DRAFT TECHNICAL PROPOSAL

Tracking Land Use Changes

That Support Sustainable Communities

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February 27, 2015

Check if applicable:

Animal subjects _____

Human subjects _____

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1. Abstract

The Sustainable Communities and Climate Protection Act of 2008 (SB 375) acknowledges that land use planning can attenuate automobile reliance. Research suggests that compact, center-focused land use, and development locating jobs and housing closer together can help people to make fewer, shorter auto trips and use non-auto modes more. Under SB375, each metropolitan planning organization's (MPO) 4-year transportation plan must include a "Sustainable Communities Strategy" (SCS), outlining measures the region will take to achieve it targeted GHG reductions. Critically, a region's SCS is expected to include infrastructure investments *and land use policies* that together would reduce the amount Californians drive and, thus, reduce transportation-related greenhouse gas (GHG) emissions.

The development of statewide land use tracking over time is of key interest to the ARB, both in its duties as technical reviewer of SCSs and its efforts to support SB375 implementation. Hence, the objective of this study is to develop a methodology, collect data, and construct baseline measures for assessing land use change in California over time. The study will serve ARB in two key dimensions, by

- supporting ARB's own evaluation of regional and local progress toward the goals of SB375; and
- enhancing the support ARB can lend to regional and local SB375 implementation efforts.

This uniquely qualified University of California-Davis research team – drawing experts in land use, transportation, and conservation planning, ecology, spatial analytics, urban growth modeling, GIS-applications and remote sensing applications – will deliver proven project management (Task 1) and five substantive tasks (Tasks 2-6) to complete this study.

Task 1	Refine the project scope with ARB Staff and provide ongoing project management.
Task 2	Research and document existing activities to monitor land use in California.
Task 3	Evaluate potential data sources to support ongoing monitoring of land use and land use planning.
Task 4	Develop quantitative indicators of land use and development. Construct baseline measures thereof.
Task 5	Assess data sources and develop indicators to track regional and local land use planning over time.
Task 6	Produce report documenting and interpreting indicators developed, and recommending next steps.

Task 2 will first research and document what other SB375-interested organizations in California (foremost, the state's MPOs) are already monitoring land use changes individually and how they are doing so. Task 3 will identify and evaluate data sources (e.g. GIS-based, imagery, Census-based, planning documents and surveys) for potential deployment in an ongoing monitoring program. Candidate data sources will be considered in light of two lines of inquiry: (a) one asks whether and how development patterns across the State are changing, and (b) the other examines the role of planning – evidenced in land use plans, zoning, and development policies – in producing observed land use change. Tasks 4 and 5 will deploy selected data sources and appropriate analytical methods in the construction of baseline measures and indicators for ongoing tracking, addressing these two dimensions of inquiry. Task 6 will deliver a final study report that describes, documents, and discusses the construction of baseline measures and indicators for ongoing assessment of both on-the-ground changes in land use and of local planning and policy change. The report will consider necessary steps for routinizing the monitoring effort, in a program of ongoing tracking that can inform ARB efforts to support SB375 implementation and assess progress toward realization of SB375 goals.

2. Introduction

SB375 Makes Land Use a Strategy for Reducing Greenhouse Gases (GHGs). Under the Sustainable Communities and Climate Protection Act of 2008 (SB 375), California's metropolitan planning organizations (MPOs) – and their member local governments – play a key role in the state's AB32-driven efforts to reduce GHG emissions. MPOs are regional planning bodies composed of local mayors, county commissioners, and state and local transportation agency representatives. They craft the long range plans and near term transportation investments in metro areas. Under SB375, each MPO's 4-year transportation plan must include a "Sustainable Communities Strategy" (SCS), outlining measures the region will take to achieve it targeted GHG reductions.

Critically, a region's SCS is expected to include infrastructure investments *and land use policies* that together would reduce the amount Californians drive and, thus, reduce transportation-related greenhouse gas (GHG) emissions. Through its SCS requirement, SB 375 acknowledges that land use planning can attenuate automobile reliance. Research suggests that compact, center-focused land use, and development locating jobs and housing closer together can help people to make fewer, shorter auto trips and use non-auto modes more (Ewing and Cervero, 2001, 2012; National Research Council, 2009). Although SB375 asks MPOs to better integrate planning for land use, transportation, and housing, MPOs have traditionally addressed land use only by reflecting regional growth forecasts in their long range plans. Further, their SCSs notwithstanding, MPOs have no land use authority. Instead, cities and counties decide where and how development occurs and whether it might reduce – or perpetuate – automobile reliance in California communities. SB 375 affirms this local control over land use.

Gauging Progress toward GHG Reduction Requires Statewide Land Use Tracking. Given SB375's reliance on voluntary local government compliance with regional GHG-reducing land use visions in the SCS, it is essential to understand how land use is changing.

Physical development patterns of cities and regions evolve slowly, in response to evolving policies and plans. Change can take years to reveal itself, particularly when residential and commercial development markets are tepid. Hence, understanding the pace and nature of changes involves two kinds of inquiry. One line of inquiry must examine whether and how development patterns across the State are changing. Are city and county planning, zoning, and development decisions in fact producing the on-the-ground changes that SB375 anticipates, and supporting reduced auto use? A second line of inquiry must explore change in regional and local planning – evidenced in land use plans, zoning ordinances, and development policies – and its role in producing observed land use changes. To understand changing development over time, the ARB must ask these two questions at regular intervals within a well-considered, longitudinal monitoring effort.

Accordingly, the state's recent Climate Change Scoping Plan Update recommends that ongoing steps be taken to "ensure GHG emission reductions from approved SCS are achieved or exceeded through coordinated planning" (Air Resources Board, 2014, p. 96). Including ARB and state lawmakers, many have an interest in tracking land use change in the California. Individual MPOs will monitor such change for future SCS development, for instance, and the Strategic Growth Council needs such information to support GHG-reducing land development in its own grants to local government. The Department of

Housing and Community Development, the Strategic Growth Council, and other stakeholders in and beyond government have a stake in tracking change in land development and urbanization trends. Yet, a framework for ongoing, statewide land use tracking has been neither developed nor implemented.

This UC Davis Research Team Will Develop a Robust Framework for Ongoing Land Use Monitoring. This research proposal addresses this gap. It would develop methods and identify and collect appropriate data for constructing baseline measures of land use statewide and for monitoring land use progress on SB375 in an ongoing fashion.

Urban geographers, land use and city planners, and ecologists and conservationists have long been interested in analyzing patterns of urbanization and land use succession. Table 1 provides a brief summary of this literature, highlighting the variety of data and methods employed in existing work.

While considerable existing research seeks either to assess or to forecast change in land use and development, almost none has analyzed such change both on a statewide basis and with sufficient directness, granularity, and consistency to assess on-the-ground changes that could impact driving patterns, and ultimately GHG-production. Many studies in the "smart growth" literature, for instance, have examined whether and how various policy levers impact land development patterns, using proxy variables (e.g. population density in urbanized areas) rather than more direct indicators (e.g. location and type of new units; zoning changes) to measure land use change. Increasingly, recent studies examine land use change using GIS-based analysis, enhanced by spatial metrics and satellite imagery. Such approaches hold promise but have not yet been exploited for the regular monitoring of land use change in California. For evaluating local land use planning and its potential to shape smart growth, existing work has used more qualitative approaches to assess the character of local comprehensive plans, zoning ordinances, and their potential for furthering efficient use of land resources. Such studies are typically restricted to small samples of cities rather than geared to statewide assessment.

Many approaches in the established literature are of interest to this study. Indeed, there is no shortage of data, qualitative and quantitative, that could shed light on how land development patterns have evolved, are evolving, or may evolve in the future. The aim of the research team is, in close consultation with the ARB, to select those data sources and methods that would most directly, robustly, and consistently provide for ongoing tracking of land use change in California in the SB375 context.

Table 1. Overview (Selected Studies): Assessing Change in (A) Land Use & Urbanization and (B) Local Land Use Planning

(A) Change in Land Use and Urbanization Patterns			
Date	**Authors**	**Data / Variables Used to Measure Change**	**Methods**
2011	Aguilera et al	Exisiting aerial orthophotographs used to generate and digitize a map of urban land uses (four levels: high- and low-density residential, commercial, industrial) based on visual interpretation. Metropolitan scale study.	Spatial modeling of future development scenarios using tiered development probabilities and assumptions.
2009	Gennaio, et al	Four Swiss municipalities (1970–2000). Developed land (topographic maps; land use layers); number of buildings; building density in and out of designated building zones.	GIS-based analysis of change in land use maps and new buildings in and out of zone boundaries.
2009	Thompson & Propoky	Rates of farmland conversion in Illinois & Indiana (1992, 2002), comparing spatial data sources (USGS EROS, NASS) against USDA data (Natural Resources Inventory, & Census of Agriculture).	GIS-based spatial analysis, using Census population and new housing units as validity measures.
2004	Kun	Portland metro area (1980-2000): Urbanized population; size & density of urbanized land area; central city employment; urbanized area housing units; auto users; transit users; commute time.	Longitudinal analysis of census-based proxy variables & comparison to other metros.
2001	Fulton et al	Study of U.S. metro areas (1982-1987): Land consumed [USDA Natural Resources Inventory] vs. population change; Population density	Longitudinal analysis of rates of land consumption & population growth.
1992	Landis	7 Calif. case study cities with growth controls & 7 control cities (1970 – 1989): population growth and growth rates; city share of regional population growth; new housing units; county housing unit growth vs. (assumed) job growth.	Longitudinal analysis of changes in urban population, employment, and new housing starts.
1978	Alterman & Hill	Grid-based mapping overlays to quantify actual land use alignment with and deviation from land use plans.	Regression analysis of effect of political & other factors on plan implementation.
1969	Bourne	Census tract based: number of properties undergoing new construction, land area, land use type (14 considered); longitudinal data (1952 and 1962).	Spatial allocation and land use conversion modeling.
(B) **Change in Land Use Policy and Planning**			
Date	**Authors**	**Data / Variables Used to Measure Change**	**Methods**
2013	Ali	State and county regulations and plans; Interviews with county planners.	Qualitative analysis; content analysis
2007	Edwards & Haines	Comprehensive plans of cities and towns: plan goals & policies; Interviews with planning staff.	Qualitative analysis; content analysis
2003	Talen & Knapp	Zoning ordinances and subdivision regulations screened for prescriptive and proscriptive smart growth policies. Sample=42% of cities and 59% of counties in Illinois.	Cross-sectional analysis of sample cities; Qualitative analysis employing scoring rubric.
1998	Weitz & Moore	3 Oregon cities in UGBs (1990-1995): amount of land & number of housing units; tax assessor data	Case-based analysis of UGB impacts on building growth.

Research Team Member Qualifications and Recent and Ongoing Work Relate Directly to this Study. The project team is uniquely qualified to conduct research on this topic. Researchers bring direct and in-depth expertise with the questions, data sources, and analytical methods under consideration, from quantitative Census-based data to spatial data and remote sensing applications to assessment of local planning documents and regulations.

Table 3. Research Team

ROLE	PERSONNEL	EXPERTISE
P.I.	**Dr. Gian-Claudia Sciara, AICP** Professional Researcher Institute of Transportation Studies Urban Land Use & Transportation Center University of California, Davis	• Land use & transportation planning • Urban planning and policy analysis • Metropolitan Planning Organizations • SB375 implementation
Co-P.I.	**Dr. James H. Thorne** Research Scientist Information Center for the Environment Dept. of Environmental Science & Policy University of California, Davis	• GIS-modeling & data coordination • Spatial assessment of urban growth • Landscape ecology • Data-analytics for studying climate change, biogeography, & conservation
Project Advisor (unfunded)	**Dr. Susan Ustin** Professor, Environmental Resource Science Director, Center for Spatial Technologies and Remote Sensing (CSTARS) Department of Land, Air, and Water Resources University of California, Davis	• Remote sensing in landscape analysis • Land use change and its relationship to ecosystem processes & structure • Geospatial data in environmental applications • Acquisition, analysis & interpretation of remotely sensed data
GIS Analyst, Programmer	**Ryan Boynton** GIS-Programmer Information Center for the Environment Dept. of Environmental Science & Policy University of California, Davis	• GIS-modeling & analysis • Spatial data decision support systems for land management • Urban growth & transportation modeling • Habitat conservation and restoration

Project Examples. Team members have engaged in numerous efforts to characterize land use, land cover, and land use planning, as well as change therein over time. Relevant work of key personnel are highlighted here.

a. Local Government General Plans in Post-SB375 California (Hewlett Foundation). P.I.: G.C. Sciara. This cross-sectional study of policies and implementation steps in General Plans assessed whether cities are incorporating SB375 principles into land use planning. It applied established protocols for General Plan assessment to review the plans' land use, transportation, and housing elements for a stratified sample of California cities. The work provides both a first measure of local planning since SB375's passage and a baseline against to assess future planning progress. http://policyinstitute.ucdavis.edu/files/Sciara_SB375-Forum_Session4.pdf

b. MPO-driven Smart Growth Programs (Hewlett Foundation). P.I.: Gian-Claudia Sciara
Four longstanding MPO-driven smart growth grant programs were analyzed to understand how regional funding incentives could shape local land use decisions. Programs in the Sacramento, San Diego, San Francisco Bay, and Southern California metro regions supported local capital and planning projects serving smart growth objectives even before SB 375 was passed. The study found the programs most commonly funded projects furthering compact development; transit-, walk- and bike-friendly communities; jobs-housing balance; vibrant downtowns; and mixed-use centers. Also, funding was more available for capital investment than for needed foundational planning work.

c. Statewide Advance Mitigation Funding and Finance Strategies (Caltrans). P.I.: Gian-Claudia Sciara.
This 3-part study examined how to support early, comprehensive environmental mitigation planning in Caltrans' project development and funding structures. A key focus was to examine potential intersection points between transportation project planning and regional and local land use planning for conservation and open space, via such tools as Habitat Conservation Plans and local-sales tax funded conservation purchases in Environmental Mitigation Plans.
http://www.its.ucdavis.edu/research/publications/publication-detail/?pub_id=2420
http://www.its.ucdavis.edu/research/publications/publication-detail/?pub_id=2421
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d. Regional Advance Mitigation Planning (RAMP; Caltrans; Dept. Water Resources). P.I.: Jim Thorne.
With funding from county-to-national levels, including from the National Academy of Sciences, Thorne initiated a decade-long effort to assess impacts of land use on natural systems and to identify sustainable processes for human-environment interactions. This program uses GIS-analysis to incorporate regional planning principles into infrastructure development and urban growth plans, and models for scenario assessment. The program has led to widespread adoption of more efficient environmental mitigation planning in California, including a new RAMP coordinator at the Strategic Growth Council, and advances in the California Department of Transportation.

e. Mapping California's Urban Forest and Ecosystem Services (US Forest Service; California Department of Fire and Resource Assessment Program). P.I.: Jim Thorne.
Thorne led this US Forest Service funded project using aerial imagery and GIS to map tree canopies across California urban areas and to calculate their environmental benefits.

f. Climate Change Vulnerability Assessments for California. P.I.: Jim Thorne.
As PI and landscape ecologist, Thorne leads this multi-disciplinary effort to project climate vulnerability in California across multiple sectors: agriculture, water availability, fire, and biodiversity. Thorne's group has produced GIS-based historic and future climates, landscape hydrology models, urban growth models, and a dynamic vegetation model (for the California Energy Commission), and is currently developing vulnerability assessments for vegetation groups and selected mammal species for the California Department of Fish and Wildlife. The work develops six urban growth models for all of California, projected to 2050, and representing six policy scenarios.

g. California Climate Change Vulnerability Assessments (Calif. Energy Commission; CA Dept. Fish and Wildlife). P.I.: Jim Thorne.
Thorne leads this multi-disciplinary effort to spatially project climate vulnerability in California across multiple sectors including: agriculture, water availability, fire, and biodiversity. The study has produced GIS-based downscaled historic and future climates, landscape hydrology models, urban growth models, and a dynamic vegetation model, and is currently developing vulnerability assessments for vegetation groups and selected mammal species. It further developed six urban growth models for all of California, projected to 2050, and representing six policy scenarios.

h. Strategic Highway Research Program (SHRP2B; National Academy of Sciences). P.I.: Jim Thorne.
Thorne led this recent project to contribute to development of a national, GIS-based web portal for environmental impact scoping of transportation projects. The study used GIS to assess impacts from all programmed transportation projects on Highway 101 in Santa Barbara and Mendocino. Thorne's group worked with national web-based tool developers (ICF) on testing and spatial datasets.

i. San Joaquin Valley Greenprint (Fresno COG; CA Dept. of Conservation). P.I.: J. Thorne.
This project developed a regional open space and sustainability design for eight counties in the San Joaquin Valley. The project was conducted under the auspices of a coalition of 8 county governments and over 60 city governments. A special focus was to incorporate agricultural interests into consideration of important open spaces for preservation.

j. Using satellite imagery for daily reference of evapotranspiration for California. Lab: S. Ustin
This study developed a protocol for making daily statewide estimates of ETo (reference ET) for the Dept. Water Resources CIMIS program. The methodology to connect near-real time data and produce operational products is relevant.

k. Using Remote Sensing to Identify Invasive Vegetation in the California Delta Ecosystem. Lab: S.L.
This study (for the CA Dept. of Boating and Waterways) provided maps of invasive aquatic species and communities in the Sacramento San Joaquin Delta, from high spatial resolution hyperspectral imagery collected over the legal delta. This work demonstrates how to process airborne and satellite data to quantify change detection and characterize conditions.

3. Objectives

The measurement and monitoring of land use and development patterns across the state has become an important research topic for the California Air Resources Board. In the policy environment established by SB 375, new approaches to land use are expected to help the state's metro regions achieve their respective targets for per capita GHG reductions by 2020 and beyond. The law is explicit that "changed land use patterns and improved transportation" will be necessary for "achieving greenhouse gas reductions, and that "[w]ithout improved land use and transportation policy, California will not be able to achieve the goals of AB 32" (SB 375, Sec. 1(c)). The law asks MPOs in their SCS to "set forth a forecasted development pattern for the region, which, when integrated with the transportation network...will reduce the greenhouse gas emissions" from cars and light trucks.

The development of statewide land use tracking over time is of key interest to the ARB, both in its duties as technical reviewer of regional SCSs and its efforts to support the state's regional agencies and local governments in SB375 implementation.

The objective of this study is to develop a methodology, collect data, and construct baseline measures for assessing land use change in California over time. The study will serve ARB in two key dimensions, by

- supporting ARB's own evaluation of regional and local progress toward the goals of SB375; and
- enhancing the support ARB can lend to regional and local SB375 implementation efforts.

Under SB375, the ARB has key responsibilities both for setting regional GHG reduction targets (first completed in 2010 and to be updated for 2035 via a public process being launched in 2015) and for reviewing and assessing whether each SCS, if implemented with the regional transportation plan, would actually achieve that region's GHG reduction targets. To fulfill these responsibilities, the ARB would benefit from new information suggesting the direction and quality of land use change in the state.

The ARB also supports MPOs as they plan to meet their existing targets; regional and local planning to support achievement of the 2020 targets is currently underway, and the ARB has acknowledge the importance of focusing on implementation (ARB, 2014b). The ARB would provide valuable assistance to both regions and local governments by developing a statewide mechanism for land use tracking over time. Baseline land use metrics and periodic reassessments would be important touchstones for regions and local governments as they implement current SCSs and update them for the future, and the state's regions and local governments would value having standardized measures of land use progress reflected back to them. Over time, such monitoring could indicate areas where SCS planning is not having the desired effect and where ARB might assist with additional implementation support. Conversely, such tracking may also reveal areas where development patterns strongly support SB375; in such cases, ARB may play a role facilitating transmission or information and best practices to other regions and local jurisdictions, to improve current SCS implementation and future SCS planning across the state.

4. Technical Plan

The research team will undertake five major tasks to complete this study. An overview of these tasks is provided below, followed by detailed discussion of the research activities to be addressed in each.

Table 3. Project Overview

Task 1	**Refine the project scope with ARB Staff** and provide **ongoing project management** during the course of the study.
Task 2	**Research and document existing activities to monitor land use** in California that may be underway by Metropolitan Planning Organizations and related stakeholder organizations.
Task 3	**Evaluate broad potential data sources to support ongoing monitoring** in California of (a) on-the-ground change in land use and urbanization patterns and (b) shifts in regional and local planning that would shape such on-the-ground change.
Task 4	Using the best data, **develop quantitative indicators of land use and development** that can be used to assess change over time. **Construct baseline measures** for these indicators.
Task 5	**Assess data sources to track regional and local land use planning** over time, quantitatively and qualitatively. **Develop indicators to characterize local planning** and, potentially, its impact on actual land use change.
Task 6	**Finalize report describing and documenting construction of the indicators** developed and baseline measures of each. **Identify and recommend next steps.**

TASK 1: ENGAGE WITH ARB STAFF TO DISCUSS PROJECT SCOPE AND PROVIDE ONGOING PROJECT MANAGEMENT.

During the project's start-up phase, P.I. Gian-Claudia Sciara and Research Team will work with ARB Staff to refine the project scope and tasks. Preliminary discussions to initiate the project will allow ARB Staff and the UCD Research Team to articulate agreed upon project objectives, goals, tasks, and schedule.

P.I. and appropriate team members will engage ARB in quarterly phone conferences to present and discuss overall study progress, the status of project tasks, and next steps. The UCD P.I. is available for additional discussions throughout the project. Quarterly progress report will provide a written summary of project activities to date and upcoming project tasks.

The P.I. and co-P.I. will serve as lead investigators and managers within the UCD Research Team and will convene the group regularly to share information and updates, to discuss overall data and analytical choices, and to plan future tasks.

TASK 2: RESEARCH AND DOCUMENT EXISTING ACTIVITIES TO MONITOR LAND USE CHANGE OVER TIME BY MPOS AND OTHER ORGANIZATIONS.

This study will first research and document what other SB375-interested organizations in California are already monitoring land use changes individually and how they are doing so.
Foremost, the state's MPOs have a clear interest in monitoring various land use indicators in their region. Where and how MPOs are already doing this? By documenting such existing activities, the Team will ensure, to the greatest extent possible, that any framework for statewide monitoring resulting from this study reflects and capitalizes on MPOs' existing work and experiences.

Through telephone interviews with key staff (i.e. MPO Planning Director and/or designated staff) at each MPO and reviews of the MPO's web-site, the research team would research and document:

- indicators being used to study land use change over time;
- data and methods used to support those indicators; and
- strengths and limitations of such indicators, as perceived by MPO staff and others.

Second, in consultation with ARB, the Research Team may identify additional organizations as appropriate that may track dimensions of land use change in California. What indicators and data do they use? Such additional entities and their relevance to this study may include:

- Department of Housing and Community Development - Meeting regional affordable housing needs is an important aspect of the SCS. The "Annual Housing Element Progress Report" that each city submits to HCD may yield longitudinal data for tracking housing provision.
- Strategic Growth Council (SGC) - With Prop. 84 funds and Cap-and-Trade revenues, SGC funds Sustainable Communities Planning and Urban Greening Grants to support sustainable growth and SB375 implementation. The criteria or vetting data SGC applies for making awards are of interest.
- Association of Bay Area Governments (ABAG) – The process, data, and spatial criteria used for ABAG's selection of Bay Area "Priority Development Areas" are of interest to this work.

TASK 3: IDENTIFY AND ASSESS DATA SOURCES FOR POTENTIAL TO SUPPORT MONITORING ON-THE-GROUND LAND USE, URBANIZATION, & PLANNING CHANGE OVER TIME.

Questions to Guide Identification of Candidate Data. In this task, the Research Team will identify and evaluate data sources for potential deployment in an ongoing monitoring program. Candidate data sources – enumerated later in this section – will be considered in light of three main questions:

1. First, what is the best way to develop a baseline measures against which current and future land use change may be measured within the SB375 context?
2. Second, using that measure or set of measures, how can data be marshalled to assess whether land use is changing in ways that support SB375 goals, SCS implementation, and GHG reduction targets?
3. Third, what data can illuminate the level of local policy adoption and implementation supporting SB 375? Where helpful or harmful land use trends are evident, it is critical to understand why.

The quantitative evaluation of land use planning outcomes has long occupied planning researchers. While for many years, a chief stumbling block was "difficulty in obtaining appropriate data" (Talen 1998), today data sources are better and more plentiful than ever. Indeed, studies of urbanization trends employ a variety of data-driven methods (Gennaio et al 2009.) Further, new technologies open a range of data resources and analytic possibilities, including areal spatial data and remote sensing.

Criteria for Assessing Potential Data. These sources need to be carefully vetted for their capacity to perform in the statewide analysis sought by ARB. It is important to select data that can serve the scale, quality, and consistency of measurement required. Aerial imagery, for instance, opens new avenues for monitoring physical change over time, but such imagery is updated irregularly, complicating longitudinal analysis, and also requires special processing for conversion to quantitative data.

In Task 2, the Research Team will assess data sources against specific criteria, depending on the data in question (e.g. demographic, spatial statistics, GIS-based). Illustrative criteria may include the following:

Data Coverage & Availability

- ✓ Over what time frame are data available? Are historical data available and to what year?
- ✓ Will the data be produced consistently in the future to support ongoing analysis?
- ✓ How frequently are data updated?
- ✓ Are the data available statewide? For all cities and/or all counties?

Data Scale and Resolution

- ✓ Spatial resolution. Are data sufficiently granular to localize land use patterns and assess changes? Are small scale dispersion processes evident?
- ✓ Data scale. Do scale and cell size allow overlaying of datasets without losing information?

Data Accuracy

- ✓ What classification scheme is used to describe categories of land use or land cover?
- ✓ Thematic accuracy. Are land uses or land use intensity classes sufficiently accurate or precise?
- ✓ Spatial accuracy. What level of spatial resolution is needed to measure change?

Other Attributes

- ✓ Data type: numeric, text, ratser, vector, imagery
- ✓ Any known data limitations.
- ✓ Level of recognition – Are the data well known and respected?
- ✓ Analytical resources required to process the data.
- ✓ Acquisition costs, where applicable.

Representative Data Sources Considered for Use in this Study. Both quantitative and qualitative data can serve this effort to develop a framework for ongoing evaluation of progress on SB 375. This work will consider a variety of data for to measuring (a) on-the-ground change in land use and urbanization patterns and (b) advances in local planning to address SB 375 in land use plans, policies, and implementation. The following list illustrates the range of data that may be considered in the study.

Quantitative Data Capturing Land Use & Proxies

Geospatial Products

U.S. Geological Survey - Land Use and Land Cover Classification System Base Maps
California Department of Conservation - Farmland Mapping and Monitoring Program
California Department of Water Resources - Land use maps and aerial photos
Parcel, subdivision, and assessor maps, as available

Aerial Imagery

National Aerial Imagery Project (NAIP) – (aerial photography)
U.S. Geological Survey – Landsat Thematic Mapper (satellite imagery)

Remote Sensing & Spatial Metrics

Digital applications for analysis of aerial photography and satellite imagery

Non-Spatial Confirmatory Data

U.S. Census Data (10 year)
American Community Survey Data (5-8 years).
Building Permit Data (Nat'l Assoc. of Home Builders; U.S. Census; U.S. Dept. of Housing and Urban Development)

Qualitative and Survey Data Characterizing Local Land Use Planning

City and County General Plans – goals, policies, and implementation steps
General Plan Amendments – for land use & zoning changes (via statewide CEQAnet database)
Zoning Codes
City and County "Annual Progress Reports" submitted to HCD (housing units permitted; infill units constructed; building and permitting activity by levels of affordability)
Office of Planning and Research - Annual Planning Survey (in particular, "Section C" results on "Housing, Density, and Infill" questions)

TASK 4: DEVELOP INDICATORS AND BASELINE MEASURES FOR LAND USE CHANGE.

Task 4 builds on the Task 3 review of land use and spatial data sources, such as USGS and state mapping and imaging products, and of confirmatory statistical data available through the U.S. Census and other sources. It also draws on the Task 2 inventory of existing activities (and measures) used by the state's MPOs and other relevant entities to monitor land use change. The objective of Task 4 is to develop quantitative and spatial baseline measures of land use in California, as well as a set of indicators that can be used to assess deviation from this baseline over time.

In constructing such baseline measures, the Research Team will work in consultation with ARB staff on key considerations. For instance, the choice of a baseline year is an important decision. On one hand, it may be desirable to temporally align any land use baselines with the 2005 existing-emissions baseline, against which ARB-adopted regional GHG reduction targets are expressed. On the other hand, data attributes and availability may also strongly influence the baseline determination.

To establish the set of desired indicators, the Research Team will weigh the specific needs and emphases of ARB, existing MPO efforts documented in Task 2, data considerations revealed in Task 3, and evolving land use and urbanization change indicators from the literature. Illustrative measures and indicators developed in this task may include:

- Measures of land use intensity (e.g. lot sizes and land uses)
- Measures of land use change (e.g. lower intensity to higher intensity uses)
- Proportion of non-agricultural development within/outside existing urban footprint
- Measures of contiguity or dispersion of new development
- Measures of farmland conversion
- New housing unit growth & density, by levels of affordability
- Proportion of added housing units in mixed-use zones
- Employment growth & location
- Jobs added in existing urban footprint
- Growth in employment relative to growth in new housing units
- Proportion of commercial square feet added in mixed-use zones
- Population growth rates & density (U.S. Census of Population)

TASK 5: DEVELOP INDICATORS AND MEASURES FOR LAND USE PLANNING AND POLICIES.

Task 5 draws on the Task 3 review of land use planning and policy data sources, including General Plans, plan amendments, and zoning ordinances. The objective of Task 5 is to develop indicators of SB375 progress in underlying planning frameworks over time. Do local land use planning structures and policies propel land development toward more compact or more sprawling, auto-dependent forms?

Existing work in this domain relies largely on mixed-method analysis of General Plans following established plan assessment protocols (Berke & Conroy, 2000; Berke & Godschalk, 2009; Jun & Conroy, 2013). Such analysis typically develops a system for quantitatively scoring how plan goals, policies, and implementation actions qualitatively align with desired smart growth or sustainability principles (Edwards & Haines). P.I. Sciara's study of post-SB375 General Plans examined plans in over 30 California communities and informed the California Legislature's mid-term review of SB375 progress (Sciara 2014). Similar analysis has been used to evaluate zoning ordinances and subdivision regulations (Talen & Knapp, 2003).

Building on existing work, Task 5 aims to develop baseline measures and indicators for ongoing assessment of local land use planning. Such indicators may assess planning process-oriented policies, larger spatial policies, or site-based policies, and may include:

- Adoption/implementation of programs/efforts to increase housing production, by income level.
- Level of policy orientation toward such principles as:
  - ✓ compact, center-focused land development
  - ✓ co-location of jobs and housing
  - ✓ land use mixing
- Presence of policies oriented toward compact growth, for example
  - ✓ cluster zoning
  - ✓ parking reform
  - ✓ infill development
  - ✓ accessory buildings as housing
  - ✓ open-space zoning
  - ✓ agricultural protection or conservation zoning
  - ✓ urban growth boundary or urban service boundary

Because many factors influence land use change in complex ways, this study does not seek to attribute causality to individual policies or programs. However, by distinguishing between the potential contribution to land use outcomes of *planning policies themselves* and *the implementation of those policies*, Task 5 can add analytical rigor to this work (Talen 1998).

If local jurisdictions are adopting SB375-supportive policies, we expect over time to observe positive on-the-ground changes in land use. If supportive policies are in place but land use does not change in the anticipated fashion, greater attention to policy implementation is warranted.

TASK 6: PREPARE DRAFT AND FINAL PROJECT STUDY REPORT.

The Research Team will complete a draft final report for ARB review by month 12 of the study period. The report will reflect the efforts undertaken in Tasks 2 through 5. It will describe, document, and discuss the construction of baseline measures and indicators for ongoing assessment of both on-the-ground changes in land use and of local planning and policy change. Additionally, the report may recommend extensions of the analysis that are of interest to ARB. In particular, the report may include discussion of

- decisions reached during the study about what sources of data to use;
- decisions reached during the study about how to establish baseline measurements;
- methodological approaches and techniques used for the construction of indicators;
- indicators and their meaning;
- baseline results and their interpretation;
- any limitations of study results that are important for analytical and policy interpretation; and
- recommended next steps for routinizing the monitoring effort, in a program of ongoing tracking.

Upon receipt of consolidated comments from ARB during the specified review period, the Team will prepare a final report for ARB approval and distribution. The Final Report will be accompanied by a "tracked changes" document that makes visible how comments and edits from the ARB Staff were addressed in the Final Report.

The Research Team will share the study results with ARB staff in a research seminar in Sacramento.

5. References

Ali, A. K. (2014). Explaining Smart Growth Applications: Lessons from the US Capital Region. Urban Studies, 51(1), 116-135.

Bengston, D.N., Fletcher, J.O., Nelson, K.C., 2004. Public policies for managing urban growth and protecting open space: policy instruments and lessons learned in the United States. Landscape Urban Plan. 69, 271–286.

Berke, P. R., & Conroy, M. M. (2000). Are We Planning for Sustainable Development? An Evaluation of 30 Comprehensive Plans. *Journal of the American Planning Association, 66*(1), 21-33.

Berke, P., & Godschalk, D. (2009). Searching for the Good Plan: A Meta-Analysis of Plan Quality Studies. *Journal of Planning Literature, 23*(3), 227-240.

Bourne, L. S. (1969). A spatial allocation-land use conversion model of urban growth. Journal of Regional Science, 10(2), 261–272.

California Air Resources Board. (2014a). First Update to the Climate Change Scoping Plan: Building on the Framework. Sacramento, CA.

California Air Resources Board. (2014b). Staff Report: SB 375 Greenhouse Gas Emissions Reduction Target Update Process. Sacramento, CA.

Edwards, M. M., & Haines, A. (2007). Evaluating Smart Growth: Implications for Small Communities. *Journal of Planning Education and Research, 27*, 49-64.

Ewing, Reid and Robert Cervero. 2001. Travel and the Built Environment: A Synthesis. Transportation Research Record number 1780: 87-114.

Ewing, Reid and Robert Cervero. 2010. Travel and the Built Environment: A Meta-Analysis. Journal of the American Planning Association,76: 265 – 294.

Fulton, W., Pendall, R., Nguyen, M. & Harrison, A. (2001) Who Sprawls Most? How Growth Patterns Differ Across the US (Washington DC: The Brookings Institution).

Gennaio, M.-P., Hersperger, A. M., & Burgi, M. (2009). Containing urban sprawl: Evaluating effectiveness of urban growth boundaries set by the Swiss Land Use Plan. *Land Use Policy, 26*, 224–232.

Jun, H.-J., & Conroy, M. M. (2013). Comprehensive Planning and Sustainability in Georgia's Exurbs. *Journal of Environmental Policy & Planning*, 1-23.

Kasanko, M., Barredo, J.I., Lavalle, C., 2006. Are European cities becoming dispersed? A comparative analysis of 15 European urban areas. Landscape Urban Plan. 77 (1/2), 111–130.

Landis, J. D. Journal of the American Planning Association. *Do Growth Controls Work?: A New Assessment, 58*(4), 489-508. doi: 10.1080/01944369208975831

National Research Council, Committee on Relationships among Development Patterns, Vehicle Miles Traveled, and Energy Consumption. 2009. Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and CO2 Emissions. Washington, D.C.: National Academies Press

Sciara, G.-C. (2014). Evaluating Progress toward SB375 Implementation: A Long-term View - Invited testimony before the California State Senate, Transportation and Housing Committee for the Hearing on the Sustainable Communities and Climate Protection Act of 2008 (SB 375) on May 13, 2014, Sacramento, CA.

Sciara, G.-C., & Handy, S. L. (2013). Cultivating Cooperation without Control: California's MPO-driven Smart Growth Programs. Davis, CA: Institute of Transportation Studies, University of California.

Talen, E. (1998). Do Plans Get Implemented? Journal of Planning Literature, 10, 248-259.

Talen, E., & Knaap, G. (2003). Legalizing Smart Growth: An Empirical Study of Land Use Regulation in Illinois. Journal of Planning Education and Research, 22, 345-359. doi: 10.1177/0739456X03022004002

Thompson, A., & Propoky, L. (2009). Tracking urban sprawl: Using spatial data to inform farmland preservation policy. *Land Use Policy*, 26, 194-202.

Weitz, Jerry, and Terry Moore. "Development inside urban growth boundaries: Oregon's empirical evidence of contiguous urban form." Journal of the American Planning Association 64.4 (1998): 424-440.

6. Project Schedule

Tracking Land Use Changes That Support Sustainable Communities

Project for the California Air Resources Board

Schedule of Tasks and Deliverables

No.	Project Tasks	Month 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	PROJECT SCOPING AND MANAGEMENT																		
	Contract and Project Scoping																		
	Ongoing Project Management																		
2	RESEARCH & DOCUMENT MONITORING ACTIVITIES																		
3	EVALUATE DATA SOURCES FOR MONITORING FRAMEWORK																		
4	DEVELOP QUANTITATIVE L.U. INDICATORS & BASELINES																		
5	DEVELOP INDICATORS & BASELINES FOR PLANNING																		
6	DEVELOP DRAFT & FINAL PROJECT SUMMARY REPORT																		
	Develop & Submit Draft Final Report																		
	ARB Reviews & Provides Comments; Prep Journal Article																		
	Revise and Submit Final Report																		

Date: Feb. 27, 2015

= Quarterly phone conference = Quarterly progress report = Draft journal article for submission

= Draft final report = Final report & research seminar

7. Preliminary Cost Proposal

Estimated Cost by Task

Task	Labor	Employee Fringe Benefits	Travel	Photocopying/ Printing	Mail, phone, fax	Misc- GAEL	Overhead	Total
1	$6,128	$2,579		$100	$719	$31	$956	$10,513
2	$13,233	$6,407				$67	$1,971	$21,678
3	$22,475	$11,368				$115	$3,396	$37,354
4	$23,118	$11,715				$118	$3,495	$38,446
5	$17,683	$8,304				$90	$2,608	$28,685
6	$7,670	$3,404	$1,000			$39	$1,211	$13,324
	$90,307	$43,777	$1,000	$100	$719	$460	$13,637	$150,000

8. Key Scientific Personnel & Curricula Vitae

ROLE	PERSONNEL	EXPERTISE
P.I.	**Dr. Gian-Claudia Sciara, AICP** Professional Researcher Institute of Transportation Studies Urban Land Use & Transportation Center University of California, Davis	• Land use & transportation planning • Urban planning and policy analysis • Metropolitan Planning Organizations • SB375 implementation
Co-P.I.	**Dr. James H. Thorne** Research Scientist Information Center for the Environment Dept. of Environmental Science & Policy University of California, Davis	• GIS-modeling & data coordination • Spatial assessment of urban growth • Landscape ecology • Data-analytics for studying climate change, biogeography, & conservation
Project Advisor (unfunded)	**Dr. Susan Ustin** Professor, Environmental Resource Science Director, Center for Spatial Technologies and Remote Sensing (CSTARS) Department of Land, Air, and Water Resources University of California, Davis	• Remote sensing in landscape analysis • Land use change and its relationship to ecosystem processes & structure • Geospatial data in environmental applications • Acquisition, analysis & interpretation of remotely sensed data
GIS Analyst, Programmer	**Ryan Boynton** GIS-Programmer Information Center for the Environment Dept. of Environmental Science & Policy University of California, Davis	• GIS-modeling & analysis • Spatial data decision support systems for land management • Urban growth & transportation modeling • Habitat conservation and restoration

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EDUCATION

University of California, Berkeley, PhD, City and Regional Planning (2009)

University of California, Los Angeles, MA, Urban Planning (2000)

Columbia University, BA, Major: History, Major: German Studies, *cum laude* (1993)

ACADEMIC APPOINTMENTS

University of California, Davis

Institute of Transportation Studies
Professional Researcher (2014 – present); Post-Doctoral Researcher (2010 – 2014)

Department of Environmental Science and Policy
Lecturer (Jan. 2013 - present)

Rutgers University, Edward J. Bloustein School of Planning and Public Policy
Visiting Lecturer (2009)

SELECT JOURNAL ARTICLES

7 (refereed) Sciara, G.C., Bjorkman, J., Lederman, J., et al. "Experimentation and Innovation in Advance Mitigation." (forthcoming) ***Transportation Research Record***.

6 (refereed) Salon, D., Murphy, S., & Sciara, G.-C. (2014). Local Climate Action: Motives, Enabling Factors, and Barriers. ***Carbon Management***, 5(1), 67-79. http://dx.doi.org/10.4155/cmt.13.81

5 (refereed) Lovejoy, K., Sciara, G.C., Salon, D., Handy, S. L., & Mokhtarian, P. (2013). "Measuring the Impacts of Local Land Use Policies on Vehicle Miles of Travel: The Case of the First Big Box Store in Davis, California." ***Journal of Transport and Land Use***, *6*(1), 25–39. http://dx.doi.org/10.5198/jtlu.v6i1.336

4 (refereed) Sciara, G.C. (2012). "Planning for Unplanned Pork: The Consequences of Congressional Earmarking for Regional Transportation Planning." ***Journal of the American Planning Association***, 78(3), 239-255. http://dx.doi.org/10.1080/01944363.2012.694269

3 (refereed) Sciara, G.C. "Earmark Pursuit Practices of MPOs and Their Members." ***Transportation Research Record***, 2119 (2009): 58-65 http://trb.metapress.com/content/u16028r40g788h4t/

2 (refereed) Sciara, G.C., and Wachs, M. "Metropolitan Transportation Funding: Prospects, Progress, and Practical Considerations." ***Public Works Management and Policy*** 12, no. 1 (2007): 378-94. http://dx.doi.org/10.1177/1087724X07303987

1 Sciara, G. C. "Making Communities Safe for Bicycles." ***Access*** 22 (2003): 28-32. (Adapted from Report 2) http://www.uctc.net/access/22/Access%2022%20-%2005%20-%20Bicycles%20and%20Communities.pdf

BOOK CHAPTERS

2 Sciara, G.C. and Handy, S.L. "Regional Transportation Planning." (forthcoming) Hanson, S. and G. Giuliano (eds) *The Geography of Urban Transportation*, Fourth Edition, New York: The Guilford Press

1 Sciara, G.C. (2002). U.S. Transportation Responses to NAFTA: A Window on U.S.-Mexico Transport Issues. In L. Fernandez & R. Carson (Eds.), *Both Sides of the Border - Transboundary Environmental Management Issues Facing Mexico and the U.S.* (378-394). Dordrecht, The Netherlands: Kluwer Academic Publishers.

MANUSCRIPTS UNDER REVIEW & WORKING PAPERS

3 Sciara, G.C., and Stryjewski, E., "Saving Money when Saving Species and Habitats: The Costs of Conventional vs. Advance Mitigation Acquisition in Transportation," (under review) *Research in Transportation Economics*.

2 Sciara, G.C. "The 1962 Highway Act: Crossroads for U.S. Metropolitan Transportation Planning." (Manuscript in preparation for submission to the *Journal of the American Planning Association*. Draft available by request.)

1 Sciara, G.C., Lovejoy, K., & Handy, S. L. "Intercept or Internet: Assessing Methods for Measuring Changes in Vehicle Miles of Travel." (Draft available by request.)

SELECT CONFERENCE PRESENTATIONS

8 (refereed) "Experimentation and Innovation in Advance Mitigation." (with J. Bjorkman, J. Lederman, et al.) **Transportation Research Board Annual Meeting**, Jan.12, 2015, Washington, D.C.

7 Cultivating Cooperation without Control: Regional Incentives and Local Policy under SB375. **2014 Meeting of the Association of Metropolitan Planning Organizations**, October 22, 2014, Atlanta, GA.

6 "Planning for Sustainable Communities: Local Progress in California." **New Partners for Smart Growth Conference**. February 15, 2014, Denver, CO.

5 (refereed) "Intercept or Internet: Survey Modes for Measuring Vehicle Miles of Travel." (with K. Lovejoy and S. Handy) **Transportation Research Board Annual Meeting**, Jan.13, 2014, Washington, D.C.

4 (refereed) "Supporting GHG Reduction with Metropolitan Planning and Discretion: Institutional Perspectives on California's SB375." **Transportation Research Board Annual Meeting**, January 14, 2013, Washington, D.C.

3 "Regulations and the Evolving Roles of Metropolitan Planning Organizations." **Transportation Research Board Annual Meeting**, Jan. 16, 2013, Washington, D.C.

2 (refereed) "Analyzing Regional Efforts to Nudge Local Land Use and Infrastructure Decisions toward GHG Reduction." **Association of Collegiate Schools of Planning Annual Conference**, November 4, 2012, Cincinnati, OH.

1 (refereed) "Measuring the Impacts of Local Land Use Policies on Vehicle Miles of Travel: The Case of the First Big Box Store in Davis, California." (with K. Lovejoy, D. Salon, S.L. Handy, & P. Mokhtarian) **Transportation Research Board Annual Meeting**, January 25, 2012, Washington, D.C.

JAMES H. THORNE
Department of Environmental Science and Policy
University of California-Davis
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Phone: 530-752-4389, E-mail: jhthorne@ucdavis.edu

PROFESSIONAL PREPARATION

1985	B.A.	Environmental Studies, University of California, Santa Cruz
1997	M. A.	Geography, University of California, Santa Barbara
2003	Ph.D.	Ecology, University California, Davis
2003-2005		Postdoctoral Center for Applied Biodiversity Studies, Conservation International

APPOINTMENTS

2006-2015	Research Scientist, Information Center for the Environment, Univ. of California, Davis
2005-2015	Adjunct Professor, Geography Graduate Group, U.C. Davis, CA. http://ggg.ucdavis.edu/people/faculty

EXPERTISE RELATED TO THE PROPOSED RESEARCH

Thorne is a landscape ecologist who focuses on climate change, biogeography, conservation and regional planning. He has developed GIS-based downscaled climate and hydroclimatic grids for all streams that flow into California at the 270m scale, with time span from 1900-2100. Additionally, has produced spatial outputs of projected future urban growth in California to 2050, under 5 policy scenarios and representing an increase in population projected at ~17 million.

SELECT PUBLICATIONS RELATED TO PROPOSED RESEARCH

Thorne, J. H., P. R. Huber, E. O'Donoghue, M. J. Santos. 2014. Regional Advanced Mitigation Planning (RAMP), a framework to unify infrastructure projects with sustainability goals *Environmental Research Letters* 9 065001. http://stacks.iop.org/1748-9326/9/065001

Thorne, JH, MJ Santos, J Bjorkman. 2013. Historic and future conservation progress and urban growth impacts in the San Francisco Bay Area, California. PLoS ONE 8(6): e65258. doi:10.1371/journal.pone.0065258

Roth, R. J. H. **Thorne**, R. Johnston, M. McCoy. 2012. Financial costs to agriculture and municipal governments of urban growth in an agricultural valley. *Journal of Agriculture, Food Systems, and Community Development.* ISSN: 2152-0801 online www.AgDevJournal.com

Schmidt, E., J.H. **Thorne,** P. Huber, N. Roth, E. Thompson, M McCoy. 2010. A new vision for prioritizing farmland preservation in the San Joaquin Valley, Calif. *California Agriculture* 64:129-134.

Beardsley, K., J. H. **Thorne**, N. E. Roth, M. McCoy. 2009. Impact of Rapid Human Population Growth on Biological Resources in the San Joaquin Valley of California. *Landscape and Urban Planning* 9:172-183. doi:10.1016/j.landurbplan.2009.07.003

ADDITIONAL PUBLICATIONS

Bjorkman J, JH **Thorne**, A Hollander, N Roth, R Boynton, J DeGoede,Q Xiao, K Beardsley, G McPherson, J Quinn. 2015. Biomass, carbon sequestration, and avoided emission: Assessing the role of urban trees in climate mitigation in California. Information Center for the Environment, U.C. Davis.

McIntyre, P., J. H. **Thorne**, C. R. Dolanc, A. Flint, L. Flint, M. Kelly, D. D. Ackerley. 2015 *Early Release.* 20th century shifts in forest structure in California: denser forests, smaller trees, and increased dominance of oaks. *Proceedings of the National Academy of Sciences.* *http://www.pnas.org/content/early/2015/01/14/1410186112.full.pdf*

Flint, L.E., A.L. Flint, J.H. **Thorne**, R.M. Boynton. 2013. Fine-scale hydrological modeling for regional landscape applications: Model development and performance. Ecological Processes. 2:25. http://www.ecologicalprocesses.com/content/2/1/25

Santos, M. J., J. H. **Thorne**, J. Christensen, Z. Frank. 2014. Assessing conservation success through reconstruction of the history of conservation land acquisitions and land-cover dynamics in a metropolitan area. *Landscape and Urban Planning.* 127:114-123.

Thorne, JH, C. Seo, A. Basabose, M Gray, T Belfiore, RJ Hijmans. 2013. Spatial management options for mountain gorilla conservation under climate change: the effects of modeling alternative biological assumptions. *Ecosphere.* 4(9):108. http://dx.doi.org.10.1890/ES13-00123.1

SYNERGISTIC ACTIVITIES

* **California's Urban Forest Mapping and Ecosystem Services Evaluation.** I coordinate a US Forest Service funded project to map the urban canopy of California, in cooperation with the California Department of Fire and Resource Assessment Program.

* **Climate Change Vulnerability Assessment for California – California Energy Commission.** I serve as a landscape ecologist, modeler and data coordinator for a multi-investigator effort to improve projections of vulnerability to California across multiple sectors including agriculture, water availability, fire, and biodiversity. My group is producing downscaled historic and future climates, urban growth models, and a dynamic vegetation model output. Overall project is 18 months and $4M.

* **Resource Management under Uncertainty, US National Parks.** I am a landscape ecologist and GIS modeler for efforts to assess biological and ecosystem vulnerability to climate change in Sequoia and Kings Canyon, Death Valley, and Joshua Tree National Parks. Proactive vulnerability assessments, and development of conservation management strategies is a new area of research for the US National Parks, which is grappling with whether it is possible to increase biological resilience to climate change, and what management strategies might be required.

* **US Forest Service, International Projects.** I developed a curriculum focused on forest ecosystems, and teach an annual 3-week course for 24 selected international mid-career forest and resource management professionals. Course locations include Washington, DC, UC Davis, and field locations throughout California. Participants are US AID, Embassy adjuncts and mangers in NGOs. I have several international collaborations developed through this program.

* **Historical and Projected Landscape Dynamics.** I am interested in the interaction and impacts of climate change and land use to human and biological communities. I use a variety of approaches to link change measured through historical studies to future projections, including landscape hydrology, vegetation dynamics and patterns of urban growth.

SUSAN L. USTIN

Director, Center for Spatial Technologies and Remote Sensing (CSTARS)
Professor of Environmental Resource Science and Vice Chair
Department of Land, Air, and Water Resources

EDUCATION

University of California, Davis, Ph.D. Botany, 1983

California State U. Hayward, B.S. and M.A. Biological Sciences, 1974 and 1978, respectively.

EXPERTISE

Environmental applications of remote sensing data, ecosystem processes and physiological functioning.

PROFESSIONAL EXPERIENCE

1990-present	Assistant to Professor, Dept. of Land, Air, and Water Resources, UC Davis, CA
2011-present	Vice Chair, Department of Land, Air and Water Resources (L.A.W.R.), UC Davis, CA
2003-present	Director, Center for Spatial Technologies and Remote Sensing (CSTARS)
2003-present	Director, CalView: State member AmericaView program
2005-present	Director, UC Davis program in the California Space Grant Consortium
2001-2006	Director, California Space Institute Remote Sensing of Agricult., Natural Resources and Environment
2001-2007	Director, DOE's Western Regional Center for Global Environmental Change (WESTGEC)
1995-2001	Associate Director, WESTGEC, University of California, Davis
1996-1999	Associate Professor of Resource Science, Dept. of L.A.W.R.
1991-1996	Assistant Professor of Resource Science, Dept. of L.A.W.R.
1990-1991	Assistant Research Resource Scientist, Dept. of L.A.W.R.

SELECTED PROFESSIONAL ASSOCIATIONS, PANELS AND COMMITTEES

2009-present	NEON representative, Domain 17 (California) Advisory Committee
2004-2008, 2010-2014	MODIS Science Team Member
2007-present	HyspIRI Science Team and HyspIRI Preparatory Science Team
2002-2007	NPOESS Science Advisory Board, Northrop-Grumman

KEY PAPERS RELATED TO PROPOSAL OBJECTIVES

Hart, Q.J., M. Brunagch, B. Temesgen, C. Rueda, S. Ustin, K. Frame. 2009. Daily reference evapotranspiration for California using satellite imagery and weather station measurement interpolation. Civil Engineering and Environmental Systems 26:19-33. This paper developed a protocol for making daily statewide estimates of ETo (reference ET) for the Dept. Water Resources CIMIS program. The methodology to connect near-realtime data and produce operational products is relevant.

Hestir, E., S. Khanna, M.E. Andrew, M.J. Santos, J.H. Viers, J.A. Greenberg, S.S. Rajapakse, S.L. Ustin 2008. Identification of invasive vegetation using hyperspectral remote sensing in the California delta ecosystem. Remote Sensing of Environment 112: 4034-4047. This study (for the CA Dept. of Boating and Waterways) provided maps of invasive aquatic species and communities in the Sacramento San Joaquin Delta, from high spatial resolution hyperspectral imagery collected over the legal delta. This paper (one of 16 we published) demonstrates how to process airborne and satellite data to quantify change detection and characterize the conditions.

Greenberg, J.A., S.Z. Dobrowski, C.M. Ramirez, J.L. Tuil, and S.L. Ustin. 2006. A bottom-up approach to vegetation mapping of the Lake Tahoe Basin using hyperspatial image analysis. Photogrammetric Engineering and Remote Sensing 72 (5): 581-589. This paper provides another example of a methodology for identifying and mapping forest communities from hyperspectral imagery.

Ustin, S.L., D.A. Roberts, J.A. Gamon, G.P. Asner, and R.O. Green. 2004. Using Imaging Spectroscopy to Study Ecosystem Processes and Properties. Bioscience 54(6): 523-534. This paper reviews the types of information that can be extracted from hyperspectral imagers from a spectroscopy perspective.

Xiao, Q-F., E.G. McPherson, and S.L. Ustin. 2003. Using AVIRIS Data and Multiple-Masking techniques to Map Urban Forest Tree Species. International Journal of Remote Sensing 25(24) 5637-5654. This paper illustrates a methodology to identify and map tree species in an urban environment. Together these papers provide an overview of the types of research we have done in the lab that is relevant to this proposal.

RECENT (REVIEWED) PUBLICATIONS (of 200)

Greenberg, J.A., M.J. Santos, S.Z. Dobrowski, V.C. Vanderbilt and S.L. Ustin. 2015. Quantifying environmental limiting factors on tree cover using geospatial data. PLOS ONE | DOI:10.1371/journal.pone.0114648.

Cheng, T., Rivard, B., Sanchez-Azofeifa, A.G., Feret, J.B., Jacquemoud, S., & Ustin, S.L. (2014b). Deriving leaf mass per area (LMA) from foliar reflectance across a variety of plant species using continuous wavelet analysis. ISPRS Journal of Photogrammetry and Remote Sensing 87: 28-38

Casas, A., D. Riaño, S.L. Ustin, P. Dennison, J. Salas. 2014. Estimation of water-related biochemical and biophysical vegetation properties using multitemporal airborne hyperspectral data and its comparison to MODIS spectral response. Remote Sensing of Environment 148:28-41.

Khanna, S, MJ Santos, SL Ustin, A Koltunov, RF Kokaly, DA Roberts. 2013. Detection of Salt Marsh Vegetation Stress and Recovery after the Deepwater Horizon Oil Spill in Barataria Bay, Gulf of Mexico using AVIRIS Data. PLOS One 8: e78989.

Cheng, T., D. Riaño, A. Koltunov, M.L. Whiting, S.L. Ustin and J. Rodriguez. 2013. Detection of diurnal variation in orchard canopy water content using MODIS/ASTER airborne simulator (MASTER) data. Remote Sensing of Environment 132: 1-12.

Kokaly, RF, Couvillion, BR, Holloway, JM, Roberts, DA, Ustin, SL, Peterson, SH, Khanna, S, Piazza, SC. 2012. Spectroscopic remote sensing of the distribution and persistence of oil from the Deepwater Horizon spill in Barataria Bay marshes. Remote Sensing of Environment 129: 210-230.

Ustin, S.L. 2012. Remote sensing of canopy chemistry. Proceedings of the National Academy of Sciences of the USA. Invited Commentary, 110: 84-85.

Koltunov, A., S.L. Ustin, E. Prins. 2012. On timeliness and accuracy of wildfire detection by the GOES WF-ABBA algorithm over California during the 2006 fire season. Remote Sensing of Environment 127:194-209.

Hestir, E.L., J.A. Greenberg & S.L. Ustin 2012. Classification Trees for Aquatic Vegetation Community Prediction from Imaging Spectroscopy. IEEE JSTARS 5: 1572-1584.

Greenberg, J.A., E.L. Hestir, D. Riaño, G.J. Scheer and S.L. Ustin. 2012. Using LiDAR data analysis to estimate changes in insolation under large-scale riparian deforestation. Journal of the American Water Resources Association. 48: 939:948.

Ryan M. Boynton

Information Center for the Environment (ICE)
Department of Environmental Science and Policy
University of California, Davis
rmboynton@ucdavis.edu

Education

Bachelor of Science (B.S.) in Environmental Biology and Management with emphasis in Conservation Biology and Management, University of California, Davis. **2006**

- Minor: Geographic Information Systems

Research Expertise and Interests

- Development of Geographic Information Systems (GIS) based models for environmental assessment
- Spatial data accessibility and decision support systems for land managers
- Urban Growth and Transportation Modeling and Planning
- Habitat Conservation and Restoration
- Biogeography and Landscape Ecology
- Ecosystem Analysis and Management

Work Experience

- 2007–Present, GIS Programmer, Information Center for the Environment, University of California, Davis
  - Perform programming tasks for GIS programs and remote sensing applications. Assist in programming and analysis of systems; use electronic data processing and other tools for data collection, integration, analysis and reports related to environmental science and policy subjects. Perform a range of GIS programming and remote sensing production tasks, including the digital development of historic maps and predicting future land use patterns in California.

- 2010, GIS Analyst, Blankinship & Associates, Inc.
  - Collected and organized spatial data, then used it to produce maps for the Sonoma-Marin Rail Transit (SMART) project's Integrated Pest Management (IPM).

- 2006, Student Assistant III, Information Center for the Environment, University of California, Davis
  - GIS assistant for the Wieslander Project. Assisted in registration, digitizing vegetation polygons, attributing, error checking and joining attribute details to Weislander tiles; performed analyses on digitized maps for preparing figures and tables for reports; updated plant species code lookup tables in Microsoft Access; trained new students; flaged errors in the database and corrected them.

Publications:

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