University of California
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# Managing for multiple ecosystem services in working landscapes of Sacramento: Urban agriculture and soil lead contamination

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**Short Summary:** This project, which addresses the multiple ecosystem services provided by urban soils, is most relevant to the ANR strategic initiative on sustainable natural ecosystems. Using a multi-scalar approach we will quantify soil lead concentrations at the patch and landscape scale in order to evaluate 1) the tradeoffs between increasing local food production via urban agriculture and potential lead exposure to human populations from soil contamination and 2) the influence of adjacent land uses, thereby addressing sections (a-e) under targeted area "balancing multiple ecosystem services and biotic diversity in California's working landscapes." In addition, our use of a new urban land cover classification to evaluate potential tradeoffs is relevant to the targeted area "tools for land science change" and our work to disseminate this information to broad and diverse audiences through a unique collaboration among documentary filmmakers, natural and social scientists is relevant to section (a) under "promoting the understanding and importance of ecosystem services provided by California's working landscapes."

## Project Summary:

**Specific objectives of the project:** The proposed project supports ANR's mission by investigating how to balance multiple ecosystem services in one of California's emerging working landscapes: cities. Working landscapes in urban areas provide many ecosystem services to residents including food provisioning and reduced bioavailability of pollutants. In urban landscapes multiple ecosystem services are managed by an extensive network of decision makers, and social and ecological dynamics at multiple scales influence the equitable distribution of those services. An integrated socio-ecological understanding of urban ecosystem service tradeoffs can identify ways to reduce vulnerability to lead exposure and address environmental injustices while maintaining critical ecological services. Despite this, urban landscapes are virtually ignored as functioning ecological systems by most of the scientific community. The proposed research and outreach activities aim to reduce potential exposure to lead from soil and encourage urban agriculture as a means of access to healthy food. By applying cutting edge ecological science in the service of improving the health effects of urban agriculture and in turn, healthy communities, the proposed project can contribute to ANR's strategic areas of Sustainable Natural Ecosystems and Healthy Families and Communities. To reach these broad goals, we have developed long and short-term objectives that draw on the strengths of a collaborative network. Following an April 6, 2011 lead exposure-related policy event planned by members of the research team, we have started to establish ties between researchers, policy makers, and advocates. All are committed to exploring the links between environmental health, food safety and access, management of multiple ecosystem services, and land use change science.

There are 3 specific objectives of the project:

**Objective 1**. *Quantify and analyze the distribution of soil lead concentrations in residential parcels, newly established household gardens, and existing community gardens and its relationship to urban land cover and specific landscape features.*

The results of the soil testing will be available to homeowners at no cost and provided as an accessible map. The results of soil lead distribution relative to land cover will be used to create a predictive model for soil lead concentrations in Sacramento. Results of the model will then be paired with social variables from the U.S. Census to examine potential inequities associated with the distribution of lead contaminated soils. Both the quantification of soil lead and the development of predictive models are medium-term outcomes that help us to achieve our overarching goal of reducing potential exposure to lead in soil by identifying hotspots of lead contamination in the urban environment and informing best practices for establishing gardens.

**Objective 2**. *Understand how perceptions of ecosystem service trade-offs may influence the efficacy of lead exposure prevention programs and healthy food access through urban gardening.*

How are potential tradeoffs to ecosystem services perceived by the community? At the policy-making scale, we will focus on the role professional orientation and social networks play in evaluating ecosystem services trade-offs. At the household scale, we will compare the social network characteristics that predict participation in an urban garden installation and education program. Across all participants, we will examine factors affecting the feasibility of implementing current best practices to limit lead exposure (Witzling et al. 2011). Completing these activities achieves a short-term outcome and a medium-term outcome: quantifying factors affecting policy maker perceptions of ecosystem service trade-offs and determining factors affecting participation in urban gardening. Completing these outcomes will help determine the feasibility of best practices for establishing gardens with respect to limiting lead exposure.

**Objective 3**. *Create useful and compelling public information relevant to California's diverse population of urban gardeners*.

We will partner with the California Center for Urban Horticulture (UCD) and Cooperative Extension's Master Gardener Program to host workshops that both bring awareness to the issue of lead contaminated soil and support and promote safe and healthy urban agriculture. In addition we will work with our community partners to develop best practices/management of urban agriculture in areas with elevated lead levels and update existing fact sheets to reflect Sacramento specific data. Finally, some activities in this proposal will be filmed as part of an ongoing collaboration with documentary filmmaker Robert Richter in which we aim to bring greater awareness to the unequal burden that urban communities face in terms of lead exposure. These activities promote the medium-term outcome of informing best practices for garden establishment/urban agriculture and the long term outcome of creating a documentary on childhood lead poisoning. Although some activities outlined in this proposal support the planning for the documentary, primary funds for the film will be sought through the NSF's Informal Science and Education competition.

**Background, significance and preliminary studies:** This proposal addresses an important knowledge gap in the understanding of the spatial distribution of lead in urban soils. The data collection will focus on two scales: the scale of the individual residential parcel and the coarser scale of surrounding land cover. By combining novel methods of classifying urban land cover with emerging technologies that allow for measuring soil lead concentrations at high spatial resolutions we will be able to address this knowledge gap. In addition we will be able to assess potential recontamination of newly installed household gardens by monitoring them throughout the project. Previous work has shown that lead concentrations in raised bed gardens increased from 150±40 ppm to 336 ppm in only 4 years (Clark et al. 2008). This work, completed in Boston (Clark et al. 2008, Estes et al. 2010), suggested that the mechanism of recontamination was wind-transported particles. The arid climate of Sacramento is an ideal place to test this mechanism. This information is needed to design and implement safe urban gardens that both promote access to healthy food and protect human populations from exposure to lead.

*Objective 1: Soil lead distribution.*
Soil is an important source of environmental lead which can be inhaled, ingested, and adsorbed to plants that are consumed by humans. Lead accumulates in urban soils at higher levels than other working landscapes. While unpolluted agricultural soils typically average 10 ppm (Holmgren et al. 1993), urban soils exhibit soil lead values that are much higher, sometimes exceeding the EPA reportable limit of 400 ppm (Mielke et al. 2010). Previous work estimates that consumption of well-rinsed produce accounts for 3% of children's daily lead exposure, but that ingestion or inhalation of fine-grained soil accounts for 82% (Clark et al. 2008). Previous work by members of our team (Schwarz and Cadenasso) illustrates the importance of analyzing both parcel and landscape level contributions to soil lead levels. This research was conducted in Baltimore and used a new tool, described below, for land change science.

Land use and land cover are two different ways to describe the landscape. Land *cover* is a physical pattern and is focused on structural heterogeneity. In contrast, land *use* defines the land in terms of social and economic function, or how people use the land. Though the distinction between land use and land cover is often ignored, it is important because not all land uses are structured the same. This difference in structure may have important implications for ecological functioning. For example, "residential" is a *functional* land use class. But all residential land is not *structurally* the same due to fine scale variation in building density, vegetation, and impervious surfaces. This naccounted for heterogeneity may influence ecological functions such as soil lead levels and opportunities for productive urban gardens. As a physical descriptor of spatial heterogeneity, land cover is more relevant to ecological processes than land use.

Cadenasso et al. (2007) developed a land cover classification that focuses on urban systems called HERCULES (High Ecological Resolution Classification for Urban Landscapes and Environmental Systems). The high spatial resolution and land cover-based logic of HERCULES divides urban landscapes into patches hypothesized to have ecological meaning. HERCULES has been shown to better describe links between the variation in buildings, vegetation, and surface materials and ecological processes such as water quality and soil C and N stores than standard land use/land cover models. We propose to classify Sacramento land cover using the HERCULES model and evaluate how variation in land cover features predict soil lead levels.

Soil lead is characteristically heterogeneous over very small spatial scales. Typically composite samples are used to describe lead concentrations found in an area. This coarse scale understanding hampers our ability to understand potential risks of exposure and potential efforts to minimize it. We will use x-ray fluorescence (XRF) which allows numerous samples to be taken quickly and easily over small spatial scales. This approach will reveal "hotspots" of lead in the soil at both residential parcel and landscape scales and inform efforts to minimize exposure.

*Objective 2: Perceptions of ecosystem service trade-offs.*

Many cities, including Sacramento, have active policy communities focused on promoting urban gardening and limiting exposure to lead. The extent to which decision-making in one policy domain considers, and is affected by, the other has not been well studied. Nor have researchers elicited expert or public opinions concerning the trade-offs related to managing for multiple ecosystem services.

Three types of national policies have contributed to declines in lead exposure: 1) elimination of lead in gasoline and paint, 2) lead abatement in homes of children with acute lead poisoning, and 3) information campaigns. Additionally, the 1991 California Childhood Lead Poisoning Prevention Act (CLPPA) has resulted in over $18 million from the petroleum and paint industries since taking effect in 1997 to fund lead exposure prevention programs. Nationally, the effectiveness of these programs has disproportionately reduced lead exposure for white and socio-economically advantaged children resulting in increasing racial/ethnic and income disparities (Dilworth-Bart and Moore 2006). With the exception of efforts to eliminate new sources of lead, policies have focused predominantly on individual and indoor sources of lead.

Separately, many nonprofit and grassroots organizations have acted to increase the number of backyard and community gardens as a means of redressing poor access to affordable and nutritious foods. Homegrown produce is associated with an increase in consumption of fruits and vegetables in areas with limited commercial food supplies (Nanney et al. 2007). The federal government also recognizes that urban gardening can help mitigate food insecurity; the “Greening Food Deserts Act” (H.R. 4971) aims to “effectively encourage local agricultural production and increase the availability of fresh food in urban areas, particularly underserved communities experiencing hunger, poor nutrition, obesity, and food insecurity, and for other purposes.” Small scale urban agriculture can provide numerous benefits. Growing fruits and vegetables in community gardens, abandoned lots, or backyards can support community revitalization and empowerment of typically underserved and under-represented populations (Brown and Jameton 2000). Participation in physical activity, access to foods that do not contain preservatives or high amounts of saturated fats or sugars, and a connection to nature and community can improve individual health and well-being (Pretty et al. 2003).

The relationships between policy imperatives, individual decision-making, lead exposure, and urban garden participation have not been adequately addressed as a manifestation of ecosystem service trade-offs. Bolund and Hunhammar (1999) identify several ecosystem services that may accrue from urban landscapes to urban residents including food provisioning and reduced bioavailability of pollutants. Through land use decisions individuals and policy makers select for different land cover types and configurations. Deliberate and unintentional manipulation of land cover affects ecosystem services. Choices and trade-offs have long lasting effects on environmental justice with respect to the distribution of environmental burden and environmental benefits, food justice, and inclusive democratic processes (Boone 2008, Gottlieb 2009).

Assessing policy maker and individual household perspectives on lead exposure and urban gardening in the context of ecosystem service priorities allows for the potential to identify opportunities and barriers to better decision-making at parcel and landscape scales. Each may construct a cognitive map to navigate the potential trade-offs between the nutritional benefits of produce from gardens and the exposure risks associated with contaminated soil. At both the household and policy scale, social networks for information sharing likely influence trade-offs in ecosystem service delivery from urban lands and concerns over environmental justice. Members of the governance network may leverage social and material resources for collective problem solving in novel ways (Ernston et al. 2008, Berkes 2009). Households may pattern their decisions after perceptions of neighborhood social norms (Bazuin et al. 2011). Understanding the structural relationships of partnerships through social network analysis can help determine the role that information exchange networks may play in promoting and/or inhibiting collaboration and incorporating justice into policy processes and outcomes (Hardy et al. 2003).

*Objective 3: Community engagement and outreach.*

Sacramento is one of the most diverse cities in the US. According to the 2000 Census, 48.3% of the population self-identified as White, 15.5% as Black or African American, 16.6% as Asian, and 21.6% as Hispanic or Latino of any race. The 2000 total population for Sacramento City was 407,018, with 20% of the population living below the poverty line. A 2000 report by the Environmental Working Group identified Sacramento as a lead risk “hot spot” for California with an estimated 3,835 children lead poisoned between the years of 1992 and 1998, or 5.1% of children aged 1-5 years old (Walker et al. 2000). Public awareness of soil dust as a source of lead exposure is low. A public health survey on caregivers’ knowledge of childhood lead poisoning showed that while 61% of participants identified eating paint chips as a source of lead poisoning, only 15% identified lead paint dust and less than 3% identified soil (Mahon 1997). This contrasts with studies identifying soil as an important pathway of human exposure to lead (Mielke and Reagan 1998). Although eating homegrown vegetables is not considered a significant exposure route, ingestion of fine grained soil particles is suspected to be significant (Clark et al. 2008). This suggests that gardening activities in which humans are in direct contact with potentially contaminated soil is a larger risk compared to consumption of homegrown produce.

**Design and Methods:**

**Biogeophysical:** Selection of parcels will take place through cooperation with Ubuntu Green's "350 edible garden campaign" and through UC Cooperative Extension Master Gardeners Program and Fair Oaks Community Garden. Ubuntu Green, in partner with Sacramento Yard Farmer and funded by the CA Endowment, is focusing on two Sacramento neighborhoods, South Sacramento and Del Paso Heights. We aim to recruit 75 properties in each neighborhood. This high rate of participation is based on the assumption that residents that engage in Ubuntu Green's program will be more interested in this project. In exchange for access to property, participants will receive free soil lead testing and results. Prior to testing, participants will sign a consent form granting access to property and will be given information clearly explaining the project and benefits and potential risk of participating.

We (Cadenasso and Schwarz) will address the research question "what factors predict soil lead levels at the household garden, parcel, and landscape scale?" Assessing soil lead concentrations at the parcel scale and displaying the results in a GIS map will identify associations between soil lead and specific features and characteristics of the urban landscape that the HERCULES land cover model describes. We can then model soil lead concentrations at the city scale.

A HERCULES land cover model will be constructed for the City of Sacramento, including South Sacramento and Del Paso Heights neighborhoods. High resolution air photography is available through the National Agricultural Imagery Program (NAIP) and we have access to LIDAR data for the study area. These two data layers will be used in an object oriented classification procedure to identify five features of HERCULES: 1) woody vegetation (shrubs and trees), 2) herbaceous vegetation (grass and herbs), 3) bare soil, 4) pavement, and 5) buildings. This approach overcomes the limitations of the available pixel-based land use classifications for urban systems because it 1) integrates built and natural components of the landscape, 2) recognizes that features can vary independently of each other (e.g. building density can vary independently of vegetation type within a residential area), 3) accounts for all combinations of elements in the landscape, 4) has greater categorical resolution, and 5) does not confound structure and function. The object oriented classification will be integrated with a visual interpretation procedure to delineate patches of land cover that differ according to the 5 features identified above. The result will be a land cover map that quantifies the structural heterogeneity of the system and, when combined with the soil lead measurements, can be used to analyze spatial patterns in lead distribution to determine links between structure and function. The land cover map can also be combined with social data, collected here or available through US Census, to determine disproportionate distributions of soil lead exposure among peoples in Sacramento.

Soil lead measurements will be made using a USEPA approved x-ray fluorescence (XRF) multi element spectrum analyzer, which allows for fast and numerous in-field soil sampling. This approach minimizes soil removal which alleviates participants' concerns about disturbance to yard and garden. A Niton XLt 700 series, owned by the Cadenasso Lab at UC Davis, will be used. In situ analysis evaluates soil metal content to a depth of approximately 2 mm. Following USEPA method 6200 (Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment, 2007), a minimum of 5% of in situ samples will be confirmed via laboratory analyses at an independent USEPA recognized lab. XRF technology has been used extensively by the USEPA and others (Clark et al. 1999, Carr et al. 2008). This method will allow us to gather the density of samples necessary to examine spatial patterns of lead in urban residential soil. The limit of detection (LOD) for lead is dependent on the type of sample being tested and the other elements that are present in the sample; however, for our purposes, lead concentrations in urban areas are generally high enough to be detected except in very few cases where readings may be below the instrument's LOD.

Within each parcel, soil readings will be taken in transects extending from the house. At every site an attempt will be made to take a reading as close to the structure as possible as this area is generally very high in lead. Moving away from the structure a minimum of 3 samples will be collected. The number of samples taken per parcel will depend on the size of the parcel. At each sampling location, the corresponding landscape feature will be recorded as 1) open lawn with no tree canopy above 2) under tree canopy, 3) adjacent, i.e. within 1 meter, to building, 4) next to the road, meaning the measurement that was closest to the major road network, or 5) landscaped (flower beds, etc.). At each location all landscape features that apply will be recorded. Raised-bed gardens within the parcel will be measured using a 0.5 meter sampling grid. The use of a grid allows us to collect detailed soil lead data that can be statistically interpolated. It will also allow us to sample the same location repeatedly without permanently marking the location.

Data collected from the individual gardens will be used to assess soil lead contamination and monitor potential recontamination. Gardens will be sampled at the time of establishment and then periodically throughout the project to determine whether lead concentrations increase. Data collected from the entire parcel will be used as the input to a statistical model that will predict the spatial distribution of lead in urban residential soils throughout Sacramento. The model will be developed within GIS using a machine learning technique called Classification and Regression Trees (CART). CART is a non-parametric statistical method used in ecology for exploration, description, and prediction of data (De'Ath and Fabricius 2000). CART produces a hierarchy of decision rules displayed in the form of a binary tree (Sutton 2005). The results of the empirically-based GIS model will be shared with Community Partners. This information can be used to inform both garden placement and best management practices. In addition, this information has the potential to assist public health officials and city agencies in focusing efforts on contaminated soil removal and remediation.

**Design and Methods:**

**Social Science:** We (Cutts and Community Partners) will evaluate how potential tradeoffs between ecosystem services are perceived by Community Members. Similar to the biophysical research design, we propose to examine two social scales that influence ecosystem service generation and distribution in Sacramento. At the household scale, we examine factors affecting empowerment and risk perception that relate to the process of environmental justice. We focus on motivation for participation in an urban garden installation and the relative importance of social networks, knowledge, economic and health concerns, and land-use preferences. At the policy-making scale, we focus on the roles professional orientation, concern for environmental justice, and social networks play in perceptions of ecosystem services, value and trade-offs. To identify communication barriers, we examine perceptions of the feasibility of current recommendations for limiting exposure to lead contaminated soils at both scales. Addressing two scales provides insight into top-down and bottom-up processes that shape urban environmental justice (Sze and London 2008, Swyngedouw and Heynen 2003). In this context, urban environmental justice refers to the inequitable distribution of environmental hazards and environmental assets across different racial, ethnic, and class populations, the restricted access to decision-making about these issues by the populations most effected, as well as the efforts of these populations to organize to improve their health and well-being. This project will contribute both to a rigorous analysis of urban environmental justice issues in the Sacramento area as well as support community and policy efforts to improve health conditions in the places and populations that are most vulnerable and under-resourced.

***Household Scale***: We will investigate how social and economic constraints, ecosystem service preferences, and social networks affect household participation in urban gardening. To do this, we will map the way participants frame trade-offs through a qualitative causal modeling and simulation technique called fuzzy cognitive mapping (Özesmi and Özesmi 2004). We hypothesize that knowing other participants in the program will improve the likelihood of participation among individuals who rate themselves as having low levels of knowledge relevant to urban gardening. Among those who rate themselves as having high knowledge, we predict that biophysical limitations (perceptions of toxic environments or poor productivity), low social support for gardening, and high opportunity costs will play a large role in limiting participation.

We will conduct interviews with residents participating in backyard and community garden installation programs sponsored by our partner organization Ubuntu Green. Examining urban gardening in the context of low income communities of color provides an opportunity to investigate the extent to which urban areas may be perceived as a benefit and/or burden in populations that are typically exposed to higher levels of environmental toxins and have lower access to healthy foods. Using fuzzy cognitive mapping as an analyses tool allows us to use face-to-face qualitative interviews to understand the primary factors affecting decision outcomes (Özesmi and Özesmi 2004). In our case, face-to-face interview is preferable to other methods because it allows researchers to avoid introducing the language of ecosystem services, which is not commonly used by the public. This interview strategy is also an opportunity to build trust before collecting biophysical data. We will ask participants open-ended questions about their motivation for participation. Probing questions will focus on the benefits and barriers to participation, specifically focusing on time, finances, knowledge, health, and local environmental conditions. We will code responses to identify values placed on ecosystem services and barriers to participation. The second part of the interview will focus on the social network of the participant. We will ask participants to identify households known to participate in the urban garden installation program. Bazuin et al. (2011) used similar methods to assess informal leadership and belief networks regarding pesticide and fertilizer use.

***Policy-maker Scale:***

At the policy-maker scale, we will investigate the effects of social networks and expertise on perceptions of ecosystem service trade-offs using an online survey. This survey will use expert elicitation methods to understand the ways in which the policy community, that focuses on urban agriculture and potential lead exposure, perceive trade-offs in ecosystem service delivery by Sacramento's urban ecosystems. The survey will also collect social network data. Together these data will help inform strategies to influence land use, environmental and public health policies at the local and regional scale. We hypothesize that professional orientation toward lead exposure or urban agriculture will significantly predict the way respondents construct bundles of ecosystem services. This effect will be moderated by the size and composition of the respondent's social network. Interacting with groups that have a specific environmental justice orientation may have a significant influence over perceived tradeoffs.

*Expert elicitation method:* We will elicit expert opinions of trade-offs through analytical hierarchy process (AHP), which is a technique to support multi-criteria decision-making (Saaty 1980, 2001). Using this method we will elicit weights for preference for one land cover over another as a way to think about sustainability in Sacramento's working landscape. AHP can be used to determine the perceived value of ecosystem services provided by several urban land cover types including: (1) urban tree canopy (2) lawns and (3) impervious surfaces. These are alternative land cover types relevant to urban agricultural and lead exposure risks. We will conduct cluster analysis on the results of the AHP to determine the suite of ecosystem services that respondents attribute to each of the three land cover types and the extent to which they are in conflict with one another. This represents a new application of the AHP method that provides social preference data that can be analyzed with ecological data on ecosystem service "bundles" and trade-offs developed by Raudsepp-Hearne et al. (2010). Preferences for one land cover type over another indicate underlying trade-offs in perceived services like air filtration, micro-climate regulation, rainwater drainage, recreation, cultural values, food production, erosion control and reduced bioavailability of environmental pollutants.

*Social network analysis*: In the same online survey containing the AHP, respondents will identify organizations and agencies with which they collaborate and indicate the extent to which they feel each of the collaborators has expertise in soils, lead contamination, factors affecting lead contamination, and urban gardening. From responses to the social network portion of the survey, we will calculate homophily, or the extent to which clusters form around shared attributes (Hanneman and Riddle 2005). We will use relational-contingency analysis in UCINET (Borgatti et al. 2002), which tests whether or not actors with similar perspectives are more likely to share ties than those with very different perspectives (Hanneman and Riddle 2005).

Lastly, we will assess public and policy perspectives concerning the feasibility and perceived impact of suggested practices for gardeners (Witzling et al. 2010) to avoid or reduce lead exposure while gardening food crops. Comparing policy and community perspectives will identify communication barriers between policy and public social scales (Brescoll et al. 2008).

**How this project will address the 7 criteria listed in the RFP:**
*Criteria 1:* This project, which addresses the multiple ecosystem services provided by urban soils, is most relevant to the ANR strategic initiative on Sustainable Natural Ecosystems, but also can contribute to learning in the Healthy Families and Communities strategic initiative. The project addresses all 5 concentrations of the Sustainable Natural Ecosystems initiative (a-e) identified in the RFP. By investigating

how the physical structure of the urban environment correlates to soil lead concentrations at the landscape scale and applying that knowledge to the future management of urban agriculture we are addressing concentration “a”. Our multi-scalar approach in both the biophysical and social components of the research further supports concentration "a". Monitoring the gardens for the duration of the project will allow us to investigate whether the plots are recontaminated over time and, if so, what influence the surrounding land cover has on recontamination. It will also allow us to determine any effects of seasonality and whether or not dust in dry climates of the Central Valley has unique implications for recontamination. These activities support the temporal component of concentration "a" as well as concentration "b". By conducting surveys at both the policy making scale and household scale we will rigorously quantify concentration “c”. Because the surveys will be administered in two different Sacramento neighborhoods we will be able to address how tradeoffs vary within the City. Our use of a multi-scalar approach to quantify soil lead concentration at individual garden and parcel scales and our ability to extrapolate to the city scale from these measurements further permits us to investigate the influence of adjacent land uses, thus addressing concentration “d”. Finally establishing relationships between soil lead concentrations and urban land cover creates an opportunity to predict how future land use change will affect the distribution of lead in the urban environment, addressing concentration “e”. In addition, our use of a new urban land cover classification (HERCULES) to evaluate potential tradeoffs is relevant to the targeted area “tools for land science change” and our work to disseminate this information to broad and diverse audiences through a unique collaboration among documentary filmmakers, natural and social scientists is relevant to concentration "a" under “promote the understanding and importance of ecosystem services provided by California’s working landscapes.”

*Criteria 2:* ANR’s strength lies in its commitment to linking UC research and extension with the diverse people of California. The data collected as part of this project will have immediate and long term benefits to the people of California. In the short-term, the data will be used to inform household garden placement. At longer-time scales data will inform best management practices and influence policy that both promotes access to healthy food and diminishes potential exposure to environmental lead. Our collaboration with CE (Ingels) and Master Gardeners (McClure) can help advance this goal. Knowledge regarding the spatial distribution of lead in soil relative to land cover features may inform future urban planning and can contribute to understanding the disproportionate distribution of environmental burdens on urban communities.

*Criteria 3:* Our network of researchers, community partners, and community members provide ample opportunity for fruitful transdisciplinary outcomes. The researchers represented on this project have successfully advanced the science of urban socio-ecological systems and environmental justice. The Center for Regional Change, within the College of Agriculture and Environmental Sciences, has built a robust and trusting network of collaborating partners, including many of the community partners involved in this project. These community partners, including Ubuntu Green, Sacramento Yard Farmer, and Legal Services of Northern California have a long-standing relationship with the community and a history of success in promoting social equity. The California Center for Urban Horticulture, a collaborator on this project, has extensive experience in organizing community workshops and will work to ensure that events are successful in reaching our goal of broad dissemination. Finally, individuals involved in this project have experience in community organizing and advocacy as well as academia.

*Criteria 4:* In addition to continuing work in California, the research team anticipates applying for funding from USDA and NSF to do cross-city comparisons. While there is significant research on exposure to lead and urban agriculture, very little research focuses on the intersection of these two issues and the ways that the public and policy makers manage the benefits and risks presented by land use decisions and their spatial configuration. Comparisons across households, neighborhoods, and policy making communities provide insight into environmental governance in Sacramento. However, cross-city comparisons will provide opportunities to examine ways in which differences in history, climate, and policy shape the social and ecological processes associated with the benefits, risks, and trade-offs of alternative food systems. In addition, the research team will apply for funding through the NSF Informal Science and Education Competition to support the documentary film project. The film, which will explore why rates of lead poisoning are disproportionately higher in urban areas, will inform broad audiences about numerous lead sources in urban areas, including soil.

*Criteria 5:* The Central Valley is one of the most productive agricultural regions and provides leadership in the nation's food supply. California has also led the nation in progressive policies related to environmental and human health. The state is a bell-weather for the integration of an increasingly diverse population in ways that lead to equitable access to the opportunities of civic engagement, health, and prosperity. This project has direct and immediate benefits to the residents of Sacramento. Furthermore, the resultant recommendations regarding best management practices for urban agriculture can serve as a model for California to promote policy that encourages healthy, sustainable, and equitable access to nutritious foods.

*Criteria 6:* Through our network of community partners we will work collaboratively to ensure that the data collected as part of this project is used in science-based decision making. By using an integrated socio-ecological approach we recognize the influence social systems have on the implementation of managing for multiple ecosystem services. We will also use this network to disseminate information through workshops and direct interaction with study participants. The potential to influence policy is enhanced by the timing of this project. For example, the Sacramento City Council and Planning Department are currently debating a community garden ordinance that would allow agriculture in residential zones. (See policy impact statement)

*Criteria 7:* Although the proposed activities are most relevant to ANR's Sustainable Natural Ecosystems initiative, the project is also relevant to the Healthy Families and Communities initiative. Low income and ethnic minority children experience especially high rates of obesity. ANR has identified "environmental interventions to promote healthy eating and active lifestyles at the individual, family, and community level" as a solution to the issue of childhood obesity. By working with community partners to establish access to healthy and safe food via homegrown vegetables we are supporting the Healthy Families and Communities initiative.

**Statement of Policy Impact and/or Outreach Efforts**

Through our network of community partners we will work collaboratively to ensure that the data collected as part of this project is used in science-based decision making. Soil lead contamination is highly heterogeneous, sometimes varying by an order of magnitude over very short distances. High spatial resolution data regarding the distribution of lead in residential parcels in essential in guiding the placement of newly established raised bed household gardens. Recontamination of raised bed gardens via wind has been shown to occur, and though the mechanism is uncertain, re-suspension of soil from areas surrounding the garden has been suggested. The dry growing season in Sacramento may make this pathway of recontamination particularly important. Therefore, it is essential that the residential parcel be sampled not only for garden placement but also for long term monitoring of the soil lead concentrations. It is important to note that these findings are not in conflict with urban agriculture; a simple method of periodically removing the top layer of soil is suggested to remedy the situation. However, without knowledge regarding the issue of recontamination or the extent of contamination in soil surrounding the gardens, science-based decision making cannot take place. In addition, the proposed modeling activities will identify hotspots of lead contamination in the landscape and promote understanding of how social variables relate to its distribution. This information can be used by city planners to incorporate environmental and social equity into planning.

Often, science provides a range of technically sound environmental management options. Policy priorities and household-level beliefs influence management priorities and the tenability of science-based decision making. Social systems alter the feasibility and effectiveness of policies. We analyze factors affecting policy and household-level environmental management perspectives to explore the degree to which management alternatives are likely to support environmentally just processes and outcomes.

Multiple members of our collaborative team (Ingels, McClure, Fujino) have extensive experience with outreach and education and all of our community partners have long standing trust in the community that will help us gain access to target communities. By working directly with community members and disseminating information through annual community workshops and direct interaction with study participants we will be enhancing knowledge of both the importance of supporting ecosystem services in urban areas and critical tradeoffs with soil lead contamination. This not only encourages systems based thinking among participants but can influence policy by highlighting the need to think about novel ways to manage systems for more than one ecosystem service.

Members of our collaborative network (Aguilera, Bailey, Mason) are directly involved in policy efforts in Sacramento to encourage and enhance urban agriculture. Their direct involvement with UC researchers and this project provides a unique opportunity for region-specific science to be communicated to decision-makers and incorporated into local policy. The potential to influence policy is enhanced by the timing of this project because Sacramento, like many other urban areas, is experiencing a renewed interest in urban agriculture. The Sacramento City Council and Planning Department are currently debating a community garden ordinance that would change the zoning laws of the City that currently do not allow agriculture in residential zones. This research encourages the new resurgence in urban agriculture to be sustained over the long-term through promoting science-based decision making that manages for multiple ecosystem services.