequestration and reduction in greenhouse gas emissions potential and addresses water quality issues related to nitrogen losses to the environment.

3. Impact.
The following are impacts and expected outcomes of the proposed research.

1. The information on N mineralization rates for different organic fertilizers will be welcomed by growers, CCAs, farm advisors and other extension personnel because this knowledge will allow them to increasingly use these organic fertility sources with confidence, thereby benefitting from increased resilience and potentially greater productivity of their cropping systems.

2. With accurate estimations of the contribution of nutrients from organic based fertility sources under various temperature regimes and different soil types, the certified organic fertilizers and soil amendments can be successfully integrated into nutrient management plans.

3. By using the information generated in the research and through modeling, growers will be able to increase crop fertilizer N use efficiency and build healthy soils.

4. Using certified organic soil amendments on a regular basis could potentially increase microbial biomass, soil carbon levels, aggregate stability, and soil tilth to promote healthy soils.

5. The optimal fertilizer N application rate will reduce nitrate leaching and nitrous oxide emission. Use of certified organic amendments will divert organic waste from landfills.

4. Long-Term Solutions.
The quest to describe and predict soil N mineralization of organic based fertilizer sources has been elusive. Much research has been done and general guidelines established for plant available N in manures, composts and biosolids. However, in practice, established N mineralization rates for these materials vary dramatically from 0 to 100%. For example, Heinrich and Pettygrove (2012) found that N mineralization in a range of California dairy manures ranged from 29 to 73%. Less data is available for certified organic materials despite
stringent labeling requirements on N content. For common high N containing organic fertilizers, such as blood meal, fish powder, feather meal and sea bird guano, between 47 and 60% of the organic N fraction mineralized within 2 weeks (Hartz and Johnstone 2006). The high mineralization rate was independent of temperature suggesting that the majority of available N was in microbial biomass or mineral forms, which cannot be guaranteed with labeling requirements.

Little is known about the long term effects from applying organic nutrient sources to crop land year after year since results of field experiments are easily confounded by repeated organic fertilizer applications without suitable control comparisons. Nitrogen mineralization from organic fertilizer sources for time periods exceeding a single cropping season are, therefore, for the most part based on untested assumptions (Thompson et al., 1997; Schmitt and Rehm, 1998) although some progress has been made through modeling (Crohn, 2006). The availability of organic soil amendments with a certified nutrient content is likely to increase and growers must know both the seasonal and long-term effects on N mineralization when applying organic nutrient sources, such as composts made from food waste mixed with bulking agents. The nutrient availability in these organic fertilizer sources is sparse (Sullivan et al., 2003; Diacono and Montemurro, 2010; Brown et al., 2011).

In today’s market of organic N based fertilizers, the number of N formulations has increased significantly. The N contents of these products vary considerably and little information exists on N mineralization rates and in-season plant available N. Lab incubations have been shown to be reliable and accurate in describing both C and N mineralization potential when done under highly controlled conditions, such as those found in agricultural research labs. The incubations often involve very specific soil conditions such as ideal temperature and moisture, leaching in columns, interpretation of rate data on N mineralization and other factors. The problem with incubation data is in generalizing conclusions across soil types and crop management systems. For this reason we propose to combine modeling efforts using DayCent and COMET Farm combined with field trials to validate our lab and model results to produce general guidelines that will increase the probability for increasing N use efficiency in cropping systems.

5. Related Research.
William Horwath has completed a FREP project entitled “Evaluation of a 24-Hour Soil CO₂ Test for Estimating Potential N Mineralization to Reassess Fertilizer N Recommendations”. The project compared a number of soil test and compared them to a new proposed test that examined the relationship of soil respiration to predict in season soil N mineralization. The results showed that soil managed with cover crops or organically showed a better relationship to in season soil N mineralization. A cross lab comparison of soil test labs showed the labs did not have enough information to use the test effectively to recommend changes in N inputs. Relating to the planned field experiments with peppers, N rate trials at the West Side Research and Extension Center in Fresno County in 2012 showed that yields maxed out at about 200 lbs N/acre. An N uptake study in Gilroy in 2012 confirmed this result as pepper fruit contained 110 and the plants 215 lbs N/acre (CA Pepper Commission).

6. Contribution to Knowledge Base.
Maintaining soil fertility and optimizing nutrient cycling are important goals in developing a sustainable cropping system and healthy soils (Douglas 1984; Doran and Parkin 1994). Crop
residues and other organic amendments contribute to processes that maintain soil fertility, conserve nutrients and promote healthy soils. Studies have shown that organic amendment additions can have additional benefits of reducing crop disease incidence and improve soil fertility (Bangar et al. 1989; Nelson and Craft 1992). The benefits of adding organic amendments as fertilizer N sources to cropping systems beyond their nutrient content is understood to increase soil health and crop productivity through increasing soil C and most importantly cropping system yield stability (Seiter and Horwath 1996).

Effects of soil carbon and organic N sources on soil productivity
The addition of composts to soil has produced both yields and plant N concentrations equivalent to similar amounts of N in mineral fertilizer (Bangar et al. 1989; Kirchman 1990; Sharma and Mittra 1991; Zaccheo et al. 199; Poudel et al., 2001). Food waste compost, if applied at high rates (>50 Mg ha\(^{-1}\)), can provide a slow release source of macronutrients for crops (Sullivan et al., 2003). The release of nutrients has also been demonstrated for animal manure composts applied at lower rates, at least for the season following the applications (Eghball, 2000; Eghball et al., 2002; Eghball et al., 2004; Diacono and Montemurro, 2010). Significant amounts of inorganic N may be present in finished green waste composts (Zhu et al., 2013). The maturity of compost is a critical factor affecting the availability of nutrients to crops (Hartz and Giannini 1998). The application of organic amendments also has the potential to increase and maintain soil C, but little is known of their potential to affect soil C.

Models of carbon and nitrogen flow
Conceptual biogeochemical models simulate C and N dynamics and to divide SOM components into biologically meaningful fractions in an attempt to emulate soil function (Juma and Paul 1981; van Veen et al. 1984; Parton et al. 1988). The scheme of multiple soil C pools is the major empirical basis of models such as DayCent and COMET Farm. These models are composed of multiple conceptual decomposable soil C fractions, ranging from active to passive (Jansson 1958). The active fraction is the most biologically significant pool in interpreting soil fertility while the passive fraction is composed of recalcitrant and physically protected organic material. We now confirm that the active fraction contains the soil microbial biomass and easily mineralizable organic matter (Paul and Clark 1996). The active soil organic fraction may contain significant quantities of recently deposited organic material including fine roots and fungal hyphae (Tisdall and Oades 1982). Organic fertilizers add to the active fraction. It is the quality of soil C found in the active fraction and not the amount that is the most important to N availability (McGill et al. 1986; Janzen et al. 1988; Duxbury and Nkambule 1994).

DayCent model application in California
Evaluating nutrients release from organic fertility sources to crop production encounters difficulties due to the variability in the quality and quantity of fertilizer materials, as well as the climate and soil conditions such as temperature, moisture, and microbial activities. Parameterizing the DayCent model using the N mineralization rates obtained at different soil temperatures and testing the model outcomes using field trial data can enhance the model performance and decrease the uncertainty, thus provide reliable predictions of nutrient release from organic sources and soil carbon sequestration potential as affected by organic sources in California’s soils and climate. The DayCent model is a biogeochemical process-based model of intermediate complexity that simulates exchanges of C, nutrients, and trace gases among the
atmosphere, soil, and vegetation (Parton et al., 1998; Del Grosso et al., 2001), and decomposition and nutrient mineralization of plant litter and SOC, plant growth and senescence, and soil water and temperature fluxes (Parton et al., 2001; 2002, 2005; Del Grosso et al, 2006). The use of the parameterized DayCent model to predict the N mineralization of organic fertilizers will contribute to the development of baseline data for reassessing nitrogen management plans in CA to avoid N loss and promote healthy soils, and will provide a path forward for implementing the soil GHG mitigation method and carbon sequestration approach in COMET-Farm.

7. Grower Use.
Information on the mineralization of soil N and N in organic amendments for crop N uptake would benefit growers in several ways. It allows them to reassess fertilizer N application rates by accounting for the mineralization of soil N and those from organic amendments. Using an optimized rate of N fertilizer and would increase N use efficiency. The reassessment of fertilizer N application rates would also provide for the reduction of gaseous N and nitrate leaching losses.

D. Objectives
The overarching objective is to provide baseline data to inform nitrogen management plans specific to CA where organic fertilizer amendments are used in agricultural production areas. Specific project objectives are:
1) Conduct an extensive literature review on soil N and organic N fertilizers
2) Characterize the temperature response of N mineralization of organic based fertilizers in soils of the major agriculture production areas in CA;
3) Incorporate temperature response and N mineralization kinetics and turnover rates in the DayCent model to predict long-term N availability;
4) Conduct field trials to assess to confirm lab and DayCent model results and to inform the Comet–Farm modeling tools; and
5) Conduct extensive engagement and outreach to inform on the value of organic fertility sources and to reassess organic fertilizer amendment rates to avoid N loss and promote healthy soils.

E. Work Plans and Methods
The 5 main tasks that comprise the work plan and timeline of completion are shown in Table 1. In summary, this proposed research will combine lab incubation and field trials with predictive modeling to evaluate the N mineralization and carbon sequestration potential of certified organic fertilizers. In the laboratory, we will determine seasonal N mineralization values, as well as the effects of repeated applications of organic fertilizers on soil N mineralization potential, as could be expected with application of these materials year after year in farming operations. The lab work will also include the temperature response of C and N mineralization in various soils amended with different types of organic based fertilizers, e.g. green waste, manure and food waste composts, fish by-products, blood-, feather-, and bonemeal, food waste hydrolysate, as well as fertilizers made from plant material, such as soybean meal. In field experiments, we will measure crop N uptake, yields, and soil N content, with select organic based fertilizer applications. The field crops will managed according to standard practices. The modeling will include initial parameterization using literature values, calibration of the model using N and C mineralization responses of the lab incubations, and validation based on the findings in the field experiments.

Details of the specific tasks are described below. Dates of completion are shown in Table 1.

**Task 1. Literature review on soil N mineralization and crop N availability as affected by organic based N fertilizers.** We will compile all published information on the organic based fertilizer composition and mineralization kinetics in California and comparable regions. This information will be used to initially parameterize the DayCent model. Of particular interest in literature review are total mass of inputs, carbon fraction of solids, organic and inorganic N, carbon to nitrogen ratios, and pH, as well as information on how (e.g. at what rates) these organic materials are being used in cropping systems in California. The literature will also inform the design of the lab incubations. The literature review will be completed by July 2017.

**Task 2. Determine seasonal N mineralization and N mineralization potential in soils repeatedly amended with organic fertilizer in CA.** We will perform lab soil incubations with varied organic based fertilizers in representative soils of the major agricultural production areas in California. The organic fertilizers will include fish by-products, blood-, feather-, and bonemeal, food waste hydrolysate, pelleted poultry litter, bat and seabird guano, fertilizers made from plant material, such as soybean meal, as well as organic fertilizers of composted materials, such as greenwaste and food waste. To measure seasonal N availability from organic fertilizers, we will measure N mineralization and carbon dioxide (CO₂) evolution in 100-day incubations. To assess the effects of repeated organic fertilizer applications on soil fertility, we

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<th>Specific tasks</th>
<th>2017</th>
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<td><strong>Task 1 - Literature review</strong></td>
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<td>Preliminary estimation of temperature coefficients based on literature</td>
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<td><strong>Task 2 - Lab-based operation and data analysis</strong></td>
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<td>Soil collection and material preparation</td>
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<td>Lab incubates</td>
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<td>Measure N mineralization rate, CO₂, DOC, pH in lab incubations</td>
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<td>Analyze N and C mineralization data</td>
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<td>Determine temperature response on N mineralization</td>
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<td><strong>Task 3 - Field-based operation and data analysis</strong></td>
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<td><strong>Task 4 - Model parameterization and development</strong></td>
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<td>Daycent model validation using field research results</td>
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<td><strong>Task 5 - Extensive engagement and outreach</strong></td>
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will, after 100 days of incubation, remove the accumulated soil nitrate by leaching to simulate crop N uptake (Stanford and Smith, 1972). We will then re-apply the organic amendments at the recommended rates. This procedure will be repeated several times. Furthermore, we will determine temperature coefficients by incubating select soils amended with the organic fertilizers at 10, 20, and 30 °C. The incubations will be conducted in Prof. Horwath’s Biogeochemistry and Nutrient Cycling Lab, UC Davis. The range of soils (texture, carbon content, pH, etc.) and the management effects tested in the lab will provide data needed to calibrate the DayCent model. This task will be completed by December of 2018.

Task 3. Conduct field trials to assess and confirm lab and DayCent model results and to inform the COMET–Farm modeling tools. Field trials will be conducted in order to compare results against findings in the lab and model projections and to verify the model performance. These trials will take place in Monterey County, in a chili pepper (*Capsicum annuum*) system that has been under organic management. Chili peppers have been chosen based on the crop’s high nitrogen demand and standard cultivation practices. Three organic based fertilizers will be applied in the field at application rates ranging from zero to over N requirement. Field trials will begin April 2017 and end December 2019.


Task 4a. Model parameterization and development: The DayCent model will be parameterized by using the Q10 temperature coefficients for C and N mineralization determined in the lab incubations. The DayCent model simulates soil organic matter dynamics and, calibrated, can predict C, N, P, and S content in the soil-plant system at a daily time step. The model includes three organic matter pools (active, slow, and passive) with different potential decomposition rates, above and belowground litter pools (structural and metabolic pool) that receive organic materials as a function of lignin to N ratio in the material, and a surface microbial pool, which is associated with decomposing surface litter. Decomposition of soil organic matter and external nutrient additions such as fertilizer N inputs and atmospheric N deposition supply the mineral N pool which is available for plant growth and microbial processes that result in N transformations and trace gas fluxes. Soil texture, pH, moisture, temperature, C and N content, lignin fraction content, C/N, C/P, and C/S ratio of the organic material in the literatures will be used to initially parameterize the DayCent model. The microbial N and C mineralization data obtained in the soil incubations will be compared with outputs of the DayCent model and will be used to validate the model.

Task 4b. Model Validation: The parameterized DayCent model will also be tested using our yield data from the proposed field trial following the validation procedure provided by Del Grosso et al. (2011). Field data collected during the experimental period will be compared with modeling outputs to develop a framework for the connection of soil carbon dynamics, organic based fertilizer mineralization and crop production in cropping systems. The DayCent model can predict crop nitrogen uptake and yield and will be used to provide estimates of soil N availability with various management practices, such as repeated applications of the organic materials. The information on soil C and N dynamics, including inorganic N availability, under different climates, site management histories, and soil characteristics will be incorporated into our data synthesis approach. This task will be completed by December of 2019.
Task 5. Conduct extensive engagement and outreach to inform on the value and to reassess organic fertilizer amendment rates to avoid N loss and promote healthy soils.

We will engage in multiple outreach activities per year for the duration of the project. However, during the first year and much of the second year, the activities are primarily associated with soil sampling and testing, as well as grower questionnaires. Initially we intend to participate widely in conferences, meetings and professional gatherings within the agricultural community, including coordinating and hosting an organic amendment workshop. During the later stage of the project we will focus our outreach efforts on developing web and printed educational material to support both UCD resources as well as those of other state agencies. Once our results have been finalized we will conclude our project by publishing the findings in trade magazines, extension bulletins and scholarly journals.

   a. Literature review. The literature review will be used to investigate the interaction of soil C and N mineralization and C sequestration potential with other factors, such as organic based fertilizer type, soil texture, crop type, and climate. We will select field studies as well as laboratory incubations from the literature where measurements of at least two different levels of organic based fertilizer inputs, including a zero input control, were applied under otherwise identical conditions, including site, growing season, crop, measurement duration, frequency, and method. We will include key characteristics for each study in a table when available: literature reference; location name and coordinates of experiment; mean annual precipitation and temperature; soil texture, organic C, N dynamics, pH, and bulk density; selected crop and management details, yield, crop N uptake, and number of replicates, and fertilizer type, mode of application, and number of applications per measurement period.

   b. Laboratory incubation. Laboratory incubations will be conducted to assess kinetics of C and N mineralization in a variety of soils treated with different organic based fertilizers (Table 2). Soils (10-15) will represent major agricultural areas in California. In the lab incubations, we will determine the temperature response of C and N mineralization for the temperature range of 10 to 30°C. In order to provide guidelines for long-term nutrient planning, all the fertilizers will be applied at intervals of 100 days for up to five applications to simulate repeated applications. To mimic crop uptake of N, nitrate will be leached with water to remove the extra N before the next fertilizer application. The comparison of synthetic fertilizer and organic fertilizer treatments allows for the estimation of the contribution of organic matter in the organic based fertilizer to N mineralization kinetics.

   The incubation vessels will contain 25 to 50g (dry wt.) of soil, with 3 replications per treatment. The fertilizer amendments will be applied at typical field rates. The soil moisture will be adjusted and maintained at 65 % of water holding capacity. One set of jars per treatment will be used for gas sampling and all the others for soil sampling.

   During each fertilizer application stage, soil respiration measurements (CO2) will be taken frequently (every 3 days) during the first 15 days of the incubation and less frequently (every 5 to 10 days) up to 100 days in total. CO2 will be measured on a Shimadzu gas chromatograph (Model GC-2014) linked to a Shimadzu auto sampler (Model AOC-5000). Soils will be extracted with 0.5 M K2SO4 (10 to 1 extractant volume to soil mass ratio) on days 0, 3, 7, 14, 28, 56 and 100 after application of fertilizers under different temperatures. NH4+ and NO3- contents in the soil extractant will be analyzed using colorimetric methods (Verdouw et al., 1978;
Soil DOC levels will be determined by UV-persulfate oxidation (Teledyne-Tekmar Phoenix 8000). Soil pH will be determined in 1 M KCl extracts (1:1 w:v). Total C and N content will be determined using an elemental analyzer (Costech EAS 4010, Valencia, CA) following sample ball milling preparation. Percent clay, silt, and sand will be determined by a modified pipet method (USDA, 1992).

N mineralization during the incubation period will be calculated using the difference of soil NH$_4^+$ and NO$_3^-$ content between two sampling times. Results will be extrapolated to kg/ha to make them comparable to field observations. Using a broader range of soil types and moisture contents will allow us to generalize the data obtained from field studies and extrapolate them to a broader level.

Table 2. Certified organic fertilizers and nutrient content, to be used in lab incubations.

<table>
<thead>
<tr>
<th>Fertilizer type</th>
<th>Nutrient content (%)</th>
<th>Manufacturer/Distributor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P$_2$O$_5$</td>
</tr>
<tr>
<td>Dairy manure</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Poultry manure</td>
<td>1.8</td>
<td>2.0</td>
</tr>
<tr>
<td>Pelleted poultry litter</td>
<td>4.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Food processing waste</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Fish by-products</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Green waste compost</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Food waste compost</td>
<td>1.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Food waste hydrolysate</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Fish hydrolysate</td>
<td>2.3</td>
<td>3.5</td>
</tr>
<tr>
<td>Fish meal</td>
<td>8.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Feather meal</td>
<td>12.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Alfalfa meal</td>
<td>2.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>7.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Blood meal</td>
<td>13.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Pelleted bone meal</td>
<td>4.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Pelleted Seabird Guano</td>
<td>12.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Biochar</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C. Field trial: Field trials will be conducted in Monterey County to assess the effects of organic based fertilizer on crop N uptake and C sequestration and to evaluate the model performance under these management practices. Three distinctly different organic fertilizers, e.g. food waste/green waste mixture, pelleted poultry litter, pelleted alfalfa meal, will be applied at five N rates (including a control). Bulk material will be applied with a spreader and disked in to a depth of 15 cm, while the pelleted material can be applied with a drill to about 10 cm depth near the plant line. The fertilizer rates will be based on the results of lab incubations and the residual inorganic N levels in the experimental plots. The crops will be irrigated by drip irrigation delivered through surface (or shallowly buried) drip lines. The experimental treatments will be set up as a randomized complete block design with three replicates. Plants will be sized 4.5 m x 4.5 m. Chili pepper (*Capsicum annuum*) will be grown according to standard grower practices. Plants will be collected from 1-m sections of the beds at each growth stage (e.g. flowering,
fruiting) and at harvest to determine crop N uptake. Plant biomass samples will be oven dried at 60°C and ground to a fine powder in a grinding mill and analyzed for total N by the elemental analyzer as above. Soil samples will be collected to a depth of 1.2 m in 30 cm depth intervals before the application of organic fertilizers and at the end of the season to determine inorganic N, total C and N, and bulk density. Additionally, dissolved organic carbon and pH will be measured in the top 30 cm. The soil and plant measurements will be used to establish N budgets for each treatment and replicate.

d. Modeling. The DayCent model version 6.0 will be used. The method to parameterize the model is described in the previous section. Briefly, the parameters of model, e.g. decomposition parameters of different soil organic pools and partition of input materials to different soil organic pools. The results of the field study and the lab incubations will be used to validate the DayCent model outputs. The DayCent model will additionally predict soil C sequestration. All the model development and simulation results will be used to develop the N management guidelines for COMET-Farm in California.

F. Project Management, Evaluation, and Outreach

1. Project Management. The Senior project leader is Professor William R. Horwath. Dr Xia Zhu-Barker and cooperators will work closely with Dr. Horwath and take responsibility for all analytical procedures, field work, data analysis, reporting, and development of guidelines. Dr. Zhu-Barker will work closely with all collaborators within and outside UC Davis to facilitate project integration. She will design and oversee the implementation of laboratory incubations, prepare input data for the DayCent model used in this project and parameterize the model, analyze and interpret results, and prepare manuscripts for publication. She will also help assign value to agricultural assets and practices, and help provide the practical linkages between the model components and agricultural inputs. Dr. Zhu-Barker will also assist in mentoring the graduate student and undergraduate student for implementing this project and provide research leadership as needed.

2. Evaluation.
Success will be measured on both the assessment of long-term nutrient management of organic based fertilizer and the calibrated predictive model on soil C sequestration and N with an aim at advancing environmentally safe and agronomically sound management practices. N mineralization and long-term effects of repeated applications of organic based fertilizers on N availability will be assessed in a wide range of soil types and temperatures. Field measurements will include analyses of soil chemical, physical and biological properties (i.e. C stocks, C stability, macro nutrient availability, soil structure and microbial biomass) to be compared with DayCent model outputs to validate the model performance and decrease the model uncertainty in predicting C sequestration, N mineralization and crop yield.

3. Outreach.
Our outreach program will engage the target audience and key stakeholders through utilizing both digital and print media, as well as public presentations and meeting attendance. Our outreach process will be based on the logic model in order to insure that our programmatic objectives align with our desired outreach impacts. Outreach efforts will be measured and
evaluated through a longitudinal follow-up survey design to measure change in attitude, behavior and knowledge.

Based on our desired impacts - increasing knowledge and use of organic amendments by clarifying and modeling their N characteristics - we will begin by using the survey software Qualtrics to evaluate grower’s baseline knowledge and usage patterns of organic amendments. Particularly for waste derived amendments such as compost, there is limited understanding of the overall application trends. These surveys will take place during the first phase of the project (2017). Within the survey we will question growers on their channels for receiving information concerning nitrogen management techniques as well as establish baseline knowledge of organic amendments. Data from these initial surveys will be complied and reported in the first report.

During the second phase of our outreach plan (2018) we will participate in the fall FREP Conference and submit our presentations for publication in the Conference Proceedings. We will also seek to participate in symposia sponsored by University of California, Western Plant Health Association, Soil Science Society of America and Western Soil Science Society, the Annual South Sacramento Valley Processing Tomato Production Meeting in Woodland, Small Grains Field Day and other Commodity group events organized by UC Davis extension, the Monterey County Annual Irrigation and Management Meeting and Western Plant Health Association Meeting (120 participants), among others. Specifically, in Monterey County, in partnership with the County Department of Agriculture, we will coordinate an all day workshop to review organic amendment use and applications, explain how to integrate them into nutrient management plans and describe how they affect long term fertilization strategies.

Desired outcomes of these meetings will be to establish grower connections and increase knowledge of organic amendments. Coordinated by the Composting Education Program we will establish an email account and hotline for technical assistance. Once rapport is established with growers, we will send 6 month follow up surveys to all workshop attendees to evaluate changes in amendment use patterns and knowledge. We will report the degree of change in behavior and knowledge within our 2018 annual report.

Once our results have been presented through public presentation, we will focus on the production of printed and digital material to enhance CDFA and FREP Certified Nutrient Manager training resources (2019). Dissemination of research results will be through the UCD Solution Center for Nutrient Management website in order to update present information on nitrogen from organic sources. Additional web based outreach will also include updating the CDFA Nutrient Management Guideline website. Currently, nutrient recommendations are limited to non-organic fertilizers. Daniel Geisseler, a former postdoctoral fellow of Prof. Horwath built this site and is now in charge of this site in his new permanent position at UCD and will help update the webpage with new information from this project.

During this final phase we will present at the California Plant and Soil Conference and will submit an article to the Conference Proceedings. We will also write articles for the Agriculture and Natural Resources (ANR) Extension Bulletin and trade news outlets like the California Farmer. At the end of the project we will submit at least one article for publication in a scientific journal.

G. Budget Narrative
Category A. Personnel Expenses
Funds are requested for a 25% Graduate Student Researcher (GSR) ($46,981 full year; with $148 benefits @ 1.3% benefit rate) for year one and 3 and 50% for year 2. The GSR amount represents support for two total years. An undergraduate student assistant(s) to assist the GSR in both lab and field work is requested
at 20% time for year one and 2 and 10% in year 3 ($21924 full year; with $60 benefits @ 1.3% benefit rate). The GSR will with the help of the undergraduate student assistant(s) will perform lab incubations on the certified nutrient content organic fertilizer materials at different temperatures to develop decomposition rate kinetics to characterize the fertilizer materials and to provide decomposition rate constants to be used in the DayCent modeling. The Assistant Research faculty at 10% in years 1 and 2 and 8% in year 3 [$69900 full year; $2824 benefits (38.1% benefit rate)] and Project Scientist at 10% in years 1 and 15% in years 2 and 3 [$59900 full year; $2420 benefits (38.1% benefit rate)] will provide support to the PI William R. Horwath in supervising and mentoring the GSR and undergraduate student assistant(s). The Assistant Research faculty and Project Scientist will parameterize the DayCent model to predict N mineralization of the different organic fertilizer sources and incorporate them into the COMET Farm framework for climate change mitigation opportunities for reduction of greenhouse gases. Salaries are escalated 3% annually to account for inflation and promotion. The total requested for salaries and benefits is $125142.

Category B. Operating Expenses including travel
Chemical reagents (analytical determination of ammonium, nitrate total C and total N), lab grade gases (standards for carbon dioxide and nitrous oxide determinations and carrier gases including dinitrogen and helium and argon), lab supplies (cuvettes for colorimetric determinations of inorganic nitrogen, incubation containers, septum and syringes for gas sampling, labels, permanent markers, notebooks, etc.), personnel protective equipment (gloves, masks, etc.) and waste disposal fees are requested at $4500 for years 1 and 2 and $1000 in year 3 for a total of $10000. Travel at $350 for years 1 and 2 is requested to obtain fertilizer materials and attend FRPE Conferences. The travel in year 3 includes the same as years 1 and 2 and additional funds to visit the field trial for setup and harvest in year 3. Total travel request is $1,400.

In years 2 and 3, outreach and engagement activities begins through efforts led by Maria de la Fuente, University of California Cooperative Extension, Monterey County, Director. We envision field days and workshops on understanding and estimating the N mineralization value and credits of organic fertilizers. The budget for outreach activities is $4000 in year 2 and $8000 in year 3 for a total of $12000. In years two and 3, field trials will begin to test the decomposition rate constants and nitrogen mineralization values developed with lab incubations and refined in the DayCent modeling effort. In year 2, a subset of materials will be tests and in year 3 additional materials will be tested to validate the N mineralization value and credits of organic fertilizers tested.

Other expenses: Tuition and Fees: $29,094
As part of the employment of a Graduate Student Researcher, funds totaling $43,675 are requested to provide tuition and support with residency status. Utilizing Academic Year 2015/2016 rates as the base, costs assume a 10% increase in each subsequent academic/fiscal year beginning in 2016/2017. The final tuition and fee costs factor in a 25% credit reduction in relation to a program funded by the Provost Office.

Other funding sources
Dr. Horwath will contribute $8,544 annually in in-kind salary contribution for a total of $25, 632.

Total request $224,771
Total Budget $250,403