



DESI—Detection of Early-Season Invasives (Software- Installation Manual and User’s Guide Version 1.0)

By Raymond F. Kokaly

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DESI—Detection of Early-Season Invasives (Software-Installation Manual and User’s Guide Version 1.0)

By Raymond F. Kokaly¹

Abstract

This report describes a software system for detecting early-season invasive plant species, such as cheatgrass. The report includes instructions for installing the software and serves as a user’s guide in processing Landsat satellite remote sensing data to map the distributions of cheatgrass and other early-season invasive plants. The software was developed for application to the semi-arid regions of southern Utah; however, the detection parameters can be altered by the user for application to other areas.

Introduction

This document describes the installation and use of the U.S. Geological Survey (USGS) Detection of Early Season Invasives (DESI) software. This software is designed for use with Landsat Thematic Mapper (TM) and(or) Enhanced Thematic Mapper (ETM) images to detect

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early-season invasive plants, specifically cheatgrass (*Bromus tectorum*). There are four modules of DESI: (1) converting Landsat TM/ETM remotely sensed data from raw digital number (DN) to radiance, (2) converting Landsat radiance to reflectance, (3) creating a mask of pixels containing cloud, snow, water, shadow, and burned areas, and (4) the cheatgrass-detection algorithm. This report describes the steps the user must take to run these software modules.

The DESI software is comprised of programs written in IDL (Interactive Data Language) that run within the ENVI (Environment for Visualizing Images) image-processing system. For more information on ENVI, see ITT Visual Information Solutions (2009). The DESI software can be downloaded from <http://pubs.usgs.gov/of/2010/1302/downloads/>. For a detailed explanation of how to acquire and process Landsat data to map cheatgrass, including explanations of how to use some simple ENVI functions to visualize and examine the results, see the DESI Tutorial (Kokaly, 2011). The example files shown in this report are included in a compressed distribution archive which can be accessed online at <http://pubs.usgs.gov/of/2010/1327/downloads/>.

Satellite remote-sensing data from the Landsat sensors have been used to detect potential infestations of the invasive plant cheatgrass on the Colorado Plateau (see Kokaly, 2011) and the Great Basin (Bradley and Mustard, 2006). In the spring, cheatgrass greens up earlier than native plants. By mid-summer, cheatgrass has reached a state of senescence; in this state, the leaves are brown and dry, while other plants are still green. In areas containing cheatgrass, it can be discriminated from other plants based on trends in the normalized difference vegetation index (NDVI). These trends are calculated from the red and near-infrared bands of the Landsat TM and ETM sensors. High NDVI values indicate the presence of abundant green vegetation. Low NDVI values indicate a low fraction of or the absence of green plants on the surface. A

difference NDVI (dNDVI) image can be calculated by subtracting a mid-summer NDVI image from an early-season (spring) NDVI image:

$$dNDVI = NDVI_{\text{early-season}} - NDVI_{\text{mid-summer}}$$

High values of dNDVI indicate areas that have the vegetation growth cycle of cheatgrass. DESI creates a cheatgrass map using pixels with dNDVI above a certain threshold.

In DESI, the algorithm for detecting cheatgrass and other early-season invasive plants relies on the computation of NDVI from Landsat data that has been converted to reflectance. The reliance on reflectance data, as opposed to radiance data or the raw Landsat DN, arises from the fact that reflectance is primarily a function of the chemical and biochemical composition of materials. In the case of reflectance derived from Landsat data over vegetated areas, the variation in reflectance as a function of wavelength (for example, the different reflectance levels in the red and near-infrared bands) is caused by the biochemical composition of plants on the earth's surface, the chemical composition and exposed area of the background soils, and the physical arrangement of plants on the surface. Thus, variations in the reflectance data over time (which result in variations in NDVI over time) are primarily a result of the biochemical changes in foliage and physical cover of plants.

In contrast, radiance data are a function of not only the reflectance of the surface but also of the illumination and the absorption of radiation by atmospheric gases, which vary through the year. Furthermore, atmospheric scattering of sunlight due to suspended dust and other aerosols in the atmosphere significantly changes radiance received by a satellite sensor. The atmospheric scattering varies in a non-linear fashion as a function of wavelength. The DESI software includes modules for converting Landsat data from raw DN to reflectance, in order to remove the atmospheric and illumination effects from the remotely sensed data. As a result, the DESI

algorithm for detecting cheatgrass and other early-season invasive plants is based on variations in plant biochemistry and fractional canopy cover—thus, the algorithm is not affected by extraneous factors such as illumination and atmospheric conditions.

The DESI software modules were developed for southern Utah using Landsat 5 and 7 data. The default values in the Landsat-masking module (for detection of cloud/snow, water, and other materials) and in the cheatgrass-mapping module will work best for Landsat scenes of southern Utah and, more broadly, the Colorado Plateau eco-region. For other ecosystems, the programs are flexible enough to allow the user to change the detection parameters to work best for their study area.

Installation of Software

1. Download the software from the following website:

<http://pubs.usgs.gov/of/2010/1302/downloads/>.

2. Copy the “usgsdesi_v1_envi47.sav” file within the “usgsdesi” folder to your ENVI “save_add” directory (for installations of ENVI 4.7, the save_add directory is commonly in the following location: C:\Program Files\ITT\IDL71\products\ENVI47\save_add\).
3. Start the ENVI program. The ENVI menu bar should now look like figure 1, with five items listed under the “DESI” item when you click on it.

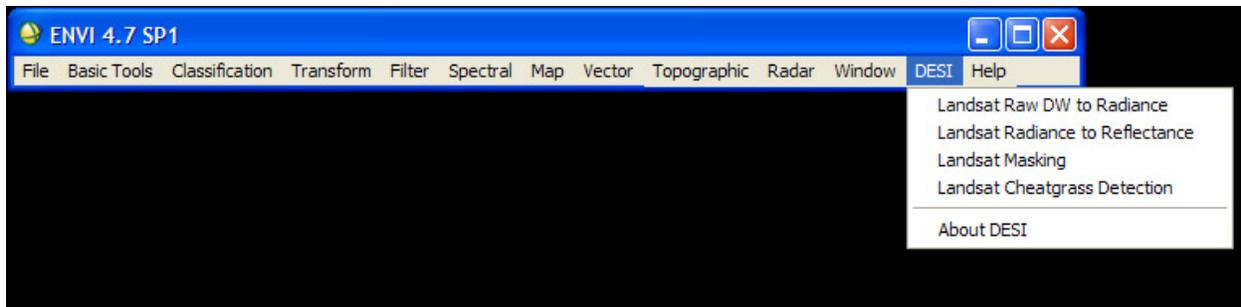


Figure 1. Environment for Visualizing Images menu bar with Detection of Early Season Invasives menu items.

Module 1. Landsat Raw Digital Number to Radiance

This module converts Landsat data from raw DN format to radiance. The program requires input data in the format distributed by the USGS via the Earth Explorer website (<http://edcns17.cr.usgs.gov/EarthExplorer/>). See the DESI Tutorial (Kokaly, 2011) for an example of acquiring Landsat imagery for use with DESI. Landsat data distributed from the Earth Explorer site comes with a metadata file (this file has a “MTL” identifier in the filename), from which DESI reads sensor and image parameters in order to convert DN to radiance in units of Watts/m²/steradian/micrometer (m², square meters). The DESI software follows the conversion procedures described by Chander and others (2009) and uses the sensor parameters embedded in the metadata file.

This module reads the raw data; calculates radiance values in units of Watts/m²/steradian/micrometer; applies a scaling factor of 100 to the radiance values; stores the data as a six-band image in 2-byte, signed-integer format in band-sequential organization; and creates an ENVI header file. Non-data pixels in the input bands are set to a value of -1 in the output radiance file. Image parameters that are needed for further conversion of the radiance

data to reflectance (see Module 2) are extracted from the metadata file and encoded in the ENVI header of the output radiance image. These data include the solar elevation, day, month, and year of the image acquisition, and the sensor type: Landsat 5 or Landsat 7. The example files shown in this module are included in a compressed distribution archive which can be accessed online at <http://pubs.usgs.gov/of/2010/1327/downloads/>.

To start the program, click the “Landsat Raw DN to Radiance” item under the “DESI” entry on the ENVI menu bar (fig. 1). The user is prompted to select the metadata file (fig. 2). After selecting the file, press the “Open” button to continue the program.

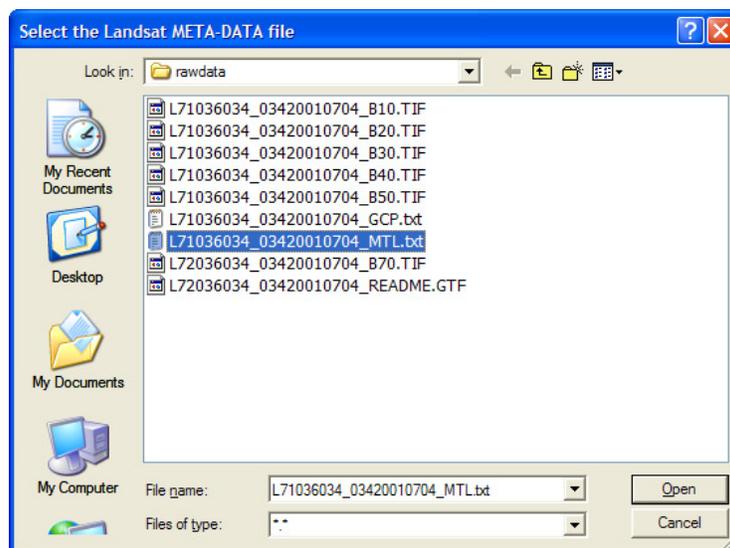


Figure 2. Selecting the Landsat metadata file.

If the program is not able to read all the required parameters from the metadata file, the user is prompted to set the missing parameters interactively.

Next, the user is prompted to select the Landsat data. If the Landsat data is in geotiff format, the user is prompted to select the geotiff file for one of the Landsat bands (fig. 3). Only one band needs to be selected; the remaining bands are found automatically by the DESI module.

If the data is in NLAPS (National Landsat Archive Production System) format, the user is prompted to select the NLAPS file for the Landsat multispectral bands (this file has a “*.H1” file extension). Press the “Open” button to continue the program.

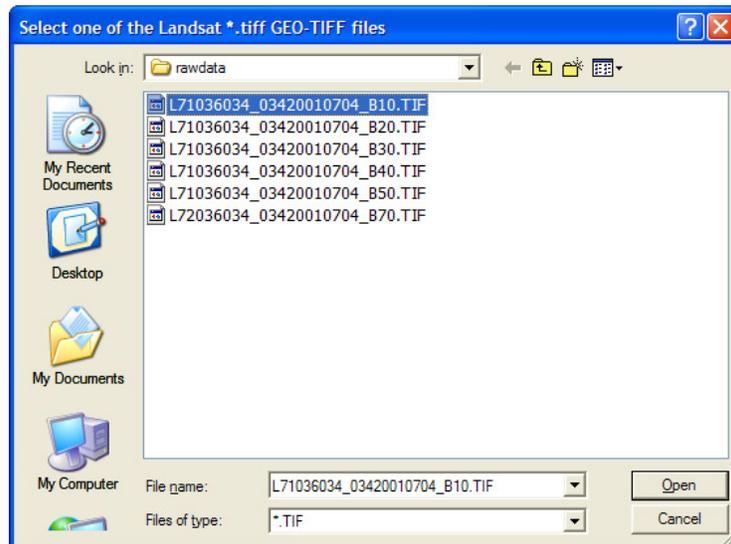


Figure 3. Selecting a Landsat file in geotiff format.

Next, the user is prompted to set the directory location and filename for the output radiance image (fig. 4). Press the “Open” button to continue the program.

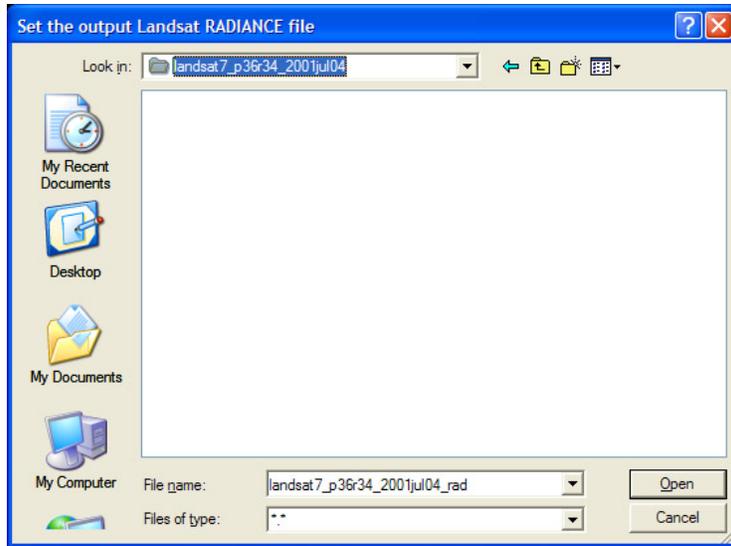


Figure 4. Setting the output radiance file.

After the output radiance file is written, the user is advised that the program has completed successfully (fig. 5). Press the “OK” button to dismiss the window.

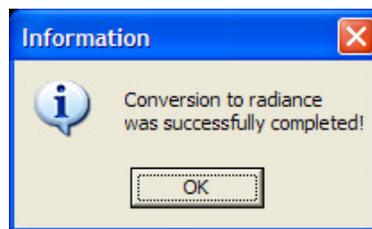


Figure 5. Message advising that the conversion to radiance was successful.

During the execution of this module, a log file containing information about selected files and parameters used in the conversion of the data is created by the program. Initially, the log file is written to the user’s IDL temporary directory. Users of full ENVI+IDL licenses can determine the name of the directory by entering the following on the IDL command line:

ENVI> print, getenv('IDLTMPDIR') . After completion of the program, the file is copied to the directory containing the output radiance image. Appendix 1 contains an example log file for this module.

Module 2. Landsat Radiance to Reflectance

This module converts Landsat data from radiance to reflectance according to the equations in Chander and others (2009). The program requires input data in units of radiance, in Watts/m²/steradian/micrometer, scaled by a multiplicative factor of 100 (as produced by Module 1 of DESI). The constant values required for converting the data from radiance to reflectance, from Chander and others (2009), are hard-coded in the program. Additional scene-specific information is needed to convert radiance data to reflectance. If Module 1 was used to produce the radiance data, the scene-specific information required for the conversion is encoded in the ENVI header of the radiance image. If the program cannot extract these values from the header file, the user will be prompted to set the required parameters (the solar elevation, day, month, and year of the image acquisition, and the sensor type: Landsat 5 or Landsat 7).

Accurate conversion to reflectance requires the removal of path radiance, that is, energy from the sun that has been scattered by the atmosphere back to the satellite sensor. An example of estimating the path radiance using dark pixels in the radiance image is demonstrated in the DESI Tutorial (Kokaly, 2011). This module will prompt for an input file containing the path radiance estimate: a text file containing the path radiance estimate for each of the six image bands in units of radiance, Watts/m²/steradian/micrometer, scaled by a multiplicative factor of 100.

The program expects that non-data pixels in the input radiance image are set to a value of -1. These same pixels are set to a value of -1 in the output reflectance image. The reflectance values are scaled by a factor of 10,000 before being stored in the output image. As a result, a reflectance of 1.0 is scaled to a value of 10,000. The example files shown in this module are included in a compressed distribution archive which can be accessed online at <http://pubs.usgs.gov/of/2010/1327/downloads/>.

To start the module, click the “Landsat Radiance to Reflectance” item under the “DESI” entry on the ENVI menu bar (fig. 1). The user is prompted to select the input radiance file (fig. 6). After selecting the file, press the “Open” button to continue the program.

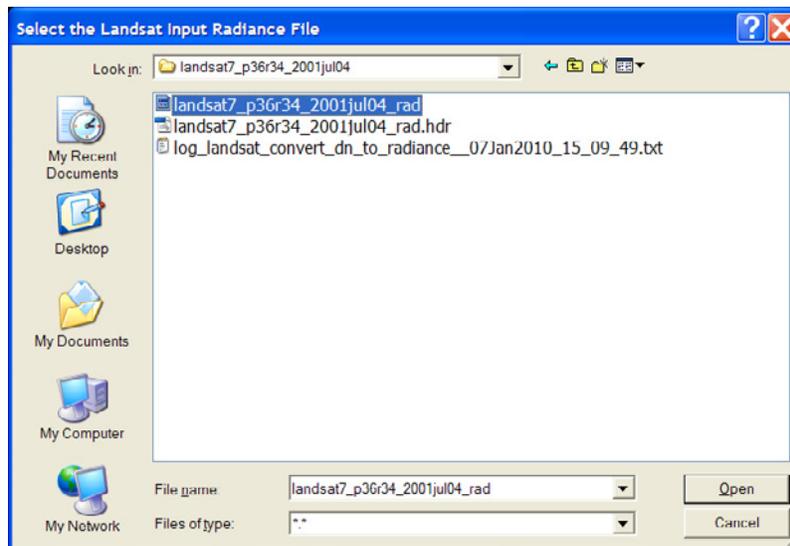


Figure 6. Selecting the input Landsat radiance file.

Next, the user is prompted to select the file that contains the path radiance estimate (fig. 7). After selecting the file, press the “Open” button to continue the program.

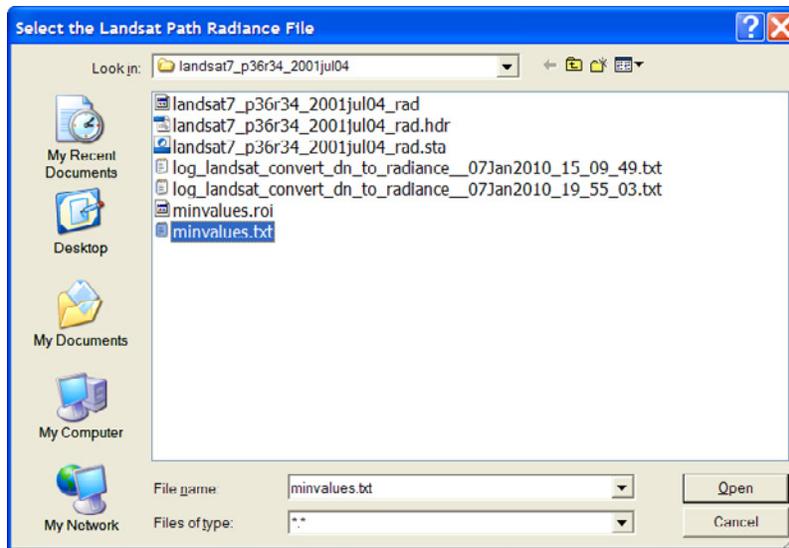


Figure 7. Selecting the text file containing the path radiance estimate.

Next, the user is prompted to set the output reflectance file (fig. 8). After the directory has been selected and the filename entered, press the “Open” button to continue the program.

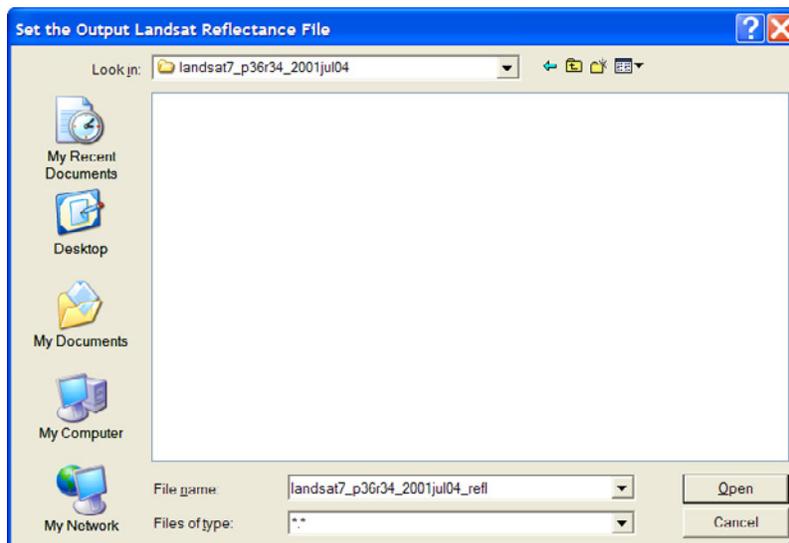


Figure 8. Setting the output reflectance filename.

After the output reflectance file is written, the user is advised that the program has successfully completed (fig. 9). Press the “OK” button to dismiss the window.

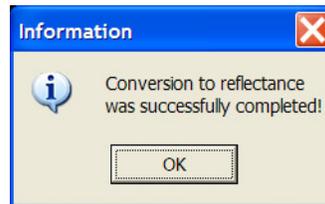


Figure 9. Message advising that the conversion to reflectance was successful.

During the execution of this module, a log file containing information about selected files and parameters used in the conversion of the data is created by the program. Initially, the log file is written to the user’s IDL temporary directory. After completion of the program, the file is copied to the directory containing the output reflectance image. Appendix 2 contains an example log file for this module.

Module 3. Landsat Masking

This module creates a mask for pixels containing cloud/snow, shadows (from clouds or steep terrain), water, and burned areas. The program uses both the radiance and reflectance images of Landsat data to identify the pixels containing these materials. The output file is an ENVI classification image. Mask files for early-season and mid-summer Landsat data are needed in “Module 4—Landsat Cheatgrass Detection” to mask pixels which contain materials that can cause false-positive detections of cheatgrass. The example files shown in this module

are included in a compressed distribution archive which can be accessed online at <http://pubs.usgs.gov/of/2010/1327/downloads/>.

To start the program, click the “Landsat Masking” item under the “DESI” entry on the ENVI menu bar (fig. 1). First, the user is shown a list of the default threshold values used in detecting the materials (fig. 10).

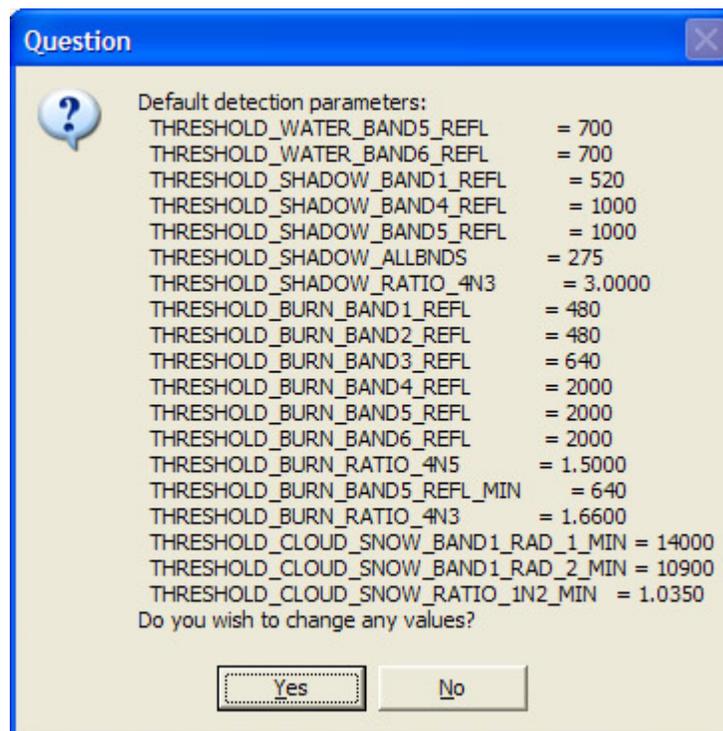


Figure 10. Material detection parameters.

The window asks the user whether they wish to change any of the detection parameters (fig. 10). If they press “No” these default values will be used. It is suggested that the defaults be used initially. If the user finds that the resultant mask image contains errors, they can run this module again, adjusting the thresholds to work best with their Landsat imagery.

In general, these parameters are the maximum-allowable values of scaled reflectance. The parameter name contains both the material for which the parameter is used and the Landsat band(s) to which the threshold is applied. For example, the first parameter listed is THRESHOLD_WATER_BAND5_REFL, indicating that only pixels with scaled reflectance value less than or equal to 700 in band five will be considered as covered by water.

The module does check a few thresholds on minimum-allowable values. For example, THRESHOLD_BURN_BAND5_REFL_MIN is a threshold for the minimum-allowable value for band five. Also, the cloud- and snow-detection thresholds are applied to scaled radiance values and are all minimum-allowable values. In other words, the scaled radiance for a pixel must exceed these thresholds in order to be masked as a cloud/snow pixel.

In a few cases, thresholds on ratios of Landsat bands are used to detect materials, for example, THRESHOLD_SHADOW_RATIO_4N3. In this case, a pixel must have the ratio of reflectance in band 4 divided by reflectance in band 3 less than or equal to the listed value of 3.0 in order to be considered as a shadow pixel.

In the detection of water, a pixel must meet all the detection criteria: a band 5 reflectance lower than the value of the THRESHOLD_WATER_BAND5_REFL parameter and a band 6 reflectance lower than the THRESHOLD_WATER_BAND6_REFL parameter. In a similar manner, the burn class detection parameters are applied. A pixel must meet all criteria shown in figure 10. The application of the shadow-detection parameters is done with two different checks of pixel values. In the first check, a pixel with reflectance values in all bands that are less than the THRESHOLD_SHADOW_ALLBNDS threshold is classified as shadow. In addition, a pixel is classified as shadow if it has reflectance values in bands 1, 3, and 4 that are all above the

default or user-defined thresholds, respectively, and a ratio of reflectance in bands 4 and 3 lower than the default or user-defined threshold.

The parameters for cloud and snow detection are used in two distinct detection algorithms. The first is a simple check for pixels that have radiance in band 1 that is greater than or equal to the value of the `THRESHOLD_CLOUD_SNOW_BAND_1_RAD_1_MIN`. If a pixel meets this criterion, it is classified as a cloud/snow pixel. A separate check is done with the other cloud and snow thresholds in combination. A pixel that has a radiance in band 1 that is greater than or equal to the value of the `THRESHOLD_CLOUD_SNOW_BAND_1_RAD_2_MIN` detection parameter and also has a ratio of the band 1 divided by band 2 radiance values greater than or equal to `THRESHOLD_CLOUD_SNOW_RATIO_1N2_MIN` is also classified as cloud/snow. In practical terms, the `THRESHOLD_CLOUD_SNOW_BAND_1_RAD_1_MIN` parameter should be a value which the user is very confident defines a radiance value that only captures cloud and snow pixels. A lower value for band 1 radiance can be set for the `THRESHOLD_CLOUD_SNOW_BAND_1_RAD_2_MIN` that mostly captures cloud/snow pixels, but may capture bright soils or other materials. The third parameter, the ratio of the band 1 and 2 radiance values, assists in the screening of these other bright materials from being included in the cloud/snow class.

If a pixel passes all the detection criteria listed for it, then that pixel in the mask image will be set to a value identifying it as that material (for example, cloud/snow, water, burned). Cloud/snow pixels are assigned the value of 1 in the output mask image. Shadow pixels are given the value 2. Water is indicated by a value of 3. Burned areas are given a value of 4. If a pixel meets the criteria for more than one material, the following hierarchy is followed in

assigning it a material class value, listed highest priority to lowest: cloud/snow, water, shadow, and burn area. Thus, if a pixel meets the criteria for both water and shadow, it is assigned the value of the water class because that material has priority over the shadow class. In addition, the program checks for pixels that have a “no data” value of -1 in any of the six Landsat bands. If “Module 2—Landsat Radiance to Reflectance” was used to generate the reflectance image, then no-data pixels are set to this value. In the output mask image, the no-data pixels are given a class value of 5. Valid Landsat pixels for which no material was detected are assigned a value 0 (zero).

If the user presses “Yes” in response to the prompt to the question of whether they would like to change any default detection thresholds (fig. 10), they will be prompted with the default values of each parameter, which they may edit (for example, fig. 11). Press “OK” to continue to the next parameter.

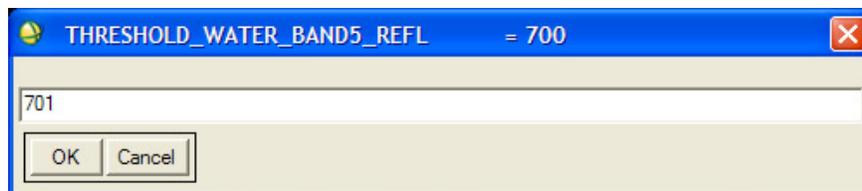


Figure 11. Changing a material-detection parameter.

After setting the material-detection parameter values, the user is prompted to select the reflectance file (fig. 12). After selecting the file, press the “OK” button to continue the program.

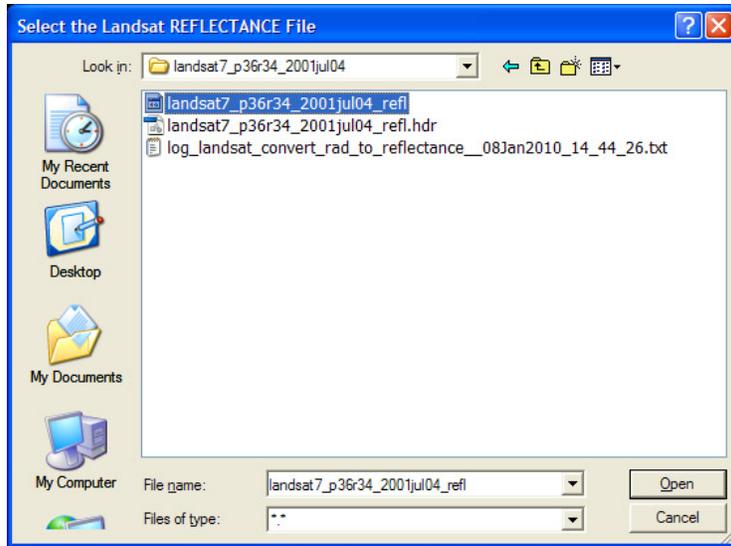


Figure 12. Selecting the reflectance file from which to generate the mask.

Next, the user is prompted to select the radiance file that corresponds to the selected reflectance file (fig. 13). After selecting the file, press the “OK” button to continue the program.

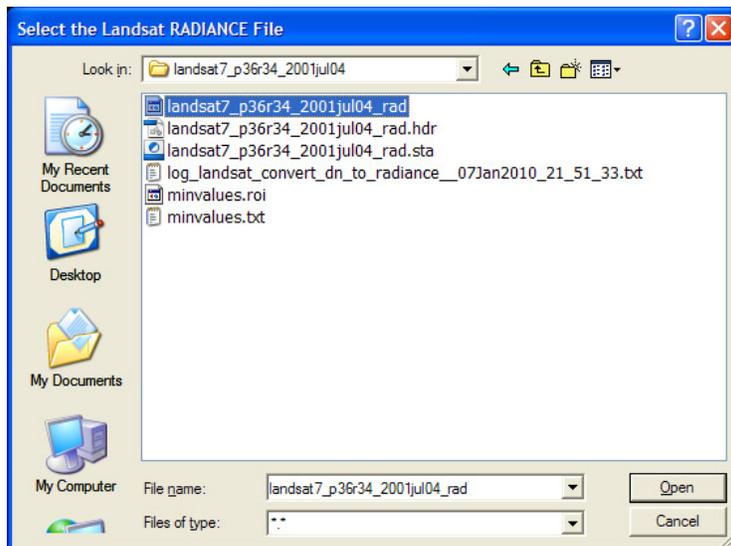


Figure 13. Selecting the reflectance file from which to generate the mask.

Next, the user is prompted to set the output mask file (fig. 14). After the directory has been selected and the filename entered, press the “Open” button to continue the program.

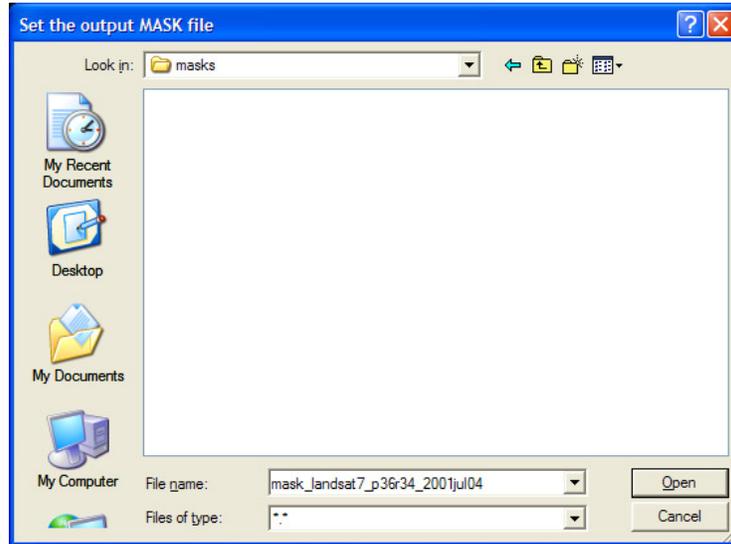


Figure 14. Setting the output mask filename.

After the output mask file is written, the user is advised that the program has completed successfully (fig. 15). Press the “OK” button to dismiss the window.

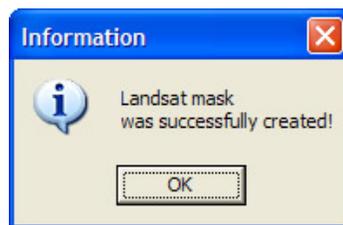


Figure 15. Message advising that the mask was successfully created.

During the execution of this module, a log file containing information about selected files and parameters used in the creation of the mask is written by the program. Initially, the log file is written to the user’s IDL temporary directory. After completion of the program, the file is

copied to the directory containing the output mask image. Appendix 3 contains an example log file for this module.

Module 4. Landsat Cheatgrass Detection

This module detects pixels which are likely to contain cheatgrass and(or) other early-season invasive plants. The program processes an input file containing five bands including the early-season and mid-summer Landsat NDVI images, dNDVI image, and the early-season and mid-summer masks, as shown in table 1. For instructions on how to create NDVI and dNDVI images, consult the DESI Tutorial (Kokaly, 2011). The example files shown in this module are included in a compressed distribution archive which can be accessed at <http://pubs.usgs.gov/of/2010/1327/downloads/>.

Table 1. Description of layerstack file contents. [NDVI, normalized difference vegetation index; dNDVI, difference NDVI]

Layerstack band	Description of contents
1	NDVI image calculated from the early-season data
2	NDVI image calculated from the mid-summer data
3	dNDVI (early-season NDVI from mid-summer NDVI)
4	Mask created from the early-season data
5	Mask created from the mid-summer data

To start the program, click the “Landsat Cheatgrass Detection” item under the “DESI” entry on the ENVI menu bar. The user is prompted to select the layerstack file (fig. 16). After selecting the file, press the “Open” button to continue the program.

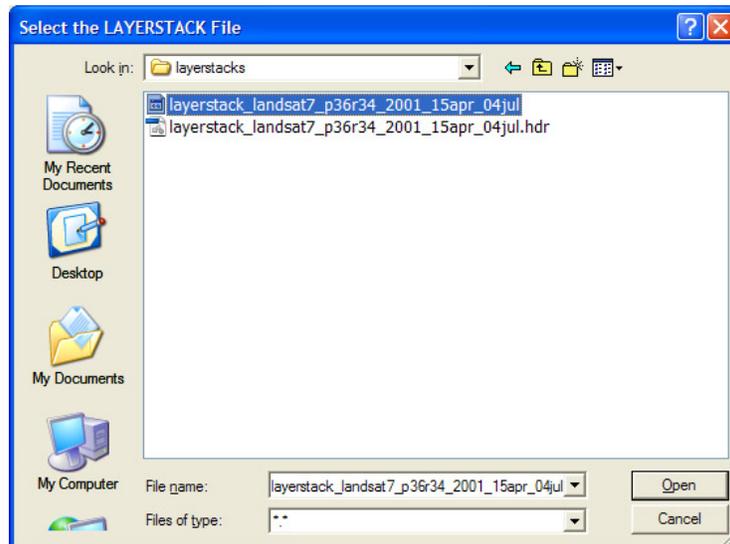


Figure 16. Selecting the layerstack file from which to generate the cheatgrass map.

Next, the user is shown a list of the threshold values used in detecting cheatgrass (fig. 17).

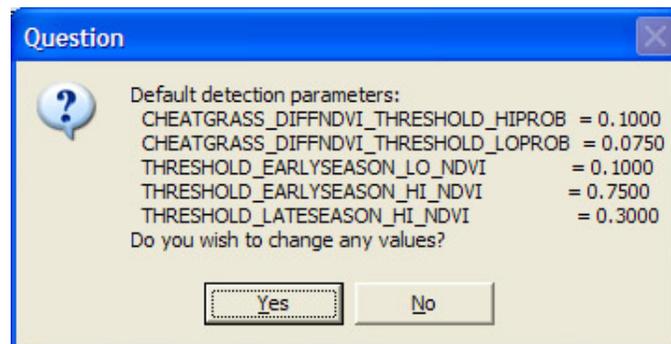


Figure 17. Cheatgrass detection parameters.

The window prompts the user whether they wish to change any of the detection parameters (fig. 17). If they press “No” these default values will be used. It is suggested that the defaults be used initially. If the user finds that the resultant cheatgrass image needs adjustment, he or she can run this module again, adjusting the thresholds to work best with their Landsat imagery. A pixel with a dNDVI value greater than the listed value for “CHEATGRASS_DIFFNDVI_THRESHOLD_HIPROB” is classified as having a high probability of containing cheatgrass. If the pixel’s dNDVI value falls between that parameter and the value of the “CHEATGRASS_DIFFNDVI_THRESHOLD_LOPROB”, then it is classified as having a lower probability of containing cheatgrass. Pixels with dNDVI values below the “CHEATGRASS_DIFFNDVI_THRESHOLD_LOPROB” threshold are not considered to contain cheatgrass.

The remaining thresholds are used to reduce false positive detections of cheatgrass, especially in agricultural areas that are irrigated during the early season. To be considered as containing cheatgrass, pixels must have early-season NDVI values that fall between the “THRESHOLD_EARLYSEASON_LO_NDVI” and “THRESHOLD_EARLYSEASON_HI_NDVI” parameters and mid-summer NDVI values below the “THRESHOLD_LATESEASON_HI_NDVI” parameter.

If the user presses “Yes” in response to the prompt in figure 17, they will be prompted with the default values of each parameter, which they may edit (for example, fig. 18). Press “OK” to continue to the next parameter.

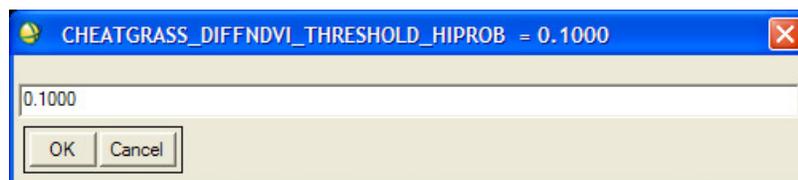


Figure 18. Changing a cheatgrass detection parameter.

After setting the material detection parameter values, the user is prompted to set the output-indexed dNDVI file (fig. 19) (a segmented ENVI classification image of the dNDVI values). After the directory has been selected and the filename entered, press the “Open” button to continue the program.

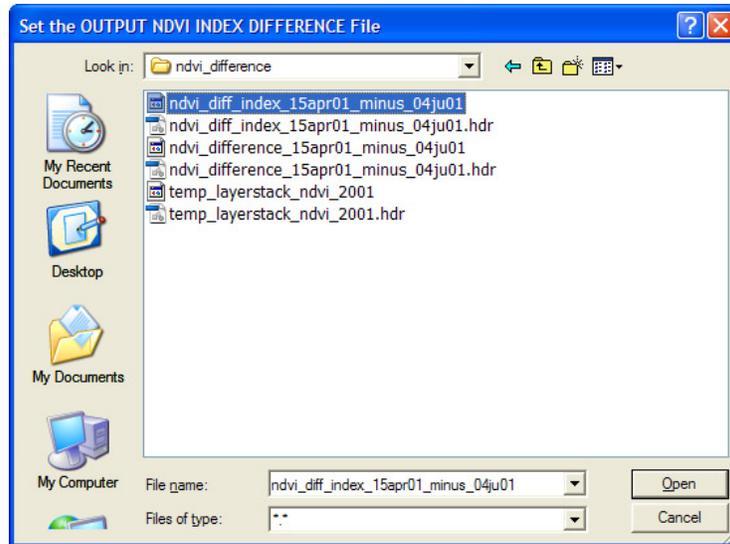


Figure 19. Setting the output indexed difference NDVI filename.

Next, the user is prompted to set the filename of the initial cheatgrass map (fig. 20). After the directory has been selected and the filename entered, press the “Open” button to continue the program.

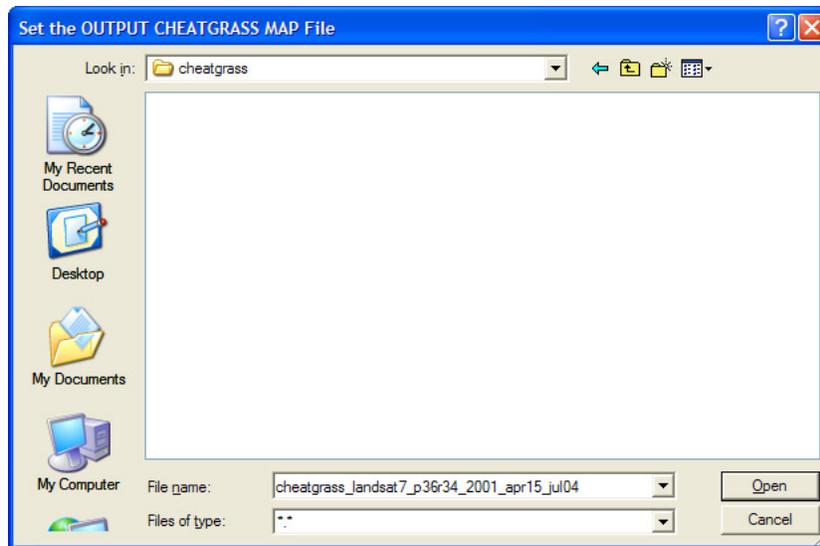


Figure 20. Setting the filename of the initial cheatgrass map.

The module processes the input data and generates the initial cheatgrass map. Subsequently, the program uses spatial filtering to eliminate false positive detections caused by spatial mismatch between the early-season (spring) and late-season (mid-summer) Landsat images. This is an important step for semi-arid regions like the Colorado Plateau. In such areas, perennial vegetation grows amidst bare soil and rock; mis-registered pixels can result in a high NDVI to low NDVI pattern that mimics the cheatgrass greenness pattern. After the spatial filtering, a final cheatgrass image is created using a “_filtered” extension appended to the filename specified by the user for the cheatgrass map (fig. 20). Next, the filtered map is masked using the masks previously generated (see Module 3). This masking eliminates pixels that contain cloud/snow, water, shadow, or burned areas; the filename of this map is the same as the initial cheatgrass map, but with a “_filtered_masked” extension added to the end of the filename. After the processing is complete, the user is advised that the program has completed successfully (fig. 21). Press the “OK” button to dismiss the window.

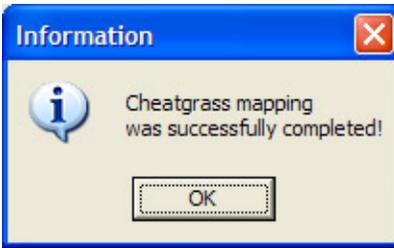


Figure 21. Message advising the cheatgrass detection was successfully created.

The final filtered and masked cheatgrass map is an ENVI classification image with six classes (see table 2). For additional details on processing Landsat data to map cheatgrass and on interpretation of the final cheatgrass map, consult the DESI Tutorial (Kokaly, 2011).

During the execution of this module, a log file containing information about selected files and parameters used in the creation of the map is written by the program. Initially, the log file is written to the user’s IDL temporary directory. After completion of the program, the file is copied to the directory containing the output mask image. Appendix 4 contains an example log file for this module.

Table 2. Classes in the filtered and masked cheatgrass map.

Pixel value	Class color	Class name (explanatory comments)
0	Black	Pixel_not_valid (masked pixels) Not_classified_as_cheatgrass
1	Gray	(pixel in which cheatgrass was not detected or in which cheatgrass is detected but none of the eight neighboring pixels contains cheatgrass; note that this class is colored black in the spatially-filtered cheatgrass map)
2	Blue	Cheatgrass_Lower_Probability_Spectral_and_Spatial (pixels which have a dNDVI above the low probability threshold but below

		the high probability threshold and only one of the eight neighboring pixels contains cheatgrass)
		Cheatgrass_Lower_Probability_Spatial
3	Green	(pixels which have a dNDVI above the high probability threshold and only one of the eight neighboring pixels contains cheatgrass)
		Cheatgrass_Lower_Probability_Spectral
4	Orange	(pixels which have a dNDVI above the low probability threshold but below the high probability threshold and more than one of the eight neighboring pixels contains cheatgrass)
		Cheatgrass_High_Probability
5	Red	(pixels which have a dNDVI above the high probability threshold and more than one of the eight neighboring pixels contains cheatgrass)

Acknowledgments

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Release Notes

December, 2010. Release of version 1.0 to public.

References Cited

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Chander, G., Markham, B.L., and Helder, D.L., 2009, Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors: *Remote Sensing of Environment*, vol. 113, p. 893–903.

ITT Visual Information Solutions, 2009, ENVI 4.7/ IDL version 7.1 user's guide: Boulder, Colo., ITT Visual Information Solutions, unpagged.

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Appendix 1

Log file from "Module 1. Landsat Raw Digital Number to Radiance"

```
; IDL Version 7.1.2, Microsoft Windows (Win32 x86 m32)
; Journal File for raymond@CHEWBACCA
; Working directory: Q:\usgsdesi\radiance\landsat7_p36r34_2001apr15
; Date: Sun Nov 21 16:31:36 2010

;Starting landsat_convert_dn_to_radiance at Sun Nov 21 16:31:36 2010
;Initiating wavelengths with default values =          0.4850          0.5600          0.6600          0.8300          1.6500
2.2150
;
;Landsat meta-data file = Q:\usgsdesi\rawdata\L71036034_03420010704_MTL.txt
;
;Checking parse of meta-data parameters:
; count_lmin   =          6
; count_lmax   =          6
; count_qcalmin =          6
; count_qcalmax =          6
;
;Extracting the values needed for processing the raw data to radiance from the meta-data file
;
;Determining Landsat image parameters:
;WRS_PATH=36
;WRS_ROW=34
;Solar Elevation =          64.4128
;Day =          4
;Month =          7
;Year =          2001
;Data format = "GEOTIFF"
;Sensor Platform = Landsat7
;
;VALUES USED IN CONVERSION TO RADIANCE:
;   LMIN   =          -6.2000          -6.4000          -5.0000          -5.1000          -1.0000          -0.3500
;   LMAX   =          191.6000          196.5000          152.9000          241.1000          31.0600          10.8000
;   QCALMIN =          1.0000          1.0000          1.0000          1.0000          1.0000          1.0000
;   QCALMAX =          255.0000          255.0000          255.0000          255.0000          255.0000          255.0000
;   GAINS   =          0.7787          0.7988          0.6217          0.9693          0.1262          0.0439
;   OFFSETS =          -6.9787          -7.1988          -5.6217          -6.0693          -1.1262          -0.3939
;
;Geo-TIFF files:
;Q:\usgsdesi\rawdata\L71036034_03420010704_B10.TIF
;Q:\usgsdesi\rawdata\L71036034_03420010704_B20.TIF
;Q:\usgsdesi\rawdata\L71036034_03420010704_B30.TIF
;Q:\usgsdesi\rawdata\L71036034_03420010704_B40.TIF
;Q:\usgsdesi\rawdata\L71036034_03420010704_B50.TIF
```

```

;Q:\usgsdesi\rawdata\L72036034_03420010704_B70.TIF
;
;Temporary META file for 6-bands:
;Q:\usgsdesi\rawdata\envi_metafile_landsat_21Nov2010_16_31_36
;
;Output radiance file = Q:\usgsdesi\radiance\landsat7_p36r34_2001jul04\landsat7_p36r34_2001jul04_rad
;
;Converting input data to radiance...
;Processing band      1
;Processing band      2
;Processing band      3
;Processing band      4
;Processing band      5
;Processing band      6
;... finished conversion.
;
;Created text file with minimum scaled radiance values (non-zero).
; Text file = Q:\usgsdesi\rawdata\envi_metafile_landsat_21Nov2010_16_31_36_minvalues.txt
; Minimum values:
;   Band      1:      0
;   Band      2:      0
;   Band      3:      0
;   Band      4:      0
;   Band      5:      0
;   Band      6:      0
;
;Adding the original meta data keywords to the envi file header
; ORIGINAL RAWDATA KEYWORD GROUP = L1_METADATA_FILE
; ORIGINAL RAWDATA KEYWORD GROUP = METADATA_FILE_INFO
; ORIGINAL RAWDATA KEYWORD ORIGIN = "Image courtesy of the U.S. Geological Survey"
; ORIGINAL RAWDATA KEYWORD REQUEST_ID = "0100912225220_00069"
; ORIGINAL RAWDATA KEYWORD PRODUCT_CREATION_TIME = 2009-12-31T05:10:11Z
; ORIGINAL RAWDATA KEYWORD STATION_ID = "EDC"
; ORIGINAL RAWDATA KEYWORD LANDSAT7_XBAND = "2"
; ORIGINAL RAWDATA KEYWORD GROUND_STATION = "EDC"
; ORIGINAL RAWDATA KEYWORD LPS_PROCESSOR_NUMBER = 8
; ORIGINAL RAWDATA KEYWORD DATE_HOUR_CONTACT_PERIOD = "0118517"
; ORIGINAL RAWDATA KEYWORD SUBINTERVAL_NUMBER = "04"
; ORIGINAL RAWDATA KEYWORD END_GROUP = METADATA_FILE_INFO
; ORIGINAL RAWDATA KEYWORD GROUP = PRODUCT_METADATA
; ORIGINAL RAWDATA KEYWORD PRODUCT_TYPE = "L1T"
; ORIGINAL RAWDATA KEYWORD ELEVATION_SOURCE = "GLS2000"
; ORIGINAL RAWDATA KEYWORD PROCESSING_SOFTWARE = "LPGS_10.1.2"
; ORIGINAL RAWDATA KEYWORD EPHEMERIS_TYPE = "DEFINITIVE"
; ORIGINAL RAWDATA KEYWORD SPACECRAFT_ID = "Landsat7"
; ORIGINAL RAWDATA KEYWORD SENSOR_ID = "ETM+"
; ORIGINAL RAWDATA KEYWORD SENSOR_MODE = "SAM"
; ORIGINAL RAWDATA KEYWORD ACQUISITION_DATE = 2001-07-04
; ORIGINAL RAWDATA KEYWORD SCENE_CENTER_SCAN_TIME = 17:46:00.0832307Z
; ORIGINAL RAWDATA KEYWORD WRS_PATH = 36
; ORIGINAL RAWDATA KEYWORD STARTING_ROW = 34

```

```

; ORIGINAL RAWDATA KEYWORD ENDING_ROW = 34
; ORIGINAL RAWDATA KEYWORD BAND_COMBINATION = "123456678"
; ORIGINAL RAWDATA KEYWORD PRODUCT_UL_CORNER_LAT = 38.4504089
; ORIGINAL RAWDATA KEYWORD PRODUCT_UL_CORNER_LON = -111.1398158
; ORIGINAL RAWDATA KEYWORD PRODUCT_UR_CORNER_LAT = 38.4203483
; ORIGINAL RAWDATA KEYWORD PRODUCT_UR_CORNER_LON = -108.3425280
; ORIGINAL RAWDATA KEYWORD PRODUCT_LL_CORNER_LAT = 36.5088645
; ORIGINAL RAWDATA KEYWORD PRODUCT_LL_CORNER_LON = -111.1362442
; ORIGINAL RAWDATA KEYWORD PRODUCT_LR_CORNER_LAT = 36.4808286
; ORIGINAL RAWDATA KEYWORD PRODUCT_LR_CORNER_LON = -108.4103198
; ORIGINAL RAWDATA KEYWORD PRODUCT_UL_CORNER_MAPX = 487800.000
; ORIGINAL RAWDATA KEYWORD PRODUCT_UL_CORNER_MAPY = 4255800.000
; ORIGINAL RAWDATA KEYWORD PRODUCT_UR_CORNER_MAPX = 732000.000
; ORIGINAL RAWDATA KEYWORD PRODUCT_UR_CORNER_MAPY = 4255800.000
; ORIGINAL RAWDATA KEYWORD PRODUCT_LL_CORNER_MAPX = 487800.000
; ORIGINAL RAWDATA KEYWORD PRODUCT_LL_CORNER_MAPY = 4040400.000
; ORIGINAL RAWDATA KEYWORD PRODUCT_LR_CORNER_MAPX = 732000.000
; ORIGINAL RAWDATA KEYWORD PRODUCT_LR_CORNER_MAPY = 4040400.000
; ORIGINAL RAWDATA KEYWORD PRODUCT_SAMPLES_PAN = 16281
; ORIGINAL RAWDATA KEYWORD PRODUCT_LINES_PAN = 14361
; ORIGINAL RAWDATA KEYWORD PRODUCT_SAMPLES_REF = 8141
; ORIGINAL RAWDATA KEYWORD PRODUCT_LINES_REF = 7181
; ORIGINAL RAWDATA KEYWORD PRODUCT_SAMPLES_THM = 4071
; ORIGINAL RAWDATA KEYWORD PRODUCT_LINES_THM = 3591
; ORIGINAL RAWDATA KEYWORD BAND1_FILE_NAME = "L71036034_03420010704_B10.TIF"
; ORIGINAL RAWDATA KEYWORD BAND2_FILE_NAME = "L71036034_03420010704_B20.TIF"
; ORIGINAL RAWDATA KEYWORD BAND3_FILE_NAME = "L71036034_03420010704_B30.TIF"
; ORIGINAL RAWDATA KEYWORD BAND4_FILE_NAME = "L71036034_03420010704_B40.TIF"
; ORIGINAL RAWDATA KEYWORD BAND5_FILE_NAME = "L71036034_03420010704_B50.TIF"
; ORIGINAL RAWDATA KEYWORD BAND61_FILE_NAME = "L71036034_03420010704_B61.TIF"
; ORIGINAL RAWDATA KEYWORD BAND62_FILE_NAME = "L72036034_03420010704_B62.TIF"
; ORIGINAL RAWDATA KEYWORD BAND7_FILE_NAME = "L72036034_03420010704_B70.TIF"
; ORIGINAL RAWDATA KEYWORD BAND8_FILE_NAME = "L72036034_03420010704_B80.TIF"
; ORIGINAL RAWDATA KEYWORD GCP_FILE_NAME = "L71036034_03420010704_GCP.txt"
; ORIGINAL RAWDATA KEYWORD METADATA_L1_FILE_NAME = "L71036034_03420010704_MTL.txt"
; ORIGINAL RAWDATA KEYWORD CPF_FILE_NAME = "L7CPF20010701_20010930_08"
; ORIGINAL RAWDATA KEYWORD END_GROUP = PRODUCT_METADATA
; ORIGINAL RAWDATA KEYWORD GROUP = MIN_MAX_RADIANCE
; ORIGINAL RAWDATA KEYWORD LMAX_BAND1 = 191.600
; ORIGINAL RAWDATA KEYWORD LMIN_BAND1 = -6.200
; ORIGINAL RAWDATA KEYWORD LMAX_BAND2 = 196.500
; ORIGINAL RAWDATA KEYWORD LMIN_BAND2 = -6.400
; ORIGINAL RAWDATA KEYWORD LMAX_BAND3 = 152.900
; ORIGINAL RAWDATA KEYWORD LMIN_BAND3 = -5.000
; ORIGINAL RAWDATA KEYWORD LMAX_BAND4 = 241.100
; ORIGINAL RAWDATA KEYWORD LMIN_BAND4 = -5.100
; ORIGINAL RAWDATA KEYWORD LMAX_BAND5 = 31.060
; ORIGINAL RAWDATA KEYWORD LMIN_BAND5 = -1.000
; ORIGINAL RAWDATA KEYWORD LMAX_BAND61 = 17.040
; ORIGINAL RAWDATA KEYWORD LMIN_BAND61 = 0.000
; ORIGINAL RAWDATA KEYWORD LMAX_BAND62 = 12.650

```

```

; ORIGINAL RAWDATA KEYWORD LMIN_BAND62 = 3.200
; ORIGINAL RAWDATA KEYWORD LMAX_BAND7 = 10.800
; ORIGINAL RAWDATA KEYWORD LMIN_BAND7 = -0.350
; ORIGINAL RAWDATA KEYWORD LMAX_BAND8 = 243.100
; ORIGINAL RAWDATA KEYWORD LMIN_BAND8 = -4.700
; ORIGINAL RAWDATA KEYWORD END_GROUP = MIN_MAX_RADIANCE
; ORIGINAL RAWDATA KEYWORD GROUP = MIN_MAX_PIXEL_VALUE
; ORIGINAL RAWDATA KEYWORD QCALMAX_BAND1 = 255.0
; ORIGINAL RAWDATA KEYWORD QCALMIN_BAND1 = 1.0
; ORIGINAL RAWDATA KEYWORD QCALMAX_BAND2 = 255.0
; ORIGINAL RAWDATA KEYWORD QCALMIN_BAND2 = 1.0
; ORIGINAL RAWDATA KEYWORD QCALMAX_BAND3 = 255.0
; ORIGINAL RAWDATA KEYWORD QCALMIN_BAND3 = 1.0
; ORIGINAL RAWDATA KEYWORD QCALMAX_BAND4 = 255.0
; ORIGINAL RAWDATA KEYWORD QCALMIN_BAND4 = 1.0
; ORIGINAL RAWDATA KEYWORD QCALMAX_BAND5 = 255.0
; ORIGINAL RAWDATA KEYWORD QCALMIN_BAND5 = 1.0
; ORIGINAL RAWDATA KEYWORD QCALMAX_BAND61 = 255.0
; ORIGINAL RAWDATA KEYWORD QCALMIN_BAND61 = 1.0
; ORIGINAL RAWDATA KEYWORD QCALMAX_BAND62 = 255.0
; ORIGINAL RAWDATA KEYWORD QCALMIN_BAND62 = 1.0
; ORIGINAL RAWDATA KEYWORD QCALMAX_BAND7 = 255.0
; ORIGINAL RAWDATA KEYWORD QCALMIN_BAND7 = 1.0
; ORIGINAL RAWDATA KEYWORD QCALMAX_BAND8 = 255.0
; ORIGINAL RAWDATA KEYWORD QCALMIN_BAND8 = 1.0
; ORIGINAL RAWDATA KEYWORD END_GROUP = MIN_MAX_PIXEL_VALUE
; ORIGINAL RAWDATA KEYWORD GROUP = PRODUCT_PARAMETERS
; ORIGINAL RAWDATA KEYWORD CORRECTION_METHOD_GAIN_BAND1 = "CPF"
; ORIGINAL RAWDATA KEYWORD CORRECTION_METHOD_GAIN_BAND2 = "CPF"
; ORIGINAL RAWDATA KEYWORD CORRECTION_METHOD_GAIN_BAND3 = "CPF"
; ORIGINAL RAWDATA KEYWORD CORRECTION_METHOD_GAIN_BAND4 = "CPF"
; ORIGINAL RAWDATA KEYWORD CORRECTION_METHOD_GAIN_BAND5 = "CPF"
; ORIGINAL RAWDATA KEYWORD CORRECTION_METHOD_GAIN_BAND61 = "CPF"
; ORIGINAL RAWDATA KEYWORD CORRECTION_METHOD_GAIN_BAND62 = "CPF"
; ORIGINAL RAWDATA KEYWORD CORRECTION_METHOD_GAIN_BAND7 = "CPF"
; ORIGINAL RAWDATA KEYWORD CORRECTION_METHOD_GAIN_BAND8 = "CPF"
; ORIGINAL RAWDATA KEYWORD CORRECTION_METHOD_BIAS = "IC"
; ORIGINAL RAWDATA KEYWORD BAND1_GAIN = "H"
; ORIGINAL RAWDATA KEYWORD BAND2_GAIN = "H"
; ORIGINAL RAWDATA KEYWORD BAND3_GAIN = "H"
; ORIGINAL RAWDATA KEYWORD BAND4_GAIN = "L"
; ORIGINAL RAWDATA KEYWORD BAND5_GAIN = "H"
; ORIGINAL RAWDATA KEYWORD BAND6_GAIN1 = "L"
; ORIGINAL RAWDATA KEYWORD BAND6_GAIN2 = "H"
; ORIGINAL RAWDATA KEYWORD BAND7_GAIN = "H"
; ORIGINAL RAWDATA KEYWORD BAND8_GAIN = "L"
; ORIGINAL RAWDATA KEYWORD BAND1_GAIN_CHANGE = "0"
; ORIGINAL RAWDATA KEYWORD BAND2_GAIN_CHANGE = "0"
; ORIGINAL RAWDATA KEYWORD BAND3_GAIN_CHANGE = "0"
; ORIGINAL RAWDATA KEYWORD BAND4_GAIN_CHANGE = "0"
; ORIGINAL RAWDATA KEYWORD BAND5_GAIN_CHANGE = "0"

```

```

; ORIGINAL RAWDATA KEYWORD BAND6_GAIN_CHANGE1 = "0"
; ORIGINAL RAWDATA KEYWORD BAND6_GAIN_CHANGE2 = "0"
; ORIGINAL RAWDATA KEYWORD BAND7_GAIN_CHANGE = "0"
; ORIGINAL RAWDATA KEYWORD BAND8_GAIN_CHANGE = "0"
; ORIGINAL RAWDATA KEYWORD BAND1_SL_GAIN_CHANGE = 0
; ORIGINAL RAWDATA KEYWORD BAND2_SL_GAIN_CHANGE = 0
; ORIGINAL RAWDATA KEYWORD BAND3_SL_GAIN_CHANGE = 0
; ORIGINAL RAWDATA KEYWORD BAND4_SL_GAIN_CHANGE = 0
; ORIGINAL RAWDATA KEYWORD BAND5_SL_GAIN_CHANGE = 0
; ORIGINAL RAWDATA KEYWORD BAND6_SL_GAIN_CHANGE1 = 0
; ORIGINAL RAWDATA KEYWORD BAND6_SL_GAIN_CHANGE2 = 0
; ORIGINAL RAWDATA KEYWORD BAND7_SL_GAIN_CHANGE = 0
; ORIGINAL RAWDATA KEYWORD BAND8_SL_GAIN_CHANGE = 0
; ORIGINAL RAWDATA KEYWORD SUN_AZIMUTH = 117.9910568
; ORIGINAL RAWDATA KEYWORD SUN_ELEVATION = 64.4128406
; ORIGINAL RAWDATA KEYWORD OUTPUT_FORMAT = "GEOTIFF"
; ORIGINAL RAWDATA KEYWORD END_GROUP = PRODUCT_PARAMETERS
; ORIGINAL RAWDATA KEYWORD GROUP = CORRECTIONS_APPLIED
; ORIGINAL RAWDATA KEYWORD STRIPING_BAND1 = "NONE"
; ORIGINAL RAWDATA KEYWORD STRIPING_BAND2 = "NONE"
; ORIGINAL RAWDATA KEYWORD STRIPING_BAND3 = "NONE"
; ORIGINAL RAWDATA KEYWORD STRIPING_BAND4 = "NONE"
; ORIGINAL RAWDATA KEYWORD STRIPING_BAND5 = "NONE"
; ORIGINAL RAWDATA KEYWORD STRIPING_BAND61 = "NONE"
; ORIGINAL RAWDATA KEYWORD STRIPING_BAND62 = "NONE"
; ORIGINAL RAWDATA KEYWORD STRIPING_BAND7 = "NONE"
; ORIGINAL RAWDATA KEYWORD STRIPING_BAND8 = "NONE"
; ORIGINAL RAWDATA KEYWORD BANDING = "N"
; ORIGINAL RAWDATA KEYWORD COHERENT_NOISE = "Y"
; ORIGINAL RAWDATA KEYWORD MEMORY_EFFECT = "N"
; ORIGINAL RAWDATA KEYWORD SCAN_CORRELATED_SHIFT = "N"
; ORIGINAL RAWDATA KEYWORD INOPERABLE_DETECTORS = "N"
; ORIGINAL RAWDATA KEYWORD DROPPED_LINES = "N"
; ORIGINAL RAWDATA KEYWORD END_GROUP = CORRECTIONS_APPLIED
; ORIGINAL RAWDATA KEYWORD GROUP = PROJECTION_PARAMETERS
; ORIGINAL RAWDATA KEYWORD REFERENCE_DATUM = "WGS84"
; ORIGINAL RAWDATA KEYWORD REFERENCE_ELLIPSOID = "WGS84"
; ORIGINAL RAWDATA KEYWORD GRID_CELL_SIZE_PAN = 15.000
; ORIGINAL RAWDATA KEYWORD GRID_CELL_SIZE_THM = 60.000
; ORIGINAL RAWDATA KEYWORD GRID_CELL_SIZE_REF = 30.000
; ORIGINAL RAWDATA KEYWORD ORIENTATION = "NUP"
; ORIGINAL RAWDATA KEYWORD RESAMPLING_OPTION = "CC"
; ORIGINAL RAWDATA KEYWORD MAP_PROJECTION = "UTM"
; ORIGINAL RAWDATA KEYWORD END_GROUP = PROJECTION_PARAMETERS
; ORIGINAL RAWDATA KEYWORD GROUP = UTM_PARAMETERS
; ORIGINAL RAWDATA KEYWORD ZONE_NUMBER = 12
; ORIGINAL RAWDATA KEYWORD END_GROUP = UTM_PARAMETERS
; ORIGINAL RAWDATA KEYWORD END_GROUP = L1_METADATA_FILE
;
;Successfully created a radiance cube (6-band BSQ file of integer values in Watts/m^2/sr/micron * 100.0)
;

```

```
;Copying default log file to Q:\usgsdesi\radiance\landsat7_p36r34_2001jul04\log_landsat_convert_dn_to_radiance_21Nov2010_16_31_36.txt  
;  
;Normal execution of landsat_convert_dn_to_radiance ... Elapsed Time =          59.219000 seconds
```

Appendix 2

Log file from "Module 2. Landsat Radiance to Reflectance."

```
; IDL Version 7.1.2, Microsoft Windows (Win32 x86 m32)
; Journal File for raymond@CHEWBACCA
; Working directory: Q:\usgsdesi\radiance\landsat7_p36r34_2001jul04
; Date: Sun Nov 21 18:35:46 2010

;Starting landsat_convert_rad_to_reflectance at Sun Nov 21 18:35:46 2010
;
;Input radiance file = Q:\usgsdesi\radiance\landsat7_p36r34_2001jul04\landsat7_p36r34_2001jul04_rad
;
;Solar Elevation found in header =      64.4128
;Year found in header =      2001.00
;Month found in header =      7.00000
;Day found in header =      4.00000
;Sensor found in header = Landsat7
;
;Input parameters = Solar_elev = 64.4128 Year = 2001 Month = 7 Day = 4 Sensor = Landsat7
;
;Irradiance factors:
;Band 1 factor = 1997.0,
;Band 2 factor = 1812.0,
;Band 3 factor = 1533.0,
;Band 4 factor = 1039.0,
;Band 5 factor = 230.8,
;Band 6 factor = 84.9,
;
;Earth-Sun Distance Parameters:
; Day of Year = 185
; Earth-sun adjustment factor = 1.01670
;
;Input PATH-radiance file = Q:\usgsdesi\radiance\landsat7_p36r34_2001jul04\minvalues_edited.txt
;Path Radiance Values in Watts/m^2/sr/micron * 100.0: 2417.00000, 1277.00000, 618.00000, 265.00000, 0.00000, 0.00000
;Gain Values applied to path radiance corrected Landsat scaled radiance: 1.802956e-005, 1.987033e-005, 2.348665e-005, 3.465355e-005,
1.560010e-004, 4.240875e-004
;
;Output filename is the same as an existing file, overwriting the existing file.
;OUTPUT reflectance file = Q:\usgsdesi\reflectance\landsat7_p36r34_2001jul04\landsat7_p36r34_2001jul04_refl
;
;CALCULATING THE REFLECTANCE VALUES
;Processing band      1
;Processing band      2
;Processing band      3
;Processing band      4
```

```
;Processing band          5
;Processing band          6
;
;Successfully created a reflectance cube (6-band BSQ file of integer values with reflectance of 1.0 scaled to 10,000)
;
;Copying default log file to
;Q:\usgsdesi\reflectance\landsat7_p36r34_2001jul04\log_landsat_convert_rad_to_reflectance_21Nov2010_18_35_46.txt
;Normal termination of landsat_convert_rad_to_reflectance ... Elapsed Time =          39.844000 seconds
```

Appendix 3

Log file from "Module 3. Landsat Masking."

```
; IDL Version 7.1.2, Microsoft Windows (Win32 x86 m32)
; Journal File for raymond@CHEWBACCA
; Working directory: Q:\usgsdesi\ndvi
; Date: Sun Nov 21 19:04:01 2010

;
;Starting landsat_cloud_snow_shadow_water_burn_mask at Sun Nov 21 19:04:01 2010
;
;DEFAULT Processing parameters for material detection:
; THRESHOLD_WATER_BAND5_REFL      = 700
; THRESHOLD_WATER_BAND6_REFL      = 700
; THRESHOLD_SHADOW_BAND1_REFL     = 520
; THRESHOLD_SHADOW_BAND4_REFL     = 1000
; THRESHOLD_SHADOW_BAND5_REFL     = 1000
; THRESHOLD_SHADOW_ALLBND5        = 275
; THRESHOLD_SHADOW_RATIO_4N3      = 3.0000
; THRESHOLD_BURN_BAND1_REFL       = 600
; THRESHOLD_BURN_BAND2_REFL       = 600
; THRESHOLD_BURN_BAND3_REFL       = 800
; THRESHOLD_BURN_BAND4_REFL       = 2500
; THRESHOLD_BURN_BAND5_REFL       = 2500
; THRESHOLD_BURN_BAND6_REFL       = 2500
; THRESHOLD_BURN_RATIO_4N5        = 1.5000
; THRESHOLD_BURN_BAND5_REFL_MIN   = 800
; THRESHOLD_BURN_RATIO_4N3        = 1.6600
; THRESHOLD_CLOUD_SNOW_BAND1_RAD_1_MIN = 14000
; THRESHOLD_CLOUD_SNOW_BAND1_RAD_2_MIN = 10900
; THRESHOLD_CLOUD_SNOW_RATIO_1N2_MIN = 1.0350
;
;No values were changed by the user.
;
;Input File for Landsat Reflectance = Q:\usgsdesi\reflectance\landsat7_p36r34_2001jul04\landsat7_p36r34_2001jul04_refl
;Input File for Landsat Radiance   = Q:\usgsdesi\radiance\landsat7_p36r34_2001jul04\landsat7_p36r34_2001jul04_rad
;Output File for Mask              = Q:\usgsdesi\masks\landsat7_p36r34_2001jul04\landsat7_p36r34_2001jul04_mask
;
;Processing the images to make the mask...
;Working on line      0
;Working on line     500
;Working on line    1000
;Working on line    1500
;Working on line    2000
;Working on line    2500
```

```
;Working on line          3000
;Working on line          3500
;Working on line          4000
;Working on line          4500
;Working on line          5000
;Working on line          5500
;Working on line          6000
;Working on line          6500
;Working on line          7000
;
;Sieving the cloud/snow pixels by a factor of 4 for 8...
;Growing the shadow pixels by a 1 pixel buffer ...
;Growing the water pixels by a 1 pixel buffer ...
;Growing the burn area pixels by a 1 pixel buffer ...
;Growing the sieved cloud/snow pixels by          2 pixels ...
;
;SUMMARY REPORT:
;Total pixels, including non-data = 58460521
;Found 38029095 pixels with valid Landsat data in all bands.
;Found 133498 pixels with shadow present 0.351042 % of pixels with data.
;Found 569080 pixels with cloud/snow present 1.49643 % of pixels with data.
;Found 516311 pixels with water present 1.35767 % of pixels with data.
;Found 38168 pixels with burn present 0.100365 % of pixels with data.
;
;Successfully created the mask as an ENVI classification file.
;
;Copying default log file to
;Q:\usgsdesi\masks\landsat7_p36r34_2001jul04\log_landsat_cloud_snow_shadow_water_burn_mask_21Nov2010_19_04_01.txt
;Normal termination of landsat_cloud_snow_shadow_water_burn_mask ... Elapsed Time =          198.04700 seconds
```

Appendix 4

Log file from "Module 4. Landsat Cheatgrass Detection."

```
; IDL Version 7.1.2, Microsoft Windows (Win32 x86 m32)
; Journal File for raymond@CHEWBACCA
; Working directory: Q:\usgsdesi\layerstacks
; Date: Sun Nov 21 19:19:23 2010

;
;Starting landsat_cheatmap at Sun Nov 21 19:19:23 2010
;
;Running cheatgrass detection...
;
;Starting landsat_cheatgrass at Sun Nov 21 19:19:29 2010
;
;DEFAULT Processing parameters for cheatgrass detection:
; CHEATGRASS_DIFFNDVI_THRESHOLD_HIPOB = 0.1000
; CHEATGRASS_DIFFNDVI_THRESHOLD_LOPOB = 0.0750
; THRESHOLD_EARLYSEASON_LO_NDVI = 0.1000
; THRESHOLD_EARLYSEASON_HI_NDVI = 0.7500
; THRESHOLD_LATESEASON_HI_NDVI = 0.3000
;
;No values were changed by the user.
;
;Input File for Landsat Layerstack = Q:\usgsdesi\layerstacks\layerstack_landsat7_p36r34_2001_15apr_04jul
;Output File for Difference NDVI (indexed) = Q:\usgsdesi\ndvi\index_diff_ndvi_landsat7_15apr_04jul_2001
;Output File for Cheatgrass Map = Q:\usgsdesi\cheatgrass\cheatgrass_landsat7_p36r34_2001_apr15_jul04
;Output File for Cheatgrass Map Combined Classes = Q:\usgsdesi\cheatgrass\cheatgrass_landsat7_p36r34_2001_apr15_jul04_combined
;
;Difference NDVI Thresholds for Cheatgrass:
; Lower Probability greater than or equal to 0.0750000 and less than 0.100000
; High Probability greater than or equal to 0.100000
;
;Processing the NDVI images...
;Working on line 0
;Working on line 500
;Working on line 1000
;Working on line 1500
;Working on line 2000
;Working on line 2500
;Working on line 3000
;Working on line 3500
;Working on line 4000
;Working on line 4500
;Working on line 5000
;Working on line 5500
```

```

;Working on line          6000
;Working on line          6500
;Working on line          7000
;Found 35614874 pixels with valid data in both Landsat images.
;Found 2252958 pixels with Cheatgrass (lower probability difference NDVI values) 6.32589 % of pixels with valid data.
;Found 1638514 pixels with Cheatgrass (high probability difference NDVI values) 4.60065 % of pixels with valid data.
;Found 3891472 pixels with Cheatgrass (high and lower probability) 10.9265 % of pixels with valid data.
;Normal termination of landsat_cheatgrass ... Elapsed Time =          143.62500 seconds
;
;Starting landsat_cheatgrass_filtering.pro at Sun Nov 21 19:21:53 2010
;Normal termination of landsat_cheatgrass_filtering.pro at Sun Nov 21 19:22:05 2010
;
;Starting landsat_cheatgrass_recombination at Sun Nov 21 19:22:05 2010
;
;Input File for Cheatgrass          = Q:\usgsdesi\cheatgrass\cheatgrass_landsat7_p36r34_2001_apr15_jul04
;Input File for Cheatgrass Combined = Q:\usgsdesi\cheatgrass\cheatgrass_landsat7_p36r34_2001_apr15_jul04_combined
;Input File for Cheatgrass Combined Sieve2-8 = Q:\usgsdesi\cheatgrass\cheatgrass_landsat7_p36r34_2001_apr15_jul04_combined_sieve2-8
;Input File for Cheatgrass Combined Sieve3-8 = Q:\usgsdesi\cheatgrass\cheatgrass_landsat7_p36r34_2001_apr15_jul04_combined_sieve3-8
;
;Output File for Cheatgrass Map      = Q:\usgsdesi\cheatgrass\cheatgrass_landsat7_p36r34_2001_apr15_jul04_filtered
;
;Processing the Cheatgrass images...
;Working on line          0
;Working on line          500
;Working on line          1000
;Working on line          1500
;Working on line          2000
;Working on line          2500
;Working on line          3000
;Working on line          3500
;Working on line          4000
;Working on line          4500
;Working on line          5000
;Working on line          5500
;Working on line          6000
;Working on line          6500
;Working on line          7000
;
;Output Cheatgrass Map Statistics:
;Found 5723 pixels with Cheatgrass (lower-probability spatial & spectral)
;Found 100596 pixels with Cheatgrass (lower-probability spatial)
;Found 1968436 pixels with Cheatgrass (lower-probability spectral)
;Found 1626576 pixels with Cheatgrass (high-probability)
;Normal termination of landsat_cheatgrass_recombination ... Elapsed Time =          28.734000 seconds
;
;Starting landsat_cheatgrass_maskbaddata.pro at Sun Nov 21 19:22:34 2010
;
;Input File for Landsat Layerstack  = Q:\usgsdesi\layerstacks\layerstack_landsat7_p36r34_2001_15apr_04jul
;Input File for Cheatgrass Map      = Q:\usgsdesi\cheatgrass\cheatgrass_landsat7_p36r34_2001_apr15_jul04_filtered
;Output File for Masked Cheatgrass Map = Q:\usgsdesi\cheatgrass\cheatgrass_landsat7_p36r34_2001_apr15_jul04_filtered_masked
;

```

```
;Processing the input cheatgrass image...
;Working on line      0
;Working on line      500
;Working on line     1000
;Working on line     1500
;Working on line     2000
;Working on line     2500
;Working on line     3000
;Working on line     3500
;Working on line     4000
;Working on line     4500
;Working on line     5000
;Working on line     5500
;Working on line     6000
;Working on line     6500
;Working on line     7000
;Found 5723 pixels with Cheatgrass Lower Spectral and Spatial Probability 0.0160691 % of pixels with valid data.
;Found 100596 pixels with Cheatgrass Lower Spatial Probability 0.282455 % of pixels with valid data.
;Found 1968436 pixels with Cheatgrass Lower Spectral Probability 5.52701 % of pixels with valid data.
;Found 1626576 pixels with Cheatgrass High Probability 4.56713 % of pixels with valid data.
;Normal termination of landsat_cheatgrass_maskbaddata.pro ... Elapsed Time =          22.954000 seconds
;
;Successfully created the cheatgrass map.
;
;Copying default log file to Q:\usgsdesi\cheatgrass\log_landsat_cheatmap_21Nov2010_19_19_23.txt
;
;Normal termination of landsat_cheatmap ... Elapsed Time =          213.204000 seconds
```