FINAL PROJECT REPORT

Vegetation Analysis & Change Detection in Israel

ABSTRACT

Analysis of the afforestation phenomenon occurring in Israel from planting trees over more than a hundred years by The Jewish National Fund.

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Spring 2017 Digital Image Processing

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Final Project Report:
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Define the study area of the project:

The purpose of this study is to confirm Israel as one of the handful of states in the world that actively pursues afforestation since The Jewish National Fund (JNF) began its legacy of planting trees since 1901.[1] This will be assessed through analyzing land cover change in Israel using satellite images from two different points in time.

Determine the temporal cope of the project:

The temporal scope of this project covers 17 years. Since the analysis of this report is vegetation across a long period, the seasonal phenological cycle of plants needs to be controlled. Additional environmental effects that need to be accounted for are atmospheric conditions, soil moisture, and solar angle variability. In order to mitigate the environmental effects the images being compared need to be from as close as possible to the same day or anniversary dates. Hence, the selected anniversary dates of April 7, 1999 to April 25, 2016 for this project.

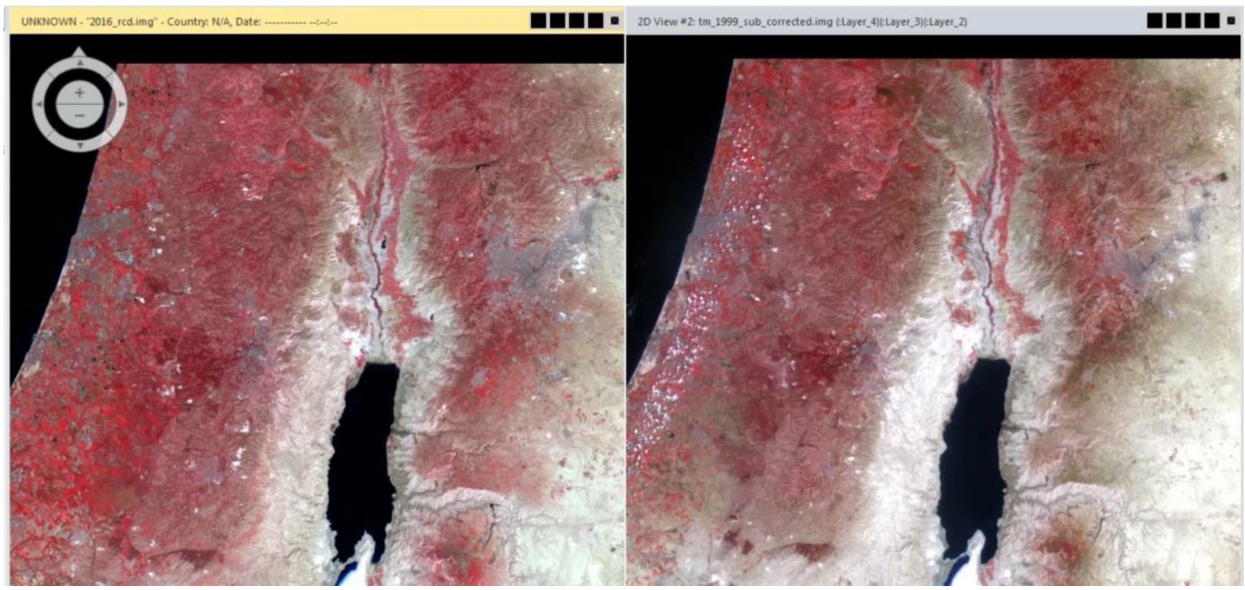
Determine scheme:

According to the U.S. Geological Survey (USGS)Anderson Land Cover Scheme, Israel falls under Level IV: Regional Scale, which requires 3-30m spatial resolution for adequate analysis the area of interest. The scheme recommends the use of Landsat Satellite data because its spatial resolution is 30m. Additionally, in order to keep information accurate between images take years

[1] "Jewish National Fund." *Jewish National Fund:* . N.p., n.d. Web. 10 May 2017. http://www.jnf.org/work-we-do/our-projects/forestry-ecology/

apart, the resolutions of sensors must remain constant. Hence, using Landsat data fulfils this necessity as resolutions across; spatial, spectral, temporal, and radiometric resolutions remain constant across each sensor in the Landsat legacy. The 1999 image uses Landsat 5 TM data and the 2016 image uses Landsat 8 OLI which both have the following resolutions: 30m spatial, have spectral bands from blue to Near Infrared (NIR), 16 days temporal, and 16 bit radiometric.

False Color Images of Israel, 2016(left) 1999(right).



Acquiring and preprocessing data:

Landsat data was acquired from USGS Earth Explorer's Landsat Level 1 data archive, which offers Landsat Ecosystem Disturbance Adaptive Processing Systems (LEADAPS) data. LEADAPS data is already radiometrically corrected, which takes care of the first step of image preprocessing. Radiometric preprocessing corrects images for directional surface reflectance and then converts this to radians using 6S approach. Reflectance is then spatially registered and images are reprojected. The second step in preprocessing data is to apply geometric corrections, which eliminates error caused by the Earth's rotation and curvature, as well as the lag experienced by the satellite sensors. Eliminating these errors ensures that two images will match when stacked on top of each other for change detection purposes. This process was completed through image registration using bilinear interpolation transformation with eight ground control points (GCPs) that had a root mean square error (RMSE) value of less than half a pixel size (15m).

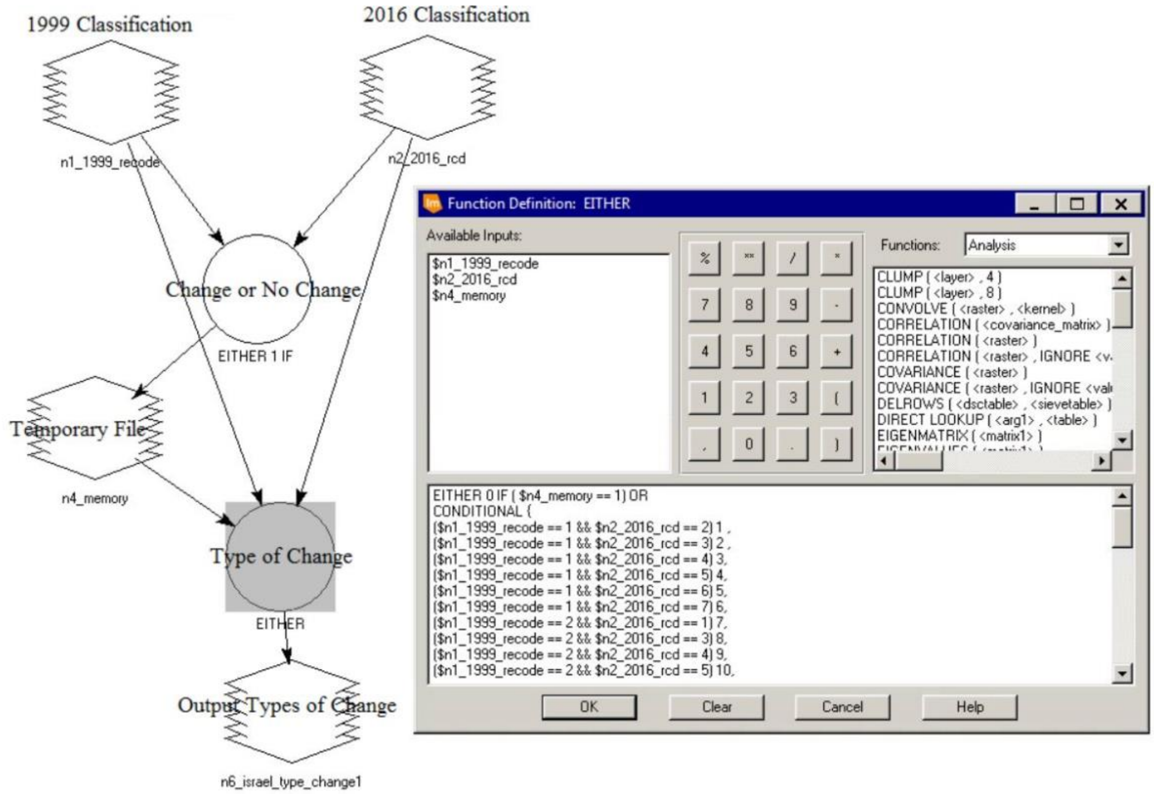
Point #	Point ID	>	Color	X Input	Y Input	>	Color	X Ref.	Y Ref.	Type	X Residual	Y Residual	RMS Error	Contrib.	Match
1	GCP #3			675476.079	3585831.523			675469.446	3585829.143	Control	0.310	-0.387	0.496	0.155	
2	GCP #4			802563.307	3581791.079			802560.047	3581790.432	Control	0.982	0.782	1.255	0.392	
3	GCP #5			781890.563	3541048.828			781889.316	3541051.152	Control	-3.264	-1.740	3.699	1.156	
4	GCP #8			655110.116	3470431.588			655160.701	3470398.116	Control	0.474	-0.351	0.590	0.184	0.852
5	GCP #9			733609.685	3467725.061			733594.522	3467725.015	Control	-2.699	-0.304	2.716	0.849	0.071
6	GCP #10			793274.479	3474721.480			793289.723	3474727.035	Control	-0.035	0.703	0.704	0.220	0.511
7	GCP #11			745101.309	3500359.684			745102.270	3500362.707	Control	6.839	-0.735	6.878	2.149	0.946
8	GCP #13			707311.069	3518968.944			707309.895	3518968.621	Control	-2.607	2.033	3.306	1.033	0.230
9	GCP #12	▶				▶				Control					

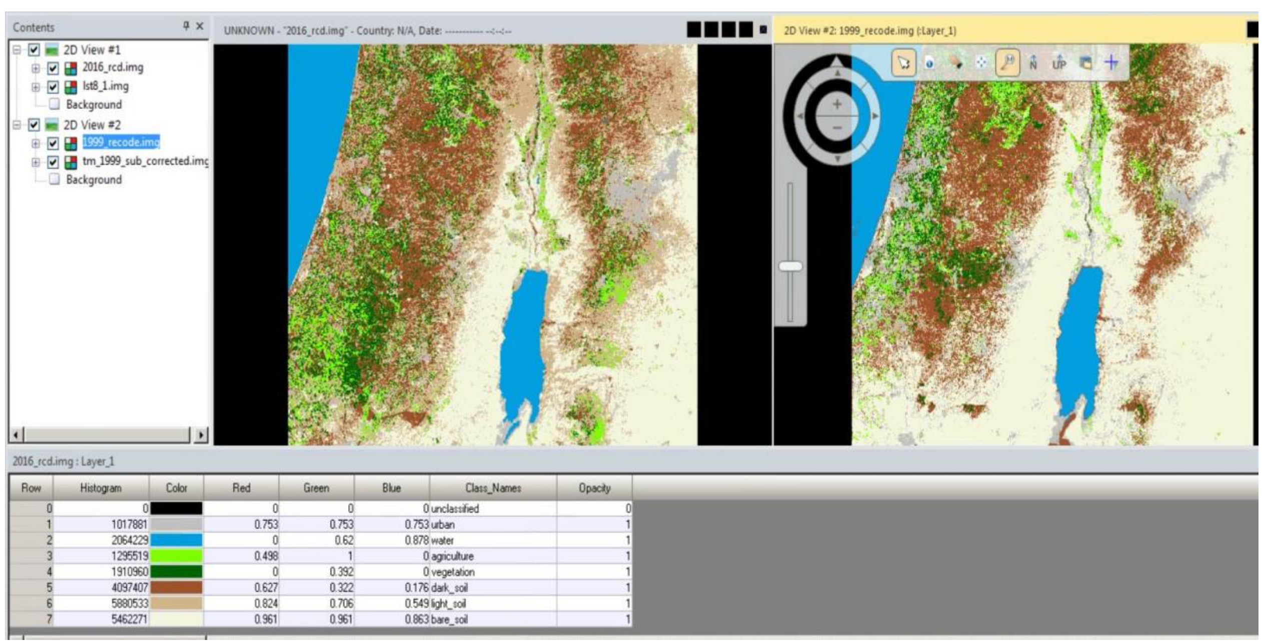
763773.64, 3564420.26 (UTM / WGS 84) Model solution is current. Cancel

Change detection algorithm:

To analyze the change of vegetation or afforestation in Israel from 1999 to 2016, post-classification change detection and Normalized Difference Vegetation Index (NDVI) analysis were performed. Post-classification change detection performs a qualitative and quantitative method to determine what type of land cover changed from1999 to 2016, and how much area of such change occurred. This process requires two classified images. The classification process organizes pixels of similar spectral reflectance into groups, which can then be labeled into a certain land cover classes. For this project, both images were classified through unsupervised classification algorithm, ISODATA, which organized the images into 36 different classes based upon seprability with a best average Jeffery-Matusita value of 1389. Each class was overlaid on top of a false-color image relying on human image-interpretation to determine its land cover type. Once all 36 classes were determined, they were recoded and consolidated into seven: 1 = urban, 2 = water, 3 = agriculture, 4 = wild vegetation, 5 = dark soil, 6 = light soil, 7 = bare soil. Next, the two classified images were inputted into a change detection model using the Model

Maker tool in Erdas Imagine. Since each class was recoded to a distinct numerical value, the model will output the 42 different possible types of land cover changes that a pixel can encounter and the number of pixels for each type of land cover change.

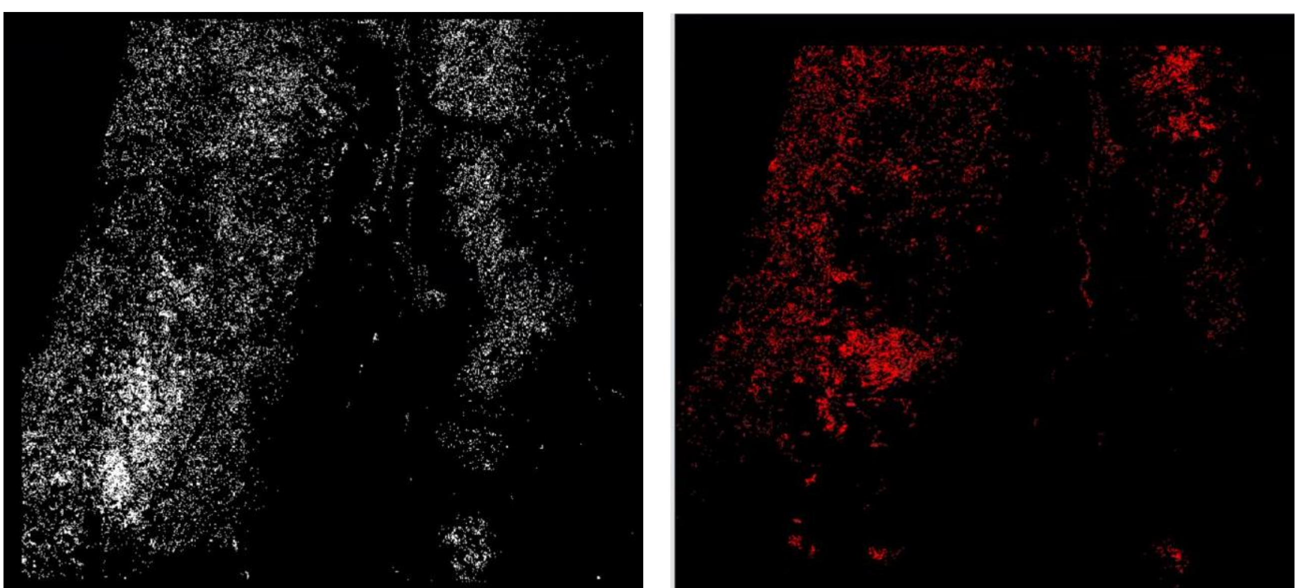




The second type of change detection algorithm performed to complement post-classification was to compare the NDVI between both images. NDVI is a form of band ratioing between the NIR and red bands of an image. Since vegetation reflects much higher in the NIR than the red portion of the electromagnetic spectrum than most other land covers, it is an effective way to isolate vegetation change. The index measures pixels on a scale of -1 to +1, where the closer to +1 the greener, healthier, and denser the vegetation. According to USGS, vegetation ranges from 0.2 to 1.0.[2] Hence, the vegetation threshold for this analysis considers pixels above 0.2 as vegetation.

Results:

The classified image for 1999 showed that there were 1,034.8 km^2 of vegetation, while the 2016 image totaled 1,719.9 km^2 for an increase, or afforestation of 685.1 km^2. Additionally, the post-classification process demonstrated that over 17 years 1,465.7 km^2 changed into vegetation, yet of the 744.1 km^2 where vegetation changed into another land cover, 662.4 km^2 changed into some class of soil, or desertification. Furthermore, comparing the total area with a value of



Left: Afforestation. Right Desertification

[2] *Remote Sensing Phenology*. N.p., n.d. Web. 10 May 2017. https://phenology.cr.usgs.gov/ndvi_foundation.php

NDVI > than 0.2 resulted with 1999 and 2016 having an area of 5,685 km^2 and 11,343 km^2, respectively, for a net change of 5,659 km^2.

Accuracy Assessment:

In order to quantify the accuracy of each land cover class in the post-classification change detection process, a stratified random sampling scheme of 50 points, with a minimum of 5 points per class was applied on the 1999 and 2016 classified images. Usually, a high spatial resolution imagery from IKONOS or Quickbird sensors is needed as a reference to accurately determine the land cover for the random points. However, access to such data was not viable due to the enormous financial cost to attain such data. Accuracy assessment was, therefore, based off of respective false color Landsat imagery.

2016 Accuracy Table

Class Name	Reference Totals	Classified	Number Correct	Producers Accuracy	Users Accuracy	Total Accuracy	Kappa
Urban	5	5	3	60%	60%		
Water	6	6	6	100%	100%		
Agriculture	7	5	3	42.86%	60%		
Vegetation	4	6	2	50%	33.33%		
Dark Soil	8	8	5	62.50%	62.50%		
Light Soil	12	10	6	50%	60%		
Bare Soil	8	10	6	75%	60%		
Overall						62%	55%

1999 Accuracy Table

Class Name	Reference Totals	Classified	Number Correct	Producers Accuracy	Users Accuracy	Total Accuracy	Kappa
Urban	6	6	1	16.67%	16.67%		
Water	6	6	6	100.00%	100.00%		
Agriculture	3	5	2	66.67%	40.00%		
Vegetation	6	5	3	50.00%	60.00%		
Dark Soil	4	8	2	50.00%	50.00%		
Light Soil	12	6	3	25.00%	50.00%		
Bare Soil	13	14	10	76.92%	71.43%		
Overall						54.00%	45.00%

Limitations & Conclusions:

Although many of the techniques employed during this analysis offer a variety of beneficial and useful insights to analyze the vegetation change in Israel, there are some limitations and errors. Referencing the accuracy table in the previous section, vegetation faced difficult classification. Thus, the probability that the lad cover changes that this project found actually occurred over 17 years is too uncertain. Additionally, the images used for this project cover areas well beyond the borders of Israel into areas where JNF does not operate such as the West Bank and parts of Jordan. The area of the change detection algorithms employed in this research are inaccurate because they include change from outside the scope of Israel. Furthermore, the results for NDVI are also skewed because although this process applied a threshold to exclude non-vegetation pixels, it did not exclude the agriculture class from its results. The change in NDVI analysis is an inaccurate method to measure afforestation because JNF plants trees, not crops. Overall, given these gross inaccuracies, it is not possible to confidently conclude that there is or is not afforestation occurred in Israel between 1999 to 2016 as a result of JNFs actions.

Possible solutions to rectify these errors and limitations without using high spatial resolution imagery would first be to narrow the area of analysis to explicitly Israel in order to analyze vegetation where JNF plants trees. This would require mosaicking several Landsat images. Second, using a supervised classification system instead of unsupervised would allow one to have more control over the classes that are classified. Third, the use of the NDVI value of crops (0.7 according to USGS) as a cap in order remove agriculture from the analysis.[3]

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[3] Ibid.