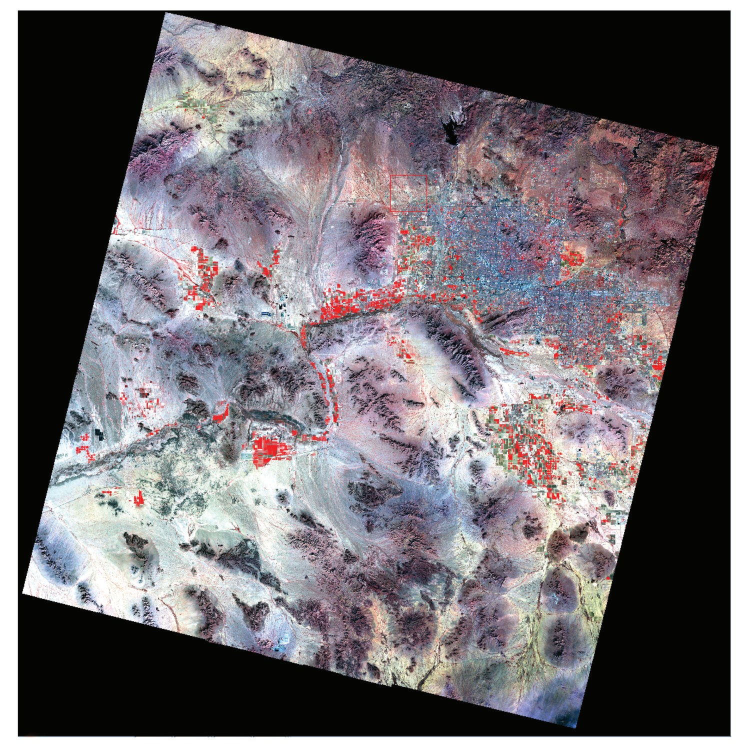
A vegetation change detection approach to analyzing the prevalance of urban irrigation in Phoenix, Arizona

BACKGROUND

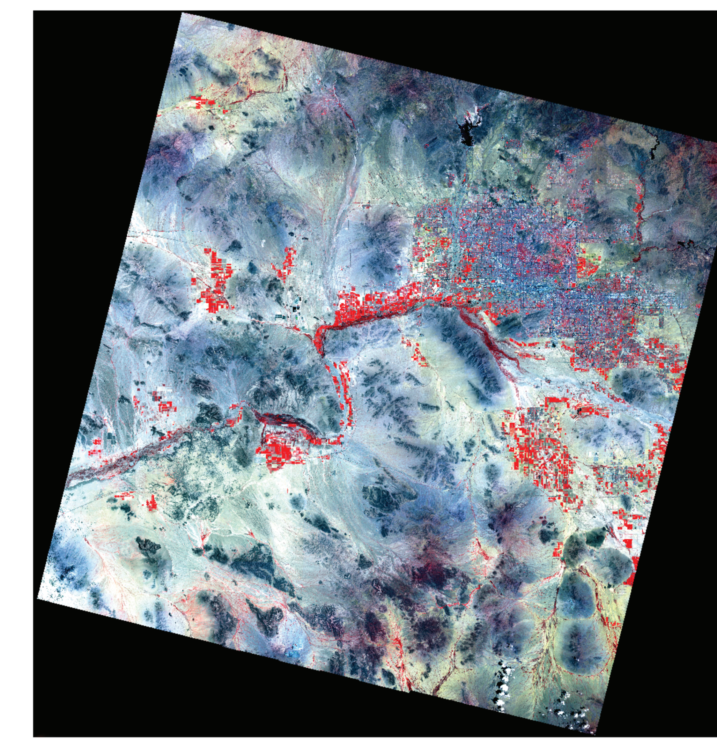
Phoenix, Arizona and its satellite cities are some of America's fastest growing desert areas. A suburban growth model fueled by water redirection and irrigation strategies has allowed the metropolitan region to sprawl across over 2,000 square miles of arid land. Desert ecologies are fragile and highly volatile. Climate change will exacerbate precipitation unpredictability, placing even greater stress on the city's current water resource management portfolio. Over half of the water managed in Arizona's Sun Corridor is linked to the Colorado River, a politically contentious supply. As populations continue to grow, limited water resources will force development to adapt, ultimately shaping a new urban character and way of life in the desert region.

Growth is characterized by master planned communities and housing developments. For the past few decades, much of this development took place on agricultural land. In *Applied Remote Sensing for Urban Planning, Governance, and Sustainability,* Maik Netzband and William Stefanov point out that "land taken out of agriculture is quickly covered with housing." It is estimated that 53% of Maricopa county's water use is residential, while 70% of Arizona's total water use is agricultural. This demonstrates a shift in the distribution of water resources, where residential water use gradually replaces agricultural usage in urbanizing areas. More than 50% of the water used in a typical household is associated with landscaping (Johnson and Belitz, 87). Identifying areas that utilize irrigation to support vegetation is critical to understanding ecology fragmentation, trends in housing development, estimating water usage associated with residential irrigation, and ultimately developing strategies to encourage responsible water resource distribution. Vegetation change detection might be useful for identifying urban irrigation and its use.

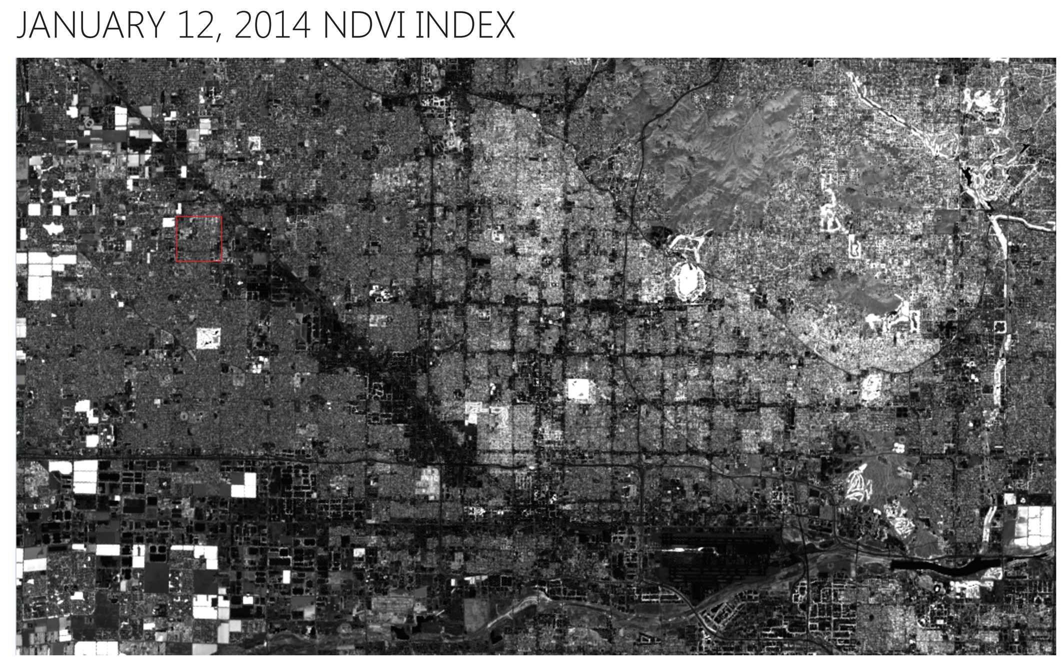
JANUARY 12, 2014 (BANDS 5,4,2)



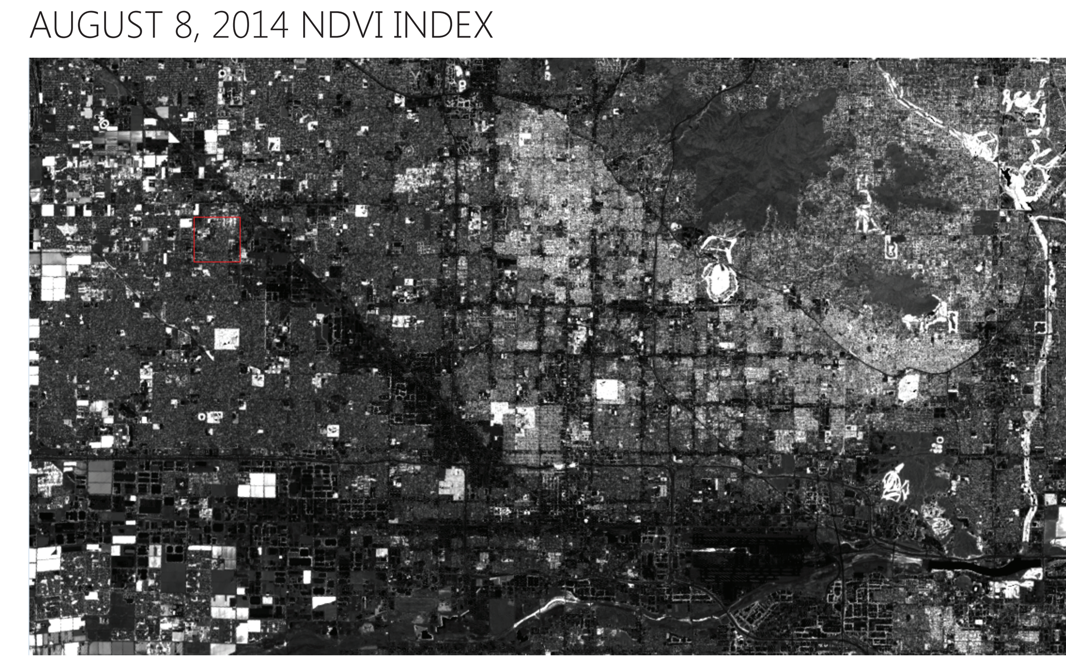
AUGUST 8, 2014 (BANDS 5,4,2)

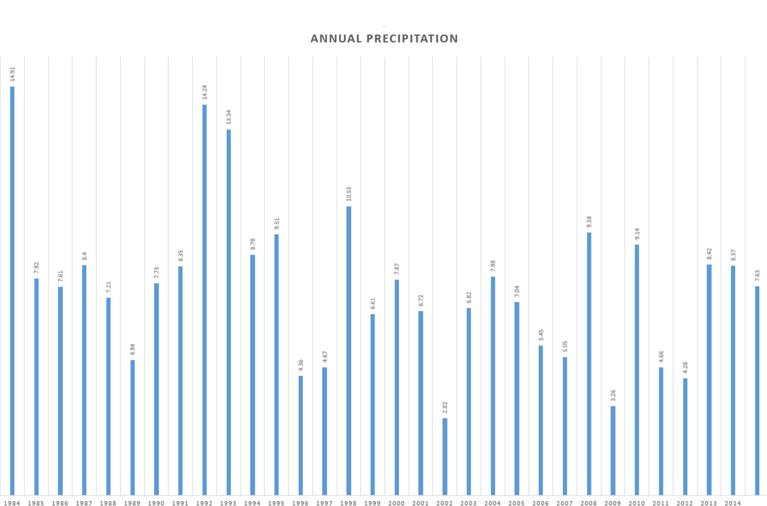


JANUARY 12, 2014 NDVI INDEX



AUGUST 8, 2014 NDVI INDEX

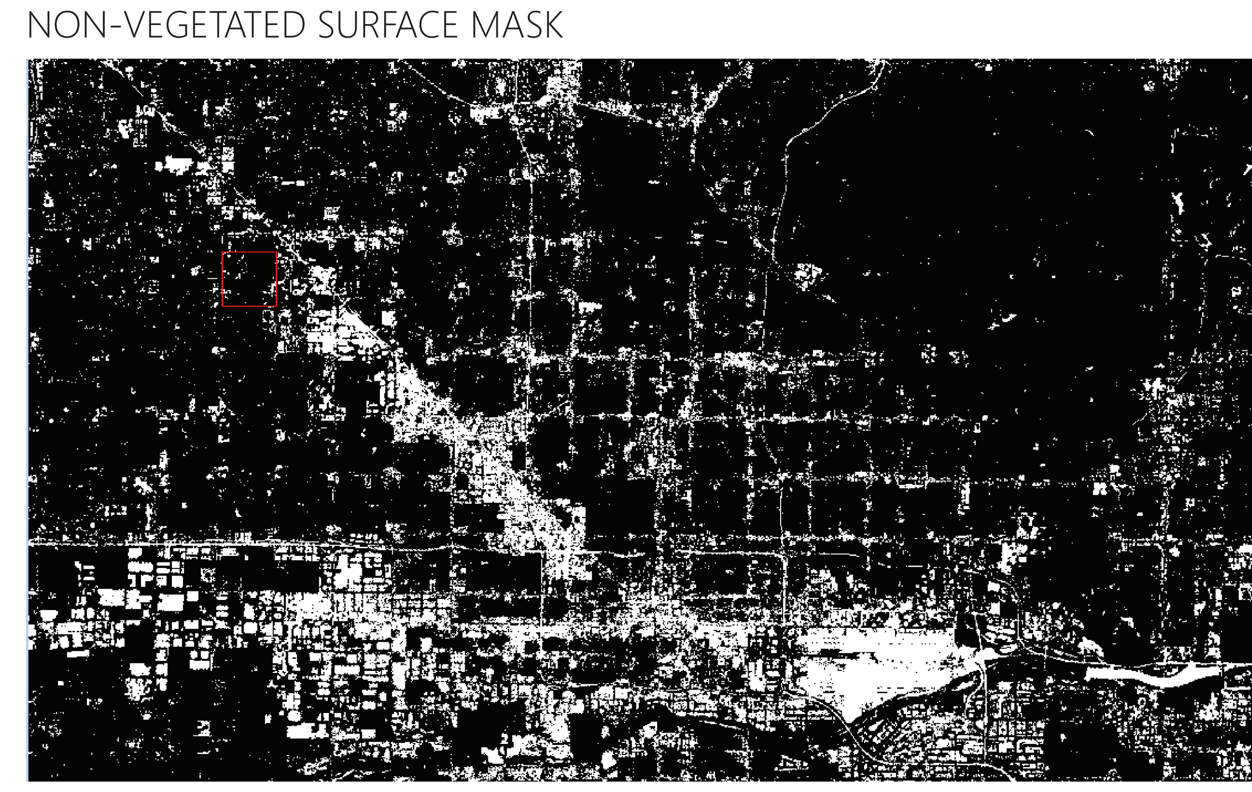




DATASETS

Two Landsat 8 CDR images (Path/Row 37/37) from the year 2014 were acquired from the US Geological Survey (USGS) Earth Explorer. CDR images are preprocessed for terrain and geospatial correction to minimize spatial distortion, although significant elevation changes remain cause for error. Image date selection was informed by climate history data, gathered from the National Oceanic Atmopheric Administration (NOAA) Applied Climate Information System (ACIS). The following tables from NOAA detail the monthly total precipitation and monthly mean average temperature for Phoenix, Arizona in a 30 year period between 1984 and 2014.

NON-VEGETATED SURFACE MASK



METHODS

1. Calculating the normalized vegetation index (NDVI)

To calculate the normalized difference vegetation index (NDVI) in ENVI, bands 4 and 5 (red and near infrared) were selected and applied to the following equation using bandmath in ENVI for each image:

$$NDVI = (NIR) – (Red) / (NIR) + (Red) \quad (1)$$

2. Identifying Non-Vegetated Surfaces

A mask was created based on a vegetation threshold determined by visual analysis, for classification in the final difference image.

3. NDVI change detection

The resulting images are NDVI index images for August 8, 2014 and January 12, 2014. To calculate change, image differencing was applied:

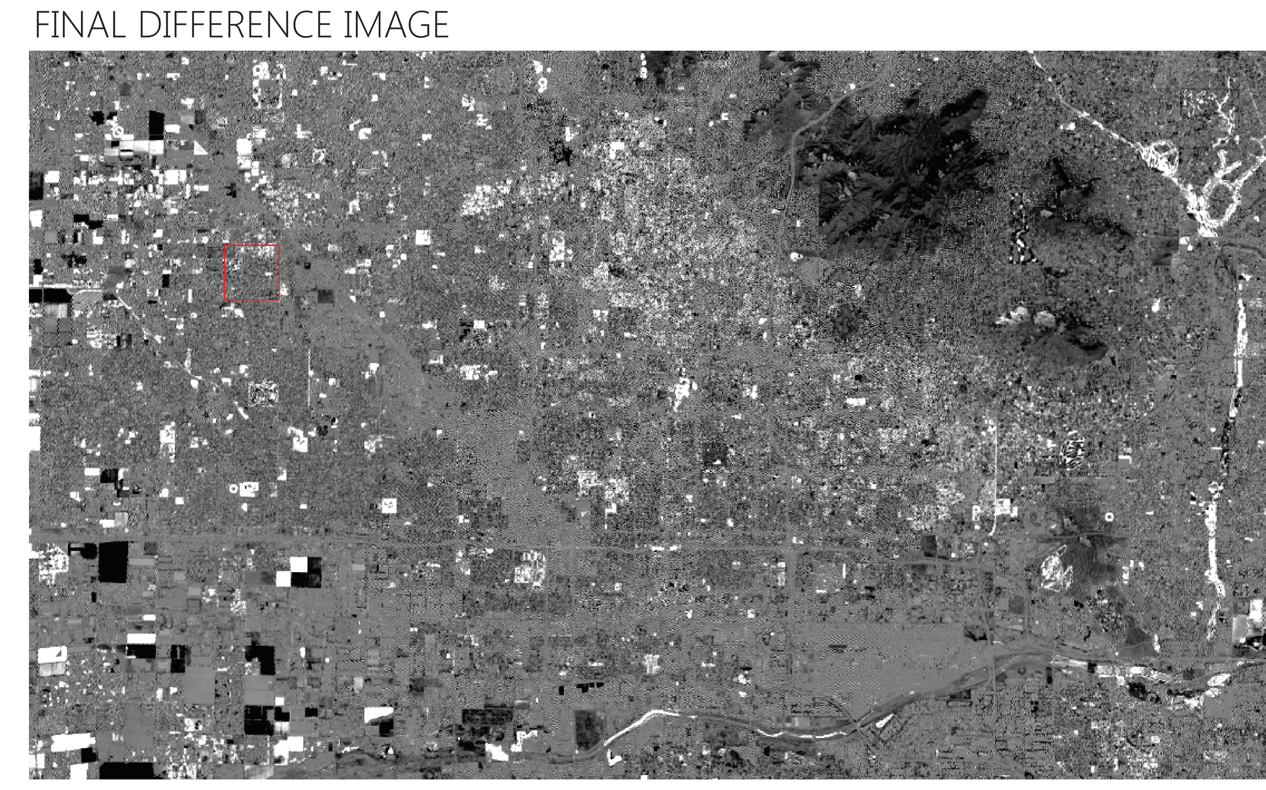
$$(float(B1) – (float(B2)) \quad (2)$$

where B1 is equal to the August NDVI index image and B2 is equal to the January NDVI index image.

4. Density Slicing

The final NDVI change image has values ranging between -66.79 and 258.32. Three ranges were selected to illustrate three landcover classifications: non-vegetated, non-irrigated vegetation, and irrigated vegetation. Values between 254.49 and 258.32 are non-vegetated surfaces, inflated and differentiable due to the former band addition operation applied to the image. Statistics for values between -1.078 and.0789 helped determine the threshold for irrigated vegetation. Approximately 77% of the data between -1.078 and .0789 lies between -1.078 and 0. If it is assumed all values under consideration are assigned to vegetated pixels, any pixel value below 0 suggests the vegetation became unhealthy during the drought between January, 2014 and August, 2014, suggesting unsubstantial irrigation. Values close to or larger than zero suggest the pixel experienced positive change in NDVI value, suggesting the vegetation is supported by vegetation. Non-irrigated vegetation would exhibit heat stress resulting in negative NDVI difference values, particularly in such a drought. Pixel values between -1.078 and 0 were classified as non-irrigated. Pixel values between 0 and .0782 were classified as irrigated.

FINAL DIFFERENCE IMAGE



RESULTS

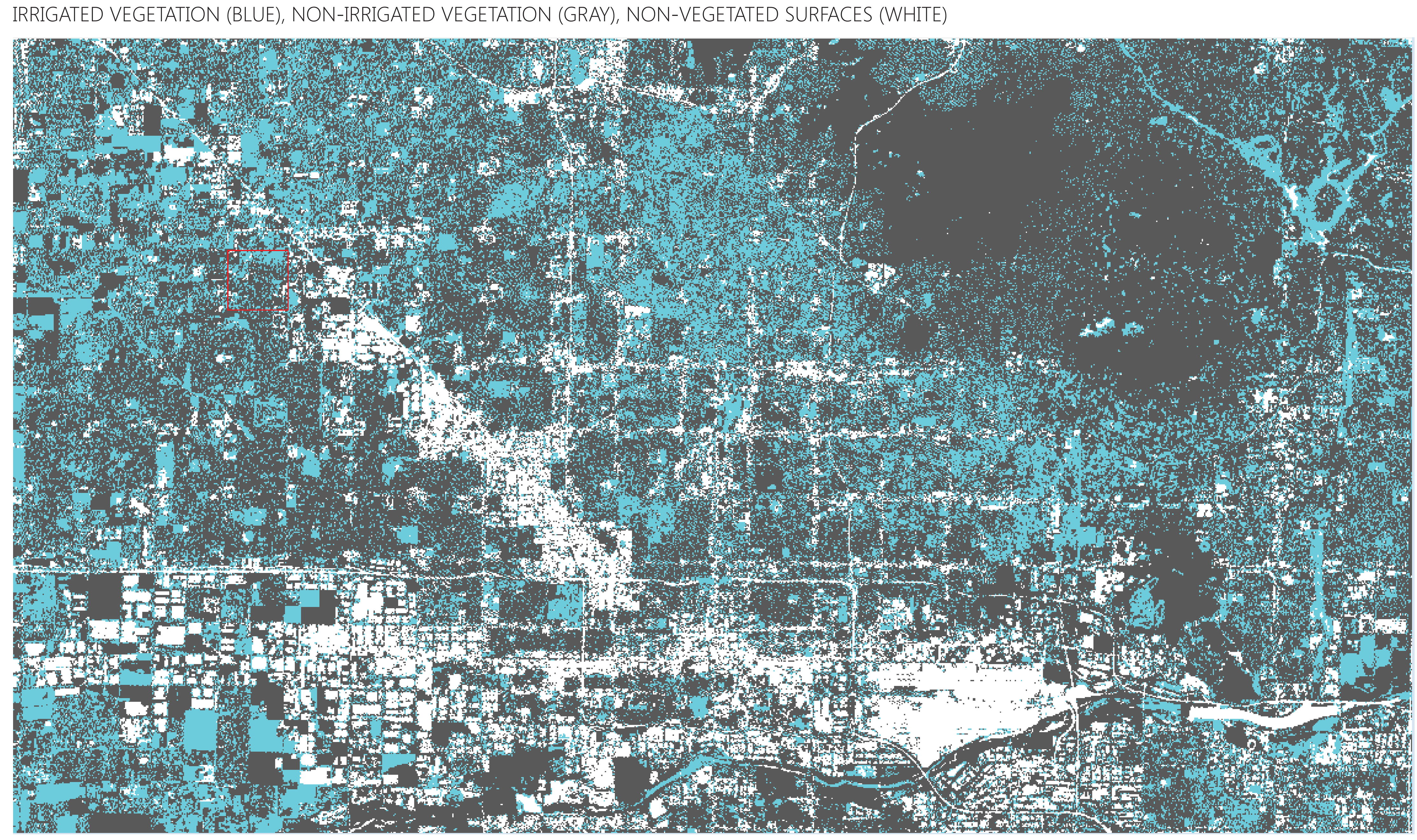
23% of the pixels in the resulting image are classified as irrigated vegetation according to the density slice. The method has mixed results, both due to issues inherent to the method and to distortion that occurred in image differencing. The most obvious inaccuracy occurs in some areas that exhibit a very high NDVI value in the NDVI index images. These areas, mostly golf courses, may have experienced negative NDVI change while still remaining irrigated. In the logic of the original hypothesis, this is an inherent flaw. Still, this information does demonstrate that vegetation dependent on irrigation experiences water and heat stress in Arizona's hot and dry summer climate, regardless of whether or not it is irrigated. A vegetation change approach may be helpful in identifying vegetation prone to water stress.

DISCUSSION

Ultimately, identification of irrigated pixels should also be applied to approximate water use rates. This would provide policy-makers and city planners with information critical to creating strategies for curbing water-use in specific geographies and neighborhoods. Planners should utilize this information, in tandem with urban heat island (UHI) studies to arrive at a more balanced approach to mitigating UHI and responsible management of water resources. The layout of cities, that is, the relationship between buildings, vegetation, landscape, streets, and solar orientation has a substantial effect on UHI. Planting desert appropriate vegetation, implementing structural shade strategies, encouraging water use reduction, and supporting more compact development is necessary in order to reimagine a sustainable way of life in the Sonoran desert. Analyzing the prevalence of urban irrigation is but one step.

FINAL DIFFERENCE IMAGE WITH DENSITY SLICE: 23% IRRIGATED VEGETATION

IRRIGATED VEGETATION (BLUE), NON-IRRIGATED VEGETATION (GRAY), NON-VEGETATED SURFACES (WHITE)



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