Integrating Remote Sensing and Modeling to Assess Temporal and Spatial Variability of Greenhouse Gas Emissions

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Objectives

Agriculture has been a major source of CO_2 and N_2O to the atmosphere. Although agricultural soil management is advocated as a viable option to reduce greenhouse gas (GHG) emissions, comprehensive assessments of GHG across multiple spatial and temporal scales have been challenging. The main objective was to use a timed series of remotely sensed plant biomass and soil moisture data as validation for a crop growth and soil water module of the ecosystem model. We seek to integrate remotely sensed measurements across spatial and temporal scales in order to reveal crop growth and production dynamics, enhancing accuracy in assessment of GHG emissions.

Approach and Procedures

The objective is met by combining remotely sensed data with field information and modeling results to estimate the potential for CO_2 and N_2O emission at the plot, field, county and, eventually, the regional scale. Carbon assimilation from the atmosphere through plant productivity is a major carbon pathway into terrestrial systems. We combine images from NASA's Earth Observing System (MODIS and ASTER satellites) to monitor crops grown on specific parcels in Yolo County in order to integrate remote sensing and modeling in agroecosystems. We are evaluating the relationships between vegetation indices and ground-measured biomass, including farm management calendar events. We quantify regional net primary production based on the satellite data in order to optimize crop parameters and then run the regional model with the optimized parameters. We are assessing how the new approach improves the scaling up from field to regional estimates of GHG emissions and are producing sensitivity analyses across multiple spatial and temporal scales.

Results

We acquired and analyzed satellite data centered on Yolo County for the period 2000-2007. A total of 2,626 MODIS images are now available showing daily Normalized Difference Vegetation index (NDVI), whereas 271 ASTER images are available for higher resolution work on biomass and moisture characterization. Our new approach produces a decision support system that can predict GHG emissions with greater accuracy at multiple scales. Estimates of GHG through modeling at regional scales are currently available (DeGryze and Six 2006). We are improving on these estimates by incorporating the spatially and temporally explicit satellite data. For example, in a field under Alfalfa, NDVI tracked greenness of the crop and reflected when cutting's occurred (*fig. 1*). The profiles of NDVI over time represent phenological developments

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in given fields and are therefore being used to identify planting dates and harvesting dates for annual crops. More accurate input dates for planting and harvesting during greenhouse gas modeling are extracted from sudden increases or decreases in otherwise smooth profiles of cloud-free NDVI imagery.

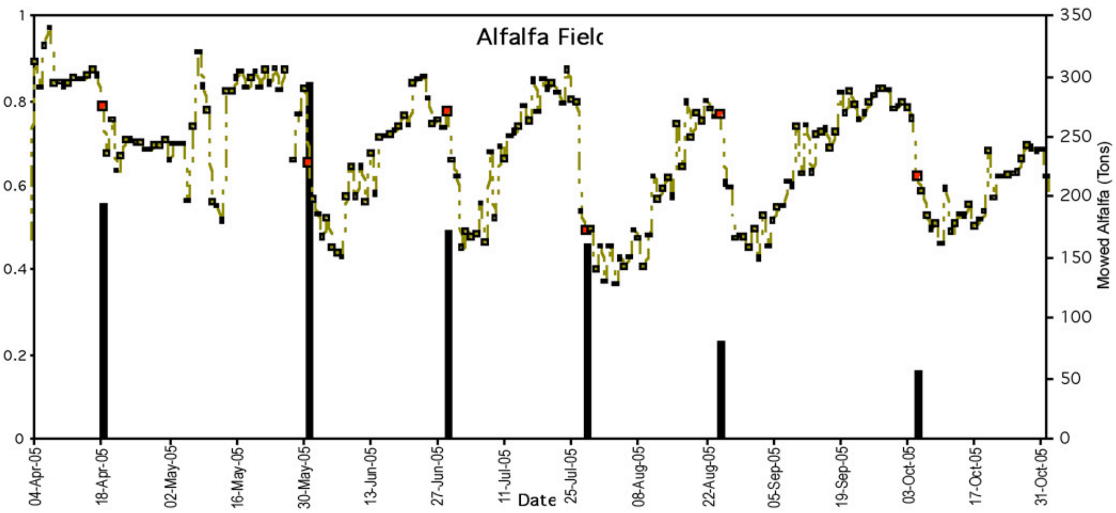


Figure 1. NDVI profile at an alfalfa field in Yolo County. Hay-cutting dates are are highlighted in red while the amount harvested is shown in the second Y-axis as black bars. A drop in NDVI values on the days that hay was harvested shows that sudden drops in cloud-free NDVI data are reliable indicators of actual harvest dates for annual crops.

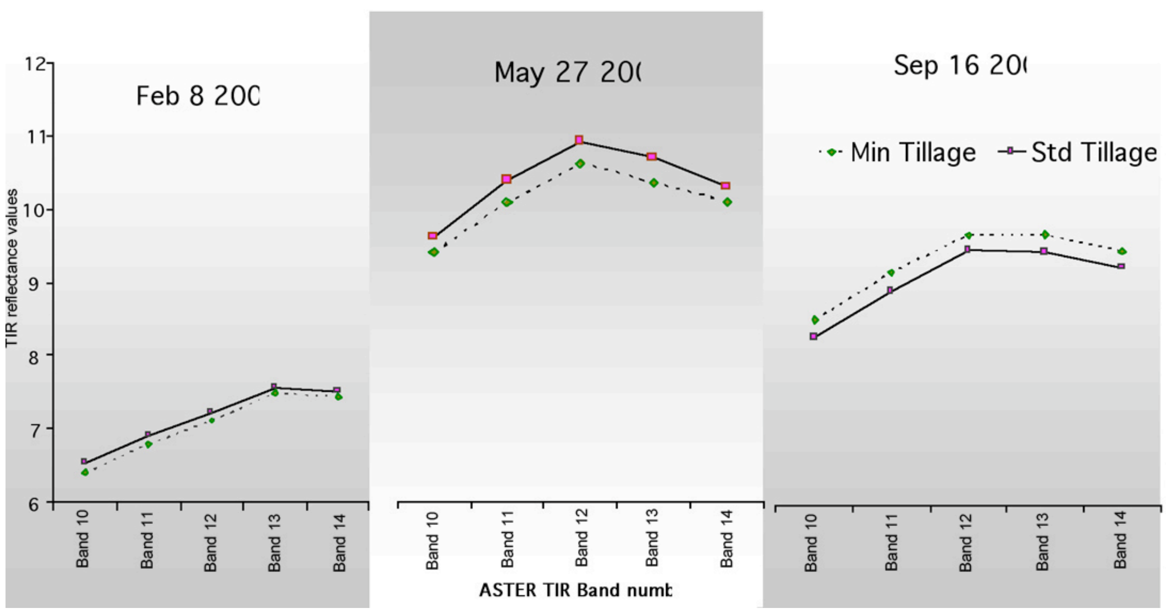


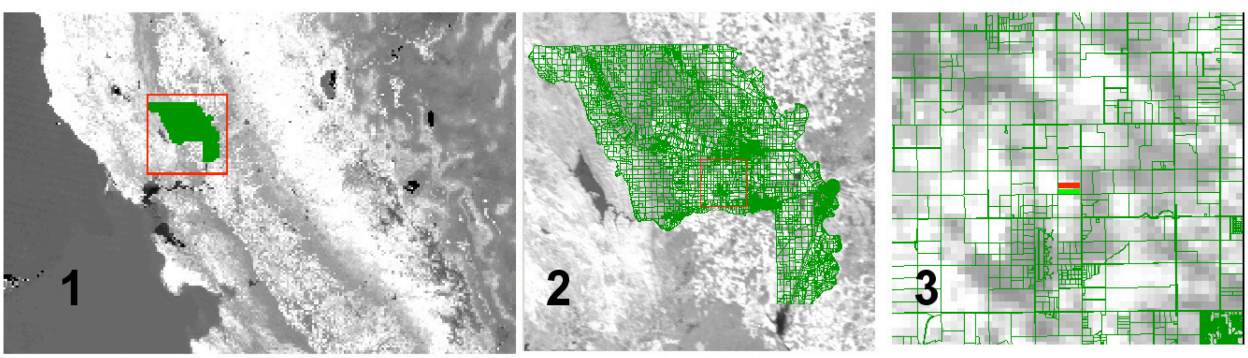
Figure 2. Thermal reflectance values for two adjacent fields in Yolo County that reflect unique temperature/moisture conditions for standard versus minimum tillage during three dates in 2005.

Moisture conditions in the field are typically modeled based on soil properties and rainfall data. We will validate model soil moisture estimates using ASTER thermal data, which are closely linked to soil moisture content (French et al. 2005). Two adjacent fields in Yolo County – one under minimum tillage and the other under conventional tillage – revealed unique trends that reflect moisture status for those fields (*fig. 2*).

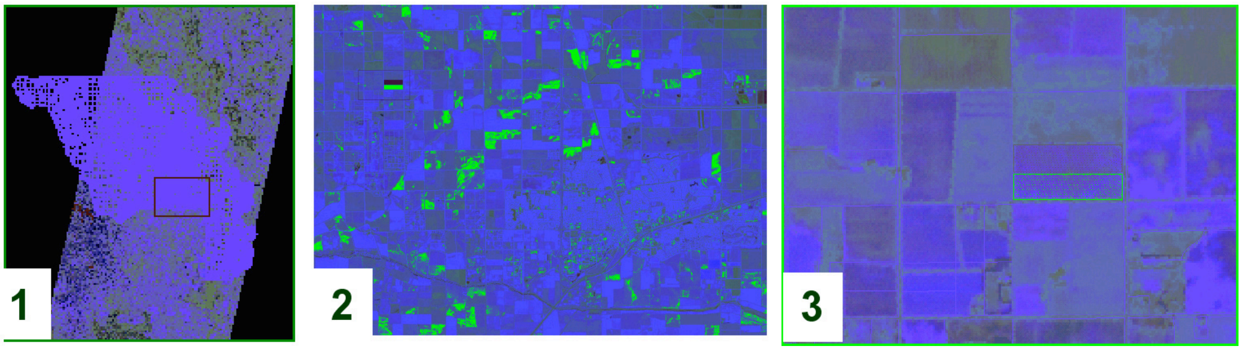
Discussion

Results from this work provides temporal and spatial details of crop growth in Yolo County that is improving greenhouse gas modeling. Previous studies have relied on several general county-wide parameters like planting dates or harvesting dates, and these can now be field specific as determined from satellite data. Moisture status of specific fields for only a few dates in the year will also be an important validation tool to counter check modeled moisture status for particular fields. Improved estimation of greenhouse gas emission from agricultural systems at the landscape level is an important goal in the Kearney 2006-2011 mission, and we are combining field, GIS and satellite data to better model emissions from agroecosystems. We expected to use satellite data to classify particular crop rotations for the entire Yolo County, but this was not feasible because unique crop signatures were difficult to isolate due to interannual variation in phenological development and highly variant management regimes even for the same farm. However annual and perennial crops could be isolated and rice fields were also easily determined specifically due to the flooded stage of growth, which results in unique water-induced low reflectance values. We expect to determine vineyard production dynamics, but the large open spaces present between vine rows will complicate interpretation of vegetation indices when entire fields are being analyzed. This is a problem too in young orchards (walnut and almond) which do not have closed canopies.

Below: Snapshots of MODIS data showing NDVI values across the study are of Yolo County with consecutive zoom-in to two fields under minimum and standard tillage. A total of 2,626 such images are used for analysis.



Snapshots of ASTER data across the study area of Yolo County with consecutive zoom-in (1,2,3) to two fields under minimum and standard tillage. A total of 271 such images are used for analysis.



References

De Gryze S. and J. Six. 2006. Assessing the potential for greenhouse gas mitigation in Californian soils, Conference Proceedings for the International Conference on The Future of Agriculture: Science, Stewardship, and Sustainability. Sacramento, CA. 08/07/2006 – 08/09/2006.

French, A.N., F. Jacob, M.C. Anderson, W.P. Kustas, W. Timmermans, A. Gieske, Z. Su, H. Su, M.F. McCabe, F. Li, J. Prueger and N. Brunsell. 2005. Surface energy fluxes with the Advanced Spaceborne Thermal Emission and Reflection radiometer (ASTER) at the Iowa 2002 SMACEX site (USA). *Remote Sensing of Environment* 99:55-65.

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