Central Arizona–Phoenix Long-Term Ecological Research: Phase 2

RE: 2008 Combined Supplements Request for NSF Grant # DEB-0423704
Nancy B. Grimm and Charles L. Redman, CAP LTER Project Co-Directors

A. INTEGRATED RESEARCH AND EDUCATION SUPPLEMENT

Investigators: Monica Elser, Nancy Grimm, Stevan Earl, Corinna Gries, and others

CAP LTER recognizes the need for integrative science that involves partnerships among disciplines to conduct research, detect change, examine impacts, and devise appropriate solutions to problems while exchanging knowledge with multiple user groups and stakeholders. In this spirit, we propose a set of education and research projects to further this agenda within CAP LTER. At the core of our proposal is an opportunity to enhance learning through electronic technologies that will communicate CAP LTER science effectively to K-12 teachers, students, citizen scientists, and the general public. As part of these efforts, we intend to feature accomplishments in our REU program and display data from a pilot initiative to establish a weather station and stormwater monitoring equipment at a local school.

LTER Schoolyard Activities

Environmental education and outreach activities are woven throughout CAP LTER. We reach out to the K-12 community in a program called Ecology Explorers that engages teachers and students in schoolyard-ecology. Students collect data similar to CAP LTER data, enter results into our database, share data with other schools, and develop hypotheses and experiments to explain their findings. We offer summer internships and school-year workshops for teachers funded by previous Schoolyard supplements. These programs are successful (Banks et al.2005) and in high demand. Due to funding and space limitations, the internship program is relatively small (10-16 teachers per summer) and typically receives two to three times as many applicants as can be accommodated. Additionally, we are also working directly with undergraduate students and classroom teachers in high-minority and underserved schools through ASU's Service Learning program. One program, *Service at Salado* received funding through LTER and EdEn in 2005 and has reached nearly 500 elementary-school children and 55 ASU undergraduates over the past three years. *Service at Salado* received the 2006 ASU President's Medal for Social Embeddedness based on its success in linking ASU research with the community.

It is important to develop more teaching and learning materials that meet the needs of the many teachers who want to be involved in CAP LTER and enhance their current curricula with place-based information. We have developed a day-long workshop with new activities based on a variety of CAP LTER projects ranging from the 200-point survey to the Phoenix Area Social Survey (PASS). We would like to develop additional materials and create workshops that meet the varying needs of elementary-school teachers *and* high-school teachers. We will add these materials to an updated Ecology Explorers website that uses electronic technology to present interactive content in ways that are engaging and encourage active learning. In addition, we will update our "Virtual Tour of CAP LTER" that allows the user to peek inside our research initiatives through podcasts and videos featuring scientists and students at work and the display of data from projects and *in situ* monitoring devices. This updated tour will provide students and citizen scientists with enhanced access to CAP LTER science and scientists. Featuring student research and involving students in the web-design process will involve undergraduate (REU) and graduate students in our effort as well.

Water-quality and water-resource issues are central to our study area, and we support a wide array of monitoring and research initiatives that address the socioecological aspects of water. We propose to incorporate this expansive research into our education and outreach programs through partnerships with elementary and high-school science programs. We envision a program in which science classes work with our researchers to investigate water and material fluxes in an urban environment, by examining stormwater flows and quality from and through their own schoolyards. This research will expand on well-established water-conservation programs prominent in school curricula by encouraging students to consider not only water sources but also the fate of water in an urban setting. The partnership will provide a unique illustration of "ecosystem" and "watershed" concepts that are integral to science curricula and complement CAP LTER research addressing complex dynamics among catchment characteristics, storm attributes, and runoff in highly urbanized settings. To facilitate this research, our researchers will work with partner schools to install weather stations, flow-metering equipment, and collectors for capturing stormwater runoff from school grounds, including parking lots, roofs, and drainage channels. One cannot request storm events on a schedule; therefore, we will work with schools to develop protocols that can be implemented on short notice and supplement these sampling experiences with web-based information. Access to real-time climate and hydrologic data specific to the partner schools' watersheds will heighten the educational experience. These and other web-based elements (e.g., watershed delineation tools) will be featured on the revised, interactive CAP LTER website, and curriculum and workshops will be designed to assist teachers in incorporating these data into the classroom. We will begin with a pilot project at a low-income, minority school in Scottsdale Unified School District.

Funds are requested to support stipends and participant costs associated with teacher workshops, travel monies for meetings and conferences, as well as the costs of purchasing stormwater sampling equipment, flow-monitoring sensors, and a weather station for the pilot project. We also request support for a programmer/web designer to work with existing staff and researchers to create new educational content for the CAP and Ecology Explorers websites. Funds are requested for materials and supplies to support evaluation activities.

LTER Schoolyard Summary Budget

Personnel, Staff	14,969
Fringe Benefits (32%)	4,790
Travel	
Participant Costs	
Stipends	5,000
Other	2,750
Other Direct Costs	
Materials & supplies	1000
Non-capital equipment	12,015
Evaluation Activities	500
TOTAL Direct Costs	40,524
F&A (26%)	8,521
Total	**49,045**

Other: Programming for Online Applications

In conjunction with the LTER Schoolyard request above, we request funds to add interactive features to the CAP LTER tour that can be used by educators and the wider public. We propose two applications: a key to the tree diseases in the CAP region and "Landscape Sim." Work on the tree disease key is currently underway, using existing software developed at CAP and an extensive image gallery. "Landscape Sim" is an interactive application that will allow users to design a hypothetical yard by picking certain landscape features (e.g., lot size, house size, pool, lawn, plants). A report generated through this application and based on existing CAP research will allow users to view expected water consumption, energy use for cooling, and effects on arthropod and bird diversity of their landscaping choices. Funds are requested for the layout, design, and programming of these two interactive web applications. We also request funds for similar programming and design tasks to support two other initiatives: an online data-gathering tool and an online graphing application. The former will support our ongoing research on avian biodiversity and involve citizen scientists in select neighborhoods (co-located with Survey 200 sample locations and the PASS sample neighborhoods) responding to surveys online in a secure area of the website. Online graphing will support the schoolyard stormwater initiative described in the section above. We will develop simple online graphing capabilities on the CAP website to visualize data from flow monitoring sensors and weather station at the school in real time. Although these capabilities will be developed primarily in collaboration with the Ecology Explorers' program, the application will foster a wider use of research data throughout the CAP website.

Other Summary Budget

Personnel, Staff	15,031
Fringe Benefits (32%)	4,810
TOTAL Direct Costs	19,841
F&A (26%)	5,159
Total	**25,000**

Research Experience for Undergraduates

We propose to engage undergraduates in our research on urban-ecological systems. Students will participate in a sequence of activities. They will begin with an assigned *question* through developing a research proposal that outlines *hypotheses, predictions,* and *tests*, proceed to collect and analyze *data*, and then present their *results* in a summer-research symposium. Our program builds upon our 18 years of experience in sponsoring undergraduate research in environmental biology (REU-EB), supported by multiple NSF-REU supplements but managed as a single program. The REU-EB (since 1990) and CAP LTER REU program (since 1999) have been successful in mentoring and training undergraduate students.

CAP LTER PIs, project managers, or postdocs will supervise REU students. We will match each student with a CAP LTER project, based partly on the investigator's ideas for a doable project and partly on the student's interests. REU students will be responsible for their own projects, but the project will interface closely with projects of the research group. It is equally important for students to learn that urban ecology must be cooperative and interactive as it is for them to gain

technical skills. The existence of the University-wide Community of Undergraduate Research Scholars program with many REU students working with IGERT in Urban Ecology Fellows, the previously mentioned summer REU-EB program, and the School of Life Sciences Undergraduate Research program means there will be ample peer role models and opportunities to interact with other students pursuing similar paths. A formal symposium and other more informal social activities are coordinated with these programs at ASU.

REU recruitment

As Table 1 indicates, we have had considerable success over the years in recruiting a diverse pool of applicants to the REU-EB and CAP LTER REU programs. Recruitment of REU fellows has been from primarily undergraduate colleges, ASU, and other universities. Many of these institutions have our program in their files, as we regularly receive inquiries beginning in December of each year. In addition, we have a web page and online application (http://sols.asu.edu/ugrad/reu/index.php). We update both this page and the CAP LTER home page (http://caplter.asu.edu) to promote our REU program. We contribute to advancing affirmative action objectives by aggressively seeking women and minority candidates and providing an opportunity for both female and male students of ecology to interact with female ecologists at faculty member, postdoctoral, and doctoral levels. We will aim our recruitment efforts toward groups underrepresented in ecology and related disciplines, particularly Latino, American Indian, African American, and female students. Our School of Life Sciences currently has a 25% minority enrollment in its undergraduate program, evidence of an increasing ability to reach and attract students traditionally underrepresented in the discipline.

Table 1**. Demographic composition of Summer REU applicant pool and fellowships awarded; 1990-2007.** "Minority" includes Latino/a, African American, and American Indian students; majority category includes Anglo and Asian American students. Values in parentheses are percentages of total applicants or fellowships.

Program	Female	Male	Minority	Ethnicity Unknown	Majority	Fresh or Soph	TOTAL
Applicants	309 (60)	209 (40)	80 (15)	209 (40)	229 (44)	NA	518 (100)
Fellowships	69 (64)	39 (36)	13 (12)	NA	95 (87)	16 (15)	108 (100)

NA= Not applicable or not available

Potential projects

Below is a list of individual projects we will offer students. Each project will feature a question that can be answered within the timeframe available. In addition, we will encourage students to help each other in their field and lab work, broadening their experience and instilling a sense of camaraderie.

- Project 1: Fossil fuels or forest fires - How black is the carbon in Phoenix soils?
- Project 2: Our carbon addiction: A study of the complex relationship between humans and carbon in the Phoenix Metropolitan Region
- Project 3: Do urban soil microorganisms utilize compounds deposited from urban air pollution?
- Project 4: In what ways do black widow spider (*Latrodectus hesperus*) populations from disturbed, urban habitats differ from populations from undisturbed, desert habitats?

- Project 5: How do Phoenix Metro area birds adapt to urbanization?
- Project 6: Stormy weather! How do summer monsoons affect carbon cycling in Tempe Town Lake?
- Project 7: The impact of land-use restrictions on the market value of residential properties and land: An application to the Phoenix Metropolitan Area
- Project 8: Socioecological functioning of residential landscapes

An example of one of these potential projects follows, which gives a sense of the type of experiences that we offer to REU students.

Our carbon addiction: A study of the complex relationship between humans and carbon in the Phoenix Metropolitan Region

Urbanization radically alters regional carbon dynamics, although the relationship between humans and carbon is quite complex. Our ability to have a sustainable future on this planet is highly dependent on how humans use and abuse this element, yet we do not have a basic understanding of how much carbon enters cities, in what form, where it is stored and how it is re-released into the atmosphere. Our goal in this project is to develop a spatially explicit carbon budget for the Phoenix Metropolitan Area where we not only quantify carbon dynamics, but also identify how lifestyle choices and development patterns drive key processes in the carbon cycle. The REU student will have an opportunity to work on many facets of this research project and gain skills in developing research questions, data mining, field work, data processing, statistical analyses, and report writing. This student will also benefit from working in an interactive multidisciplinary environment with other students, post-doctoral researchers, faculty, and resource practitioners. Working with Drs. Melissa McHale and Nancy Grimm, the REU student will help develop spatially explicit theory on how cities can reduce their carbon footprint.

Past REU support

Last summer, REU fellows conducted individual research in the field of urban ecology. Genevieve Likart (New College of Florida) worked with Sharon Harlan to examine the effects of vegetation density on neighborhood crime and residents' perceptions of crime and park quality. This research, part of PASS, contributed to an award-winning poster at the CAP LTER poster symposium in January 2008. Katie MacCormich (Arizona State University) conducted research on acoustic adaptation in urban and rural bird populations with Pierre Deviche's lab. Work conducted in the summer months has contributed to this ongoing research.

REU Summary Budget

Participant Costs	
Stipends	4,800
Travel	1,500
Subsistence	2,000
Other	2,500
TOTAL Direct Costs	10,800
F&A (25% stipends)	1,200
Total	**$12,000**

C. SOCIOECOLOGICAL GRADIENTS AND LAND-USE FRAGMENTATION: A CROSS-SITE COMPARATIVE ANALYSIS

Investigators: Abby York, Christopher Boone, Nancy Grimm, and Marcia Nation

In 1970, the United States became a suburban nation. The US Census Bureau recorded in that year that more people lived in suburbs than in central cities. While some growth on the periphery is contiguous, "leap-frog" developments, edge cities, and exurban enclaves have created discontinuous patterns of settlement across the American landscape. Growth on the periphery has been made possible by a number of factors, from federally insured mortgages to transportation technologies and investments, but little attention has focused on the role of ecosystem services in defining the characteristics of such growth. In this proposal, our goal is to understand how a single but critical ecosystem service — *water provisioning* — in concert with proximate social causes of peripheral growth — *population growth* and *urbanization rates* — is linked to landscape fragmentation. To understand the relative strength of each of these proximate causes of landscape fragmentation, we employ a LTER cross-site analysis along water, population, and urbanization gradients using data from 1970 to the present (figure 1).

Theory

Landscape fragmentation affects biodiversity and ecosystem processes as portions of the landscape become isolated without connecting corridors. These changes decrease the ability of species to recover from disturbances (e.g. MacArthur and Wilson 1967; Marzluff and Ewing 2001; O'Neill and Hunsaker 1997) and reduce connectivity that can promote ecosystem processes (Peters et al. 2008, Grimm et al. 2008*b*). Likewise, landscape fragmentation has important social implications, such as increased costs for public service provision (Camagni et al. 2002), decreased ability to use lands for agricultural (Carjens and van der Knaap) or forest production (Rickenbach and Gobster 2003; Kline et al. 2004; Alig et al. 2002; Wear et al. 1999), and loss of culturally relevant openspaces and natural amenities (Deller et al. 2001; Rickenbach and Gobster 2003). Development of greenfield sites and conversion of farmland and wildlands to subdivisions, while central city lots and brownfields lie vacant, underscores the inefficiencies that accompanies such growth (Boone and Modarres 2006). Conflict on the urban-rural fringe between farmers, ranchers, and residents can also lead to further fragmentation (Bunce 1994).

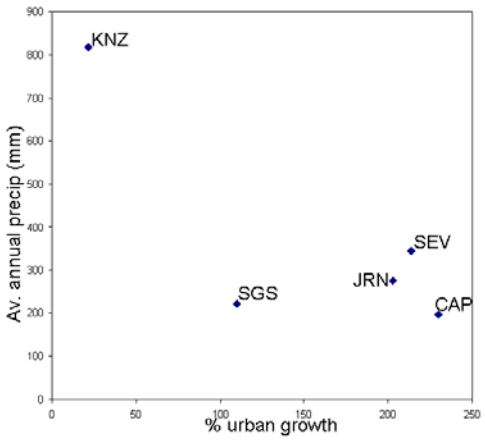

Figure 1 Average annual precipitation (92-06) and percent urban population growth (70-00) for case LTER sites.

Landscape fragmentation may include fragmented land cover and/or land use, while fragmented land ownership is typically conceptualized as a driver of increased land cover/use fragmentation (Mitchell et al. 2002; Gosnell et al. 2006; Stanfield et al. 2002). Some types of land cover may be more affected by land-ownership fragmentation than others; in a study of Colorado ranch-subdivision ownership, fragmentation caused more significant impacts on grasslands than forests (Mitchell et al. 2002). Fragmentation of land cover, use, and ownership all have potentially significant effects on and feedbacks with the social-ecological system (Redman et al. 2004, Grimm et al. 2008*a*).

In an effort to outline new directions for research, the LTER community developed a novel conceptual framework that links social and ecological dynamics. Ecosystem services provide the critical linkage between biotic structure and function and human outcomes and behavior. This proposal intends to examine *some* components of that framework by analyzing how ecosystem services bear on social systems to generate land fragmentation. Findings from this research will provide the foundation knowledge for "closing the loop" between social and ecological systems, specifically to examine how the fragmentation of land impacts biotic structure and function and in turn the ecosystem service of water provisioning.

Our proposal intends to answer the following **research question**: *How does the degree of land fragmentation vary with magnitude and/or rate of change of water provisioning, population growth, and urbanization?* While this question addresses critical *proximate* causes of land fragmentation, we recognize that fragmentation is also a function of availability of technology, institutional change, cultural factors, land use legacies, and economic development pressures (Geist and Lambin 2002, Geist and Lambin 2004). At each site we will investigate the role of these drivers, in addition to our proximate drivers, in the process of land fragmentation. In order to make such an undertaking manageable, we will describe land changes along banded transects at each of the sites, described below.

Study Design

Our study brings together social scientists at five LTER sites with herbaceous cover (CAP, JRN, KNZ, SEV, and SGS) and where landscape fragmentation is ongoing. The ecosystems at these five sites are all strongly regulated by variations in water resource availability, with four being semi-arid to arid. The study will first evaluate the explanatory power of the magnitude and rates of change of water provisioning, population, and urbanization on the present degree of land fragmentation, defined by land cover, land use, and land ownership. The study will test the following hypotheses:

- **H_0:** *Sites with higher water provisioning will have greater fragmentation of land cover, use, and ownership*. One of the primary linkages between humans and ecosystems are the ecosystem services that are provided (Daily 1997, Collins et al. 2007); freshwater provisioning (quality and quantity) is perhaps the most important service provided by ecosystems and greatly shapes a landscape's carrying capacity for humans. We hypothesize that water provisioning will partially explain amount and pattern of land fragmentation within the western grasslands context, with more water associated with greater fragmentation. Water provisioning will include precipitation, surface and groundwater (minus evapotranspiration) (Fekete and Vorosmarty 2000), and water delivered by engineered infrastructure (minus measured water loss, typically 20-30%, in the system). Building on methods employed by Jenerette et al. (2006) the analysis of water provisioning will include an assessment of *water supply and demand*, but will extend the analysis to include an assessment of *water rights* as a limiting factor. If time and resources permit, we may also extend the analysis to water pricing.
- **H_1:** *Sites with greater human populations and growth rates will have greater fragmentation of land cover, use, and ownership.* Larger populations will increase competition for land, decreasing parcel size and increasing fragmentation. Those sites facing greater growth rates, in absolute and in proportional terms, will also have greater

fragmentation due to the increased demand for lands, and the inability to respond quickly with comprehensive planning and controls.

- **H_2:** *Sites with larger urban population and higher rates of urbanization will have higher fragmentation of land cover, use, and ownership.* Dense settlement and intense competition for land in urban areas will amplify the relationship described in **H_1**. An "urban effect" on land dynamics within and beyond urban areas will be a major driver of fragmentation. Higher magnitudes and rates of urbanization will lead to greater fragmentation throughout the study area.

Methods

Following Stanfield et al. (2002) and Munroe et al. (2005), we will evaluate fragmentation of land cover, use, and ownership at the parcel level. The post-doctoral scholar will work with each site to create banded transects that begin at a point that was agricultural or wildland in 1970 but is currently classified as urban land use (residential, commercial, or industrial) using Anderson Level II specifications. The transect will end at a point that is currently classified as wildland, and each site will determine the length of the transect according to site characteristics and other research considerations (e.g. existing study sites that have appropriate data for this study). As a starting point, we will choose a bandwidth corresponding to the median parcel size of all interesting parcels, and all parcels that intersect the banded transect will be included in the analysis of fragmentation. The bandwidth will be selected using present-day parcels and held constant for historical analysis (1970-present). Where digital boundaries are not available, we will digitize selected parcels and attribute them with ownership, use, and cover characteristics. Ownership characteristics are available as public records, usually from tax assessor offices. Purchase histories are typically included with present-day attributes, which will allow us to track changes in ownership. If not, these data can be collected from Deeds offices in respective county courthouses. The advantage of using transects is that the number of records will be manageable. Land-use data are available from county and city planning departments. To account for different resolutions of classification, we will collapse land-use categories from each of the sites into Anderson Level II classes. Land cover will be derived from satellite and aerial imagery and classified using National Land Cover Data definitions (http://landcover.usgs.gov/classes.php).

Using the banded transects for each site, we will quantify the degree of fragmentation in a landscape as measured by the number and distribution of patches or distinct (non-adjacent) areas of the same land-cover type, the IJI_L index (Crossiant et al. 2005; O'Neill and Hunsaker 1997). The IJI_L index is useful in measuring the degree to which all patch types within a landscape are adjacent or interspersed with each other. It is the observed interspersion divided by the maximum interspersion for the number of patch types, defined as:

$$\mathrm{IJI\_L} = \frac{-\sum_{i=1}^{m'}\sum_{k=i=+1}^{m'}\left[\left(\frac{e_{ik}}{E}\right)^{\ln}\left(\frac{e_{ik}}{E}\right)\right]}{\ln\left(1/2[m'-1]\right)}(100)$$

Where:

m' = Number of patch types or classes present in the landscape, including the landscape border if present i = 1, . . ., m or m' patch types or classes; k = 1, . . ., m or m' patch types or classes; e_{ik} = Total length (m) of edge in landscape between patch types or classes (distinguished by i and k); E = Total length (m) of edge in landscape

The IJI_L index provides context for a particular parcel; then we will correlate fragmentation, cover, and use with each other and with our proximate drivers of water provisioning, population size and rate, and urbanization magnitude and rate. In addition, we will correlate our findings with other variables considered in the literature, including distance to urban centers, major highways, natural amenities, parcel size, and county or municipal zoning rules affecting the parcel (Munroe et al. 2005). Previous research has demonstrated a relationship between rural land-cover fragmentation and zoning policies (Croissant and Munroe, 2002) and the urbanization pressure gradient (Wickham et al. 2000). Levia (1998) and LaGro and Degloria (1992) found distance to city center, nearby highways, and parcel size to be related to the probability of conversion to residential use. We will include distance to urban centers as a controlling variable in line with LaGro and DeGloria (1992). We will also include distances to major natural amenities, such as Tuttle Creek Reservoir in Kansas, which are drivers of residential land conversion in the Western United States. We will conduct this analysis at roughly ten-year intervals from 1970 to 2000 to correspond with the availability of census data. We will evaluate subdivisions that have occurred during those time periods to assess factors relating to ownership fragmentation and conversion to residential, suburban, or exurban use.

Work Plan and Budget Justification

The budget for this request includes a $20,000 request from this site as well as $47,252 allocated to CAP from KNZ, JRN, SEV, and SGS ($11,813 per site). Work will be initiated with the hiring of a post-doctoral scholar in fall 2008, who will be based at CAP and supervised by Dr. Abby York, a faculty member in the Center for the Study of Institutional Diversity at ASU who specializes in land-use dynamics and policy. A research planning workshop in Tempe in October 2008 will involve scientists from each site in defining research tasks for the coming year and sharing data and information pertinent to the project. Individual sites have requested funds to support travel and accommodation at this meeting, and the CAP budget includes a request for meeting costs. Subsequent meetings among the sites, which will be scheduled on a quarterly basis, will use the Polycom system. While the project makes use of data available electronically, funds in the CAP budget will pay for post-doc travel. A research synthesis meeting in September 2009 at the LTER ASM will allow researchers to discuss research findings and initiate work on a scholarly publication from the research. Drs. Abby York and Christopher Boone (see attached biographical sketches) will participate in this project. Abby brings considerable expertise in land-use dynamics to the project, and Christopher contributes several years of experience in applying GIS techniques to study historic land-use change. Dr. Nancy Grimm with Dr. Marcia Nation will provide overall management for this cross-site initiative.

Social Science Summary Budget

Personnel, post-doc	41,000
Fringe benefits (25%)	10,250
Travel	1,088
Participant meeting costs	800
Other meeting costs	400
TOTAL Direct Costs	53,538
F&A (26%)	13,712
Total	**67,250**