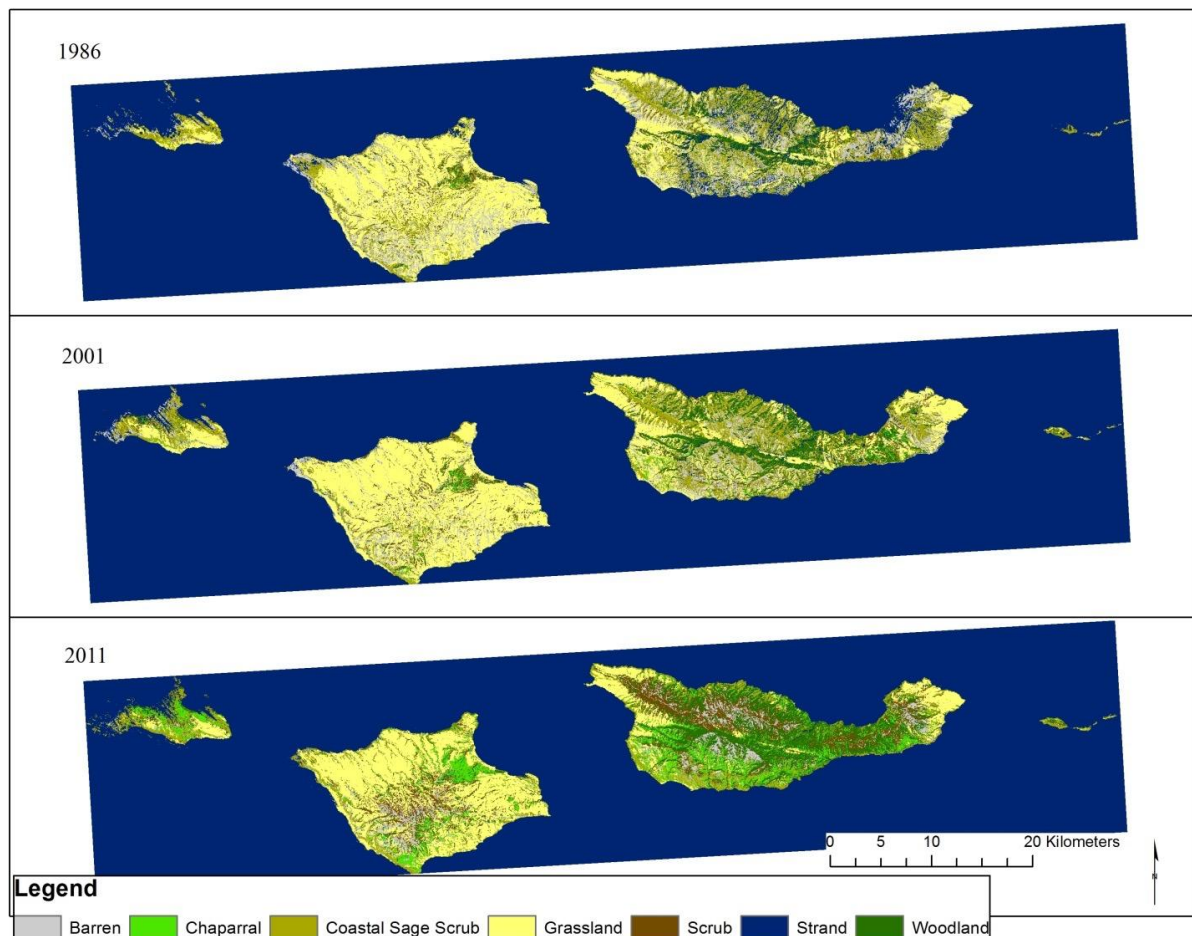




Protocol for Monitoring Landscape Dynamics in the Mediterranean Coast Network of Southern California

Standard Operating Procedures, Version 1.0



ON THE COVER

Land cover change analysis at Channel Islands National Park. Note the increase in chaparral and scrub, which is presumably a result of the removal of feral nonnative animals from the islands.

Image credit: K. Willis

Protocol for Monitoring Landscape Dynamics in the Mediterranean Coast Network of Southern California

Standard Operating Procedures, Version 1.0

Katherine S. Willis¹, Stacey Ostermann-Kelm², Felicia Federico¹, Lena Lee²,
Glen M. MacDonald¹, Thomas W. Gillespie¹

¹ University of California, Los Angeles
Institute of the Environment and Sustainability
La Kretz Hall, Suite 300
Los Angeles, CA 90095

² Mediterranean Coast Network
NPS Inventory & Monitoring Program
401 West Hillcrest Dr.
Thousand Oaks, CA 91360

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Change History

Version numbers will be incremented by a whole number (e.g., Version 1.3 to Version 2.0) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.6 to Version 1.7) when there are minor modifications that do not affect requirements or procedures for publication in the series.

Revision Log. Provides an overview of the changes made to different versions of this protocol over time. Update cells and add new rows as needed.

Version #	Date	Revised by	Changes	Justification
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–

- 1) Version numbers increase incrementally by tenths (e.g., version 1.1, version 1.2, ...etc.) for minor changes. Major revisions should be designated with the next whole number (e.g. version 2.0, 3.0, 4.0 ...). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, and the reason for making the changes along with the new version number.
- 2) Notify the MEDN Data Manager and MEDN Program Manager of any changes to the Protocol Narrative or SOPs so that the new version number can be incorporated in the Metadata of the project database.
- 3) Post new versions on the internet and forward copies to all individuals with a previous version of the Protocol Narrative or SOPs. A list will be maintained in an appendix at the end of this document.

Contents

	Page
Change History	iii
Figures.....	vi
Tables	vi
Overview	vii
List of Acronyms	viii
Standard Operating Procedure (SOP) 1: Land Use / Land Cover and Vegetation Type Change	1
1. Introduction	1
1.1 File Directories	1
1.2 Download and process datasets	1
1.2.1 Topography dataset	1
1.2.2 Gap Analysis Program (GAP) dataset	2
1.2.3 Landsat imagery	5
1.3 Stack datasets.....	7
1.4 Run Classifications.....	8
1.4.1 Study area vector files	8
1.4.2 Create Regions of Interest (ROIs)	8
1.4.3 Base Classification	10
1.4.4 Applying Classifications to Other Images.....	12
1.4.5 Analyzing changes between years.....	13
Standard Operating Procedure (SOP) 2: Phenological Variability	14
2. Introduction	14
2.1 File Directories	14
2.2 Download MODIS data	14
2.3 Compute Changes in NDVI.....	15
Standard Operating Procedure (SOP) 3: Nighttime Lighting	18

3. Introduction	18
3.1. File Directories	18
3.2. Acquiring the nighttime light imageries.....	18
3.3. Getting the brightness value of each pixel area using ENVI.....	19
3.4. Display and export the new point layer	19
3.5. Converting point layer to a raster dataset	19
3.6. Change Detection using the Raster Calculator	19
Standard Operating Procedure (SOP) 4: Data Management.....	20
4. Introduction	20
4.1. Overview	20
4.2. Metadata	20
4.3. File structure and naming	21
4.4. Data storage and archival procedures.....	22
Literature Cited	23

Figures

	Page
Figure 1.1. Raw GAP dataset for southern California outlined by SAMO boundary.....	3
Figure 1.2. Subset land use classes of GAP data in ArcGIS (agriculture shown in SAMO).....	5
Figure 1.3. Make sure to select the bands in the correct order when stacking.....	7
Figure 1.4. Selecting new ROIs within the shapefile allows for data to be trained more accurately.....	10
Figure 1.5. Class parameter match in ENVI	12
Figure 4.1. Suggested directory structure for image processing.....	22

Tables

	Page
Table 1.1. Abbreviations for land cover types currently used in the analysis.....	4
Table 1.2. Abbreviations for land cover types previously used in the analysis.	4
Table 4.1. Image processing steps and their metadata requirements	21

Overview

These Standard Operating Procedures (SOPs) accompany the Mediterranean Coast Network's protocol for monitoring landscape dynamics (Willis et al. 2018). They provide detailed data processing instructions for the variables associated with the protocol's three monitoring objectives: 1) land use/land cover and vegetation type change; 2) phenological variability; and 3) nighttime lighting. SOP 4 provides important information about data storage and archiving procedures.

List of Acronyms

ALI:	Advanced Land Imager
ANI:	Anacapa Island
ASTER:	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CABR:	Cabrillo National Monument
CHIS:	Channel Islands National Park
DEM:	Digital Elevation Model
DMSP-OLI:	Defense Meteorological Satellite Program – Operational Linescan System
DN:	Digital Number
EMZ:	Ecological Management Zone
ENSO:	El Niño Southern Oscillation
ENVI:	ENvironment for Visualizing Images (remote sensing application software)
ERA:	Ecological Reserve Area
ERDAS:	Earth Resources Data Analysis System (remote sensing application software)
ESA:	Endangered Species Act
ETM+:	Enhanced Thematic Mapper +
EVI:	Enhanced Vegetation Index
GAP:	Gap Analysis Program
GCM:	Global Climate Model
GIS:	Geographic Information System
GRTS:	Generalized Random Tessellation Stratification
I&M:	NPS Inventory and Monitoring Program
IDL:	Interactive Data Language (programming language used in ENVI)
IUCN:	International Union for Conservation of Nature
LULC:	Land Use and Land Cover
MEDN:	Mediterranean Coast Network of the NPS Inventory and Monitoring Program
MODIS:	MODerate-resolution Imaging Spectroradiometer
NDVI:	Normalized Difference Vegetation Index
NASA:	National Aeronautics and Space Administration
NDVI:	Normalized Difference Vegetation Index
NLCD:	National Land Cover Dataset
NOAA:	National Oceanographic and Atmospheric Administration

NPS:	National Park Service
OLI:	Operational Land Imager
PLECA:	Point Loma Ecological Conservation Area
RMZ:	Santa Monica Mountains Resource Management Zone
ROI:	Region of Interest
SAMO:	Santa Monica Mountains National Recreation Area
SBI:	Santa Barbara Island
SCI:	Santa Cruz Island
SMI:	San Miguel Island
SOP:	Standard Operating Procedure
SPOT:	Système Pour l'Observation de la Terre
SRI:	Santa Rosa Island
SRTM:	Shuttle Radar Topography Mission
TERRA:	Terrestrial Ecosystems Regional Research and Analysis
TM:	Thematic Mapper
USGS:	United States Geological Survey

Standard Operating Procedure (SOP) 1: Land Use / Land Cover and Vegetation Type Change

1. Introduction

This SOP has been created to monitor the changes in land use and land cover as well as the changes in vegetation type in the entire landscape over time. This may be completed once every year to compare landscape changes as long as the images are all from the same season to account for phenological differences that may be detected in the spectral data. Land use and land cover types and changes in these types will be calculated from the 1970's until present day. User must have some knowledge of Environment for Visualizing Images (ENVI) and ArcMap software programs.

1.1 File Directories

Navigate to the Landscape Dynamics workspace. If not present, create the following folders:

/<park>	
/DEM	(used in SOP-1)
/GAP	(used in SOP-1)
/study_area	(used in SOP-1)
/image_<year>	(used in SOP-1)
/class	
/Landsat_raw	
/Landsat_bands	
/roi	
/MODISndvi	(used in SOP-2)
/DMSP-OLS	(used in SOP-3)

1.2 Download and process datasets

1.2.1 Topography dataset

Datasets will be saved to the /DEM directory under each park unit.

High resolution elevation data are obtained from the Shuttle Radar Topography Mission (SRTM) program. Slope and aspect data will be extracted from this dataset.

1.2.1.1 Download dataset

- Use your internet browser to go to the Global Land Cover Facility Earth Science Data Interface website: (<http://glcfapp.glcf.umd.edu:8080/esdi/index.jsp>).
- Click on “Map Search”.
- Click on the “Path Row” tab above the map and search Start Path “040” End Path “042” and Start Row “036” End Row “037”
- Click the checkbox on the left for “SRTM, WRS2 Tiles” and click “Update Map”.
- Select the image area desired and click “Preview and Download”.
- Select the dataset with the following parameters and download the “.tif.gz” for each:
 - 182-223 WRS [P/R]: **2: 040/037 (for CABR)**
 - 182-250 WRS [P/R]: **2: 042/036 (for CHIS top 4)**

- 182-237 WRS [P/R]: **2: 041/037 (for CHIS SBI)**
- 182-236 WRS [P/R]: **2: 041/036 (for SAMO)**
- Acq. Date: **2000**
- Attr.: **1 arcsecond, Filled, Finished-B**
- Save the dataset in /DEM.
- These files will need extracted. This can be done by right clicking on the downloaded file and selecting extract or using an application like 7zip.

1.2.1.2 Extract Slope and Aspect data

- Open ENVI 4.8 or higher and go to File → Open and open the elevation tif data file for the desired park (ex: C:\WORKSPACE\SAMO\DEM\STRM_ffb01_p041r036.tif).
 - **040/037 (for CABR)**
 - **042/036 (for CHIS top 4)**
 - **041/037 (for CHIS SBI)**
 - **041/036 (for SAMO)**
- Search in Toolbox → Topographic Modeling and select Band 1 of the elevation file. Click OK.
- Select Slope (Degrees), Aspect, and, if desired, Shaded Relief from the Topo Model Parameters dialogue.
- If using, Shaded Relief, click on Compute Sun Elevation and Azimuth and enter the date and time at which the corresponding Landsat image you wish to associate this file to for your classification. This information can be found in the MTL metadata file. Enter the Latitude and Longitude under Geographic Position. Use the information below to determine the Latitude and Longitude for each park unit. Click OK to begin data extraction.
 - Lat 33.178, Lon -117.189 **(for CABR)**
 - Lat 34.612, Lon -119.879 **(for CHIS top 4)**
 - Lat 34.612, Lon -117.242 **(for CHIS SBI)**
 - Lat 34.612, Lon -118.334 **(for SAMO)**
- Save the topographic output with a file name using the image year, month and day followed by “topo” in /DEM (ex: C:\WORKSPACE\SAMO\DEM\19890714topo).

1.2.2 Gap Analysis Program (GAP) dataset

Datasets will be saved to the /GAP directory under each park unit.

1.2.2.1 Download dataset

- Use your internet browser to go to the USGS GAP Land Cover Data Portal (<http://gapanalysis.usgs.gov/gaplandcover/data/download/>).
- Scroll down to “Download Data by Area”. Download by state- California - do not select an LCC - click “Download ESRI GRID File”.
- Download the GAP data as an ArcGIS shapefile.
- Save the dataset in /GAP.

1.2.2.2 Process dataset

- Open ArcGIS and load the GAP raster into the view.
- Make sure that all files are in the same projection. Typically this will be NAD_1983_albers
- Subset (using the Clip (data management) tool) the GAP dataset by the sampling boundary shapefile for the desired Park. Save the clipped raster dataset in /GAP as <park>_GAP (see Figures 1.1 and 1.2).
- In ArcGIS, convert the clipped GAP raster (<park>_GAP) to a polygon shapefile (<park>_GAP_poly.shp) using the Raster to Polygon tool. Subset the raster based on NVC_CLASS. **Make sure to uncheck the “Simply polygons” box.** Save the datasets in /GAP.
- Make sure to load the new shp into your arc session. Right click and select properties then select the symbology tab. Sort by categories, unique values and use NVC_CLASS as the value field.
- For each land cover type, select polygons (see Figure SOP 1.2) by going to select by attributes and selecting all polygons that belong to the desired land class. Only do this for classes with over 100 features shapes. (For example, in the select*from box it will say "NVC_CLASS" = 'Agricultural Vegetation'). Right click on the GAP shapefile layer – data-export data. Export each land use layer as a shapefile in <park>_GAP_poly_<land cover type>.shp as the land cover type label is listed in Table 1.1. Save the dataset in /GAP.

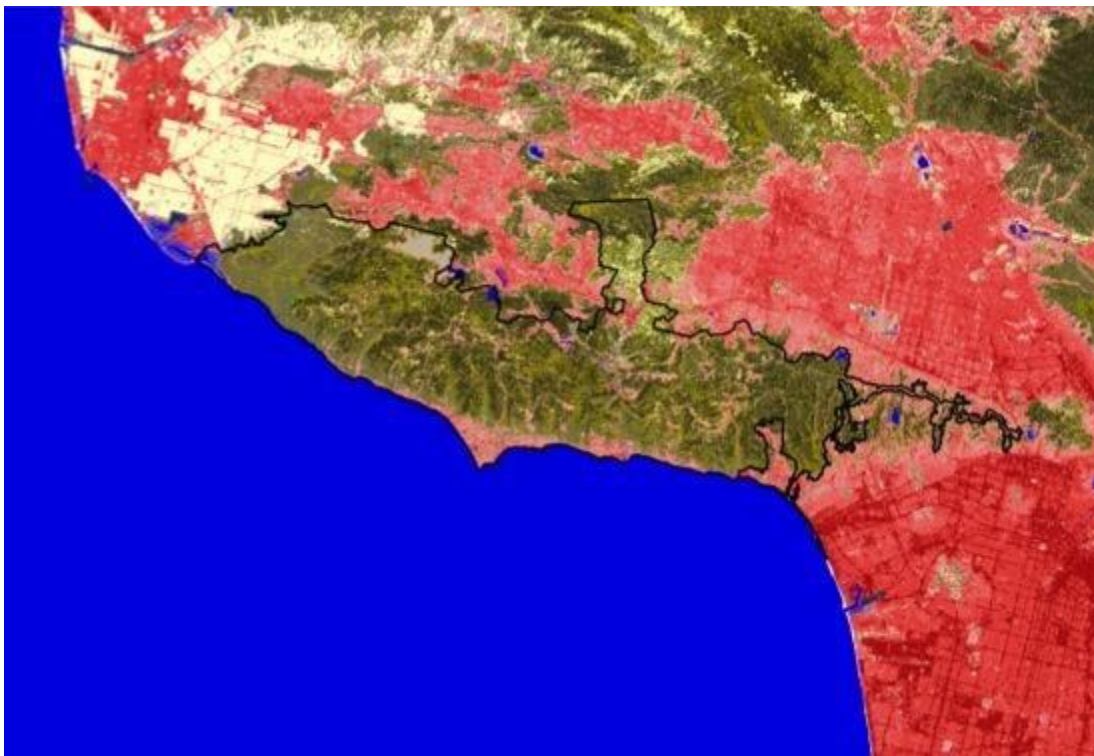


Figure 1.1. Raw GAP dataset for southern California outlined by SAMO boundary.

Table 1.1. Abbreviations for land cover types currently used in the analysis.

Class	Abbreviation
Agricultural Vegetation	AGRI
Developed & Other Human Use	DEVE
Forest & Woodland	FORE
Nonvascular & Sparse Vascular Rock Vegetation	NONV
Open Water	OPEN
Semi-Desert	SEMI
Shrubland & Grassland	SHRUB

Table 1.2. Abbreviations for land cover types previously used in the analysis.

Class	Abbreviation
Agriculture	AGRI
Beach, Shore, Sand	SAND
Chaparral	CHAP
Cliff, Canyon, and Talus	CLFF
Coastal Grassland	CGRS
Conifer Dominated Forest Woodland (Mesic-Wet)	CONF
Conifer Dominated Forest Woodland – Xeric-Mesic	CONF
Deciduous Dominated Savanna Glade	DSAV
Developed – High Intensity	DVHI
Developed – Medium Intensity	DVMD
Developed – Low Intensity	DVLO
Developed – Open Space	DVOP
Floodplain Riparian	RIPE
Freshwater Herbaceous Marsh, Swamp, or Baygall	MRSH
Mixed Deciduous/Coniferous Forest and Woodland (Mesic-Wet)	MXWD
Open Water	WATR
Scrub Shrubland	SCRB

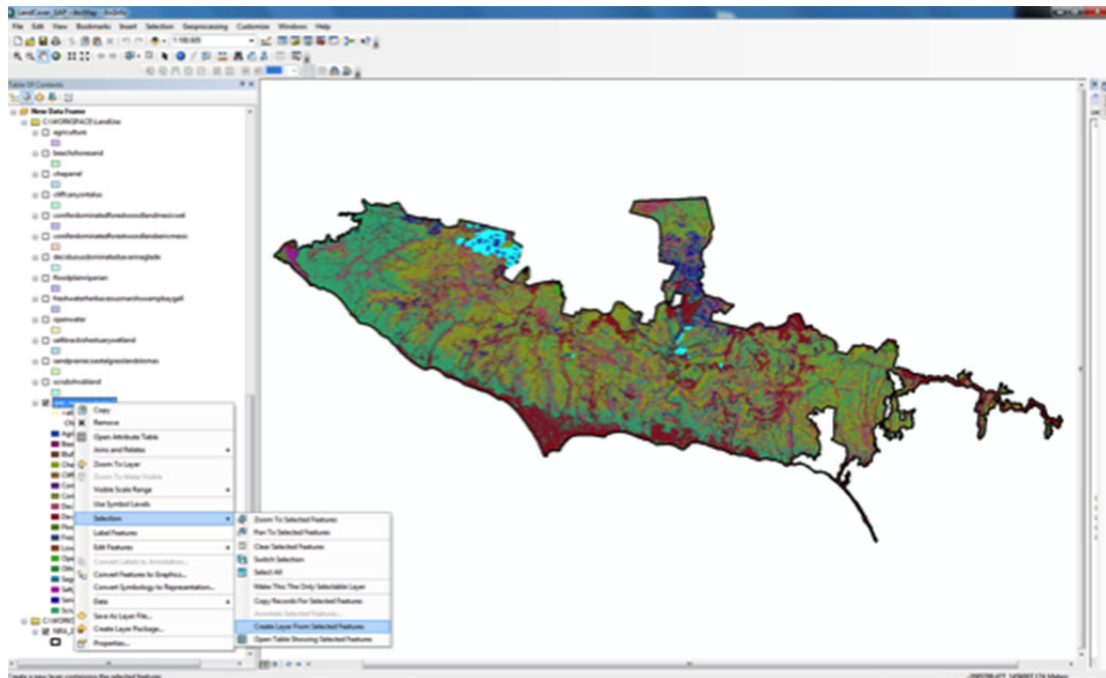


Figure 1.2. Subset land use classes of GAP data in ArcGIS (agriculture shown in SAMO).

1.2.3 Landsat imagery

Datasets will be saved to the /image_<year> directory under each park unit.

1.2.3.1 Download dataset

- Use your internet browser to go to the USGS Earth Explorer website (<https://earthexplorer.usgs.gov/>). Make sure to log into the website or create a free account to log in.
- Zoom in on the desired area of research interest and click on the “Use Map” option to select the geographic region for your search criteria. Drag the four corners surrounding your selection to define your exact region of interest.
- Choose the range of dates and months desired. Under the Data Sets tab, select the appropriate Landsat Archive (L7 ETM+ SLC-off for 2003-present, L7 ETM+ SLC-on for 1999-2003, L4-5 TM for 1984 to 2001, and L1-5 MSS for 1972-1984) under “Landsat Archive”.
 - NOTE: Month's chosen for Southern California comparison should be between July and September in order to ensure comparability between years. Precipitation records for the area may also be checked from downloading by station from the National Climatic Data Center by NOAA (<http://gis.ncdc.noaa.gov/map/cdo/?thm=themeDaily>) before choosing an annual image in order to ensure that the spectral information for vegetation has not been changed due to a recent rain event. However, for the Channel Islands, you may go a little beyond these months in order to find an image with minimal cloud cover.
- Click the “Results” tab and all available Landsat data for the applicable years and region should appear. Try to find images with minimal cloud cover - often a percentage will be

shown. Click on the download options icon of the desired scene. You will be given a few options for file formats - select Level 1 Product. Scenes may also be ordered via the shopping cart icon if not available for immediate download.

- The image will download as a tar.gz file. Using a program like 7zip, extract this to a .tar file. The .tar file can then be extracted to a .tif file.
- Save the Landsat imagery to /Landsat_raw (ex: C:\WORKSPACE\SAMO\image_1989\Landsat_raw). Each band of Landsat (7 total) will appear as a separate TIFF image. The band number will be listed at the end of each file name as B10, B20, etc. (ex: C:\WORKSPACE\SAMO\image_1989\Landsat_raw\L5041036_03619890714_B10). Several other metadata files, including the MTL (metadata) file, will also be downloaded.

1.2.3.2 Landsat correction

Once your Landsat data is extracted, look in the MTL file at the Correction Gain for each band. If it reads “CPF” then it is already corrected and you may skip to layer stacking. If not, follow the steps below.

- Open ENVI 4.8 or higher and go to **File → Open**.
- Open the downloaded Landsat data files for bands 1, 2, 3, 4, 5 and 7. Band 6 measures heat which is unnecessary in this classification. Use the ctrl key to select multiple files.
- Open the “Radiometric Calibration” tool and select Band 1. Using the MTL metadata file, enter the calibration information for Landsat Satellite Sensor, Data Acquisition Month, Day and Year, Sun Elevation and Data Acquisition Band. Make sure that the data acquisition band matches the band that you are calibrating.
- Enter an output filename using the image year and band number and save in /Landsat_bands (ex: C:\WORKSPACE\SAMO\image_1989\Landsat_bands\1989b1).
- Repeat this Landsat correction for each band.

1.2.3.3 Landsat Layer Stacking

When all bands have been individually corrected, Search for the tool “Layer Stacking”, and import all six Landsat corrected to create an image stack. Make sure that the bands are in the following order: 7, 5, 4, 3, 2, 1 (Figure 1.3). Leave all other parameters as is.

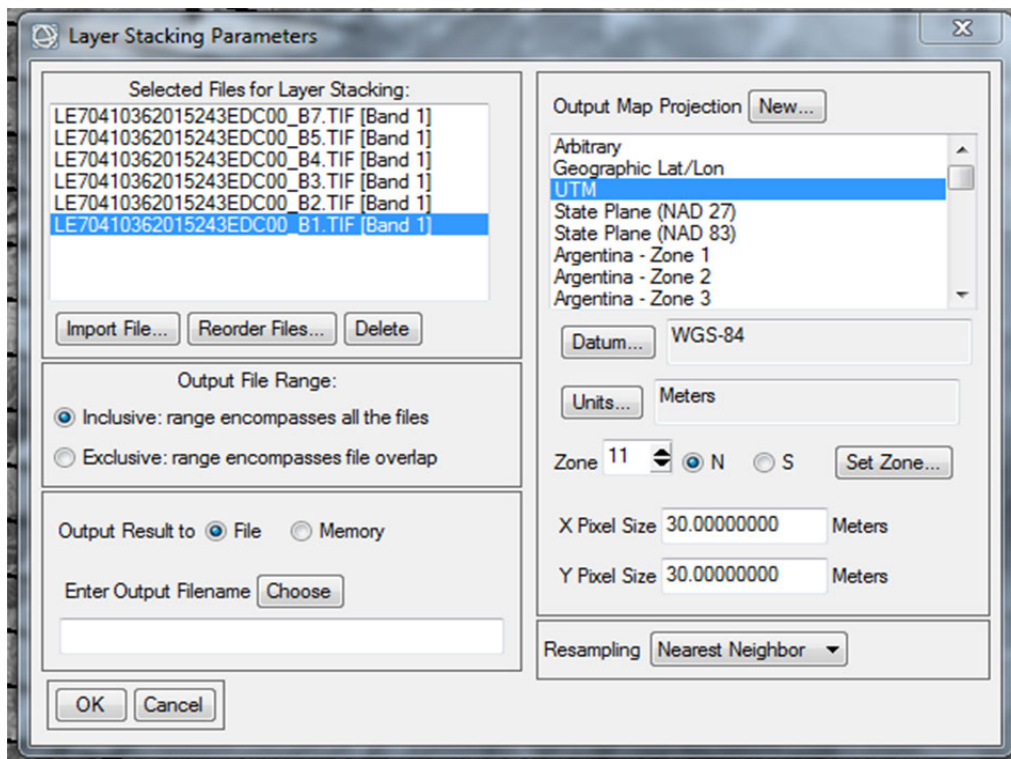


Figure 1.3. Make sure to select the bands in the correct order when stacking.

Save the combined image stack output with a filename using the image year followed by “all” in /Landsat_bands (ex: C:\WORKSPACE\SAMO\image_1989\Landsat_bands\1989all.tif).

1.2.3.4 Dark Object Subtraction correction

If your Landsat data was pre-corrected, you may skip this section. Otherwise follow the steps below.

- Open ENVI 4.8 or higher and go to **File** → **Open** and open combined image stack file (e.g. 1989all) created in step 1.2.3.3.
- Search for Dark Subtract and select the file image as your input file (ex: C:\WORKSPACE\SAMO\image_1989\Landsat_bands\1989all). Leave all other parameters as is.
- Save the Dark Object Subtraction correction output with a filename using the image year followed by “DOS” in /Landsat_bands (ex: C:\WORKSPACE\SAMO\image_1989\Landsat_bands\1989DOS.tif).

1.3 Stack datasets

Datasets will be saved to the /image_<year>/class directory under each park unit.

- Open ENVI 4.8 or higher go to **File** → **Open**
- Open the original SRTM elevation file, the pre-corrected Landsat OR Landsat DOS images (*.TIFF) for bands 1, 2, 3, 4, 5, and 7, and the topographic (slope/aspect) files. A total of eight files will be opened.

- Search in Toolbox → Layer Stacking
- Import Files and choose the eight files making sure that they are in the following order: topographic (slope/aspect) file, Landsat DOS image files, and the original SRTM elevation file.
- When selecting each file, click on **Spatial Subset → Subset Using ROI/EVF** and choose the park study area *.evf file (ex: C:\WORKSPACE\SAMO\study_area\SAMO_2002.evf) in order to decrease the output file size and increase processing speed.
 - NOTE: *.evf and .shp are, for these purposes, the same file type. If you cannot create an .evf, a .shp will be fine as well.
- Under “Output File Range” select “Exclusive: range encompasses file overlap”.
- Choose an output filename with a *.dat extension according to park unit and year (ex: images from the Santa Monica Mountains Recreation area, Channel Islands National Park, and Cabrillo National Monument for 1986 were named SAMO1986.dat, CHIS1986.dat, and CABR1986.dat, respectively).
- Save the output files in \<park>\image_<year>\class (ex: C:\WORKSPACE\SAMO\image_1989\class).
- Click OK to stack the datasets. The output file should contain 9 layers: Slope, Aspect, Landsat Band 7, Landsat Band 5, Landsat Band 4, Landsat Band 3, Landsat Band 2, Landsat Band 1, and the SRTM elevation file.

1.4 Run Classifications

Datasets will be saved to the /image_<year>/class directory under each park unit.

1.4.1 Study area vector files

- Open ENVI 4.8 or higher and go to **File → Open**.
- Navigate to the image_<year> directory and select the stacked file or previously downloaded (section 1.3) 2001 stacked Landsat and elevation image for the park of interest (ex: C:\WORKSPACE\SAMO\image_1989\SAMO2001). Because GAP data was collected from 1999-2001, the 2001 Landsat and elevation image will be used as the base image file.
- In ENVI go to **File → Open**.
- Select and open all shapefiles desired for land use types.
- Once all of these vectors are overlaid onto your image, select them one at a time and in the vector window click on **File → export as *.shp**
- Save each park study area as <park>_year with an *.shp file extension. Save the dataset in /study_area.

1.4.2 Create Regions of Interest (ROIs)

- If your Landsat stacked image is not already open in ENVI 4.8, go to **File → Open**.
- Navigate to the image_<year> directory and select the stacked file or previously downloaded (section 1.3) 2001 stacked Landsat and elevation image for the park of interest (ex: C:\WORKSPACE\SAMO\image_1989\SAMO2001). Since GAP data was collected from 1999-2001, the 2001 Landsat and elevation image will be used as the base image file.

- Display the image in the Display #1 window by clicking the RGB toggle, and selecting Landsat bands 3,2,1 in order to display the image in natural color file open image.
- In the image window, **overlay** → **vector**.
- Overlay each land cover type shapefile as vectors onto the Landsat image. Save as *.shp.
- In order to ensure accuracy in your classification, manually draw the ROIs in order to best train the data (Figure 1.4).
- In the image window, **overlay** → **region of interest**.
- Create a new ROI by selecting the “Create new ROI tool” or selecting **File** → **New** → **Vector Layer**. Use the desired vegetation type as input.
- Right click on the new region name and name your class according to Table 1.1.
- Make sure the Zoom button is selected in the region of interest window (this will ensure that you are drawing your ROI from the zoom window).
- Your vectors should still be overlaid onto the Landsat image already, and should be visible. This is important so you can create a new ROI of areas that are truly the desired vegetation.
- Scroll to an area with a large cluster of pixels from the land use type you are drawing. Click multiple times to create a polygon surrounding the cluster of that land use type. Right click 2X to complete the polygon. This creates one part or polygon of your ROI. **(***When selecting an area to assign as an ROI make sure that this area is certain to be the land use type that you are assigning it to be. This can be double checked using GoogleEarth and/or through field validation.)**
- Create at least 30 polygons for one land use type to complete the ROI (this should be between 200-500 total pixels approximately)
 - NOTE: It is often difficult to find Landsat images for CHIS that do not contain any clouds. In order to avoid misclassifying clouds in the CHIS images as a land use type class, an ROI may be created for clouds to simply separate them out as a separate class.
- Be sure to save your work! In the region of interest window go to File-Save ROIs and save each output ROI as a new ROI file with a filename using the land cover type abbreviation from Table 1 and an *.roi extension in the /roi subdirectory (ex: C:\WORKSPACE\SAMO\image_1989\class\roi\agri.roi).
- Repeat for each land cover layer.

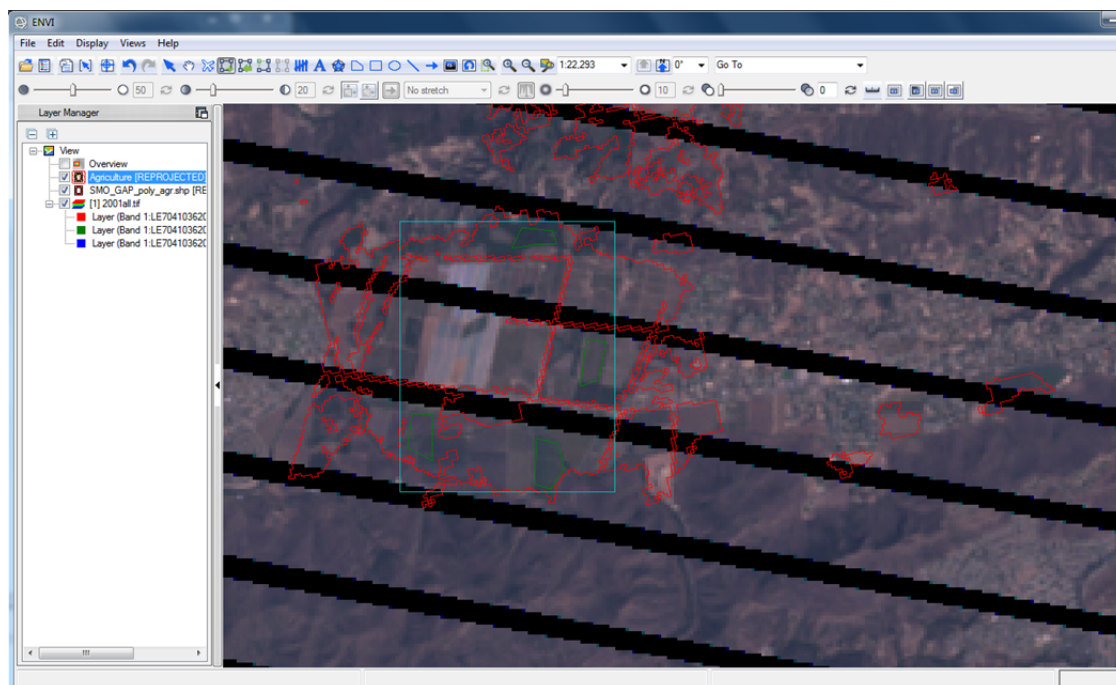


Figure 1.4. Selecting new ROIs within the shapefile allows for data to be trained more accurately.

1.4.3 Base Classification

- Open ENVI 4.8 or higher and go to File → Open File.
- Navigate to the image_<year> directory and stacked image select the previously downloaded (section 1.3) 2001 Landsat cloud-free image plus elevation/topography for the park of interest (ex: C:\WORKSPACE\SAMO\image_1989\SAMO2001). Since GAP data was collected from 1999-2001, the 2001 Landsat image will be used as the base image file.
- Open the image file in the ENVI display by clicking on a layer and clicking Load Band
- In the image window go to File → Open → Desired Region of Interest. If none appear, you must reconcile the ROIs.
- Under the image head bar go to File → Reconcile ROIs. Select all ROIs needed. Click Set Values from Source/Destination Files and select source file where ROI was drawn (SAMO2001.dat) and then the file to reconcile ROIs to (in this case, the same file SAMO2001.dat). If the ROI toolbox has been closed, then in the image box click Overlay – ROIs and the ROIs should all appear overlaid on the image.
- On the main ENVI toolbar Search → Maximum Likelihood classification.
- Select the stacked 2001 Landsat, elevation/topography image (SAMO2001) as the Classification Input File. Use the Full Scene, 9/9 bands, and click on mask → open EVF file and navigate to the boundary file for the park you are working with. Click OK.
- If the mask won't select the boundary, select mask options, under mask definition go to options, ROI, select the boundary. Save and use as boundary
- Select all classes to include in the classification from the ROIs.

- Enter a new Output Class Filename (ex: C:\SAMOclass\classified\classML2001) and an Output Class Rule Image Name (ex: C:\SAMOclass\classified\classML2001ri). Click OK and the Maximum Likelihood Classifier should run.

To test the outcome of your base classification you may run a confusion matrix.

- Open the maximum likelihood classification image and the ROIs that were hand drawn.
- Go to Classification → Post Classification → Confusion Matrix → Using Ground Truth ROIs.
- Select the maximum likelihood classification created above as the input file. Then Match the class parameters Ground Truth ROIs with the classification type that they should align with (Figure 1.5). Click OK and OK.
- A Class Confusion Matrix should appear with an overall accuracy and comparison of pixel accuracy for each class.
- Save this by clicking File → Save to ASCII and save to a stats folder in the classification folder set (ex: C:\SAMOclass\stats\conmatrix01full). This can be imported into Excel later for further calculations.
- In the ENVI main bar, go to File – Save File As. Select the maximum likelihood classification image you have just created and save as a *.TIFF/GeoTIFF file or any other file desired to import into ArcGIS (ex: C:\SAMOclass\classifiedGIS\classML2001gis.tif).
- Open ArcGIS. Add the .tif file that you have just created to the blank map.
- Double click on the layer to open Layer Properties. Under Symbology click on Unique Values. Click on Add all Values.
- Change all land use class displays to the desired colors and display names. To save these associated colors, go to Colormap and Export Colormap and save this as a .clr file (ex: colormap.clr). Display the map as desired.
- Open the Raster to Polygon tool. Input the .tif file as your Input raster, keep field as Value (default), and enter an Output filename (ex: C:\SAMOclass\classifiedGIS\ml2001vec.shp) and be sure to **unclick the Simplify polygons box**.
- Double click on the file to open the Symbology Tab. Click on Categories → Unique Values and Import → Import Symbology from a Layer File. Open the ml2001.lyr file from the Classified GIS folder to import its symbology, or create your own, new symbology if desired.

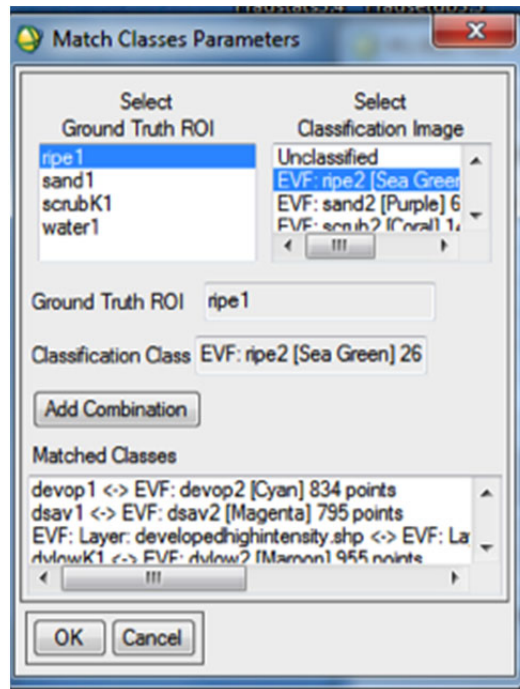


Figure 1.5. Class parameter match in ENVI

1.4.4 Applying Classifications to Other Images

- Open ENVI 4.8 or higher and go to File → Open.
- Open the 2001 classification and new Landsat and elevation/topography stacked image to classify.
- Go to File → Open → ROIs
- In the ENVI main toolbar go to File → Open and open the Park boundary file (ex: C:\WORKSPACE\SAMODATA\NRA_2002.evf).
- In the ENVI main toolbar, go to Classification → Endmember Collection and select the stacked image you would like to classify (SAMO1986, SAMO2011, etc.). Choose Mask Options → Build Mask → Options → Import EVFs and select *.evf for the desired Park boundary (ex: Layer: NRA_2002.evf). Click OK. Select the image file to classify to be associated with the .evf mask file and click OK. Choose to save the mask layer to memory (or save it as a mask layer if desired). Click OK.
- In the Endmember Collection toolbar, click Import → From ROI/EVF from other File and select the 2001 Landsat base image file (SAMO2001.dat). Select for all ROIs – select all ROI land cover types associated with file. Then in the Endmember Collection toolbar, go to Select Algorithm → Maximum Likelihood → Apply and enter an output filename and output rule filenames (ex: ML1986, ML2011).
- In the ENVI main toolbar, go to File → Save File As. Save the output as a TIFF/GeoTIFF (*.tif) file or any other file desired for import into ArcGIS (ex: C:\SAMOclass\classifiedGIS\ML1986gis.tif).
- Open ArcGIS. Add the .tif file that you have just created to the blank map.

- Double click on the layer to open Layer Properties. Under Symbology click on Unique Values. Click on Add all Values.
- Change all land use class displays to the desired colors and display names. To save these associated colors, go to Colormap and Export Colormap and save this as a .clr file (ex: colormap.clr). Display the map as desired.
- Open the Raster to Polygon tool. Input the .tif file as your Input raster, keep field as Value (default), and enter an Output filename (ex: C:SAMOclass\classifiedGIS\ml1986vec.shp) and be sure to **unclick the Simplify polygons box**.
- Double click on the file to open the Symbology Tab. Click on **Categories → Unique Values** and **Import → Import Symbology from a Layer File**. Open the ml2001.lyr file from the Classified GIS folder to import its symbology, or create your own, new symbology if desired.
- Display these results as desired in ArcGIS.

1.4.5 Analyzing changes between years

- After completing classifications for various years of comparison, in the ENVI main toolbar, go to **Basic Tools → Change Detection → Change Detection Statistics** and select the initial year and ending year to compare the statistics of changes in land cover type.
- The resulting file may be saved as a text (*.txt) file and may be imported into Excel and analyzed as desired.

Standard Operating Procedure (SOP) 2: Phenological Variability

2. Introduction

Changes in phenology show one of the effects of climate change on an area. This SOP will determine the protocol to measure changes in phenology by measuring NDVI every 16 days over the landscape for each land use type. Phenology will be calculated from the year 2000 until present day to look for anomalies in the inter-annual cycles.

2.1 File Directories

Navigate to the Landscape Dynamics workspace. If not present, create the following folders:

/<park>	
/DEM	(used in SOP-1)
/GAP	(used in SOP-1)
/study_area	(used in SOP-1)
/image_<year>	(used in SOP-1)
/class	
/Landsat_raw	
/Landsat_bands	
/roi	
/MODISndvi	(used in SOP-2)
/DMSP-OLS	(used in SOP-3)

2.2 Download MODIS data

- Go to ReVerb online database:
(http://reverb.echo.nasa.gov/reverb/#utf8=%E2%9C%93&spatial_map=satellite&spatial_type=rectangle)
- To select the type of MODIS data desired:
- First, under Step 1: Select Search Criteria, do a spatial search by place name. (i.e. Los Angeles, CA). In the “Search Terms” box to the right, search for “MOD13Q1”. Indicate the time from which you want your information in the temporal search.
- Under Step 2: Select Datasets select the box to the right of MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V005
- Under Step 3: Discover Granules make sure that MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V005 is selected. Then click search for granules. A list of all the granules will pop up. Select the column title that says “All” with a shopping cart below it. This should highlight all of the granules from your search. Select “View Items in Cart” under Step:2 Go to Cart.
- Once you see the shopping cart with all the granules you selected, hit download. In the box that pops up with download instructions - Select URLs to Download should be Data and Select Download Option should be Text File. Then select save. This will download a text file with url downloads to each granule.
- In order to avoid downloading these granules individually, you can use cmd and curl. Curl can be downloaded here (<http://curl.haxx.se/download.html#Win32>). Select the "Without SSL" version. Download and Unzip

- In our example we are saving to the “example” folder which will also house our data_url_script_yyyy-mm-dd_HHMMSS.txt downloaded from ReVerb but you can save to any workspace.
- Then enter the following script into cmd but with the proper file extension and updated .txt name:
- C:\Users\example> for /f%f in (data_url_script_yyyy-mm-dd_HHMMSS.txt) do curl %f – OL
- That will use curl to fetch and download the url for each file in the data_url_script file. Files will be created locally with the same name as it is stored remotely.

2.3 Compute Changes in NDVI

- Open ENVI 4.8 and IDL.
- Run the teviext.pro program to extract NDVI over time. The code for this program is listed below. Make sure to read it carefully as there are parts you must edit and make specific to your computer and files. Once edited, it may be simply pasted into IDL:

(Note: Make sure to compile the program before running.)

```
;code by Kate Willis 1/16/13, updated 2/11/16
;code extracts NDVI from MOD13 data
;finds the average NDVI from MEDN shapefiles (as ENVI rois)
;outputs .txt file of time series for each roi, columns are: image #,
mean NDVI, median NDVI

pro ndvi_batch_mod13_MEDN, filelist, outfile

;-----
;reads HDF files bands b01 and b02
;-----

; search for data files in the specified directory
;change E:\kwillis\WORKSPACE\PHENOLOGY\MODIS13\h08v05 to your own
specified directory
  tmp_dir = 'E:\kwillis\WORKSPACE\PHENOLOGY\MODIS13\h08v05' + '\*.hdf'
  filelist=file_search(tmp_dir, count=nfiles) ;find all the files
  hdf_list = strarr(nfiles) ;to create a general list of filenames
  filesize=size(filelist, /dimension)

;creates a template file or recovers a reexisting template file to
choose NDVI from .hdf file to read NDVI data into IDL
;change E:\kwillis\WORKSPACE\PHENOLOGY to your own specified directory

;when running in idl for the first time, a pop up box will appear. Make
sure to select NDVI and check the “read” box
  hdf_template_file =
'E:\kwillis\WORKSPACE\PHENOLOGY\hdf_template13.hdf'
  if file_test(hdf_template_file) eq 1 then begin
```

```

        restore, hdf_template_file
    endif else begin
        mytemplate=hdf_browser(filelist[0])
        save, mytemplate, filename=hdf_template_file
    endelse

;create an empty array for each Park with 3 columns
    SAMO=fltarr(3, nfiles)
    CHIS=fltarr(3, nfiles)

;loop through each file in the file list and open
    for j=0, nfiles-1 do begin
        print, j

;opens each hdf file ndvi based on mytemplate
        temp=hdf_read(filelist[j], template=mytemplate)
        NDVI = temp.MODIS_Grid_16DAY_250m_500m_VI_250m16daysNDVI

;-----
;subset by ROI
;-----

;This portion done in ENVI by user, NOT automated.  Use the following
instructions:
;Open .hdf file in ENVI
;File - Overlay ROI - open each Park .shp files here to overlay
;Save .shp files as a .roi using the vector to ROI tool or
Classification to roi tool
;Options - Create class image from ROI - Save as SAMO_class and
CHIS_class (now where class value=1 is where this roi exists)

;This portion in IDL - associates class image/Park roi areas with .hdf
images
;change H:\kwillis\WORKSPACE\PHENOLOGY\ROIs\ to your own directory
    openr, lun, 'H:\kwillis\WORKSPACE\PHENOLOGY\ROIs\SAMO_class',
/get_lun ;change to scrub_class or whatever roi you used
        A = assoc(lun,bytarr(4800,4800))
        roi = A[0]
    close, lun
    free_lun, lun

    openr, lun1, 'H:\kwillis\WORKSPACE\PHENOLOGY\ROIs\CHIS_class',
/get_lun ;change to scrub_class or whatever roi you used
        B = assoc(lun1,bytarr(4800,4800))
        roi2 = B[0]
    close, lun1
    free_lun, lun1

```

```

;-----
;extract NDVI mean/median from each ROI
;-----

    SAMO(0,j)=j
    SAMO(1,j)=mean(NDVI(where(roi eq 1,/NULL)))
    SAMO(2,j)=median(NDVI(where(roi eq 1,/NULL)))

    CHIS(0,j)=j
    CHIS(1,j)=mean(NDVI(where(roi2 eq 1,/NULL)))
    CHIS(2,j)=median(NDVI(where(roi2 eq 1,/NULL)))

endfor

;-----
;output data
;-----

;creates .txt file of: filename, mean NDVI, median NDVI
;change H:\kwillis\WORKSPACE\PHENOLOGY\Output\ to your own directory
for output

    get_lun, lun
    openw, lun, 'H:\kwillis\WORKSPACE\PHENOLOGY\Output\UpperSJ.txt'
    printf,lun, SAMO
    close, lun
    free_lun, lun

    get_lun, lun
    openw, lun, 'H:\kwillis\WORKSPACE\PHENOLOGY\Output\LowerSJ.txt'
    printf,lun, CHIS
    close, lun
    free_lun, lun

;optional section:
;write filelist of MODIS file names for reference
    get_lun, lun
    openw, lun, 'H:\kwillis\WORKSPACE\PHENOLOGY\Output\MOD13filelist.txt'
    printf,lun, filelist
    close, lun
    free_lun, lun

    print, "done"

return
end

```

Standard Operating Procedure (SOP) 3: Nighttime Lighting

3. Introduction

Nighttime light imagery may be used to determine the amount of ecological light pollution in an area. This SOP will describe how to detect values of light and changes in these values over the landscape. Nighttime lighting and brightness changes will be calculated and analyzed from the year 1992 until present.

The Defense Meteorological Satellite Program-Operational Linescan System (DMSP-OLS) is originally designed to view clouds by moonlight and to map the locations of permanent lights on the Earth's surface. The files are cloud-free composites made using all the available archived DMSP-OLS smooth resolution data for calendar years. In cases where two satellites collect data, composites will be produced. The products are 30 arc second grids, spanning -180 to 180 degrees longitude and -65 to 75 degrees latitude. Each composite set is named with the satellite name and the year. The imageries used in this project are also called average light x pct. It is derived from the average visible band digital number (DN or brightness value) of cloud-free light detections multiplied by the percent frequency of light detection. The inclusion of the percent frequency of detection term normalizes the resulting digital values for variations in the persistence of lighting. For instance, the value for a light only detected half the time is discounted by 50%.

3.1. File Directories

Navigate to the Landscape Dynamics workspace. If not present, create the following folders:

/<park>	
/DEM	(used in SOP-1)
/GAP	(used in SOP-1)
/study_area	(used in SOP-1)
/image_<year>	(used in SOP-1)
/class	
/Landsat_raw	
/Landsat_bands	
/roi	
/MODISndvi	(used in SOP-2)
/DMSP-OLS	(used in SOP-3)

3.2. Acquiring the nighttime light imageries

- Go to (http://maps.ngdc.noaa.gov/viewers/dmsp_gcv4/)
- Selecting images with product “avg_lights_x_pct”, pick the following images:
 - DMSP-OLS F10 (1992 to 1994)
 - F12 (1994 to 1999) satellites
 - F14 (1997 to 2003) satellites
 - F 15 (2000 to 2007) satellites
 - F16 (2004 to 2009) satellites
 - F18 (2010) satellites

- Once the desired images are selected, click download data. Specify -180 to 180 degrees for longitude and -65 to 75 degrees for latitude. Then click download.

3.3. Getting the brightness value of each pixel area using ENVI

- Open ENVI and load the downloaded night light images as well as the vector shapefile for the park(s) of interest.
- Open the ROI tool.
- File → Import Vector. Select the .shp file of the desired park. Select record subset to a single ROI
- File → Export → Export to CSV
- In the csv file - ID number, latitude and longitude of each pixel points in the polygon, and brightness value will be notified
- Save in the desired directory and this can be opened in Microsoft excel.
- Open the file in excel and format such that the first row in each column is the name of the column, and the data points start in row two for each column.

3.4. Display and export the new point layer

- In ArcMap, go to File → Add Data → Add XY data.
- Select the csv as the input layer and x and y should populate themselves with latitude and longitude. This will produce the point data layer. Export them to the appropriate folder.

3.5. Converting point layer to a raster dataset

- In ArcMap, search for the “Point to Raster” tool.
- Input Features : Original point data layer
- Value Field : B1 (This means the output raster dataset will be based on the brightness value of each point)
- Cell assignment type : Most Frequent
- Cell size :0.00833333 (because the pixel value of the image is 0.0083333333).
- Hit OK

3.6. Change Detection using the Raster Calculator

- In ArcMap, search for the “Raster Calculator” tool
- Within map algebra expressions, calculate your later years raster minus your earlier year (later year - earlier year) – save, hit ok
- In new file - 0 means there is no change between years. Positive means there is more brightness than old years. Negative means there is less brightness.
- This file can be used as is or converted to a .shp file if desired.

Standard Operating Procedure (SOP) 4: Data Management

4. Introduction

This SOP describes the steps needed to ensure that images, image processing steps, and interpreted data are maintained and documented clearly.

4.1. Overview

Data management is critical to the success of all long-term datasets, and especially long-term remote sensing projects. Acquisition of Landsat satellite images as well as other mediums of high resolution aerial imagery used for validation entail large volumes of digital data, and may require more than 1 terabyte of data storage, depending on the size of the park and pixel resolution of the imagery. In addition to the large volume of data and multiple versions of processed data, management of geospatial data is an ever-changing field as users are continually trying to keep pace with new spatial database models.

4.2. Metadata

Good metadata will allow complete replication of a product. The processing of imagery requires many steps, each of which requires documentation to be replicable. The major steps in image processing through this protocol are listed in Table 4.1 along with the resultant image and the information that must be stored in the metadata. These metadata requirements are in addition in those that NPS specifies in its current version of “Specifications for Geospatial and Other Data Deliverables of GIS and Resource Mapping, Inventories, and Studies” (current version dated March 2, 2007: <http://npshistory.com/publications/interdisciplinary/gis/gis-specs-2007.pdf>).

Although key steps leading up to any geospatial product also will be stored in the metadata, it is recommended that an electronic text file journal be maintained to keep track of all filenames and decisions made during the steps of this protocol. This journaling process allows much more flexibility in keeping track of details than the prescribed metadata process. The journal should be maintained in chronological order, with the date of each entry noted. Whenever a processing step is conducted, all of the relevant information about that step is entered into the journal. Enough detail should be given to fully replicate the step, including the names of all input and output files, the software module and tool used for analysis, and all the processing options (buttons selected, data types, etc.). The use of hyperlinks to other files also can be a useful feature because it provides full pathnames of files that can be used later for interpretation, even if the hyperlinks themselves become out of date because files are moved. Additionally, the journal should be used to record rationale for making decisions and for noting observations about imagery or datasets that may be useful later for error tracking or evaluation of unexplained results.

Table 4.1. Image processing steps and their metadata requirements

Step	Resultant Image	Required Metadata
Image download	7-band Landsat TM or EMT+ image	Date of image acquisition, date image was downloaded, all header information included with image.
Geometric rectification	Terrain corrected images	Name of parent image and of terrain-corrected image used for reference, number of image tie points found, means of finding tie points, RMS error X, Y, and total, resampling method, order of polynomial model for resampling, digital elevation model used for terrain, software used to do terrain correction.
Atmospheric correction	COST corrected image	Name of parent image, dark object values, gains, bias, solar elevation
MADCAL	Radiometrically normalized image	Name of parent image and of radiometric reference image, calculated gains and offsets relating each band in parent image to reference image, location and size of image subsets used to identify no-change pixels, name of control file used to run MADCAL algorithm.
Application of tasseled-cap coefficients	Tasseled-cap image	Name of parent image, coefficients used for tasseled-cap calculations.
Supervised classification	Spectral class image	Name of parent image, source of original classes, number of iterations for classification, threshold for stability.

4.3. File structure and naming

File names should be structured to uniquely describe a file. Descriptive code names allow users to immediately identify the purpose of each file. A filename usually consists of a root name with an additional component describing the file.

File folders and subfolders should provide clear separation of the different image processing steps. A directory structure is recommended where the primary node of the directory is defined by the park unit, followed by directories defined by image year. Each year of imagery contains its own sequence of processing outputs. Datasets that do not change from year to year (DEMs, study area, etc.) are static folders at the same level as the image-year folders. All steps that involve combinations of images from different years (such as difference images, etc.) must be placed in a separate folder clearly labeled with both years over which change is occurring. A suggested directory structure for image processing is shown in Figure 4.1.

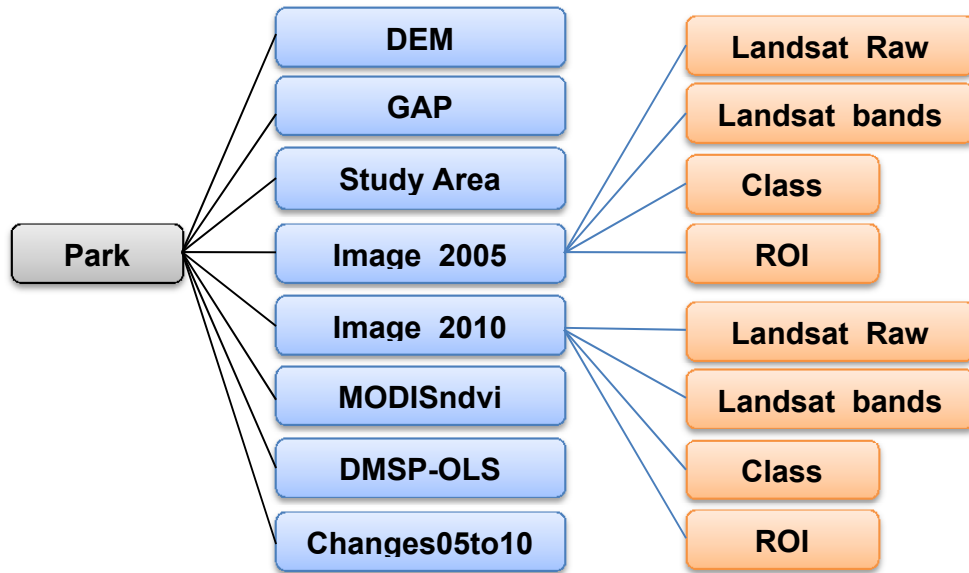


Figure 4.1. Suggested directory structure for image processing.

4.4. Data storage and archival procedures

Because of the potential of large sizes of the data used for processing, the archival of data will be necessary when processing steps are completed. Raw and final datasets will be stored on each park's server. A copy of the raw and final datasets, as well as intermediate datasets used to derive final datasets, will also be stored on an external hard drive with the MEDN Data Manager.

Literature Cited

- US Geological Survey, Gap Analysis Program (GAP). National Land Cover, Version 2. Available at: <http://gapanalysis.usgs.gov/gaplandcover/data/download/> (Accessed August 2011).
- Willis, K. S., S. Ostermann-Kelm, F. Federico, L. Lee, G. M. MacDonald, and T.W. Gillespie. 2018. Protocol for monitoring landscape dynamics in the Mediterranean Coast Network of southern California. Natural Resource Report NPS/MEDN/NRR—2018/1830. National Park Service, Fort Collins, Colorado.