2004 Water Use Efficiency Proposal

Section B: Research and Development;

Identifying Total Urban Irrigated Landscape Areas in the San Joaquin Valley by Satellite Remote Sensing Image Spectral Mixture Analysis

Submitted by
Dr. Xiaoming Yang, Ph.D.
California State University, Fresno
Interdisciplinary Spatial Information Systems Center

January 11, 2005

California Department of Water Resources
Office of Water Use Efficiency
1416 Ninth Street, Room 338, Sacramento, CA 95814
Attention: Debra Gonzalez

Section B: Research and Development;

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Interdisciplinary Spatial Information Systems Center

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APPENDIX A: Project Information Form

Applying for: **X** Urban ❑ Agricultural

1. (Section A) **Urban or Agricultural Water Use Efficiency Implementation Project**

❑ (a) implementation of Urban Best Management Practice, #_____

❑ (b) implementation of Agricultural Efficient Water Management Practice, #_____

❑ (c) implementation of other projects to meet California Bay-Delta Program objectives, Targeted Benefit # or Quantifiable Objective #, if applicable _____

❑ (d) Specify other: _____

2. (Section B) **Urban or Agricultural Research and Development; Feasibility Studies, Pilot, or Demonstration Projects; Training, Education or Public Information; Technical Assistance**

X (e) research and development, feasibility studies, pilot, or demonstration projects

❑ (f) training, education or public information programs with statewide application

❑ (g) technical assistance

❑ (h) other

3. Principal applicant (Organization or affiliation): **Interdisciplinary Spatial Information Systems Center , California State University, Fresno**

4. Project Title: **Identifying Total Urban Irrigated Landscape Areas in the San Joaquin Valley by Satellite Remote Sensing Image Spectral Mixture Analysis.**

5. Person authorized to sign and submit proposal and contract:

Name, title _____

Mailing address _____

_____

Telephone _____

Fax. _____

E-mail _____

Senior 6. Contact person (if different):	Name, title.	**Dr Xiaoming Yang**
	Mailing address	**2255 E Barstow Ave M/S IT9**
		Fresno, CA 93740
	Telephone	**559-278-8457**
	Fax.	**559-278-8492**
	E-mail	**xmyang@csufresno.du**

7. Grant funds requested (dollar amount): *(from Table C-1, column VI)*	**$165,685**
8. Applicant funds pledged (dollar amount):	**0**
9. Total project costs (dollar amount): *(from Table C-1, column IV, row n)*	**$165.685**
10. Percent of State share requested (%) *(from Table C-1)*	**100%**
11. Percent of local share as match (%) *(from Table C-1)*	**0**
12. Is your project locally cost effective? *Locally cost effective means that the benefits to an entity (in dollar terms) of implementing a program exceed the costs of that program within the boundaries of that entity.* *(If yes, provide information that the project in addition to Bay-Delta benefit meets one of the following conditions: broad transferable benefits, overcome implementation barriers, or accelerate implementation.)*	❑ (a) yes **X** (b) no
11. Is your project required by regulation, law or contract? If no, your project is eligible. If yes, your project may be eligible only if there will be accelerated implementation to fulfill a future requirement and is not currently required. *Provide a description of the regulation, law or contract and an explanation of why the project is not currently required.*	❑ (a) yes **X** (b) no

12. Duration of project (month/year to month/year):	**Dec 2005 – Nov 2006**
13. State Assembly District where the project is to be conducted:	**25, 29, 30**
14. State Senate District where the project is to be conducted:	**12, 14, 16**
15. Congressional district(s) where the project is to be conducted:	**18, 21, 20**
16. County where the project is to be conducted:	**Stanislaus, Fresno, Kern**
17. Location of project (longitude and latitude)	
18. How many service connections in your service area (urban)?	**Unkown**
19. How many acre-feet of water per year does your agency serve?	**NA**

20. Type of applicant (select one):

- ❑ (a) City
- ❑ (b) County
- ❑ (c) City and County
- ❑ (d) Joint Powers Authority
- ❑ (e) Public Water District
- ❑ (f) Tribe
- ❑ (g) Non Profit Organization
- **X** (h) University, College
- ❑ (i) State Agency
- ❑ (j) Federal Agency
- ❑ (k) Other
  - ❑ (i) Investor-Owned Utility
  - ❑ (ii) Incorporated Mutual Water Co.
  - ❑ (iii) Specify _____

21. Is applicant a disadvantaged community? If 'yes' include annual median household income.

(Provide supporting documentation.)

- ❑ (a) yes, _____ median household income
- **X** (b) no

2004 Water Use Efficiency Proposal Solicitation Package
APPENDIX B: Signature Page

By signing below, the official declares the following:

The truthfulness of all representations in the proposal;

The individual signing the form has the legal authority to submit the proposal on behalf of the applicant;

There is no pending litigation that may impact the financial condition of the applicant or its ability to complete the proposed project;

The individual signing the form read and understood the conflict of interest and confidentiality section and waives any and all rights to privacy and confidentiality of the proposal on behalf of the applicant;

The applicant will comply with all terms and conditions identified in this PSP if selected for funding; and

The applicant has legal authority to enter into a contract with the State.

_____	_____	_____
Signature	Name and title	Date

Appendices C, D, E Statement of Work

Identifying Total Urban Irrigated Landscape Areas in the San Joaquin Valley by Satellite Remote Sensing Image Spectral Mixture Analysis

Appendix C Section One: Relevance and Importance

The 2004 Water Use Efficiency Proposal Solicitation Package Has specified as an area of interest "***Identify total urban irrigated landscape areas in State by region***". This proposal addresses that area of interest.

San Joaquin Valley (SJV) in the heart of California is one of the nation's top agriculture producing regions for a great array of fruits and vegetables. The eight counties, from San Joaquin to Kern, have an estimated population more than 3.2 million. The population is anticipated to double in the next 20 years. Recent population growth in the valley has been outpacing the state growth rate which results in a great urban sprawl in all cities in the valley.

The consequence of the changes in the valley's fast urbanization causes a huge demand on the water resource for both drinking and landscape irrigation purposes. In order to improve water management for beneficial uses of the Bay-Delta system, it is important to have a better understanding of the extent of the irrigated landscape areas and how much water is used for landscape purposes in the urban areas. The knowledge of water consumption by the irrigated landscape will help decision-makers and planners to develop sound water-management plans to conserve water, preserve and enhance ecosystems, and to conserve the water supply of the region.

The objective of this study is to examine potential benefits of employing low-cost remote sensing technology to improve water use efficiency planning. The project will determine the extent to which Landsat Thematic Mapper imagery can be used to quantify irrigated landscape abundance and distribution in the urban areas in San Joaquin Valley. In addition to the spatial view of large urban areas, Landsat's 16-day revisit period allows monitoring of seasonal and inter-annual changes in urban irrigated landscape areas (UILAs). It may also be possible to investigate temporal changes in UILAs abundance that have occurred during the past 18 years that the TM instruments have been operational. Landsat TM imagery, while relatively low cost, has had the disadvantage of being too low resolution to provide useful vegetation data in high-density, mixed-use urban areas. This project proposes apply to the Landsat TM data an enhancement model to increase its usefulness and still retain the relatively low cost. This technological advancement is expected to then render satellite remote sensing useful and affordable over larger areas therefore bringing increased benefits.

The need for this technology is to enhance the tools available to water management planners in terms of usefulness and economical cost outlay. The need is also implicit inasmuch as the Proposal Solicitation Package has identified the topic as a 'project of "interest".

Appendix D Section Two: Technical/Scientific Merit, Feasibility

1. Introduction

Mapping urban environments with Landsat TM remote sensing imageries is challenging. Urban environments are generally recognized in remotely sensed imagery by their geometric and textural characteristics. At 30 to 60 meter spatial resolution of the sensor, few urban pixels are thematically 'pure'. In other words, the majority of the pixels contain a mix of man-made objects, such as buildings, roads, etc., and vegetation. Therefore, spectral characteristics of the urban areas are usually heterogeneous in nature.

Pixels of a remotely sensed image represent a spatial average over the ground-projected spread function. As the mixing portions change from pixel-to-pixel, the net spectral vector changes. All natural, and most man-made, surfaces are non-uniform at some level of spatial resolution. For some specific ground surface objects, an increase in spatial resolution may reduce the percentage of mixed pixels, but mixed pixels will still occur at the boundary between the objects regardless of their size or the sensor resolution. In addition, atmospheric effects will always exist to mix the signature recorded. Thus, signature mixing does not go away even if one uses higher resolution imagery.

The characteristics of spatial resolution and spectral variability of urban areas creates serious problems for traditional, so called 'hard', classification algorithms. By determining some measure of similarity of the spectral reflectance of a pixel to the spectral reflectance of a particular class, the information contained in multi-band spectral reflectance imagery is reduced to a single thematic map of limited classes. In areas where the land cover types are homogeneous, the assignment of each pixel to one specific class can be done with reasonable accuracy. In the areas where small patches of heterogeneous land cover types are present, the spectral reflectance of an individual pixel will generally contain a mixture of the reflectance of more than one class. Under this circumstance, the assignment of a mixed reflectance pixel to a single homogeneous class produces inaccuracies in the resulting thematic map.

Spectral Mixture Analysis (SMA) provides a quantitative strategy for studying multi-spectral images and is a model based on the existence of signature mixture in image pixels (Adams and Smith, 1986). The assumption of the SMA is that variability of composition and illumination within an image make a distinct contribution to the net reflectance observed by the image sensor and that this contribution can be estimated by mathematical inversion of spectral mixture models of the observed reflectance.

SMA has been extensively applied to characterization of urban environments. It has been used to estimate urban impervious surface with Landsat TM data (Wu and Murray, 2003), to perform urban areas change detection (Kressler and Steinnocher, 1996), to monitor urban environment development (Kressler and Steinnocher, 2000; Phinn et al., 2002), to measure temporal composition of urban morphology (Rashed, et al., 2002)

and to quantify spatial and spectral characteristics of urban reflectance (Small, 2003). Since SMA can provide full spectrum measurement of vegetation response, fractions modeled by SMA have been used to estimate urban vegetation abundance (Small, 2001), to describe fraction vegetation cover (Cross et al, 1991) and seasonal changes in vegetation (Roberts, et al, 1997; Garcia and Ustin, 2001).

2. Methods and procedures

a. Linear mixture model

The proposed research will focus on a sub-pixel classification method called Linear Spectral Unmixing. This method assumes that macroscopic combination of homogeneous "endmember" materials within the Ground Instantaneous Field Of View (GIFOV) often produce a composite reflectance spectrum. This complex spectrum can be described as a linear combination of the spectra of the endmembers (Singer and McCord, 1979). An endmember is defined as the idealized, pure signature for a class. Because of sensor noise and within-class signature variability, endmembers only exist as a conceptual convenience and as idealizations in real images. Reflectance modeling suggests that nonlinearity occurs with multiple scattering of radiation among different target materials (Clark and Lucey, 1984). However, if mixing between the endmember spectra is predominantly linear and the endmembers are known a priori, it may be possible to "unmix" individual pixels by estimating the fraction of each endmember in the composite reflectance of the mixed pixel (Adams et al. 1986, Gillespie et al. 1990, Smith et al. 1990)

The Linear Mixing Model describing mathematically a linear combination of endmember spectra is:

$$f_1 E_1(\lambda) + f_2 E_2(\lambda) + \ldots + f_n E_n(\lambda) = R(\lambda) \qquad (1)$$

where $R(\lambda)$ is the observed reflectance profile, a continuous function of wavelength λ. The $E_i(\lambda)$ are the endmember spectra and the f_n are the corresponding fractions of the n endmembers contributing to the composite reflectance spectrum for the area within the GIFOV. Because the sensor actually measures radiance in a finite number of spectral bands, the surface reflectances are estimated from measured radiances by compensating for sensor calibration and interaction with the atmosphere. As a result, the continuous reflectance profiles are represented as vectors of discrete reflectance estimates at specific wavelengths as:

$$E(\lambda) = [e_{\lambda 1}, e_{\lambda 2}, \ldots, e_{\lambda n}] \qquad (2)$$

$$R(\lambda) = [r_{\lambda 1}, r_{\lambda 2}, \ldots, r_{\lambda n}] \qquad (3)$$

where each $r_{\lambda i}$ represents a portion of the observed reflectance spectrum $R(\lambda)$, integrated over a finite spectral band with a center wavelength λ_i; and each $e_{\lambda i}$ represents the contribution to this observed reflectance from the corresponding endmenber $E(\lambda)$. The relationship in equation (1) is constrained by the assumption that an exhaustive set of endmembers (classes) has been defined, so that,

$$\sum_{i=1}^{n} f_i = 1 \qquad (4)$$

at each pixel. This assumption is somewhat problematic in practice since one is never sure that a sufficient number of endmembers has been defined for a given set of data. However, the validity of the linear mixture model is determined by the ability of the sensor to resolve differences in the characteristic spectra of the target material given a limited sampling of the continuous reflectance spectra with finite number of bands (Small, 2001). In the case of typical multi-spectral sensors such as Landsat, the spectra are generally under sampled so that materials with different reflectance spectra can yield indistinguishable reflectance vectors in the six bands that are imaged. As a consequence, this can simplify the mixing problem by reducing the number of possible endmembers that can be resolved. An additional constraint can be incorporated at each pixel on the fraction estimates, namely that each fraction must be positive:

$$f_i \geq 0 \qquad (5)$$

The tractability of the unmixing problem is determined by the discrete sampling of the reflectance spectra and the number of discernible endmembers that contribute to the target reflectance. In the equation (1), if the number of endmembers is less than the number of bands, the problem is over determined and there may be no exact solution if the data contain measurement errors. In this case, the equation (1) can be modified to accommodate errors in the reflectance estimates:

$$\mathbf{r} = \mathbf{Ef} + \varepsilon$$

where ε is an error vector which must be minimized to find the fraction vector **f** which gives the best fit to the observed reflectance vector **r**.

The result of minimizing

$$\varepsilon^T \varepsilon = (\mathbf{r} - \mathbf{Ef})(\mathbf{r}\text{-}\mathbf{Ef}) \qquad (6)$$

is a set of endmember fraction estimates for each pixel which together provide a fraction image for each endmember. The endmember fraction for a given pixel represents the fraction area of the pixel containing that endmember. In this study, the primary objective is the estimation of the urban irrigated landscape fraction, F_v.

b. Endmember selection

Estimation of endmember fractions from the linear mixture model is based on the assumption that there is knowledge about what spectral endmembers the mixed pixels are composed of and what materials actually constitute the spectral endmembers. The simplest model that can describe the urban spectral distribution has three components, low albedo, high albedo, and vegetation. This three-component mixing model is physically consistent with the spectral characteristics that might be expected for an urban environment. Although a wide variety of target materials is present in the urban mosaic, the differences in their spectral reflectance are not necessarily resolved by the TM sensor's spectral sampling. Vegetated areas in the San Joaquin Valley

urban environments are typically irrigated during the summer time. Therefore, vegetation component in the three-component model can be considered as irrigated landscapes.

The success of spectral unmixing depends on the selection of the endmember components. An optimal approach for selecting endmembers is to use laboratory-based measurements of endmember's spectra. In the case of urban reflectance, the relative simplicity of the feature space topology suggests that it may be possible to select endmembers from the image data (Smith, et al, 1990, Adams, et al 1995). The approach for choosing endmembers in the study is based on the selection of homogeneous pixels from satellite images through visualizing spectral scatter plots of image band combinations (Rashed et al, 2001). Principal component (PC) transformation will also be used to guide image endmember selection since it puts almost 90% of the variances on the first two or three components and minimizes the influence of band to band correlation (Smith et al, 1985).

c. Irrigated landscape area estimation

A city limits mask will be created using Geographical Information Systems (GIS) data from selected cities. The mask will be applied to the process to provide boundaries for the image processing extents.

The three-component linear mixture model will be inverted for endmember fractions using the Landsat TM data. The inversion will be performed both with and without a unit sum constraint. In order for the inversion to be stable, small differences in the endmember spectra should not result in large differences in the fraction estimates. The sensitivity of the solution to the choice of the endmember spectra will be indicated by the consistency of the endmember fraction distributions and correlations between different solutions. The mathematical validity of the three-component linear mixture model will be assessed by reconstructing reflectance vectors using the model endmembers and the estimated fractions. Comparing an observed reflectance vector with the corresponding vector constructed from the estimated fractions of model endmembers will show how well the linear mixing model describes the reflectance of that pixel.

d. Accuracy assessment

In order to quantify the accuracy of the urban irrigated landscape area fraction estimates, it is necessary to validate the model with independently derived ground truth estimates of the actual irrigated landscape area fraction. The ground truth measurements of the aerial irrigated landscape fraction and distribution will be obtained from high-resolution imagery in which irrigated landscape areas can be unambiguously identified by texture, color, and context. If the unmixed irrigated landscape fractions estimated from the Landsat data are similar to the irrigated landscape fractions derived from validated high-resolution imagery, the agreement will provide independent confirmation of the unmixing estimates and give an idea of the detection limit of the Landsat TM sensor.

In this study, the Landsat-derived irrigated landscape area fraction estimates will be validated by comparing with high-resolution images from DigitalGlobe. Using stratified sampling, a minimum of 50 samples will be taken for each category of older developments (>30 years), medium age developments (6-29 years), and newer developments (<5years) from each study area. For every sampled TM pixel, the corresponding high-resolution image will be digitized and irrigated landscape areas will be calculated from the digital map.

In addition to the accuracy assessment by image comparison ground truthing, the actual water consumption for the sampled areas will be collected through the local water conservation office. Statistical analysis will be performed on the data to explore the relationship of the irrigated landscape areas and their water usage.

Literature Cited

Adams, J. B. and Smith, M. O. (1986). Spectral mixing modeling: a new analysis of rock and soil types at the Viking Lander site. Journal of Geophysical Research 91, 8098-8112

Adams, J. B., Sabol, D. E., Kapos, V., Almeida-Filho, R. Roberta, D. A., Smith, M. O., and Gellispie, A. R., 1995. Classification of multiple images based on fractions of endmembers: application to land cover change in the Brazilian Amazon. Remote Sensing of Environment, 52, 137-154

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Cross, A. M., Settle, J. J., Drake, N. A., and Paivinen, R. T. M., 1991. Subpixel measurement of tropic forest cover using AVHRR data. International Journal of Remote Sensing, 12:1119-1129.

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Garcia M., and Ustin, S. L., 2001. Detection of interannual vegetation responses to climatic variability using AVIRIS data in a coastal savanna in California. IEEE Transactions on Geoscience & Remote Sensing, 39:1480-14990.

Gillespie, A. R. Smith, M. O., Adams J. B., Willis, S. C., Fischer, A. F., and Sabol, D. E., 1990. Interpretation of residential images: spectral mixture analysis of AVIRIS. Proceedings of the 2nd AVIRIS Workshop, 4-5 June 1990 (Pasadena, CA: JPL) pp. 243-270

Kressler, F., and Steinnocher, K., 1996. Change detection in urban areas using satellite images and spectral analysis. Proceedings of the ISPRS.

Kressler, F., and Steinnocher, K., 2000. Monitoring urban development using satellite images. Proceedings of the Second International Symposium on Remote Sensing of Urban Areas, Regensburg, Germany.

Lu, D. and Wand, Q, 2004. Spectral mixture analysis of the urban landscape in Indianapolis with Landsat ETM+ imagery. Photogrammetric Engineering & Remote Sensing, 70(9):1053-1062.

Phinn, S., Stanford, M., Scarth, P., Murry, A. T., and Shyy, P. T., 2002. Monitoring the composition of urban environments based on vegetation-impervious surface-soil (VIS) model by subpixel analysis techniques. International Journal of Remote Sensing, 23:4131-4153

Rashed, T., Weeks, J. R., and Gadalla, M. S., 2001. Revealing the anatomy of cities through spectral mixture analysis of multi-spectral satellite imagery: a case study of the greater Cairo region, Egypt. Geocarto International, 16(4), 5-15

Rashed, T., Weeks, J. R., Stow, D., and Fugate, D., 2002. Measuring temporal compositions of urban morphology through spectral mixture analysis: Toward a soft approach to change analysis in crowded cities. Proceedings of the Third International symposium on Remote Sensing on Urban Areas, Istanbul, Turkey.

Roberts, D. A., Gardner, M., Church, R., Ustin, S. L., and Green, R. O., 1997. Optimum strategies for mapping vegetation using multiple endmember spectral mixture models. Imaging Spectrometry III, SPIE Optical Engineering Press, Bellingham, WA, pp. 108-119.

Singer, R. B. and McCord, T. B, 1979. Mars: large scale mixing of bright and dark surface materials and implications for analysis of spectral reflectance. Proceedings of 10th Lunar and Planetary Science Conference, American Geophysical Union, Washington, DC pp. 1835-1848

Small, C., 2001. Estimation of urban vegetation abundance by spectral mixture analysis. International Journal of Remote Sensing, 22:7, 1305-1334

Small, C., 2003. High spatial resolution spectral mixture analysis of urban reflectance. Remote Sensing of Environment, 88:170-186

Smith, M. O., Johnson, P. E., and Adams, J. B., 1985. Quantitative determination of mineral types and abundances from reflectance spectra using principal component analysis. Journal of Geophysical Research, 90, 792-804

Smith, M. O., Ustin, S. L., Adams, J. B., and Gillespie, A. R., 1990. Vegetation in deserts: I. A regional measure of abundances from multiple spectral images. Remote Sensing of Environment, 31. 1-26.

Wu, C. and Murray, A. T., 2003. Estimating impervious surface distribution by spectral mixture analysis. Remote Sensing of Environment, 84: 493-505.

Appendix E Section Three: Monitoring and Assessment

The progress of the project will be managed according to the timeline following. The timeline will define specific schedule for the tasks. A weekly log will be implemented to document the project progress.

In addition to the evaluation method mentioned in the section two above, the results of the project will be evaluated in terms of cost and benefits with the previous studies done by two of the cooperating cities (Clovis and Bakersfield).

- The research project is an attempt to provide a vegetated area monitoring tool based on current data. Therefore water consumption data baselines are not included as part of the project.

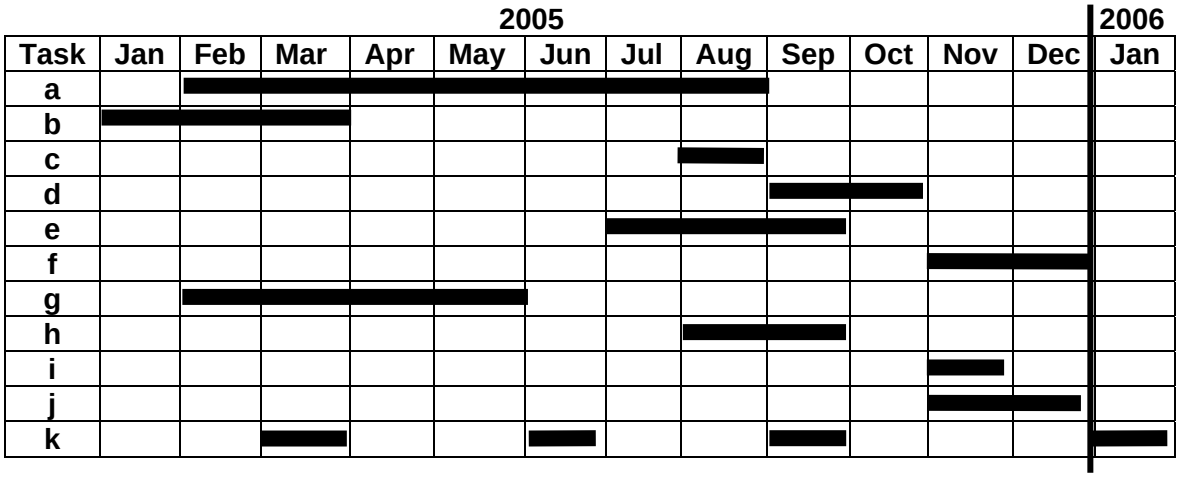
- The measure of project success will be in the technical assessment (see section 2 above) of the methodology applied. In order to quantify the accuracy of the urban irrigated landscape area fraction estimates, it is necessary to validate the model with independently derived ground truth estimates of the actual irrigated landscape areas. Accuracy assessment will be conducted by image-comparison ground-truthing, the actual water consumption for the sampled areas will be collected through the local water conservation offices of the cooperating cities, Bakersfield, Clovis, and Modesto.

- As a technical project the usefulness of the tool developed will be the measure of success. Cost / benefit comparisons of high-resolution aerial imagery versus enhanced low-resolution aerial imagery are key components.

- External confounding factors are minimal for the project as it is initially not examining change over time. Weather factors will play a significant role in the choice of image capture dates but with a 16 day return time of the satellite poor atmospherics will only be an temporal inconvenience, not a limiting factor.

- Data will be reported back to collaborating cities specifically about their own areas of interest. A journal article will be prepared, professional conference presentations will be given, a website explanation will be constructed, and all data and summary materials and work products forwarded to DWR.

Tasks and schedule



a. Study area identification and Landsat TM Image acquisition
b. Urban limits GIS mask development
c. Image pre-processing
d. Image spectral mixture analysis
e. High-resolution image acquisition
f. Sampling for accuracy assessment
g. Address data collection for sampled areas
h. Water usage data acquisition
i. Accuracy assessment
j. Statistical analysis on irrigated landscape areas and water usage
k. Reports

Appendix F Qualifications of the Applicants and Cooperators

Dr. Xiaoming Yang, Sr. Analyst, Interdisciplinary Spatial Information Systems Center, California State University, Fresno. 2255 E Barstow Ave, MS IT9, Fresno, CA 93740. Phone: (559)278-8457; Fax: (559)278-8492; Email: xmyang@csufresno.edu

Education

Ph.D. Geographic Information System and Forest Resource Management; State University of New York, College of Environmental Science and Forestry, Syracuse, NY 1990 – 1994

MS Quantitative and statistical methods for forest resource management; State University of New York, College of Environmental Science and Forestry; Syracuse, NY 1986 – 1989

BS Forestry; Beijing Forestry University, Beijing, China 1978 – 1982

Professional Experience

Senior Analyst Interdisciplinary Spatial Information Systems Center, CSU Fresno.

- Supervises spatial analysis, photogrammetry and remote sensing operations; manages The San Joaquin Valley Crop, Water and Land Use Mapping Project and has a significant role in the Remote Sensing for Vineyard Management Project.

Chief Analyst Resource Studies Center, Saint Mary's University of Minn., 1997– 2000

- Supervised GIS analysts and GIS technicians; designed spatial databases for natural resource & land use management and planning; designed, implemented and managed GIS and digital photogrammetry projects, GIS data automation, and performed geo-statistical analysis; designed, programmed, and implemented decision support models for urban development, environmental impact analysis, and hazardous sites monitoring; established QA/QC standards of GIS/digital photogrammetrical projects; taught graduate classes in remote sensing and GIS.

Technical Manager GIS/RS Center, Wilkes University, Wilkes-Barre, PA 1994 – 1997

- Coordinating all research projects involving GIS, remote sensing (RS), global positioning systems (GPS), and photogrammetry technologies; providing technical advice and training; designed and managed a GIS database for environmental monitoring; conducting research on GPS accuracy, water quality, watershed analysis, and economic development; applications; Conducting satellite imagery and aerial photo analysis and classification.

Senior Research Assistant State University of New York College of Environmental Science and Forestry, Syracuse, NY; June '93 – July '94

- Conducted spatial analysis on urban forest meteorology and meteorological morphology analysis on urban vegetation distribution; designed spatial database for research projects; geo-statistical analysis

Teaching / Research Assistant State University of New York College of Environmental Science and Forestry, Syracuse, NY; Sep '87 – May '93

- Integrated GIS, decision support system, and expert system technologies into a spatial decision support system (SDSS) for timber and wildlife management; Acquired and engineered an wildlife knowledge base for New York state; Designed and developed a wildlife expert system;

Special Training in remote sensing, GIS, and statistical software

Robert P. Slobodian, Director, Interdisciplinary Spatial Information Systems Center
California State University, Fresno, 2255 E. Barstow Ave M/S IT9, Fresno, CA 93740
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Education

Ph.D. Program: •Geography, University of Victoria, Victoria, BC adv to candidacy 1995
Ph.D. Program: •Geography, University of California, Los Angeles (1977-1978)
Master of Arts: •Geography, San Diego State University (1970)
Bachelor of Science: •Geography, Brigham Young University, Provo, UT (1968)

Professional Experience

- 2001- present California State University, Fresno, Director, Interdisciplinary Spatial Information Systems Center
- 1999-2001 Fresno City College, Fresno, CA, Instructor Geography/GIS
- 1970-1999 Malaspina University-College, Nanaimo, B.C.
  Instructor, Geography / Computing Science
  Chair, Geography Department / Computing Science
  Coordinator, Instructional Computing Center
  Supervisor, Computing Support Services
- 1995-1997 National Center for Geographic Information and Analysis: Community College Technical Program: Advisory Committee
- 1996-1997 National Center for Geographic Information and Analysis: Community College Technical Program: Advisory Committee
- 1996 Association of American Geographers Annual Meeting, Charlotte 1996
  Geographic Information Systems and Geographic Education Specialty Group: GIS in the Community Colleges: Directions for the Community College Special Interest Group GIS Task Force, Presentation "*An Implementation Model for a One-Year GIS Technician Program*"
- 1995 Association of American Geographers Annual Meeting, Chicago 1995
  National Center for Geographic Information and Analysis: Geographic Information Systems Community College Geography: Issues and Examples
  Presentation: "*GIS within the Curriculum / GIS across the Curriculum"*

Grants

2004 Great Valley Center – San Joaquin Valley Metadata Catalog
2002 Great Valley Center – Fresno / Madera Land Use
2002 Calif. Endowment/Rockefeller Foundation – Calif. Works for Better Health
2000 Calif Dept of Education – Centralized Eligibility List
2000 ARI – The San Joaquin Valley Crop, Water, and Land Use Mapping Project

Qualifications cont ….

The cooperating agencies are:

City of Bakersfield

Florn Core, Water Resources Manager
City of Bakersfield
Water Resources Department
1000 Buena Vista Road
Bakersfield, CA 93311
661-326-3715
fcore@ci.bakersfield.ca.us

City of Clovis

Lisa Kohen, Assistant Public Utilities Director
Public Utilities Department
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155 N. Sunnyside Ave.
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City of Modesto

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Appendix G Outreach and Community Involvement

The project has secured collaboration with communities throughout the CALFED San Joaquin Valley Region. City of Bakersfield, City of Clovis, and City of Modesto Water Resources managers have agreed to participate in the project. Working with ISIS Center staff, each city will be involved in designating specific study areas(older, medium-age, newer) in their community. The ISIS Center staff will do the technical implementation of the project. The cities will then provide the water consumption data for the designated study areas for the designated time periods. The ISIS Center staff will then do the statistical and spatial-analytical work combining the enhanced imagery data with the real-world water consumption data. The results will be returned to the community water resources managers for their own use as well as for their comments about validity and usefulness.

The local communities will not only be relied upon for providing primary data for analysis, their role as ultimate consumers of the finished work product will be critical to understanding whether this particular use of technology has merit for water resources planning and management. For their part the local communities will receive area specific analyses of the water consumption comparisons with the remote sensing data.

The cooperating agencies are:

City of Bakersfield

Florn Core, Water Resources Manager
City of Bakersfield
Water Resources Department
1000 Buena Vista Road
Bakersfield, CA 93311
661-326-3715 fcore@ci.bakersfield.ca.us

City of Clovis

Lisa Kohen, Assistant Public Utilities Director
Public Utilities Department
City of Clovis
155 N. Sunnyside Ave.
Clovis, CA 93611
559-324-2607 lisak@ci.clovis.ca.us

City of Modesto

Allen Lagarbo, Water Operations Superintendent
City of Modesto, Water Operations Division
P.O. Box 642
Modesto, CA 95353
209-342-2203 alagarbo@modestogov.com

Appendix H Innovation

The main innovation accompanying thus project is to take existing and proven methods for identifying urban vegetated areas and attempting to make them significantly less-costly. Spectra-analysis of urban landscapes has been done for years. The difficulty of identifying discreet land uses in the urban landscape has thus far required high resolution, and high cost, muti-spectral-imagery. The technique is satisfactory, the cost in many cases, is prohibitive for large areas or for frequent return/revisit studies. This project will demonstrate that reduced costs can be achieved through mathematical modeling of low-resolution data.

Spectral mixture analysis provides a systematic way to quantify spectrally heterogeneous urban reflectance. It has been proven successful for a variety of quantitative applications with multispectral imagery (Adam et al., 1995; Elmore et al., 2000; Lu and Wang, 2004; Wu and Murray, 2003). The methodology proposed in the study is an innovative way to examine the feasibility of using low cost satellite imagery to identify irrigated urban landscape areas. By correlating the information acquired from satellite images with actual water consumption of an area, it will provide more accurate information for decision-makers and planners to make better decision regarding to water resource management.

Budget and Narrative

Excel.xls spreadsheet attached

Applicant: California State University, Fresno - Interdisciplinary Spatial Information Systems Center(ISIS)

THE TABLES ARE FORMATTED WITH FORMULAS: FILL IN THE SHADED AREAS ONLY

Section A projects must complete Life of investment, column VII and Capital Recovery Factor Column VIII. Do not use 0.

Table C-1: Project Costs (Budget) in Dollars)

	Category (I)	Project Costs $ (II)	Contingency % (ex. 5 or 10) (III)	Project Cost + Contingency $ (IV)	Applicant Share $ (V)	State Share Grant $ (VI)	Life of investment (years) (VII	Capital Recovery Factor (VIII)	Annualized Costs $ (IX)
	Administration[1]								
	Salaries, wages	$75,358	3	$77,619	$0	$77,619	0	0.0000	$0
	Fringe benefits	$32,473	3	$33,447	$0	$33,447	0	0.0000	$0
	Supplies	$14,808	0	$14,808	$0	$14,808	0	0.0000	$0
	Equipment	$0	0	$0	$0	$0	0	0.0000	$0
	Consulting services	$4,800	0	$4,800	$0	$4,800	0	0.0000	$0
	Travel	$1,600	0	$1,600	$0	$1,600	0	0.0000	$0
	Other	$5,400	0	$5,400	$0	$5,400	0	0.0000	$0
(a)	Total Administration Costs	$134,439		$137,674	$0	$137,674			$0
(b)	Planning/Design/Engineering	$0	0	$0	$0	$0	0	0.0000	$0
(c)	Equipment Purchases/Rentals/Rebates/Vouchers	$0	0	$0	$0	$0	10	0.0000	$0
(d)	Materials/Installation/Implementation	$0	0	$0	$0	$0	0	0.0000	$0
(e)	Implementation Verification	$0	0	$0	$0	$0	0	0.0000	$0
(f)	Project Legal/License Fees	$0	0	$0	$0	$0	0	0.0000	$0
(g)	Structures	$0	0	$0	$0	$0	0	0.0000	$0
(h)	Land Purchase/Easement	$0	0	$0	$0	$0	0	0.0000	$0
(i)	Environmental Compliance/Mitigation/Enhancement	$0	0	$0	$0	$0	0	0.0000	$0
(j)	Construction	$0	0	$0	$0	$0	0	0.0000	$0
(k)	Other (Specify)	$4,000	0	$4,000	$0	$4,000	0	0.0000	$0
(l)	Monitoring and Assessment	$0	0	$0	$0	$0	0	0.0000	$0
(m)	Report Preparation	$2,400	0	$2,400	$0	$2,400	0	0.0000	$0
(n)	**TOTAL**	$140,839		$144,074	$0	$144,074			$0
(o)	Cost Share -Percentage				0	100			

1- excludes administration O&M.

	Budget Narrative		
a	**Salaries**		**75,358**
	Analyst 1 - 70%	50,736	
	Analyst 2 - 30%	21,870	
	Admin Coord 1 - 10%	2,752	
	Benefits		**32,473**
	Analyst 1 - 70%	22,324	
	Analyst 2 - 30%	9,185	
	Admin Coord 1 - 10%	963	
	Supplies		**14,808**
	Landsat Imagery 648*4*3	7,776	
	DigitalGlobe Imagery 162*4*3*3	5,832	
	Office Consumeables	1,200	
	Consulting Services		**4,800**
	Groundtruth data collection	4,800	
	Travel		**1,600**
	Site Inspections	1,600	
	Other		**5,400**
	ERDAS Software	5,400	
k	**Other**		**4,000**
	Computing Services	4,000	
m	**Report Preparation**		**2,400**
	Report Preparation	2400	

Applicant: California State University, Fresno - Interdisciplinary Spatial Information Systems Center

THE TABLES ARE FORMATTED WITH FORMULAS: FILL IN THE SHADED AREAS ONLY

Table C-2: Annual Operations and Maintenance Costs

Operations (1) (I)	Maintenance (II)	Other (III)	Total (IV) (I + II + II)
$144,074	$0	$21,611	$165,685
		University Indirect at 15%	

(1) Include annual O & M administration costs here.

Table C-3: Total Annual Project Costs

Annual Project Costs (1) (I)	Annual O&M Costs (2) (II)	Total Annual Project Costs (III) (I + II)
$0	$165,685	$165,685

(1) From Table C-1, row (n) column (IX)
(2) From Table C-2, column (IV)