Lesson 4.4: Digital number to reflectance conversion

Data Source: *dataset5.zip*

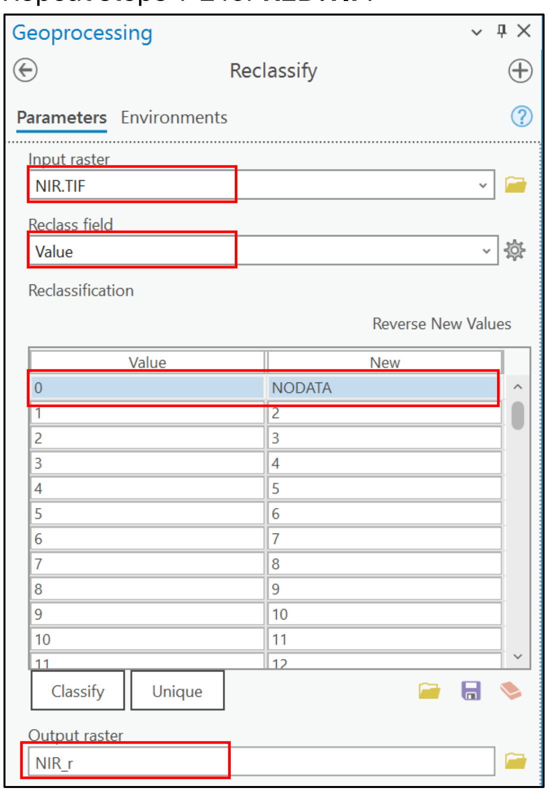
Landset8 OLI images used in this tutorial are acquired from [USGS Global Visualization Viewer]. These images should not be used directly to calculate NDVI because they have been pre-corrected and formatted as a 16-bit number or called digital number data (DN). For NDVI purpose, these images should be converted back to reflectance value.

Schema of the process from Landsat7 digital number to reflectance:

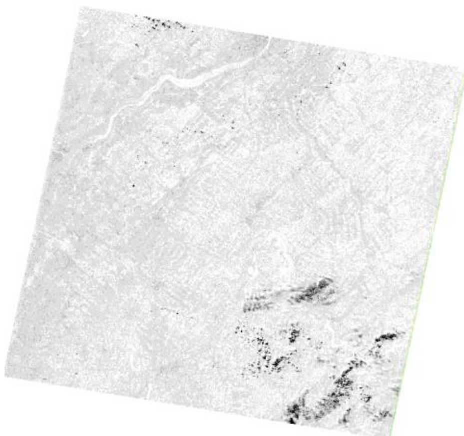
Reflectance Calculation

Step 1: Reclassify DN Image.

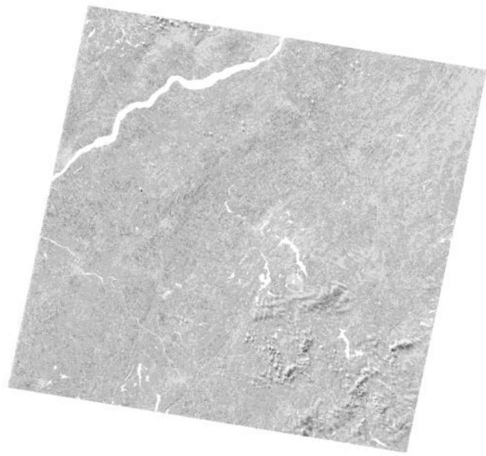
1. In the project saved from Lesson 4.3, right-click on NIR.TIF and select **Symbology**. Change **Primary Symbology** to **Unique Values**.
2. Search **Reclassify**. Change the **Old 0 Value** to **NODATA**. Name the new layer **NIR_r**.
3. Repeat steps 1-2 for **RED.TIF**.



RED_r Resultant Layer



NIR_r Resultant Layer



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/(m²*µm*ster)]

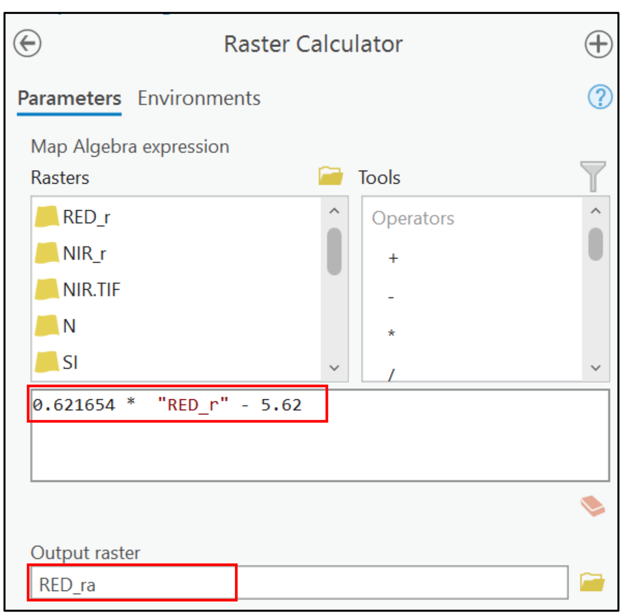
DN7: Landsat8 digital number data

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

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

1. Search **Raster Calculator**.

2. Create radiance images for **RED_r** based on the above expression. Name the output **RED_ra**.



3. Repeat the same process for **NIR_r** using the appropriate values from the table for NIR.

Step 3: Convert radiance image to reflectance image.

1. Formula to find reflectance.

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

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 the necessary values for the above equation.
   - $E_{su,\lambda}$

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}
     Find SUN_ELEVATION = 62.47 = 62.47 (degree)
     Note: in ArcGIS, the value for sin() should be in radians.
     So, = 62.47(degree) = 62.47 * π/180 (radians) = 0.703978 (radians)

```
CLOUD_COVER = 3.59
CLOUD_COVER_LAND = 3.63
IMAGE_QUALITY_OLI = 9
IMAGE_QUALITY_TIRS = 9
TIRS_SSM_MODEL = "FINAL"
TIRS_SSM_POSITION_STATUS = "ESTIMATED"
TIRS_STRAY_LIGHT_CORRECTION_SOURCE = "TIRS"
ROLL_ANGLE = -0.001
SUN_AZIMUTH = 141.04300379
SUN_ELEVATION = 62.47242388
EARTH_SUN_DISTANCE = 1.0150347
SATURATION_BAND_1 = "Y"
SATURATION_BAND_2 = "Y"
SATURATION_BAND_3 = "Y"
SATURATION_BAND_4 = "Y"
SATURATION_BAND_5 = "Y"
SATURATION_BAND_6 = "Y"
SATURATION_BAND_7 = "Y"
SATURATION_BAND_8 = "N"
SATURATION_BAND_9 = "N"
```

- *d*
  To find the earth-sun distance, we should find which day of the year (DOY) the image was taken. DATE_ACQUIRED = 2018-08-06, which means DOY = 159 (the 159th day of the year).

```
SENSOR_ID = "OLI_TIRS"
WRS_PATH = 13
WRS_ROW = 28
NADIR_OFFNADIR = "NADIR"
TARGET_WRS_PATH = 13
TARGET_WRS_ROW = 28
DATE_ACQUIRED = 2018-06-08
SCENE_CENTER_TIME = "15:30:54.5724640Z"
CORNER_UL_LAT_PRODUCT = 47.07019
CORNER_UL_LON_PRODUCT = -72.96593
CORNER_UR_LAT_PRODUCT = 47.13596
CORNER_UR_LON_PRODUCT = -69.82155
CORNER_LL_LAT_PRODUCT = 44.89622
CORNER_LL_LON_PRODUCT = -72.81343
CORNER_LR_LAT_PRODUCT = 44.95721
CORNER_LR_LON_PRODUCT = -69.78987
```

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

Earth-Sun distance (d) in astronomical units for Day of the Year (DOY)

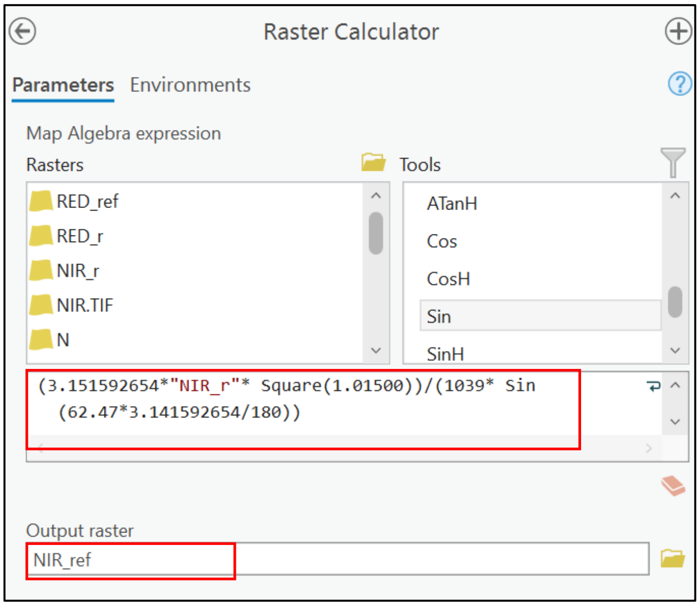
DOY	d	DOY	d	DOY	d	DOY	d	DOY	d	DOY	d
1	0.98331	**61**	0.99108	**121**	1.00756	**181**	1.01665	**241**	1.00992	**301**	0.99359
2	0.98330	**62**	0.99133	**122**	1.00781	**182**	1.01667	**242**	1.00969	**302**	0.99332
3	0.98330	**63**	0.99158	**123**	1.00806	**183**	1.01668	**243**	1.00946	**303**	0.99306
4	0.98330	**64**	0.99183	**124**	1.00831	**184**	1.01670	**244**	1.00922	**304**	0.99279
5	0.98330	**65**	0.99208	**125**	1.00856	**185**	1.01670	**245**	1.00898	**305**	0.99253
6	0.98332	**66**	0.99234	**126**	1.00880	**186**	1.01670	**246**	1.00874	**306**	0.99228
7	0.98333	**67**	0.99260	**127**	1.00904	**187**	1.01670	**247**	1.00850	**307**	0.99202
8	0.98335	**68**	0.99286	**128**	1.00928	**188**	1.01669	**248**	1.00825	**308**	0.99177
9	0.98338	**69**	0.99312	**129**	1.00952	**189**	1.01668	**249**	1.00800	**309**	0.99152
10	0.98341	**70**	0.99339	**130**	1.00975	**190**	1.01666	**250**	1.00775	**310**	0.99127
11	0.98345	**71**	0.99365	**131**	1.00998	**191**	1.01664	**251**	1.00750	**311**	0.99102
12	0.98349	**72**	0.99392	**132**	1.01020	**192**	1.01661	**252**	1.00724	**312**	0.99078
13	0.98354	**73**	0.99419	**133**	1.01043	**193**	1.01658	**253**	1.00698	**313**	0.99054
14	0.98359	**74**	0.99446	**134**	1.01065	**194**	1.01655	**254**	1.00672	**314**	0.99030
15	0.98365	**75**	0.99474	**135**	1.01087	**195**	1.01650	**255**	1.00646	**315**	0.99007
16	0.98371	**76**	0.99501	**136**	1.01108	**196**	1.01646	**256**	1.00620	**316**	0.98983
17	0.98378	**77**	0.99529	**137**	1.01129	**197**	1.01641	**257**	1.00593	**317**	0.98961
18	0.98385	**78**	0.99556	**138**	1.01150	**198**	1.01635	**258**	1.00566	**318**	0.98938
19	0.98393	**79**	0.99584	**139**	1.01170	**199**	1.01629	**259**	1.00539	**319**	0.98916
20	0.98401	**80**	0.99612	**140**	1.01191	**200**	1.01623	**260**	1.00512	**320**	0.98894
21	0.98410	**81**	0.99640	**141**	1.01210	**201**	1.01616	**261**	1.00485	**321**	0.98872
22	0.98419	**82**	0.99669	**142**	1.01230	**202**	1.01609	**262**	1.00457	**322**	0.98851
23	0.98428	**83**	0.99697	**143**	1.01249	**203**	1.01601	**263**	1.00430	**323**	0.98830
24	0.98439	**84**	0.99725	**144**	1.01267	**204**	1.01592	**264**	1.00402	**324**	0.98809
25	0.98449	**85**	0.99754	**145**	1.01286	**205**	1.01584	**265**	1.00374	**325**	0.98789
26	0.98460	**86**	0.99782	**146**	1.01304	**206**	1.01575	**266**	1.00346	**326**	0.98769
27	0.98472	**87**	0.99811	**147**	1.01321	**207**	1.01565	**267**	1.00318	**327**	0.98750
28	0.98484	**88**	0.99840	**148**	1.01338	**208**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29	0.98496	**89**	0.99868	**149**	1.01355	**209**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	0.98509	**90**	0.99897	**150**	1.01371	**210**	1.01533	**270**	1.00234	**330**	0.98694
31	0.98523	**91**	0.99926	**151**	1.01387	**211**	1.01522	**271**	1.00205	**331**	0.98676
32	0.98536	**92**	0.99954	**152**	1.01403	**212**	1.01510	**272**	1.00177	**332**	0.98658
33	0.98551	**93**	0.99983	**153**	1.01418	**213**	1.01497	**273**	1.00148	**333**	0.98641
34	0.98565	**94**	1.00012	**154**	1.01433	**214**	1.01485	**274**	1.00119	**334**	0.98624
35	0.98580	**95**	1.00041	**155**	1.01447	**215**	1.01471	**275**	1.00091	**335**	0.98608
36	0.98596	**96**	1.00069	**156**	1.01461	**216**	1.01458	**276**	1.00062	**336**	0.98592
37	0.98612	**97**	1.00098	**157**	1.01475	**217**	1.01444	**277**	1.00033	**337**	0.98577
38	0.98628	**98**	1.00127	**158**	1.01488	**218**	1.01429	**278**	1.00005	**338**	0.98562
39	0.98645	**99**	1.00155	**159**	1.01500	**219**	1.01414	**279**	0.99976	**339**	0.98547
40	0.98662	**100**	1.00184	**160**	1.01513	**220**	1.01399	**280**	0.99947	**340**	0.98533

d = 1.01500 for DOY = 159

3. Creating the reflectance image. Search **Raster Calculator**.

4. <u>For RED_ra</u>:
   Equation = (3.151592654*"RED_r"* Square(1.01500))/(1533* Sin(62.47*3.141592654/180))
   Output = RED_ref

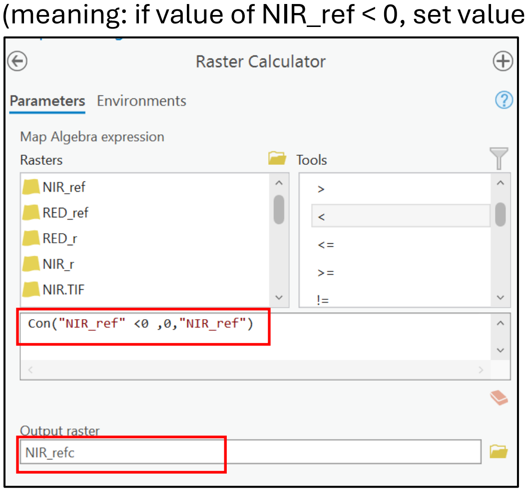
   <u>For NIR_ra</u>:
   Equation = (3.141592654 *"NIR_ra.TIF" *Square(1.01500))/(1039* Sin(62.47 *3.141592654/180))
   Output = NIR_ref



Step 4: Correct reflectance image.

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

1. Search **Raster Calculator**.
   Equation = Con("RED_ref" <0 ,0,"RED_ref") and Con("NIR_ref" <0 ,0,"NIR_ref")
   (meaning: if value of NIR_ref < 0, set value = 0, if not, keep same value)



2. Results of RED_refc and NIR_refc: