

Tutorial Set 4: Remote sensing

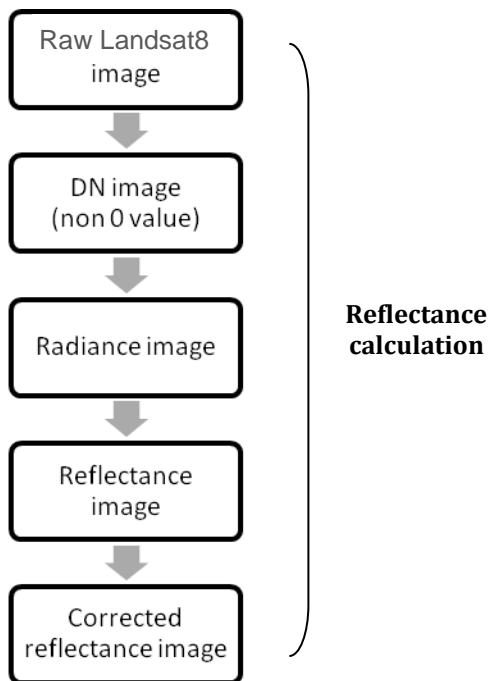
Exercise Site20_4-4 Digital number to reflectance conversion

Learning objective: Converting a Landsat8 OLI 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:



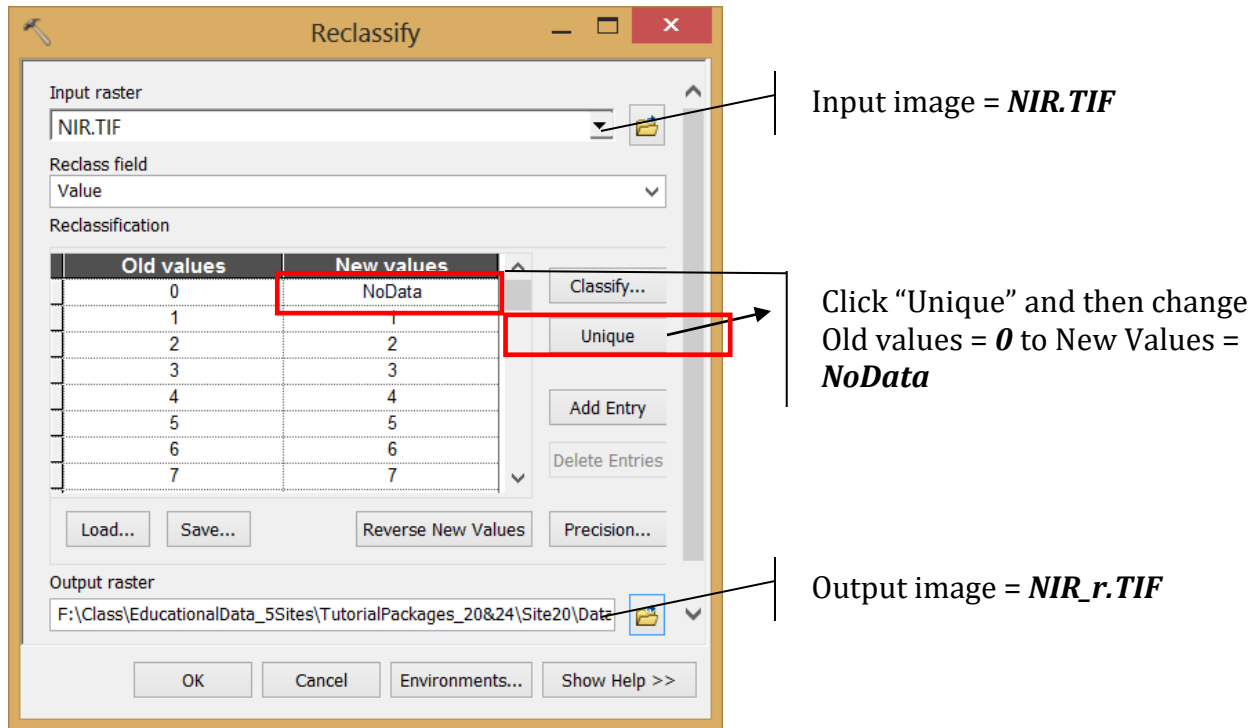
Landsat8 OLI images used in this tutorial are acquired from [USGS Global Visualization Viewer](#). These images should not be used directly to calculate NDVI because they have been pre-corrected and formatted as an 16-bit number, or called digital number data (DN). For NDVI purpose, these images should be converted back to reflectance value.

Part 1: Reflectance calculation

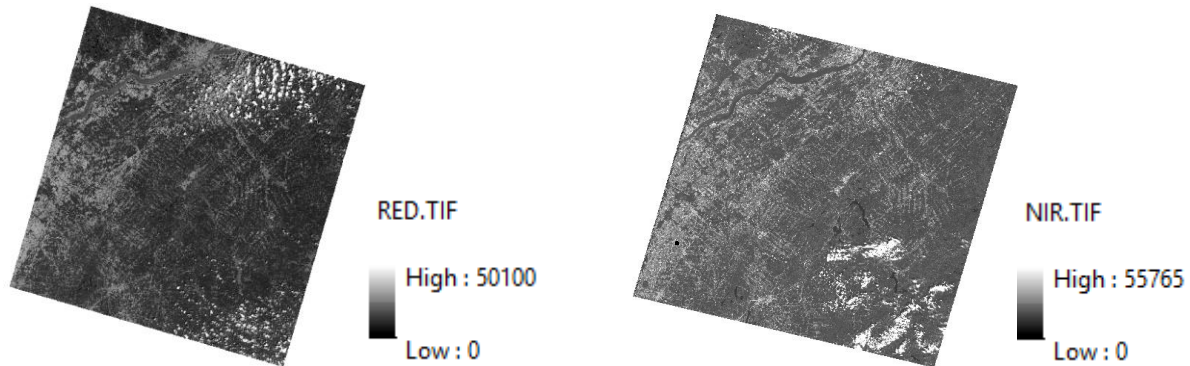
Step 1: Reclassify DN image.

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 4) and **NIR.TIF** (Band5).



3. Result:



Before reclassifying. Cells value range 0-50100 After reclassifying. Cells value ranges 1-55765

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

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

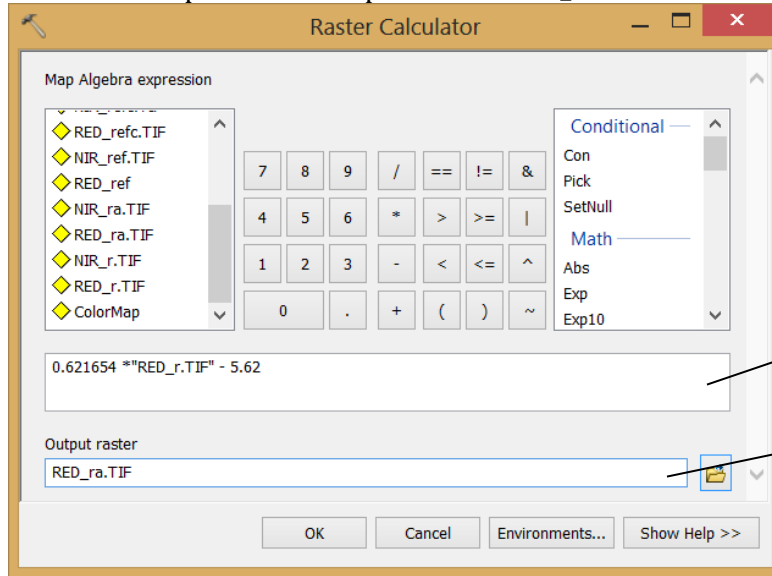
L_{λ} : Radiance [Watts/(m²*μm*ster)]

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

R_{λ} : Reflectance [unitless ratio]

L_{λ} : Radiance [Watts/(m²*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 <i>et al</i> , 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 = 62.47**

$\theta_{SE} = 62.47$ (degree)

Note: in ArcGIS, the value for $\sin()$ should be in radians.

So, $\theta_{SE} = 62.47(\text{degree}) = 62.47 * \pi/180$ (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

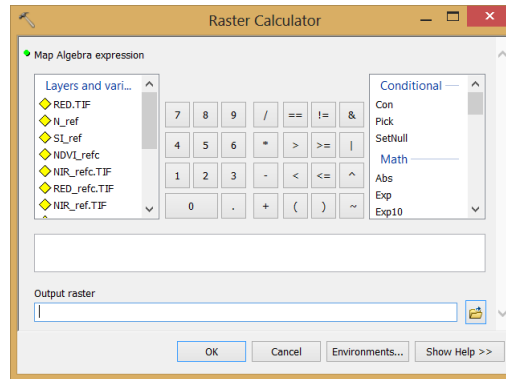
To find the earth-sun distance, we should find which day of the year (DOY) the image was taken. This information is recorded in the file “*_MTL.txt”. Find **DATE_ACQUIRED = 2018-08-06**, which means DOY = 159 (the 159th day of the year).

```
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	1.015	d = 1.01500 for DOY = 159			
29	0.98496	89	0.99868	149	1.01355	209	1.015				
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

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



For RED ra.TIF:

$$\text{Equation} = (3.141592654 * \text{"RED_ra.TIF"} * \text{Square}(1.01500)) / (1533 * \text{Sin}(62.47 * 3.141592654/180))$$

Output = ***RED_ref.TIF***

For NIR ra.TIF:

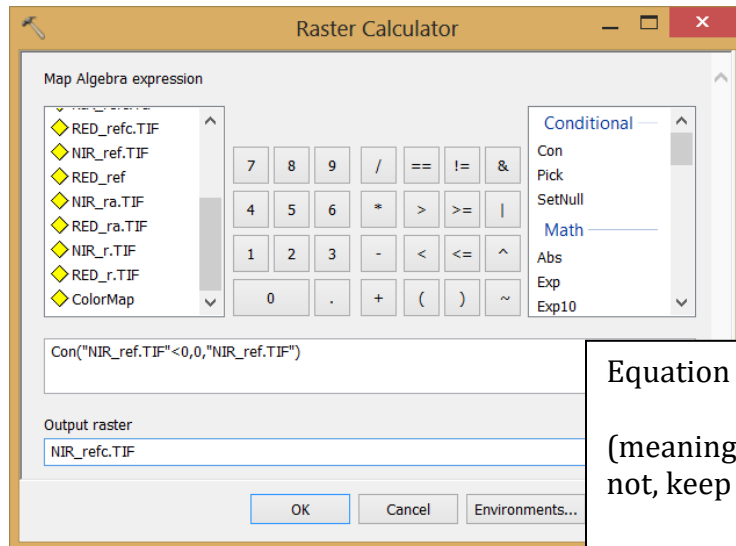
$$\text{Equation} = (3.141592654 * \text{"NIR_ra.TIF"} * \text{Square}(1.01500)) / (1039 * \text{Sin}(62.47 * 3.141592654/180))$$

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_refc.TIF** and **NIR_refc.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**.

