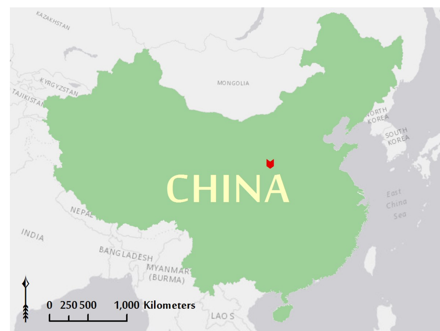
SUCCESSES AND FAILURES OF CHINA'S GRAIN-FOR-GREEN PROGRAM

A Remote Sensing Analysis of Reforestation in the Ansai, Shaanxi Region

Introduction

In 1998, the Yangtze River experienced catastrophic flooding at a once unheard-of scale of destruction. The events led to about 3,656 casualties, left 1.2 million more homeless, devastated 5.8 million buildings, and cost the Chinese economy $36 billion. The source of the flooding was found to be extreme soil erosion and environmental degradation over hundreds of years of cultivating sloped lands for agriculture and livestock pastureland.



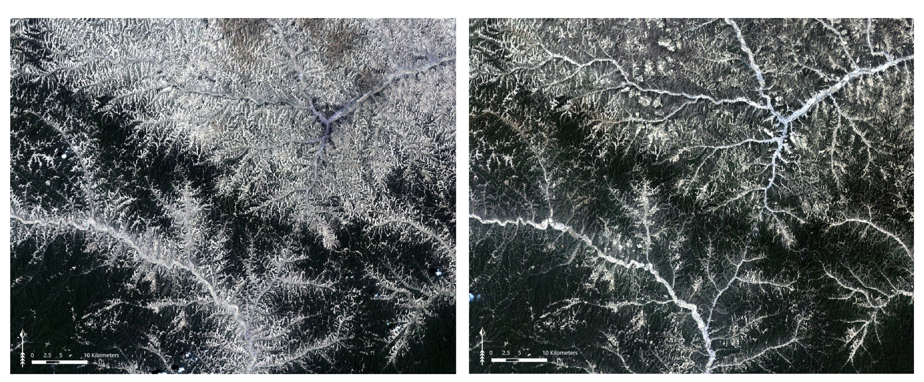
To combat this severe soil erosion, China's government initiated the Grain-for-Green Program (GFGP) in 1999. This program subsidizes the conversion of sloped crop-land to forest by incentivizing farmers to replant trees instead of cash crops. GFGP was intended to address issues of large-scale wetland and grassland degradation, desertification, and soil erosion. It also took on watershed management, to resolve altered hydrology from years of drought and flood cycles due to overcultivation and deforestation. GFGP also intended to focus on many socioeconomic issues, including poverty alleviation. Farmers were compensated with grain or money for crop conversion to forest. Today, the GFGP is now the largest state-run reforestation project in the world.

Despite its intentions, GFGP has recently been met with several criticisms. GFGP areas often still exhibit landscape and habitat fragmentation, and replanted forest cover is not always returned to areas needed by wildlife. Also, GFGP forests are often subject to continued logging and harvest, producing a dynamic landscape of human use that threatens biodiversity, especially of forest-obligate species. Thus, this remote sensing project aims to determine whether or not GFGP lives up to some of its promises.



Methodology

The study site is Ansai County/District of Yan'an Prefecture, in the Shaanxi Province. The area lies in the Loess Plateau, a region experiencing severe soil erosion and water loss and deemed a GFGP priority. The initial date is June 16, 1998, prior to GFGP's establishment and around the time of the flood. The end-point date is June 17, 2010, a suitable timespan for changes in new vegetation to be detectable. Anniversary dates were chosen to minimize temporal variation. Including the growing season enabled the detection of crops as well. Image data were obtained from USGS Earth Explorer. Landsat 5 Thematic Mapper (TM) was selected as the sensor.



Left to right: *True-color, pre-processed images from Landsat 5 TM, Resized to study extent, from 1998 and 2010, respectively.*

All pre-processing and analytical steps were performed in ENVI 5.3.1. An atmospheric correction was performed on the raw images via a manual Dark Object Subtraction. All images were then Resized by ROI.

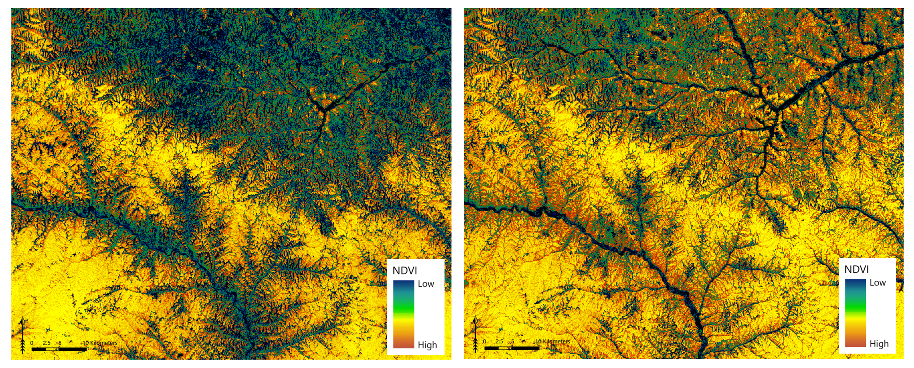
NDVI Difference

NDVI Difference Change Detection

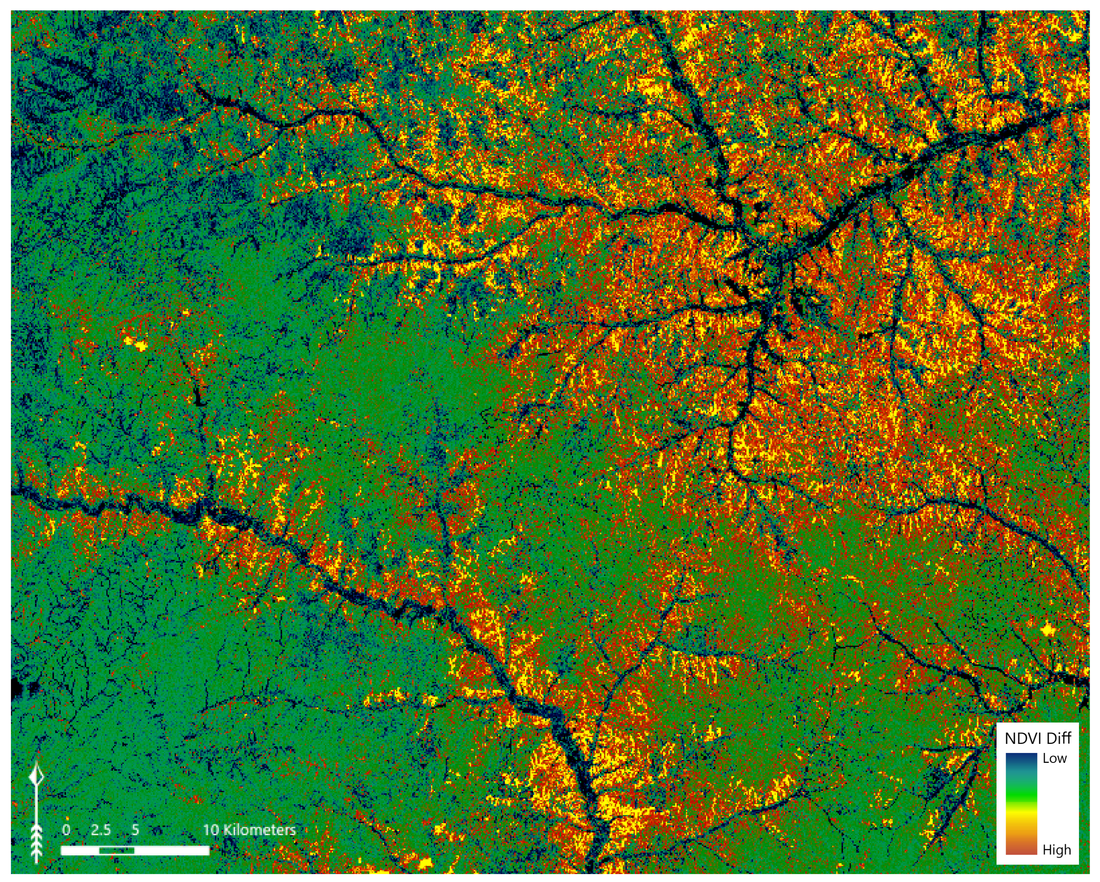
To determine how vegetative land cover changed overall in the study site from 1998—2010, an NDVI Difference Change Detection was done. For both dates, the Normalized Difference Vegetation Index (NDVI) operation was performed, and a Difference output was generated.

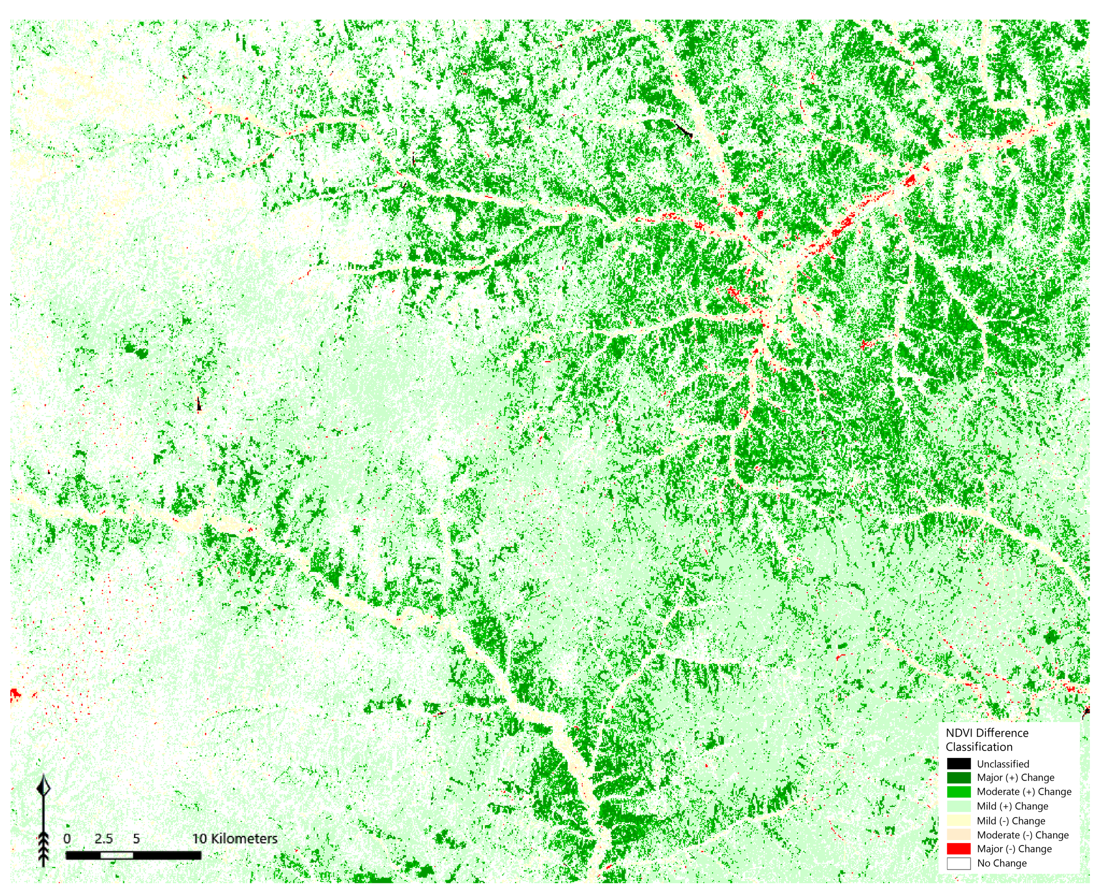
$$NDVI = (NIR - Red)/(NIR + Red)$$
$$NDVI_{Diff} = (NDVI)_t - (NDVI)_{t-1}$$

Density Slicing was used to create thresholds, which were converted to regions of interest (ROIs) and classified. This produced a final output depicting the classification of vegetative change from 1998—2010.



Top to bottom: *Intermediate NDVI images for 1998 and 2010, respectively; NDVI Difference output image; Classification of vegetative change from 1998—2010.*

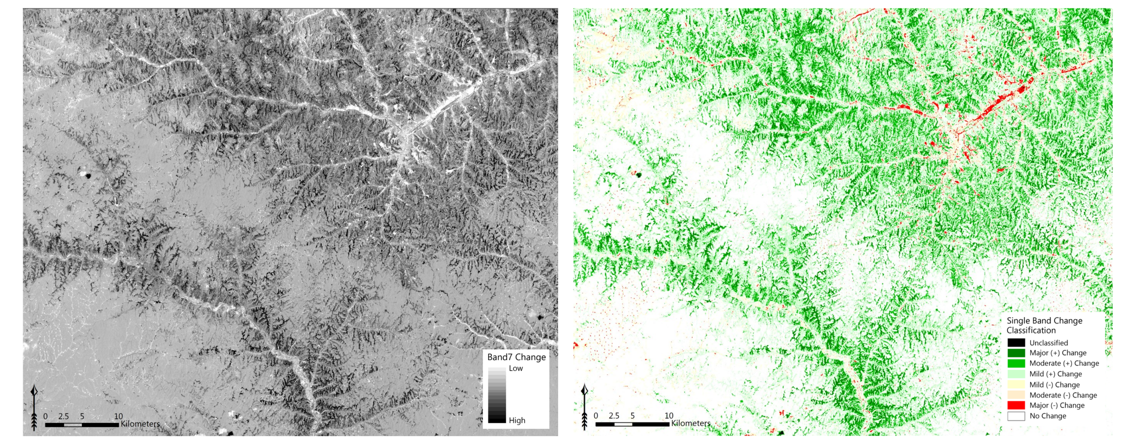




Single-Band Change

Simple Single-Band Change Detection

To compare this change classification with another method, a Single-Band Change Detection using Band 7 was performed. Again, thresholds were employed to generate ROIs and classify change, producing a final output depicting the classification of change from 1998—2010.

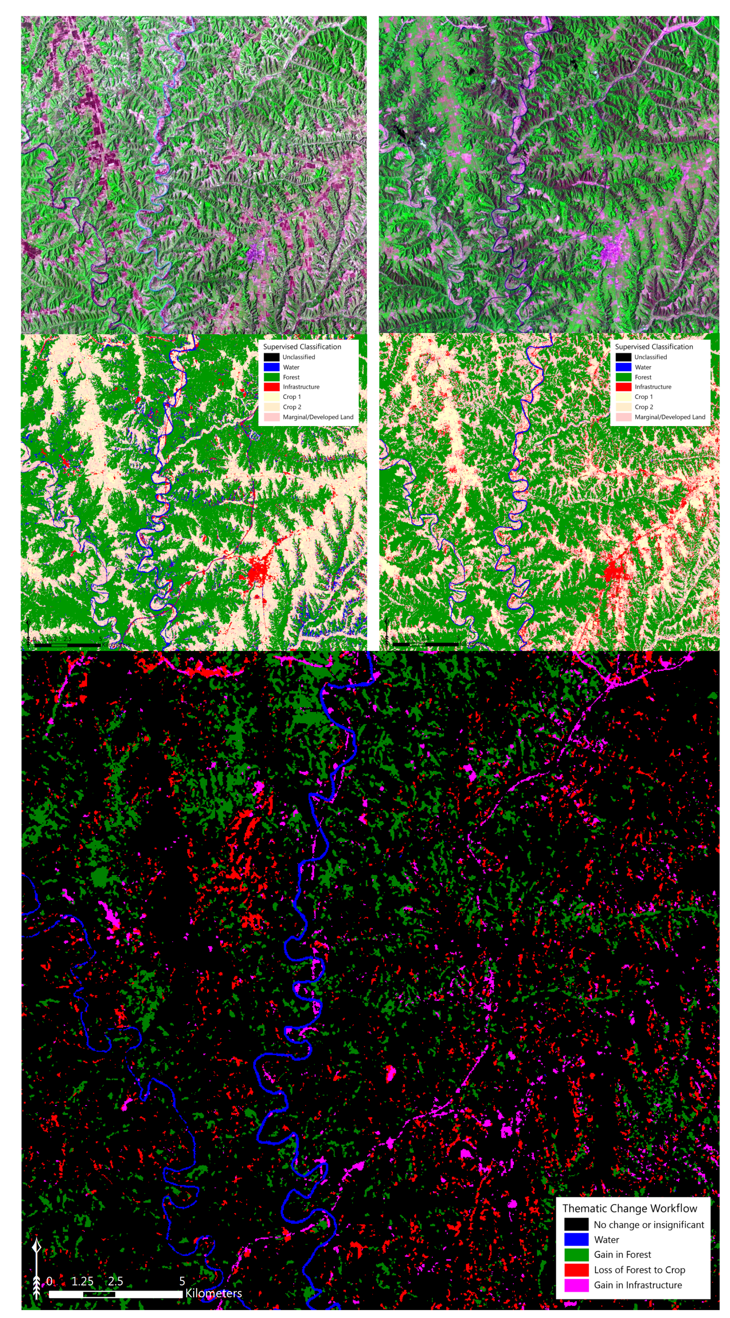


Left to Right: *Image depicting the output of a simple single-band change detection between 1998 and 2010, using Band 7. Final output of classification of vegetative change using Band 7 change detection.*

Supervised Classification

Supervised Classification and Thematic Change Workflow

A smaller area slightly to the south of the initial study site was selected for a supervised classification. ROIs were manually drawn in both images to be used as training sites. For both dates, the classification scheme was selected to be Maximum Likelihood, which demonstrated the greatest accuracy for both dates. A change detection between the two images was performed using Thematic Change Workflow, producing a final output of land cover and vegetation type changes from 1998—2010.



Overall, the region gains infrastructure, partly at the expense of forest. In addition, some forest is lost to agricultural land, but only modest gains in forest were made, thus showing the continuous impact of anthropogenic land use in the region. Despite the intentions of the GFGP, the growth of the human population is usually prioritized over protection and stewardship of the environment.

From top to bottom, left to right: *False-color images (bands 7, 4, 2) from 1998 (left) and 2010 (right).*

Supervised Maximum Likelihood Classifications for 1998 (left) and 2010 (right). Classes of interest: Water (blue), Forest (green), Crop 1 (yellow), Crop 2 (orange), Infrastructure (red), and Marginal or other Developed Land (pink).

Classification of change from 1998—2010. Classes of interest: Gain in Forest (green), Loss of Forest to Cropland (red), Gain in Infrastructure (pink), and Water (blue). Remaining areas (no change) are depicted in black.

Conclusions

When interpreting the results of the vegetative change classifications, it appears that there was a net gain of vegetation from 1998—2010 in the Ansai region of Shaanxi. Based on the Class Statistics output, there was more positive change (increase in vegetation) overall when compared to negative change (a decrease in vegetation). With the NDVI Difference, about 3,814 km^2 saw positive vegetative change (gain), and 248 km^2 had negative vegetative change (loss or decrease), while 4,348 km^2 saw no change. With the Band 7 Change Detection Classification, approximately 1,997 km^2 experienced gain, 239 km^2 experienced loss, and 2,111 km^2 saw no change. Thus, the magnitude of vegetative gain appears to be high.

When examining the supervised classifications, it seems that while much of the forest remained as such, gain in forest was quite small (5.28 km^2). This shows that while there have been some successes with the GFGP, there are also forest losses, likely due to the necessity of feeding China's growing population, as well as increasing infrastructure development.

A program such as GFGP has many potential benefits, but with challenges in implementation, these benefits are oftentimes not fully realized. This study demonstrates that vegetation increased from 1998—2010 in Ansai in Shaanxi. However, while some forest was gained, some was also re-converted to cropland, and some was converted to infrastructure. This shows that while the GFGP has had some modest successes in this region, human population growth is also a huge driver of land cover. Ultimately, this project illustrates that emote sensing can be a critical tool for the protection of biodiversity, especially when used in conjunction with GIS.

Category	Pixel Count, NDVI Difference	Pixel Count, Band 7 Change Detection	%, NDVI Difference	%, Band 7 Change	Area, NDVI Difference	Area, Band 7 Change
Unclassified	960	740	0.02%	0.02%	0.864 km^2	0.666 km^2
Major (+) Change	1,670,850	203,639	34.6%	4.2%	1,504 km^2	183.3 km^2
Moderate (+) Change	1,974,691	562,100	40.9%	11.6%	1,777 km^2	505.9 km^2
Minor (+) Change	592,578	1,453,374	12.3%	30.1%	533.3 km^2	1,308 km^2
No Change	317,380	2,346,022	6.6%	48.5%	285.6 km^2	2111 km^2
Minor (-) Change	219,726	172,767	4.5%	3.6%	197.8 km^2	155.5 km^2
Moderate (-) Change	41,035	53,810	0.8%	1.1%	36.9 km^2	48.4 km^2
Major (-) Change	15,208	39.976	0.3%	0.8%	13.7 km^2	36.0 km^2

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JENNIFER YU

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Data Sources: USGS Earth Explorer, Landsat 5 TM
Image Sources: Wikipedia, Wikimedia Commons; Pixabay