Measuring Change in the San Pedro Riparian Ecosystem:

A Comparison of Two Methods

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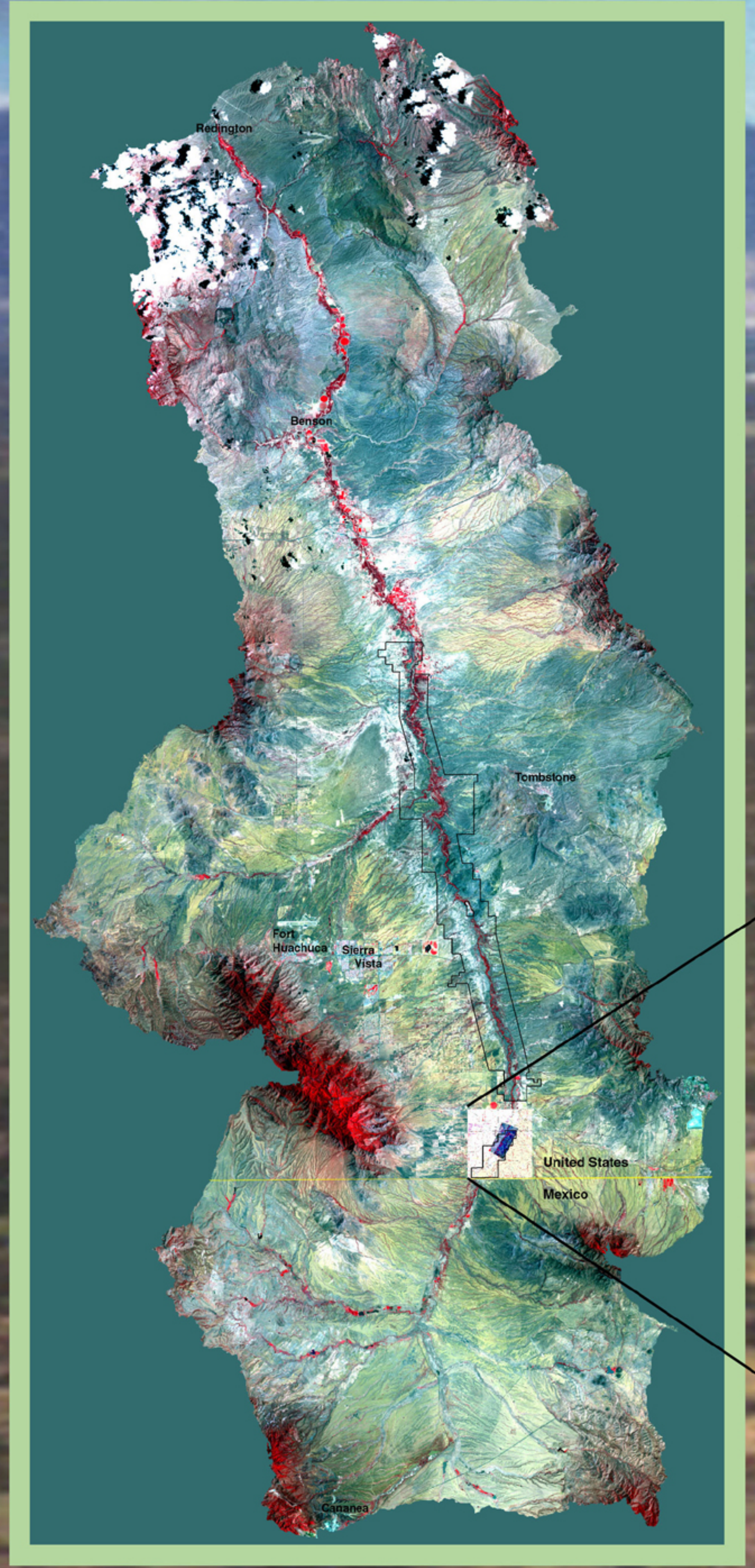

Abstract

Riparian ecosystems in the Southwest are thought to make up less that 1% of the total land cover, and are generally in poorer condition as compared to their extent and condition prior to the settlement of the West. Riparian zones play a major part in filtering sediment that would other wise result in reduced water quality. Riparian zones also aid in the control of floods and preventing soil from eroding. The San Pedro Riparian National Conservation Area (NCA), was established in 1988, by the Bureau of Land Management (BLM) to protect and enhance this riparian desert ecosystem. Using historical satellite imagery, from the North American Landscape Characterization (NALC) satellite imagery data base, we will document the change that has occurred in this regionally-important Southwestern riparian ecosystem. Two methods of analysis and the implications for monitoring riparian ecosystems across the Southwestern U.S. will be presented.

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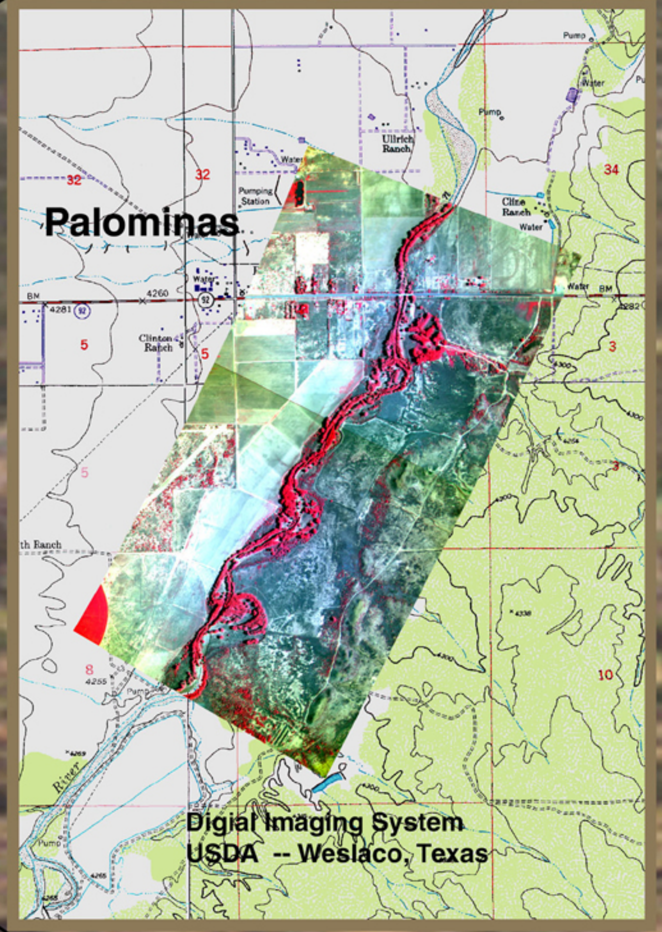
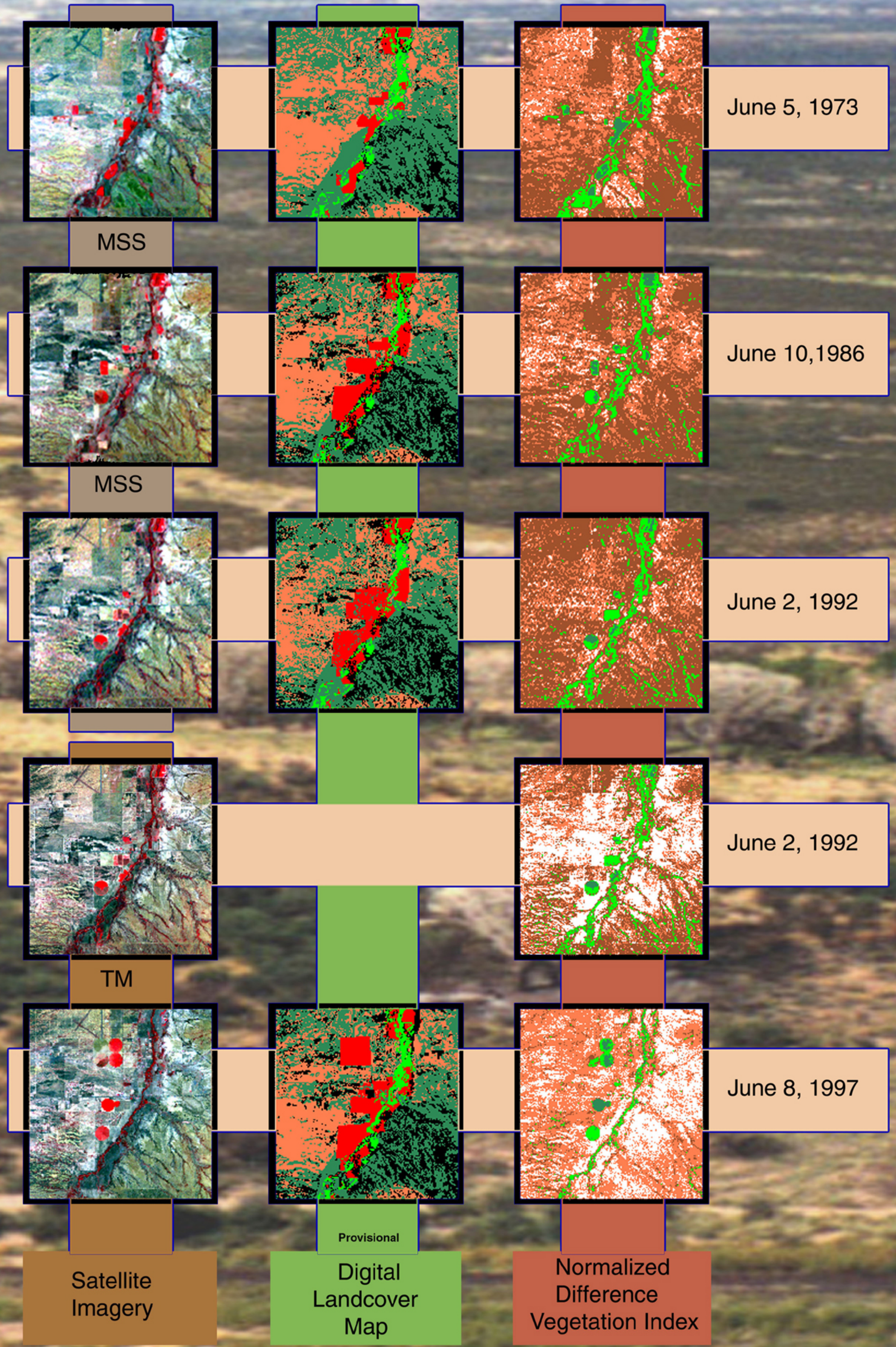


Location

The study location is the upper San Pedro River basin which originates in Sonora, Mexico and flows north into southeastern Arizona. The Upper San Pedro Watershed represents a transition area between the Sonoran and Chihuahuan deserts and topography, climate, and vegetation vary substantially across the watershed. Elevation ranges from 900 - 2,900 m and annual rainfall ranges from 300 to 750 mm. Biome types include desertscrub, grasslands, oak woodland-savannah, mesquite woodland, riparian forest, coniferous forest, and agriculture. The upper watershed encompasses an area of approximately 7,600 km^2 (5,800 km^2 in Arizona and 1,800 km^2 in Sonora, Mexico).



Landcover Legend

- Mesquite
- Grassland
- Desert Scrub
- Riparian
- Agriculture
- Urban
- Water

Normalized Difference Vegetation Index (NDVI) Method

The same images as used in the landcover classification method described above were also used to calculate NDVI. Images were then created from the NDVI values. NDVI is calculated from the following equation:

$$NDVI = \frac{(NIR - red)}{(NIR + red)}$$

where NIR represents the band in the near infrared and red represents the band in the visible red. Values derived using NDVI, range from -1.0 to 1.0, where negative index values represent clouds, water, and snow, index values near zero represent barren soil and rocks, and positive index values are indicators of the vegetation biomass. A difference image was then generated by subtracting the 1970s NDVI image from the 1990s NDVI image. Positive values represent gains in vegetation, negative values depict losses in vegetation. The standard deviation was calculated from the difference image across the entire basin. Pixels which exceeded 2.0 standard deviations were considered loss, and pixels which exceeded 1.5 standard deviations of gain were considered gain. The net gain was calculated for each of the images, and the difference determined for the given span of years. The results are shown in the table under Normalized Difference Vegetation Index .

Methods and Materials

Remote imagery was derived from the Landsat Multi-spectral Scanner (MSS) earth observing satellite (path/row 35/38 and 35/39) and Landsat Thematic Scanner (TM). MSS satellite scenes were selected from the North American Landscape Characterization (NALC) project. The scenes available in the NALC database are for three pre-monsoon dates for a period of approximately 20 years (i.e. 5 June 1973, 10 June 1986, 2 June 1992). The Landsat TM scene was selected from 8 June 1997 and was resampled and mapped at 60 m resolution for comparison. All the imagery in the database is coregistered and georeferenced to a 60 x 60 meter Universal Transverse Mercator (UTM) ground coordinate grid with a nominal geometric precision of 1-1.5 pixels (60-90 m). Digital land cover maps were developed separately for each year using 10 classes: Forest, Oak Woodland, Mesquite Woodland, Grassland, Desertscrub, Riparian, Agriculture, Urban, Water, and Barren. A decision was made to classify the images separately prior to change detection analysis because of the difficulty in normalizing images derived from different satellite sensors. The landscape changes were analyzed in a geographical information system using ARC/INFO software.

The first step in the image classification was using ERDAS IMAGINE 8.3 software procedure ISODATA to perform an unsupervised classification using bands 1 (green), 2 (red) and 4 (near infrared) to produce a map with 60 spectrally distinct classes. The choice of 60 classes was based on previous experience with NALC data and usually gave satisfactory trade-off between the total number of classes and the number of mixed classes. In this context, it proved helpful to define a larger set of 21 intermediate classes, which were easier to relate to the spectral information. For example, the Barren class contains bare rock, chalk deposits, mines, tailing ponds, etc. which have very different spectral signatures. Each class was then displayed over the false-color image and classes were assigned into one of the 21 land cover categories or as mixed. The software allows the interactive manipulation of the signatures for each class which allowed many of the mixed classes to be resolved.

The remaining mixed classes were separated into different categories using a variety of ancillary information sources, such as the topographic maps (scale 1:50,000) produced by INEGI, the Mexican National Institute of Statistics, Geography and Information, and by the U.S. Geological Survey (scale 1:24,000). The land use information used varied depending on the image being analyzed. Thus the classification of the 1992 image relied heavily on field visits to establish ground control. Five 3-day site visits were carried out from September 1997 to June 1998 to enable analysts to collect specific land cover data with the aid of Global Positioning System equipment which were incorporated into successive iterations of the classification process.

Landsat-MSS 1973 was used for the baseline condition. Change between time intervals, i.e. 1973, 1986,1992, and 1997 was measured and the discrete landscape metrics were described. Landscape statistics that describe shape and size were used to assess dominance, fragmentation, and rates of conversion in an effort to determine sensitive measures for resistance to change (= landscape resilience). Sample size was 2,100,407 pixels (60-m resolution) per digital image map.

Percent of change in Riparian landcover, and Normalized Difference Vegetation Index (NDVI) in the San Pedro Riparian National Conservation Area through various time spans.

YEARS	Landcover Change	NDVI
1973 to 1986	-1.7	+4.93
1986 to 1992	+0.19	+4.48
1992 to 1997	+2.15	-6.59 (-6.54tm to tm)
1973 to 1997	+0.64	-3.48

Results

The results show that the riparian landcover change for the classified images decreased between 1973 and 1986, remained stable through 1992, and increased between 1992 and 1997. The probable reason for this tread is that this area was designated a riparian conservation are in the mid 1980s. NDVI data does not appear to have any correlation to the landcover change data. The lack of correlation may be due to difficulty of delineating the agricultural area from the riparian vegetation, the resolution of the images, the reflectance of soil, the spectral response, and linearity of the satellite sensors.

Conclusions

Although NDVI shows great promise as a method of vegetation change in highly vegetated areas, it would not be the method of choice to detect vegetative changes in a desert riparian areas. Digital landcover mapping is the method of choice for any change detection analyses done with existing historical Multispectrial Scanner data. If higher resolution imagery becomes available, then the separation of agricultural fields from the riparian vegetation might be possible using the NDVI method. NDVI may hold promise for changed detection analysis in areas that do not have multiple land use practices.

Acknowledgements

Landcover Generation 1973, 1986, 1992, and 1997 -- Instituto del Medio Ambiente y el Desarrollo Sustentable del Estado de Sonora, Reyes y Aquascalientes Esq., Colonia San Benito, Hermosillo, Sonora, Mexico 83190-- http://www.cideson.mx/imades.html

Accuracy Assessment 1992 landcover -- University of Arizona, Office of Arid Land Studies, Arizona Remote Sensing Center, Tucson, AZ -- http://ag.arizona.edu/oals/oals/arsc/arsc.html

Painted Shaded Relief of Basin --Lockheed Martin Environmental Services, Las Vegas, Nevada

North American Landscape Characterization (NALC) -- U.S. EPA/USGS EDC Distributed Active Archive Center -- http://edcwww.cr.usgs.gov/loaddaac/pathfinder/pathpage.html