CHARACTERIZATION OF MICROCLIMATIC AND VEGETATION STRUCTURE WITHIN RIPARIAN AREAS ALONG URBANIZED AND NON-URBANIZED EPHEMERAL STREAMS - PRELIMINARY RESULTS

By G.N. Zaimes[1], J.R. Martin[2], M.A. Crimmins[3] and D.M. Green[4]

[1]Assistant Professor/Extension Specialist, School of Natural Resources, University of Arizona,

[2]Graduate Student, School of Natural Resources, University of Arizona,

[3]Assistant Professor/Extension Specialist, Department of Soil Water and Environmental Sciences, University of Arizona,

[4]Associate Professor, Department of Applied Biological Sciences, Arizona State University Polytechnic Campus.

Introduction

The population of Arizona has doubled in the last 15-20 years and is expected to double again by the year 2040 (Department of Commerce, 2005). With Arizona's population increasing substantially, it has become common to see large tracts of desert bladed for development before adjacent subdivisions have been completed. Such growth has the potential to impact ephemeral riparian ecosystems in ways that are not fully understood. To better understand the urban/ephemeral riparian interface, an interdisciplinary team of researchers from the University of Arizona and Arizona State University are conducting a study that compares microclimatic and vegetative data along ephemeral streams with different levels of urbanization in the Sonora Basin and Range ecoregion (Chronic, 1983). This paper highlights preliminary results from the study regarding the proper installation and shielding of certain microclimatic equipment, the initial vegetative survey of the species present in the ephemeral streams chosen for the study, and on the development of working relationships with landowners and HOAs (Homeowner's Associations).

Environmental Issues

Riparian areas are transitional zones between upland terrestrial and aquatic ecosystems, located along the banks of rivers, perennial, intermittent and ephemeral streams, lakes, ponds, springs bogs and meadows (National Research Council, 2002). In the arid western United States, riparian areas are less than 2% of the total area (Ffolliott et al., 2004). Despite their small area, their role is disproportionate to their size, particularly in the semi-arid and arid regions, because of their many ecological functions (Patten, 1998). Riparian areas support more productive and diverse vegetation than their upland counterparts (Johnson et al., 1977). A large percentage of wildlife depends on riparian areas for some portion of their life cycle (DeBano and Schmidt, 2004). Compared to adjacent uplands, the higher vegetation density of riparian areas reduces overland flow, effectively removing sediment, nutrients, and protecting stream banks (Correll, 1997). Although the ecological functions associated with riparian areas along perennial streams have long been recognized, the same is not true for riparian areas along ephemeral streams. The importance of riparian areas along ephemeral streams in Arizona may be more significant than in other states because the largest percentages of the state's streams are ephemeral.

Pima County of Arizona is one of the most rapidly expanding areas in the United States. The increase of Arizona's population is associated with rapid residential development of urban centers that in many cases expands along riparian areas of ephemeral streams. Though development of high density housing is not inherent to the decline of riparian habitat, deterioration generally occurs and is driven by external rather than internal forces, including the introduction of exotic plants, animals, and increased human presence in riparian patches (Green and Baker, 2003). It is expected that the strength of these stressors and the degree of habitat fragmentation will increase with increasing housing density. Although other studies have assessed the impacts of upland timber management on the microclimates of riparian areas associated with perennial streams (Brosofske et al., 1997), the impacts of other upland management activities remain largely unknown (National Research Council, 2002). Influences of upland management practices, particularly urban development, on the microclimate and vegetation of riparian areas along ephemeral stream systems, are currently not known.

One of the unique aspects of the riparian areas is that they have more moderate daily and seasonal climatic variations, through shading and transpiration, than the adjacent upland areas. Evidence of the potential effects of urbanization on climatic conditions is largely regarded as the 'heat island' effect. Research in the Phoenix area has found the average heat island effect ranged from 9.4 to 12.9°C compared to rural baseline climate data (Hawkins et al., 2004). Conversion of land use types from an unimproved desert landscape to built-up urban areas changes surface energy balances. The conversion to a more urbanized landscape increases the surface area and thermal mass through the construction of buildings and roads and typically decreases the cooling effect of evapotranspiration by removing vegetation. These changes can be observed at large city scales, but start as impacts to local microclimate. These smaller scale microclimatic changes may impact riparian ecological processes. Other studies on perennial streams have shown the importance of riparian vegetation in moderating stream temperature regimes and local microclimate (Mitchell, 1999; Meleason and Quinn, 2004). To our knowledge, no studies have examined the importance of riparian vegetation on controlling the microclimate of ephemeral streams in semi-arid climates.

Processes such as decomposition and nutrient cycling are dependent upon soil temperature and moisture. Microbial activity, as indicated by soil respiration rates and enzyme activities, varies significantly between urban and non-urban reaches and is significantly correlated with soil temperature and moisture (Green and Oleksyszyn, 2002). Decomposition rates are closely correlated with microbial activity (Schlesinger, 1997). Many species are adapted to specific microclimate conditions, and this can be reflected for example by their seeds dispersal and germination requirements (Malanson, 1993). Changes in factors influencing a habitat's microclimate can potentially cause changes in its suitability for some species, by altering ecosystem level processes. A study of urban and rural riparian areas in the Phoenix area found differences in species composition and density, one explanation being the introduction of propagules from the urban setting (Green and Baker, 1997). Although there are differences in microclimate, microbial activity, and species composition between urban and rural reaches, insufficient data exists to assess the impact of specific housing densities on these variables.

Objective

The overall objective of the project is to evaluate how different levels of urbanization impact riparian areas along ephemeral streams in the Sonora Basin and Range ecoregion of Arizona. The specific objectives of the project are to evaluate within the riparian areas of ephemeral streams the impact of different levels of urbanization on the following ecosystem parameters:

a. Microclimatic conditions.
b. Plant composition and structure as affected by microclimatic and disturbance drivers associated. The focus on composition and structure will be in the understory (for both herbaceous and woody species).
c. Leaf litter decomposition rates as affected by microclimatic and disturbance drivers associated.

Study Area

The study area is located in Marana, Arizona. Nine ephemeral stream reaches have been chosen flowing northeast from Safford Peak (northern section of the Tucson Mountains) into the Santa Cruz River. The reaches are a short distance from each other (the radius of the study area is ~2 km) to minimize other environmental factors that could impact the results of the study. The approximate center of the study area is located at 32.350081 N, 111.114354 W. Aerial photos were used to initially scout for potential reaches in Tucson and surrounding areas. Ninety-seven ephemeral stream reaches were physically examined in Tucson, Oro Valley, Marana, and Vail, before the final nine reaches were selected.

With the focus of this study encompassing both the climate and flora within the reaches, it was necessary for our reaches to have comparable physical watershed characteristics and certain vegetation compositions. The main attributes considered when selecting each reach were:

a. level of urbanization
b. limited alterations by humans
c. age of the housing development
d. maximum stream discharge,
e. stream slope,
f. sun's aspect,
g. elevation,
h. reach length with the similar levels of urbanization on both sides of its banks,
i. riparian area width,
j. riparian overstory flora and
k. soil types.

The three levels of urbanization are: **Dense** (<14 and >12 houses/hectare), **Moderate** (< 7 and > 4 houses/hectare), and **Very Low** (<1 house/hectare). These three levels are the treatments, with each treatment having three replications. The stream reaches selected have minimal instream human alterations. We avoided streams that have been channelized as those stream reaches introduce impacts on riparian areas due to alterations on stream morphology. We found that most heavy and moderate subdivisions built prior to 2000 had stream reaches that were either redirected into large man-made channels, or were channelized. The younger developments (after 2000) were designed to leave many ephemeral stream channels unmodified, making the urban expansions on the outskirts of Tucson our focal point.

How long a housing development has been established also has a major impact on the riparian area. Our initial desire was to study ephemeral reaches in urban developments ~10 years old. As we began searching for the nine reaches for this study, we realized how difficult it was finding housing developments of the same age and with similar stream characteristics. With most unmodified channels flowing through newer developments, we were resigned to choosing younger housing for our Dense urban reaches (average age ~ 4 years), and slightly older housing for our Moderately urbanized reaches (average age ~10 years).

Stream reaches with maximum discharges less than 29 m^3s^{-1} (Pima County Department of Transportation) were selected because they best support the study's goal to observe direct impacts from urban infrastructure. These streams have smaller urban/riparian buffers, and microclimate shifts due to urban infrastructure should affect their riparian areas much faster with less climatic interferences experienced than in stream reaches with larger maximum discharges.

All of the stream reaches selected have similar slopes, aspects (north to north-east facing), and elevations (650 to 670 m). These reaches have lengths greater than 150 m with continuous and similar levels of urbanization on both banks. In the Dense and Moderate urban reaches, riparian area buffer widths are less than 60 m. The buffer width was measured as the average distance between the urban structures on each side of the banks along the reach. Measurements were taken at five equidistant points: 0%, 25%, 50%, 75%, and 100%, based on the total distance of the reach.

The dominant overstory flora for the nine reaches can be characterized by an abundance of creosote bush (*Larrea tridentata*) and catclaw acacia (*Acacia greggii*), with a smaller presence of little leaf palo verde (*Parkinsonia microphylla*). All riparian areas of the nine reaches have three similar soil types are located within the study area (Cochran and Richardson, 2003). These are: a) loam-skeletal, mixed, thermic Typic Haplargids, b) loam-skeletal, mixed, thermic Typic Calciorthids, and c) coarse-loamy, mixed, thermic Typic Cambiorthids.

All six of the stream reaches with Dense and Moderate urbanized areas are regulated by HOAs. The three reaches with Very-Low urbanization run through the properties of homeowners or potential home builders. In order to have a successful project it is essential to get permission and build good relationships with the HOAs and homeowners. This also offers the opportunity to engage and involve the public in research. Because this is an important issue that researchers face in urban settings, the logistics and legal issues involved with this project, our strategies used for gaining cooperation from the HOAs and the landowners, and the concerns expressed by both groups will be discussed in the results and discussion section.

Methods

Microclimatic conditions: Micrometeorological sensor and datalogger packages will be used to collect data on microclimatic conditions only in riparian areas along ephemeral streams. Sensors will not be placed in the active stream channel due to the high possibility of loss during floods. New and relatively inexpensive dataloggers with extended memory capabilities will allow for frequent sampling (30 min intervals) over extended periods with little need for maintenance. Multi-channel loggers will allow several meteorological sensors to be attached to a single datalogger and for the development of simple sampling routine programs and data download protocols. The variables monitored will be air temperature, soil temperature and moisture, and precipitation. Each reach will have two soil moisture sensors, one soil temperature sensor, six air temperature sensors (including two that also record relative humidity) and one raingage.

Before installing this equipment in the field, tests were conducted on what type of structures the instrument should be shielded in and the optimal locations for the equipment in riparian area. The idea was to maximize the best possible comparison among treatments to compensate for the limited number of microclimatic sensors.

Plant composition and structure: The first step was a preliminary vegetation survey for each reach. Based on this survey, a handout will be written highlighting the most common species present in our reaches. This handout will be used during the more detailed vegetation surveys.

The detailed vegetation surveys will include two types of transects, one for woody and one for herbaceous species. For woody perennial vegetation, two 2 x 20 m belt transects for shrubs and three 25 m radius plots for trees will be sampled. Species considered shrubs within the 2 x 20 m subplots will be measured for crown density, maximum height, and radius by species of shrub originating within the subplot (Bonham 1989). Tree species within the 25 m plot will be quantified for density, basal circumference, height, and canopy radius. Herbaceous species cover will be sampled using 20 x 50 cm plots placed at 2 m intervals within each shrub transect. Canopy cover of herbaceous species will be estimated using cover classes (Daubenmire, 1968). The transects will run parallel to the main axis of the stream reach.

Decomposition rates: The three dominant woody species from all of the reaches, creosote bush, catclaw acacia, little leaf palo verde, and a control species alfalfa (Medicago L.), will be assessed for the decomposition rates using the litter bag technique (Harmon et al., 1999). Bags of all four species will be placed in all nine reaches, and thereafter collected four times each year (pre and post monsoon and pre and post winter rainy season) for a period of two years. Numbered tags will be used to identify each bag. Litter bags dimensions will be ~10 x 10 cm, constructed from nylon cloth with a mesh size of ~1 cm. Approximately ~9 gr of leaf litter will be used for each litterbag. A total of 16 bags for each species will be placed beneath their respective canopies at each reach, with two bags for each collection period. Eight bags will be attached to a line running parallel to the stream reach beneath one canopy, while another eight bags will be stationed similarly beneath a different canopy of the same species. At each collection period, one bag from each canopy will be collected at random. For each bag collected from the species of interest, a bag of alfalfa will also be collected. An equal number of bags of alfalfa will be placed adjacent to the strands of native species under the same canopies. Litter will be dried, weighed and analyzed for total nitrogen (Wilde et al., 1972; Allen, 1989) and lignin (Van Soest, 1963; Allen, 1989).

Preliminary Results and Discussion

This section will highlight the findings from the preliminary studies conducted up to this point. Specifically it will focus on the multiple solar radiation shield designs, temperature sensor locations and placements, and the completed preliminary vegetation survey of the nine reaches. This section will also provide an overview of our interactions with the HOAs and the private homeowners.

Solar Radiation Shield Designs: With a total of 54 air temperature sensors required for the study, we needed affordable and easy-to-install solar radiation shields. Three separate protocols were tested against a standard 6-plate Gill solar radiation shield.

The first protocol used ~8 or 10 cm pvc tubing that was white, ribbed, and perforated. Tubes were cut into lengths of ~26, 30, and 46 cm, and ~3 cm diameter holes were drilled along the top and bottom of the tube to promote air-flow while reducing the amount of solar radiation allowed the shield. Each shield was then tested with: the top and bottom completely open, with the top and bottom capped with an elbow joint facing north (allowing only direct solar radiation entering at 27^{o} C or higher and reducing reflected solar radiation from entering the base), and with the top capped with an elbow and the bottom completely open. The final test of these protocols against the standard solar radiation shield showed that our design was not efficient in capturing the true ambient air temperature during the day (with our best design still recording 2º C higher in the daytimes). Nighttime readings were lower in the pvc pipe designs than the standard shield by approximately 1º C, suggesting that the larger mass of the plated shield insulates the temperature sensor at night.

We then developed an inexpensive design using standard items found at any hardware store to replicate a plated Gill shield. Tarara and Hoheisel (2007) tested several do-it-yourself radiation shields and found that a plated Gill shield design similar to ours produced the lowest solar radiation errors. Our design used six plastic flower pots stacked on top of each other, connected by three ~15 cm screws and spaced apart using vinyl tubing cut at ~2 cm, with the three middle pots having their bottoms cut out to provide space for the sensor to hang in. Each pot was coated with white roofing material to prevent long-term radiation damage.

With a slight modification to their proposed design, we used seven plastic pot-saucers to imitate the plated design of the Gill shield. Their construction was similar to that of the previous protocols using the plastic pots. The only new feature was the use of a rubber tip (one used for the end of canes or crutches) screwed into the bottom of the shield to act as the joint between the shield and the rebar the shield rests on.

Once the designs were completed, we installed 12 sensors strategically throughout one of the dense urban reaches to determine which six reaches would best reflect the nature of the relationship between the riparian ecosystem and the urban developments. Six of the sensors were placed beneath the canopies of the three representative members of the three dominant woody species, creosote, little leaf palo verde and catclaw. Each species had one open sensor (no solar shield) hanging beneath the canopy approximately ~30 cm above the ground, and one adjacent sensor within a solar radiation shield. This test was designed to see if there is a substantial difference between the three types of vegetation, and also if the nighttime readings from the open sensors are that much lower than from the sensors within the shields. Displayed in **Figure 1** are the results from the test conducted beneath the palo verde for 48 hr period. The graph demonstrates how solar radiation penetrating the canopy of a palo verde has a major impact on the temperature readings of a non-shielded sensor. Our concern was that the solar radiation shields were going to insulate the sensors at night and record higher than normal temperatures. The results showed that the difference in minimum temperatures is minimal.

We also used six sensors to test the difference in readings taken near the wash, near the urban boundary, and at a location in approximately the middle between the first two locations. Two sensors within shields were placed at each location; one under the north facing canopy of the representative woody species at each location (catclaw on the wash, creosote in-between, and a desert willow at the urban boundary), and one in the open. This test was designed to see if there are any substantial differences between locations, and if these differences are greater in the shade of woody species or under direct sunlight. **Figure 2** shows the temperature readings for the three sensors placed in the open, and **Figure 3** shows the readings for the sensors placed under the north facing canopies. With only two days of data collected, it is impossible to determine if there is a significant difference between any of the placements, but there are indications that

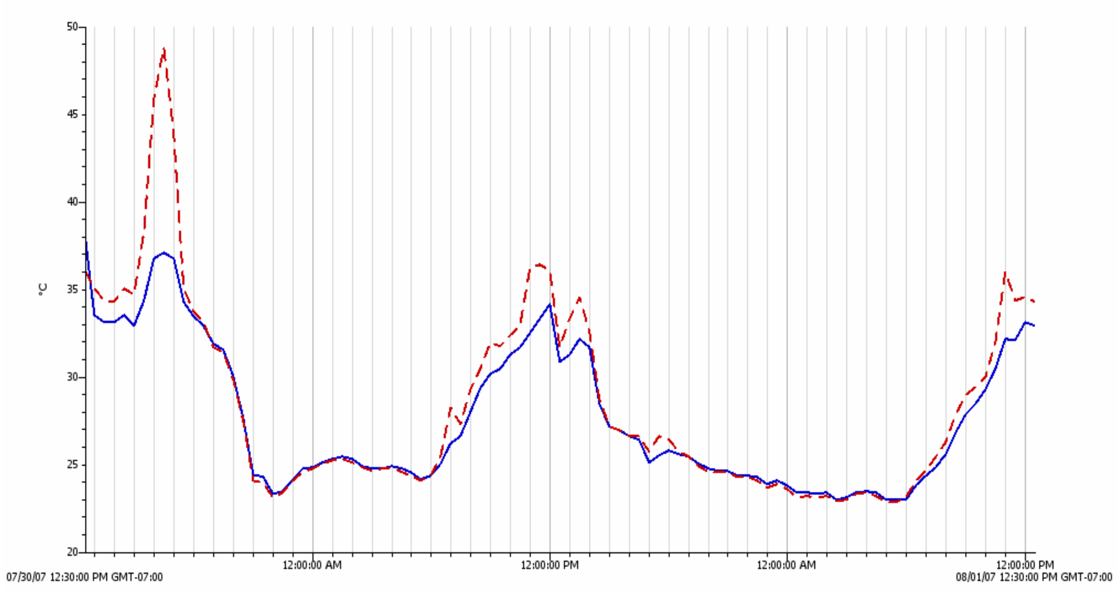

Figure 1. Temperatures recorded (ºC) for open sensor (red colored line) versus shielded sensor (blue colored line) underneath the canopy of a mature palo verde within the riparian area of a Dense ephemeral reach. Temperature is on the y-axis while time of day is on the x-axis.

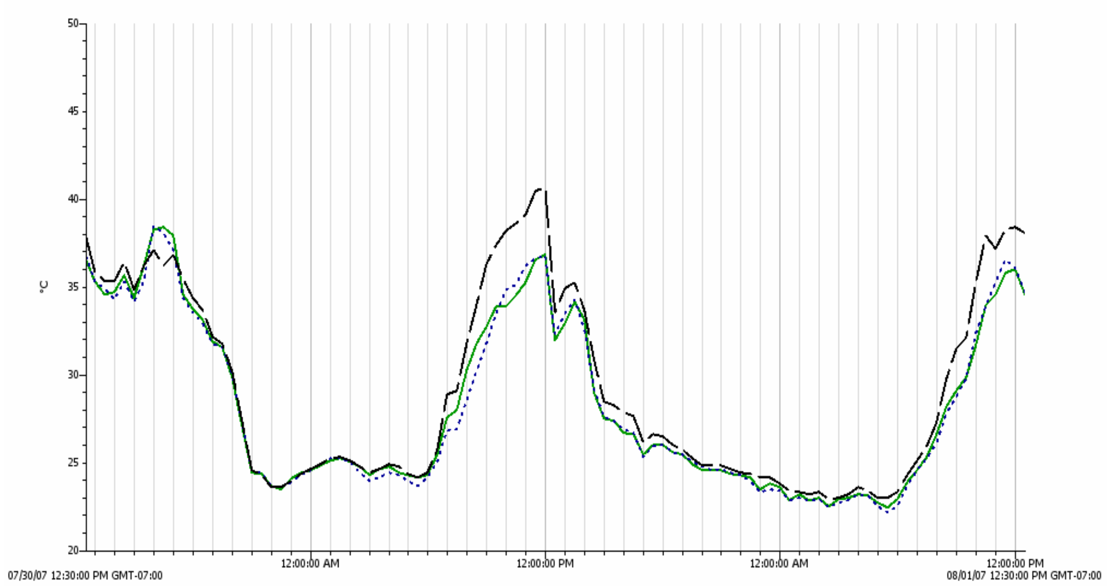

Figure 2. Temperature comparison (ºC) of three shielded temperature sensors [next to the wash (blue colored line), in approximately the middle distance between the wash and the urban development (green colored line), and within 1 m of the boundary between the riparian area and the urban development (black colored line)] placed in direct sunlight within the riparian area of a Dense ephemeral reach. Temperature is on the y-axis while time of day is on the x-axis.

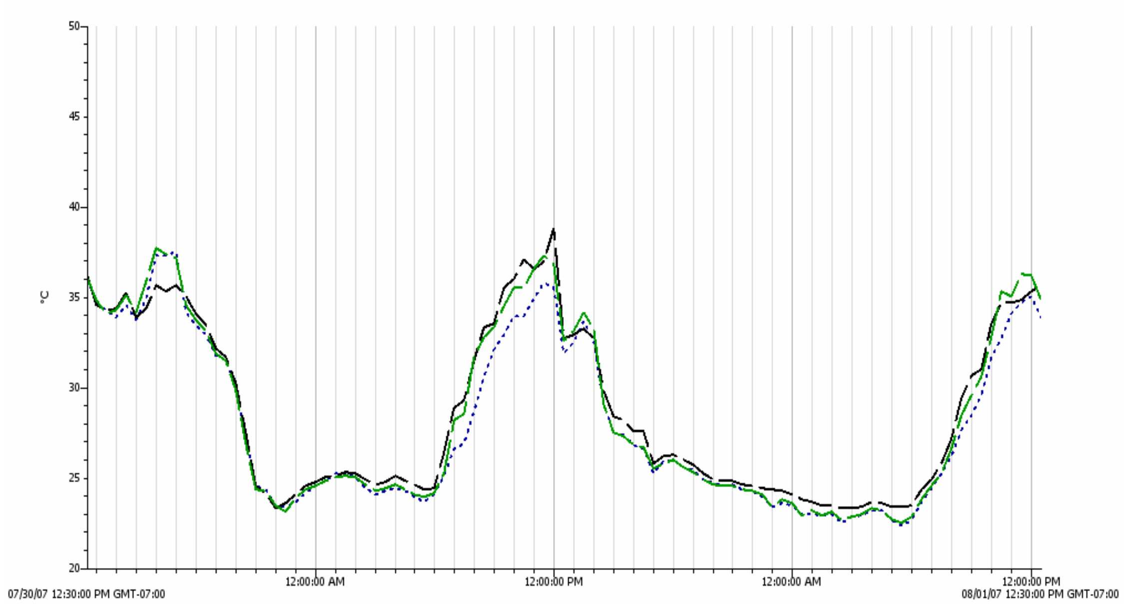

Figure 3. Temperature comparison (ºC) of three shielded temperature sensors [next to the wash (blue colored line), in approximately the middle distance between the wash and the urban development (green colored line), and within 1 m of the boundary between the riparian area and the urban development (black colored line)] placed under the north facing canopy of representative vegetation for each location within the riparian area of a Dense ephemeral reach. Temperature is on the y-axis while time of day is on the x-axis.

show that the sensor placed at the urban boundary in direct sunlight experienced a greater maximum temperature than any of the other five sensors.

Plant Composition and Structure: Photos and physical samples of every species from the nine reaches were brought into the University of Arizona Herbarium for identification. These species found in our reaches are separated in three main categories: woody, herbaceous, and succulent (**Table 1**).

Establishing Collaborative Relations with HOAs and Private Landowners: All nine ephemeral reaches selected for the study run through private property. Despite the low-profile of our project, we were inclined to seek permission from the property owners and managers for several reasons; the most important reason being the need to strengthen relations between the general public and the scientific community.

The two HOAs we have worked with have property managers that act as liaisons between our group and the HOAs committee. One of the HOAs is for the all three Dense reaches and the other HOA if for all the three Moderate reaches. Where applicable, the property managers provided us with lists of restrictions. None of these restrictions applied to our study, but examples are: not introducing new plant species, no permanent structures and/or disturbance of

Table 1. The species found in our nine reaches based on the preliminary vegetation survey.

Species	Common Name
Woody species	
Larrea tridentata	Creosote
Acacia greggii	Catclaw
Acacia constricta	Whitethorn
Prosopis velutina	Velvet Mesquite
Celtis pallida	Desert Hackberry
Parkinsonia microphylla	Little Leaf Palo Verde
Ambrosia ambrosioides	Canyon Ragweed
Encelia farinosa	Brittlebush
Tamarix dioica	Tamarisk
Baccharis sarothroides	Desert Broom
Chilopsis linearis	Desert Willow
Olneya tesota	Ironwood
Lycium exsertum	Arizona Desert-Thorn
Ambrosia deltoidea	Triangle Burr Ragweed
Lycium macrodon	Desert Wolfberry
Porophyllum gracile	Slender Poreleaf
Leucophyllum frutescens	Texas Barometer Bush
Ditaxis neomexicana	New Mexican Silverbush
Herbeceaous species	
Nicotianna obtusifolia	Desert Tobacco
Muhlenbergia microsperma	Littleseed Muhly
Sphaeralcea ambigua	Globemallow
Aristida purpurea	Purple Threeawn
Gnaphalium americanum	American Everlasting
Euphorbia capitellata	Head Sandmat
Datura stramonium	Jimsonweed
Erioneuron pulchellum	Fluff Grass
Salsola tragus	Tumbleweed/Russian Thistle
Dyssodia pentachaeta	Dogweed
Kochia scoparia	Summer Cypress Belvedere
Senna covesii	Cove's Cassia
Succulent species	
Cylindropuntia leptocaulis	Christmas Cactus
Cylindropuntia spinosior	Walkingstick Cactus
Ferocactus wislizenii	Barrelcactus
Opuntia englemanii	Pricklypear
Cylindropuntia versicolor	Staghorn Cholla
Carnegia gigantia	Saguaro Cactus
Mammillaria grahamii	Graham's Nipple Cactus

the property. The property managers also presented to the HOA committees with a detailed outline of our study asking for their permission. Both committees responded favorably.

The two HOA's we are working with although similar in some ways, differ in others. The three Dense washes are part of a "commons" area, where the HOA is responsible for managing the grounds. Once the HOA agreed we had permission to work on the reaches. As all three washes are considered floodways, any large-scale projects require further analysis from the Army Corp of Engineers. In the three Moderate washes the HOA behaves more as a supervisor of the wash as it flows through private lots. In this neighborhood, the individual homeowner is required to submit building and landscaping designs to the HOA committee if their designs fall outside of the HOA agreement. We were required to submit a similar proposal for the solar radiation shields and the rain gages to be placed along the reaches. Once the HOA approved of the designs, we then were required to obtain the consent from each individual homeowner for access to the wash via their property and to conduct our study on their property. This last step was repeated for the three washes that run through Very Low urban densities. The Very Low urban densities are managed by one or more landowners, but not by an HOA.

Seventy three letters were sent out in early June asking for permission to conduct our study on their properties. Fifteen people responded, half of which approved of the study. In mid July, 34 homeowners were called about the project, with 15 responses, 13 of which providing permission. Currently we have a total of 30 responses nine of which declined permission but are we still contacting more owners to gain permission to more segment of the reaches.

There have been a wide range of responses from homeowners regarding our study on their property: excitement, anger, indifference . . . many of which first protected by a layer of skepticism. Some homeowners have been willing to talk through the skepticism, some have not. A few people have expressed their concern about our project's impact on the wildlife and the biota within the wash, and have declined our request even when it was clarified that our study is observational and that our visits will be infrequent. Our experience so far has shown that people are more inclined to express enthusiasm about the study if they meet with us face-to-face. We hope that as our study progresses we will have more opportunities to engage homeowners at this level, eliminating the cloud of uncertainty that comes with a formal letter and a phone-call from an unknown voice.

References

Allen, S.E. 1986. Chemical analysis of ecological materials. Blackwell Science Publications, Oxford, UK.

Bonham, C.D. 1989. Measurements for terrestrial vegetation. J. Wiley & Sons, New York, NY.

Brosofske, K.D., J. Chen, R.J. Naiman, J.F. Franklin. 1997. Harvesting effects on microclimatic gradients from small streams to uplands in western Washington. Ecological Applications 7: 1188-1200.

Chronic, H. 1983. Roadside Geology of Arizona. Mountain Press Publishing Company, Missoula, MT.

Cochran, C.C and M.L. Richardson. 2003. Soil survey of Pima County, Arizona, eastern part United States. Natural Resources Conservation Service. Washington, D.C.

Correll, D.L. 1997. Buffer zones and water quality protection: General principles. In: Hancock, N.E. et al. (eds.), Buffer zones: Their processes and potential in water protection. Quest Environmental. Hertfordshire, England.

Daubenmire, R. 1968. Plant communities: A textbook of plant ecology. Harper & Row, New York, NY.

DeBano, L.F. and L.J. Schmidt. 2004. Settings and history. In: Baker, M.B et al. (eds.), Riparian areas of the southwestern United States hydrology ecology and management. CRC Press. Boca Raton, FL. pp. 29-50.

Department of Commerce. 2005. Population and Demographics. Available at: http://www.commerce.state.az.us/prop/eir/popanddemo.asp (accessed 01-37-2005)

Ffolliott, P.F., M.B. Baker, Jr., L.F. DeBano, and D.G. Neary. 2004. Introduction. In: Baker M.B. et al. (eds.), Riparian areas of the Southwestern United States: Hydrology, ecology and management. CRC Press. Boca Raton, FL. pp. 1-9.

Green D.M. and M.G. Baker. 2003. Urbanization impacts on habitat and bird communities in a Sonoran desert ecosystem. Landscape and Urban Plan. 63:225-239.

Green,D.M. and M. Oleksyszyn. 2002. Enzyme activities and carbon dioxide flux in a sonoran desert urban ecosystem Soil Science Society of America Journal 66: 2002-2008.

Hawkins, T.W., A. Brazel, W. Stefanov, W. Bigler and E.M. Saffell. 2004. The role of rural variability in urban heat island determination for Phoenix, Arizona. Journal of Applied Meteorology 43:476-486.

Harmon, M.E., K.J. Nadelhoffer, J.M. Blair. 1999. Measuring decomposition, nutrient turnover, and stores in plant litter. Pp. 202-240, in G.P. Robertson, D.C. Coleman, C.S. Bledsoe, P. Sollins. Standard soil methods for long-term ecological research. Oxford University Press, New York, NY.

Johnson, R.R., L.T. Haight, and J.M. Simpson. 1977. Endangered species vs. endangered habitats: a concept. In: Johnson, R.R. and D.A. Jones (eds.) Importance, preservation and management of riparian habitat: a symposium. USDA Forest Service General Technical Report RM-43. Ft. Collins, CO. pp. 68-79.

Malanson, G.P. 1993. Riparian landscapes: Cambridge University Press. Cambridge, UK.

Meleason, M. A. and J. M. Quinn, 2004. Influence of riparian buffer width on air temperature at Whangapoua Forest, Coromandel Peninsula, New Zealand. Forest Ecology and Management 191:365-371.

Mitchell, S., 1999. A simple model for estimating mean monthly stream temperatures after riparian canopy removal. Environmental Management 24:77-83.

National Research Council. 2002. Riparian areas: functions and strategies for management. National Academy of Science. Washington, DC.

Patten, D.T. 1998. Riparian ecosystems of semi-arid North America: diversity and human impacts. Wetlands 18:498-512.

Pima County Department of Transportation (DOT). 2007. Pima County MapGuide Available at: http://www.dot.co.pima.az.us/gis/maps/mapguide/ (Assessed 08-02-2007)

Tarara J.M. and G.-A.Hoheisel, 2007. Low-cost Shielding to Minimize Radiation Errors of Temperature Sensors in the Field. HortScience 42(5) accepted

Van Soest, P.J. 1963. Use of detergents in the analysis of fibrous feeds. II. A rapid method foe the determination of fiber and lignin. Journal of the Association of Official Analytical Chemistry 49:546-551.

Wilde, S.A., G.K. Voigt, and J.G. Iyer. 1972. Soil and plant analysis for tree culture 4th edition. Oxford and IBH Publishing Company, New Delhi, India.