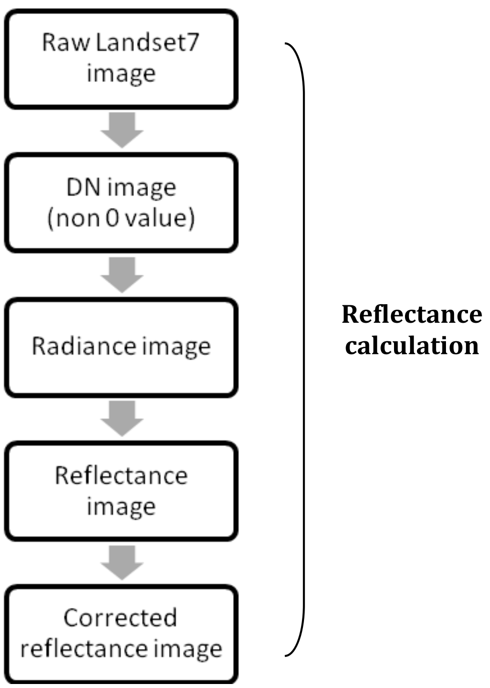
Tutorial Set 4: Remote sensing

Exercise Site20_4-4 Digital number to reflectance conversion

Learning objective: Converting a Landset 7 ETM image from a digital number to reflectance
Techniques: Reclassifying and compositing new rasters using the **Reclass** and **Raster Calculator**
Data Source: Dataset5

Schema of the process from Landsat7 digital number to reflectance:



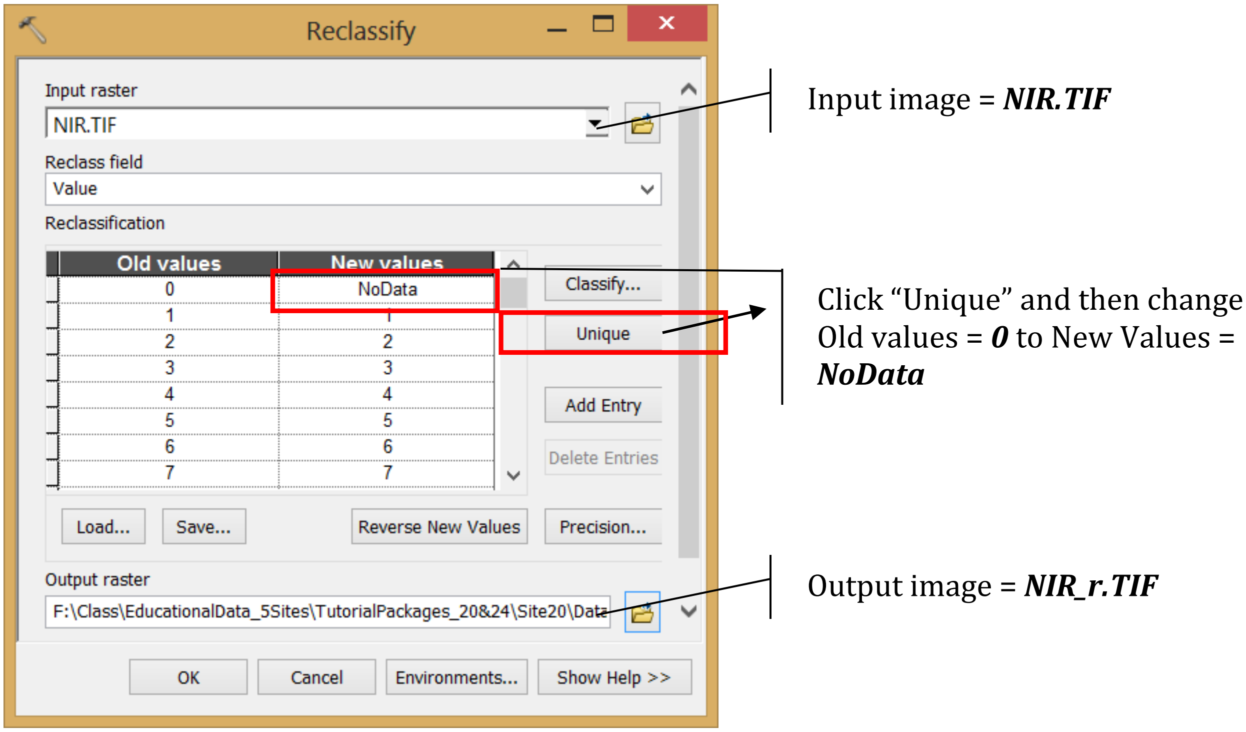
Landset7 ETM images used in this tutorial are acquired from [USGS Global Visualization Viewer](). These images should not be used directly to calculate NDVI because they have been pre-corrected and formatted as an 8-bit number (ranges from 0-255), or called digital number data (DN). For NDVI purpose, these images should be converted back to reflectance value.

Part 1: Reflectance calculation

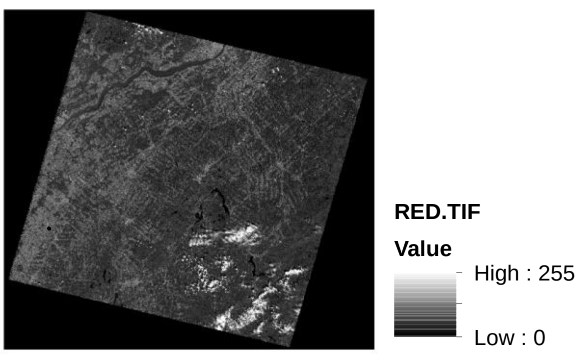
Step 1: Reclassify DN image.

Reclassify **0 value** to **NoData** using **Reclassify (Spatial Analyst Tools**). Cells with value = 0 in a Landsat image indicates missing data.

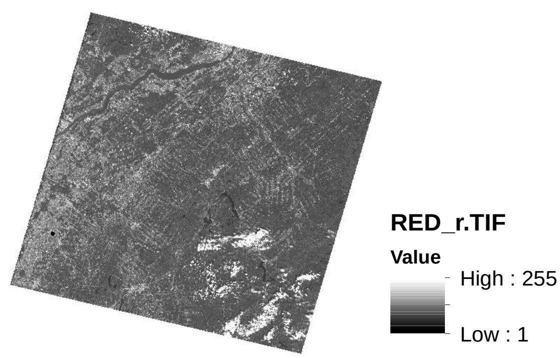
1. Go to **ArcToolbox** > **Spatial Analyst Tools** > **Reclass** > **Reclassify**.
2. Reclassify ***RED.TIF*** (Band 3) and ***NIR.TIF*** (Band4).



3. Result:



Before reclassifying. Cells value range 0-255



After reclassifying. Cells value ranges 1-255

Step 2: Convert DN image to radiance image (Chander *et al*, 2009)

Formula: $L_\lambda = (gain_\lambda \times DN7) + bias_\lambda$

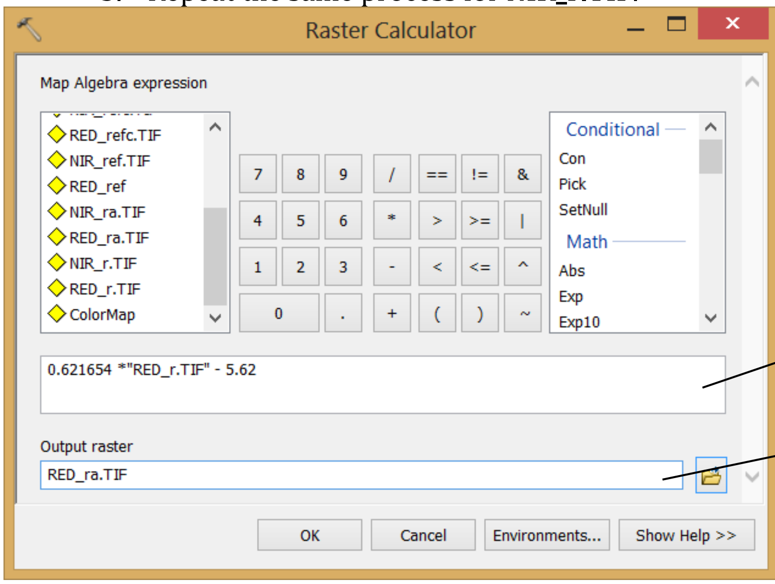
L_λ: Radiance [Watts/(m^2*µm*ster)]

DN7: Landsat7 digital number data

$gain_\lambda$ and $bias_\lambda$: Band specific number

Band	*Gain*	*Bias*
3 (RED)	0.621654	-5.62
4 (NIR)	0.639764	-5.74

1. Go to **ArcToolbox** > **Spatial Analyst Tools** > **Map Algebra** > **Raster Calculator**
2. Create radiance images for **RED_r.TIF**.
3. Repeat the same process for **NIR_r.TIF**.



0.621654 * “RED_r.TIF” – 5.62

Output = ***RED_ra.TIF***

Step 3: Convert radiance image to reflectance image

1. Formula: $R_\lambda = \dfrac{\pi \times L_\lambda \times d^2}{E_{su,\lambda} \times \sin(\theta_{SE})}$

   R_λ : Reflectance [unitless ratio]
   L_λ : Radiance [Watts/(m^2*µm*ster)]
   d: earth-sun distance [in astronomical units]
   $E_{su,\lambda}$: Band-specific radiance emitted by the sun
   θ_{SE} : Solar elevation angle

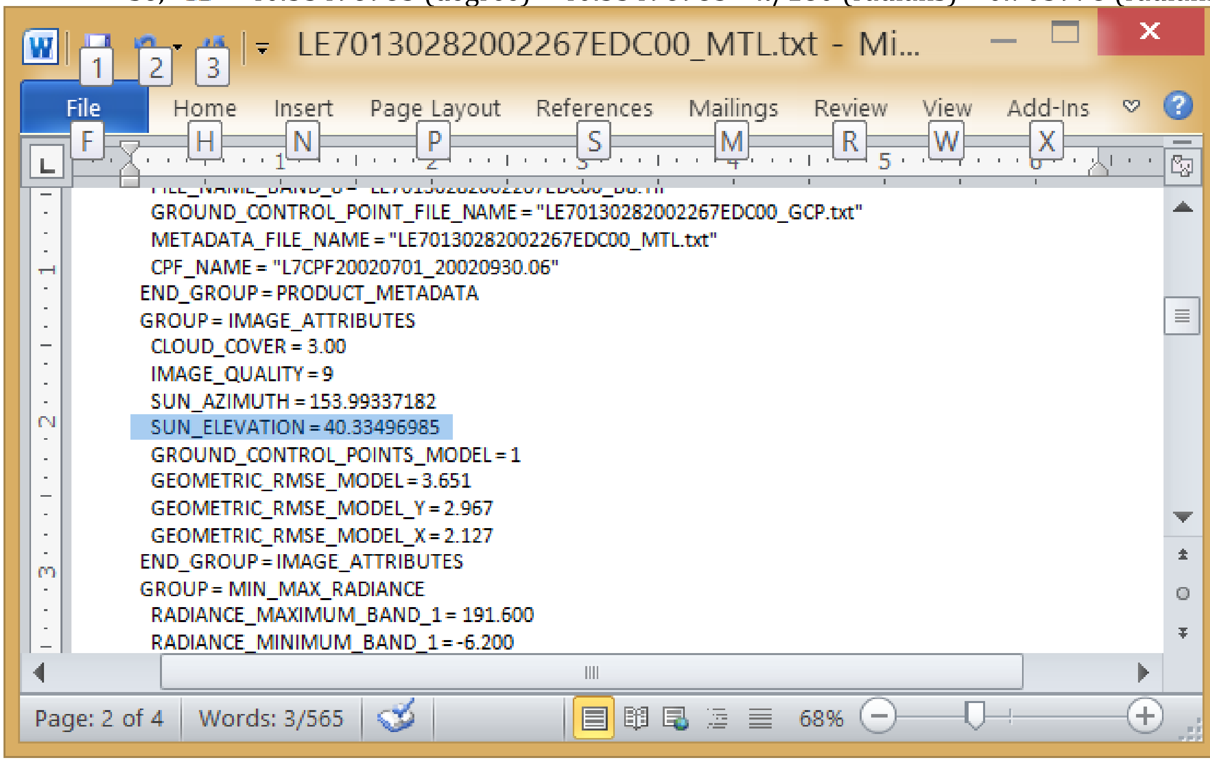
2. Find values:

   - $E_{su,\lambda}$

Band	$E_{su,\lambda}$ [Wats / (m^2 *µm)] (Chander *et al., 2009*)
1	1997
2	1812
3	1533
4	1039
5	230.8
7	84.9

- θ_{SE}

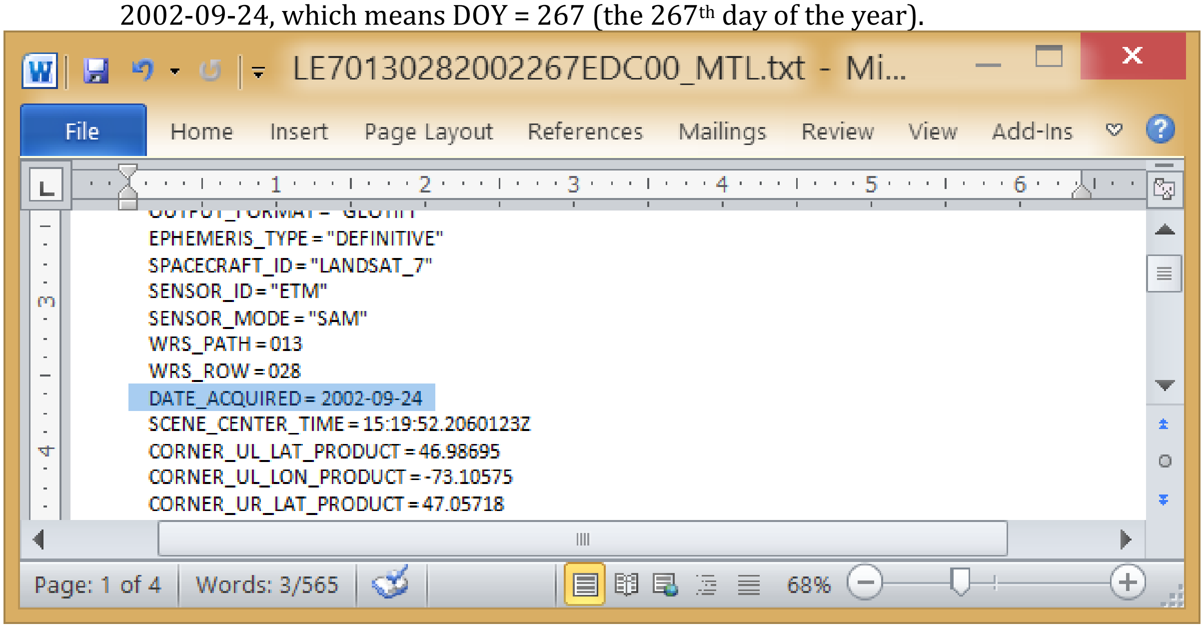
  Open the file **"*_MTL. txt"**. Find **SUN_ELEVATION** = **40.334696985**
  θ_{SE} = 40.33496985 (degree)
  Note: in ArcGIS, the value for sin() should be in radians.
  So, θ_{SE} = 40.33496985 (degree) = 40.33496985 * π/180 (radians) = 0.703978 (radians)



GROUND_CONTROL_POINT_FILE_NAME = "LE70130282002267EDC00_GCP.txt"
METADATA_FILE_NAME = "LE70130282002267EDC00_MTL.txt"
CPF_NAME = "L7CPF20020701_20020930.06"
END_GROUP = PRODUCT_METADATA
GROUP = IMAGE_ATTRIBUTES
CLOUD_COVER = 3.00
IMAGE_QUALITY = 9
SUN_AZIMUTH = 153.99337182
SUN_ELEVATION = 40.33496985
GROUND_CONTROL_POINTS_MODEL = 1
GEOMETRIC_RMSE_MODEL = 3.651
GEOMETRIC_RMSE_MODEL_Y = 2.967
GEOMETRIC_RMSE_MODEL_X = 2.127
END_GROUP = IMAGE_ATTRIBUTES
GROUP = MIN_MAX_RADIANCE
RADIANCE_MAXIMUM_BAND_1 = 191.600
RADIANCE_MINIMUM_BAND_1 = -6.200

- *d*

  To find the earth-sun distance, we should find which day of the year (DOY) the image was taken. This information is recorded in the file "*_MTL.txt". Find DATE_ACQUIRED = 2002-09-24, which means DOY = 267 (the 267th day of the year).



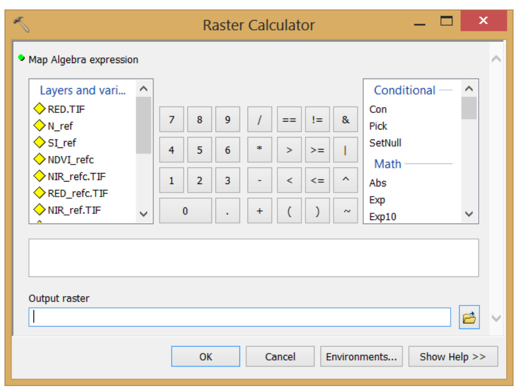
EPHEMERIS_TYPE = "DEFINITIVE"
SPACECRAFT_ID = "LANDSAT_7"
SENSOR_ID = "ETM"
SENSOR_MODE = "SAM"
WRS_PATH = 013
WRS_ROW = 028
DATE_ACQUIRED = 2002-09-24
SCENE_CENTER_TIME = 15:19:52.2060123Z
CORNER_UL_LAT_PRODUCT = 46.98695
CORNER_UL_LON_PRODUCT = -73.10575
CORNER_UR_LAT_PRODUCT = 47.05718

Earth-Sun distance (d) in astronomical unit DOY is listed below (Chander et al., 2009):

DOY	d	DOY	d
241	1.00992	301	0.99359
242	1.00969	302	0.99332
243	1.00946	303	0.99306
244	1.00922	304	0.99279
245	1.00898	305	0.99253
246	1.00874	306	0.99228
247	1.00850	307	0.99202
248	1.00825	308	0.99177
249	1.00800	309	0.99152
250	1.00775	310	0.99127
251	1.00750	311	0.99102
252	1.00724	312	0.99078
253	1.00698	313	0.99054
254	1.00672	314	0.99030
255	1.00646	315	0.99007
256	1.00620	316	0.98983
257	1.00593	317	0.98961
258	1.00566	318	0.98938
259	1.00539	319	0.98916
260	1.00512	320	0.98894
261	1.00485	321	0.98872
262	1.00457	322	0.98851
263	1.00430	323	0.98830
264	1.00402	324	0.98809
265	1.00374	325	0.98789
266	1.00346	326	0.98769
267	1.00318	327	0.98750
268	1.00290	328	0.98731
269	1.00262	329	0.98712

d = 1.00318 for DOY = 267

3. Go to **ArcToolbox** > **Spatial Analyst Tools** > **Map Algebra** > **Raster Calculator**
4. Create reflectance image for ***RED_ra.TIF*** and ***NIR_ra.TIF***.



<u>For RED_ra.TIF:</u>

Equation = (3.141592654 * "RED_ra.TIF" * Square(1.00318)) / (1533 * Sin(40.33496958 * 3.141592654/180))
Output = ***RED_ref.TIF***

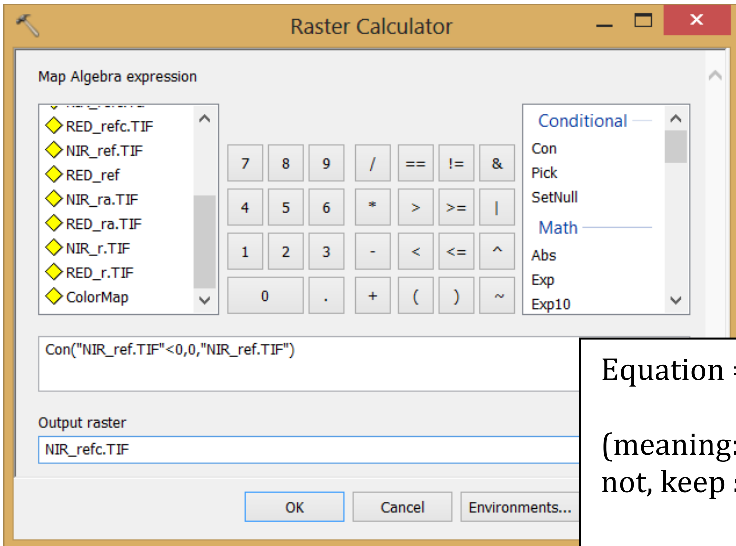
<u>For NIR_ra.TIF:</u>

Equation = (3.141592654 *"NIR_ra.TIF" *Square(1.00318))/(1039* Sin(40.33496958 *3.141592654/180))
Output = ***NIR_ref.TIF***

Step 4: Correct reflectance image, i.e., reclassify the negative value to 0.

> *During the previous calculation, some negative values are produced We have to correct them and set them to 0.*

1. Go to **ArcToolbox** > **Spatial Analyst Tools** > **Map Algebra** > **Raster Calculator**.
2. Create corrected reflectance image for ***RED_ref.TIF*** and ***NIR_ref.TIF***.



Equation = CON("NIR_ref.TIF"<0,0,"NIR_ref.TIF")

(meaning: if value of NIR_ref.TIF < 0, set value = 0, if not, keep same value)

Output = NIR_refc.TIF

3. Result of ***RED_refc.TIF*** and ***NIR_refc.TIF***.