

Manual: Module 1 & 2

*Advanced Application of Geospatial Information
Technology for Drought Risk Management*

Implemented by:

*The United Nations Institute for Training and Research (UNITAR's) Operational
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Introduction to the Course Manual

This training manual contains all the practical exercise modules for the training “Advanced Application Geospatial Information Technology for Drought Risk Management”. The content of the Manual is divided into two thematic chapters which mostly focus on the advanced operational use of geospatial information technology in areas such as land use classification, change detection analysis, geomorphology detection, decision support services. This training manual is designed to be used in conjunction with different concepts that are imparted through face-to-face lectures and interaction during the training. It is assumed that all the participants using this manual attended the basic training GIT4DrRM held in November, 2017, Phnom Penh, Cambodia.

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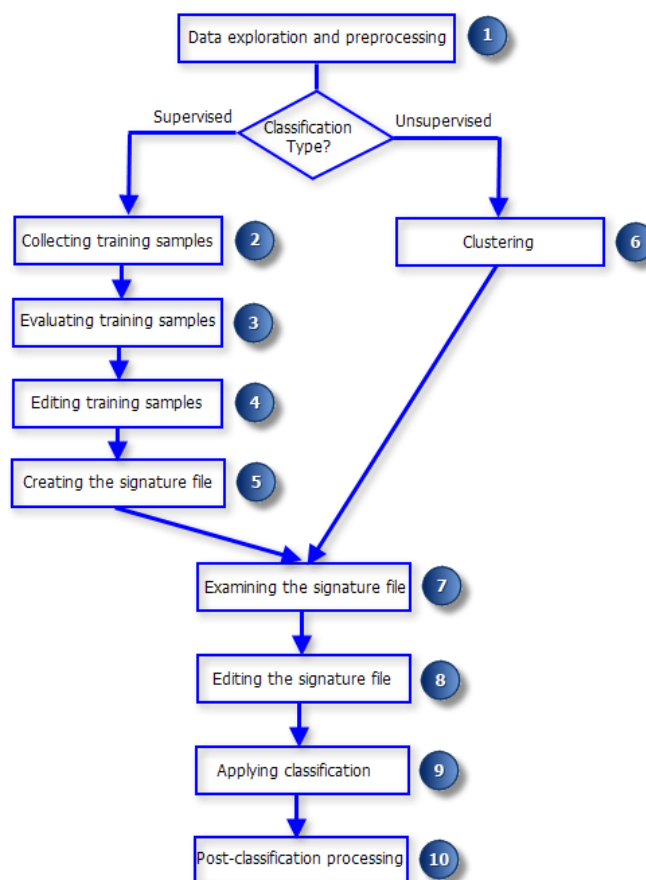
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Chapter 1 – Digital Image Classification

Introduction

Digital Image Classification is the process of automatic or semi-automatic interpretation of imagery with the help of certain given condition. Digital image classification uses the quantitative spectral information contained in an image, which is related to the composition or condition of the target surface. There are two kinds of image classification schemes – Supervised, and Unsupervised. Supervised classification uses the spectral signatures obtained from training samples to classify an image. Unsupervised classification finds spectral classes (or clusters) in a multiband image without the analyst's intervention.

With the ArcGIS Spatial Analyst extension, there is a full suite of tools in the Multivariate toolset to perform supervised and unsupervised classification. The classification process is a multi-step workflow; therefore, the Image Classification toolbar has been developed to provide an integrated environment to perform classifications with the tools.



Learning Objectives

By going through this exercise, you will familiarize with techniques of digital image classification using ArcMap and you will be able to:

- Create training samples for supervised image classification
- Explain separability of landcover classes from histogram and feature space plot
- Perform Maximum Likelihood classification
- Perform unsupervised image classification
- Create and explain a dendrogram (Optional)
- Relate unsupervised classes to landcover

Data Inputs

X:\AGIT4DrRM\Training_Material\ModA1\s2-s3\Practical\Data_Input\

File Name	Data Type
Raster\S2A_PhnomPenh_20180205_10m_8bit.tif	Multiband Raster

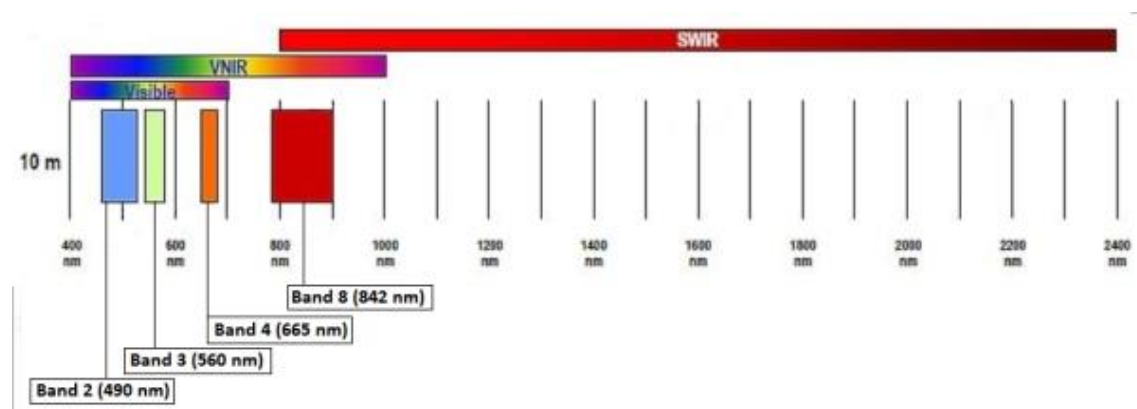
Section A: Explore the Raster Dataset:

- Open “A1S2_Digital_Image_Classification_v105.mxd” from the following location-

X:\AGIT4DrRM\Training_Material\ModA1\s2-s3\Practical\Workspace\

In this workspace you are going to find “S2A_PhnomPenh_20180205_10m_8bit.tif” is arranged under “Raster\Sentinel-2” group layer. This is a small scene clipped from Sentinel 2 data freely provided by ESA from their scientific data hub¹. Sentinel 2 has 4 spectral windows (Bands) sensed at 10m spatial resolution these are bands 2,3,4 and 8 respectively. For this exercise we are going to use these 4 Bands only. The original data was converted to 8bit² DN values for ease of comparison of different classification metric.

But it also senses six other bands at 20m spatial resolution bands 5,6,7,8A, 11and 12. Three other bands at 60m spatial resolution bands 1, 9, 10.



The colour assignment is the following red = B4, Green = B3. Blue = B2. So, the scene will look similar to the colour our eyes perceive and hence it's called true or natural colour composite.



Natural Colour

False Colour

- Right click on the layer “S2A_PhnomPenh_20180205_10m_8bit.tif” and rename it to “S2A_PhnomPenh_20180205_10m_8bit_Natural”
- Right click on the layer “S2A_PhnomPenh_20180205_10m_8bit_Natural” > Copy the Layer and paste the Layer Right clicking on the Sentinel2 group layer

¹ <https://scihub.copernicus.eu/>

² <http://desktop.arcgis.com/en/arcmap/latest/tools/data-management-toolbox/copy-raster.htm>

- Change the band combination of this duplicate
“S2A_PhnomPenh_20180205_10m_8bit_Natural” to (843 : RGB) and the rename the layer to “S2A_PhnomPenh_20180205_10m_8bit_False”

Play with different band combination and answer the following questions, explore the area for detecting different landcover types.

⇒ *What is the colour of vegetation in Sentinel 2 band combination (843: RGB)?*

⇒ *What will be the colour of urban area in Sentinel 2 band combination (843: RGB)?*

⇒ *List the main thematic landcover category that can cover your area of interest?*

Section B: Unsupervised Image Classification

Unsupervised classification finds the spectral classes (or clusters) in a multiband image without the analyst's intervention. The Image Classification toolbar aids in unsupervised classification by providing access to the tools to create the clusters, capability to analyse the quality of the clusters, and access to classification tools.

Running the classification with small number of classes

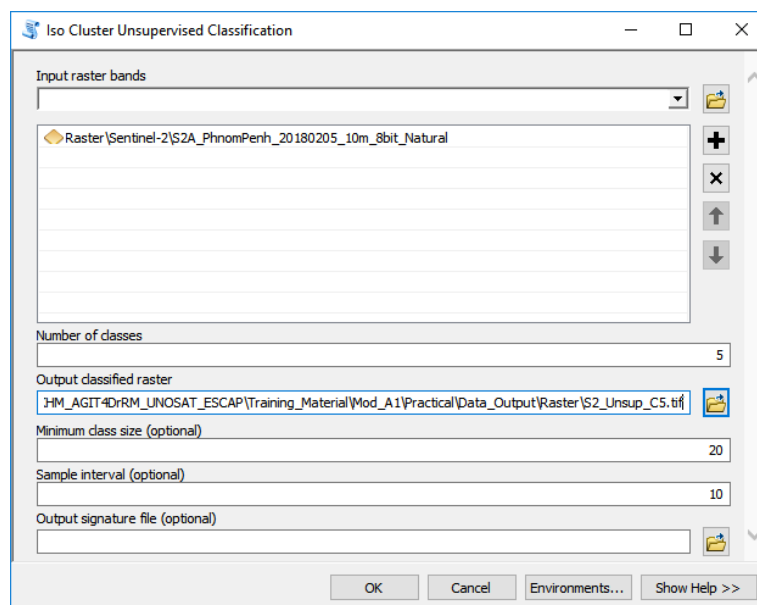
- Go to ArcToolbox
- Spatial Analyst > Multivariate > Iso Cluster Unsupervised Classification

Following window will come up

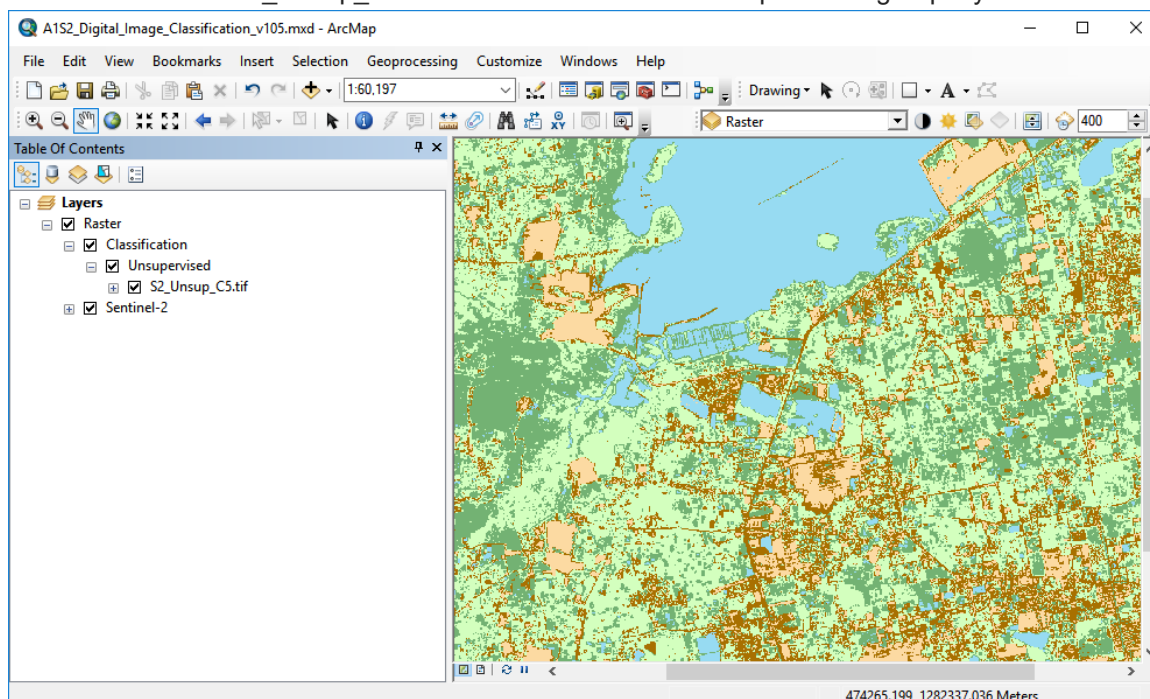
- Set Input raster bands = “S2A_PhnomPenh_20180205_10m_8bit_Natural”
- Number of classes = 5
- Output file name as “S2_Unsup_C5.tif” in location

X:\AGIT4DrRM\Training_Material\ModA1\s2-s3\Practical\Data_Output\Raster

- Use default value for other
- Click OK



- Move the “S2_Unsup_C5.tif” under “Classification\Unsupervised” group layer



Now you will get a raster file with 5 code values.

⇒ Match raster code to most applicable landcover -

Raster Code	Probable Landcover
1	
2	
3	
4	
5	

⇒ Is there any landcover missing? Why did this happen?

Improving unsupervised classification:

From the above example it is clearly evident that running with only few number of classes cannot cover all the different thematic landcover classes. We are going to perform the same exercise with 15 classes.

- Go to ArcToolbox
- Spatial Analyst > Multivariate > Iso Cluster Unsupervised Classification
- Set Input raster bands = “S2A_PhnomPenh_18032016_10m_Natural”
- Number of classes = 15
- Output file name as “S2_Unsup_C15.tif” in the following location

X:\AGIT4DrRM\Training_Material\ModA1\s2-s3\Practical\Data_Output\Raster

- Use default value for other
- Output signature file “S2_Unsup_C15.gsg” in the following location

X:\AGIT4DrRM\Training_Material\ModA1\s2-s3\Practical\Data_Output\Raster

- Click OK

- Now you will get a raster file with 15 coded values.

⇒ Now group the raster codes under different common landcover categories –

Landcover	Raster Codes
Water	
Tree	
Grass	
Sand	
Bare Soil	
Urban	

Optional

From the 15 classes it is very difficult to understand which pixel value relates to which landcover. Understanding each of the 15 classes will take a long time. However, we can use a dendrogram to understand the hierarchy of the values, if we want to merge the classes to meaningful or target landcover classes.

A dendrogram is a diagram that shows the attribute distances between each pair of sequentially merged classes. To avoid crossing lines, the diagram is graphically arranged so that members of each pair of classes to be merged are neighbours in the diagram.

- Go to ArcToolbox
- Spatial Analyst > Multivariate > Dendrogram
- Input the signature file “S2_Unsup_C15.gsg” in the following location

[X:\AGIT4DrRM\Training_Material\ModA1\s2-s3\Practical\Data_Output\](#)

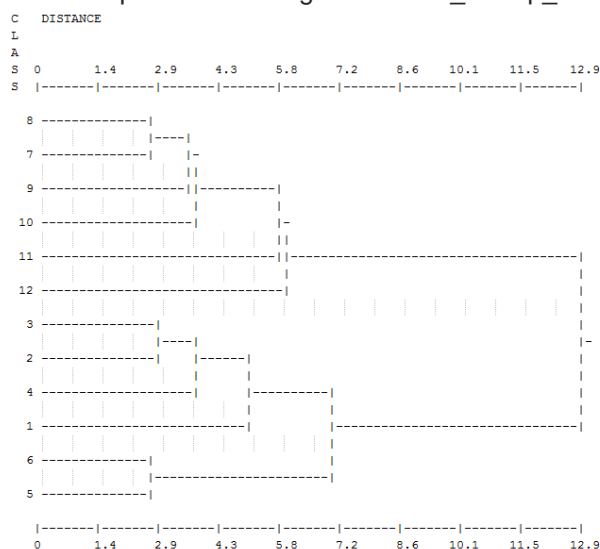
- Output the dendrogram file “S2_Unsup_C15_Dendo.txt” to the following location

[X:\AGIT4DrRM\Training_Material\ModA1\s2-s3\Practical\Data_Output\](#)

- Use the default value for the other fields
- Click ok
- Now from windows explorer browse to the following folder

[X:\AGIT4DrRM\Training_Material\ModA1\s2-s3\Practical\Data_Output\](#)

- Open the dendrogram file “S2_Unsup_C15_Dendo.txt”



Section C: Supervised Classification

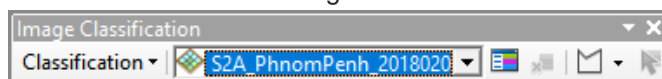
Supervised classification requires the image analyst to choose an appropriate classification scheme, and then identify training sites in the imagery that best represent each class. A simple land cover classification scheme might consist of a small number of classes, such as urban, water, wetlands, forest, grass/crops. The classification algorithm then uses spectral characteristics of the training sites to classify the remainder of the image.

Image Classification Toolbar

The Image Classification toolbar contains interactive tools for creating training samples and signature files. Some commonly used classification tools from the Multivariate toolset of the Spatial Analyst toolbox are also exposed through this toolbar³.

Opening the Image Classification Toolbar:


- Click Customize menu > Toolbars> Image Classification




- Make sure the classification image target is “S2A_PhnomPenh_20180205_Natural”

The Training Sample Manager

The Training Sample Manager is the mechanism for managing training samples. With it, you can edit the class name and value, merge and split classes, delete classes, change display color, load and save training samples, evaluate training samples, and create a signature file.

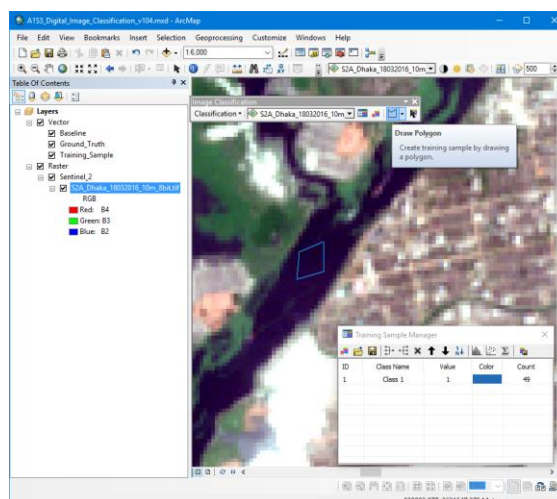
The manager is accessible from the Image Classification toolbar by clicking the Training Sample Manager button . The following image shows the dialog box of the manager⁴:

Sample Training

- Click the training sample manager button . The training sample manager window will come up.

Now we are going to train the image classification toolbar for water areas in the images

- Zoom to an area in the image with water pixels
- Click the polygon draw icon from image classification window
- Draw a polygon around the water pixels, but make sure to only capture pixels that are definitely water, avoid those you are unsure about
- Draw a few other water areas
- CRTL+ select all the water classes and Click merge training sample button




ID	Class	Merge training samples	Color	Count
1	Class 1	1		49
2	Class 2	2		94
3	Class 3	3		58

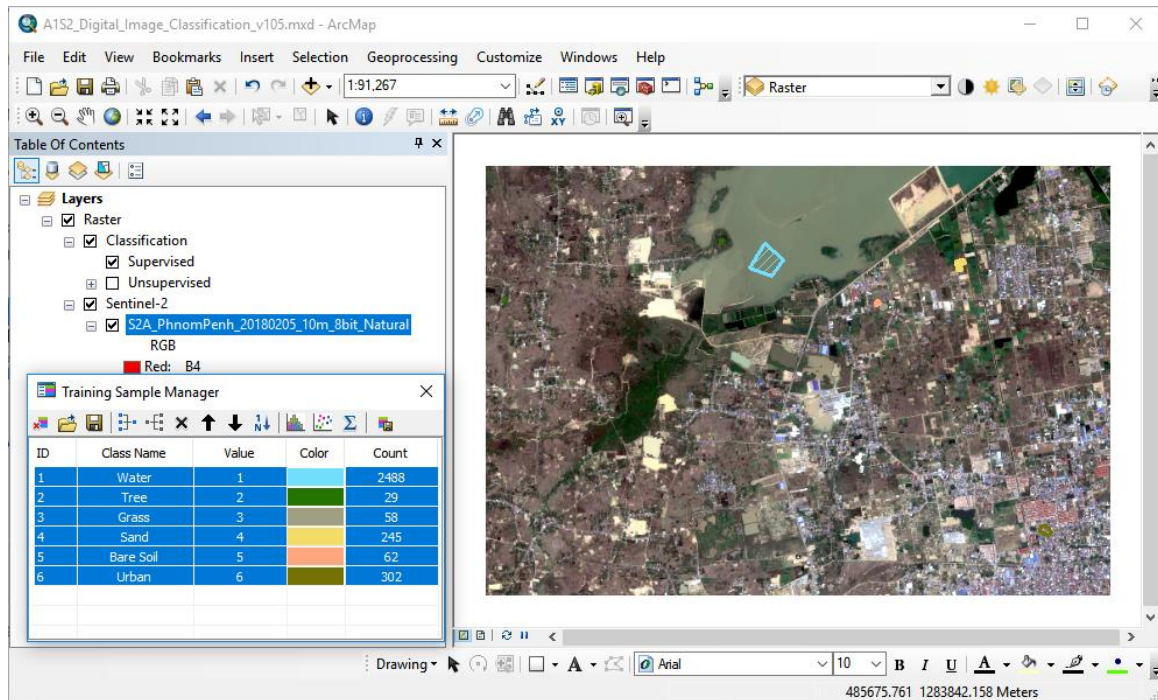
³ <http://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/image-classification/an-overview-of-the-image-classification-toolbar.htm>


⁴ <http://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/image-classification/the-training-sample-manager.htm>

- Rename the class to “Water” assign a blue color

ID	Class Name	Value	Color	Count
1	Water	1		174


- Now also train the following cover in a similar way –
 - ✓ Tree
 - ✓ Grass/Crop
 - ✓ Sand
 - ✓ Bare Soil
 - ✓ Urban

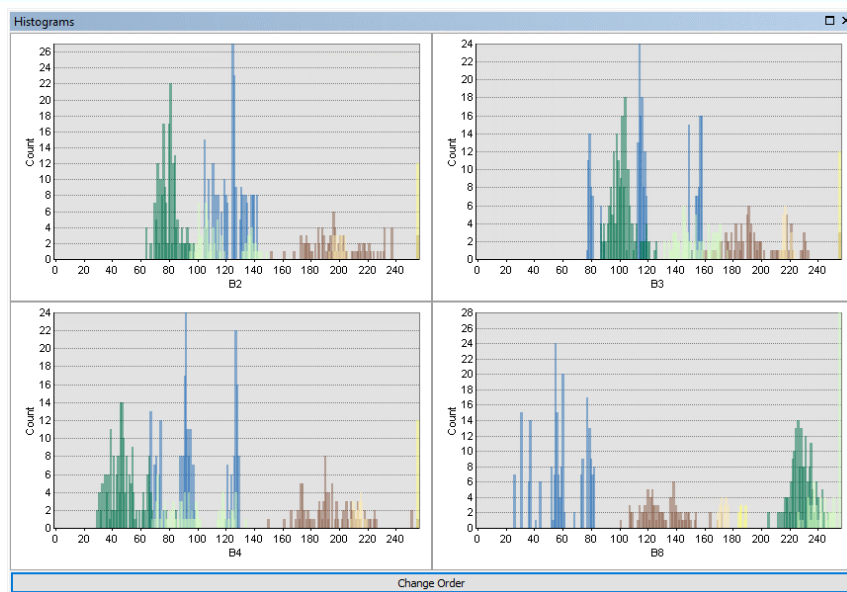


- Click  the save training samples button in the training sample manager to save the training sample as a shapefile.
- Give the filename “S2A_PhnomPenh_6C.shp” and place in the following location -

X:\AGIT4DrRM\Training_Material\ModA1\s2-s3\Practical\Data_Output\Vector

Evaluation of separability of classes

- Select all classes from the training sample manager
- Click on Histogram 
- Use the Change order button to bring up any hidden histograms to have a complete idea




From these histograms of 4 bands it can be seen that –

Only few landcover are separable if we consider single bands,

- Put (x) mark on the box which landcover are separable for which band -

Bands	Water	Tree	Grass	Sand	Bare Soil	Urban
Band 1 (B2)						
Band 2 (B3)						
Band 3 (B4)						
Band 4 (B5)						

Observing this we can clearly come to the conclusion that looking at a single band cannot help us classifying the image. Now we are going to plot the feature space to observe which band combination will be best to classify the image we will also modify the training samples if necessary.

- Select all classes from the training sample manager
- Click on show scatterplots  . The following window will come up-

Observe your own scatterplots and answer the following questions-

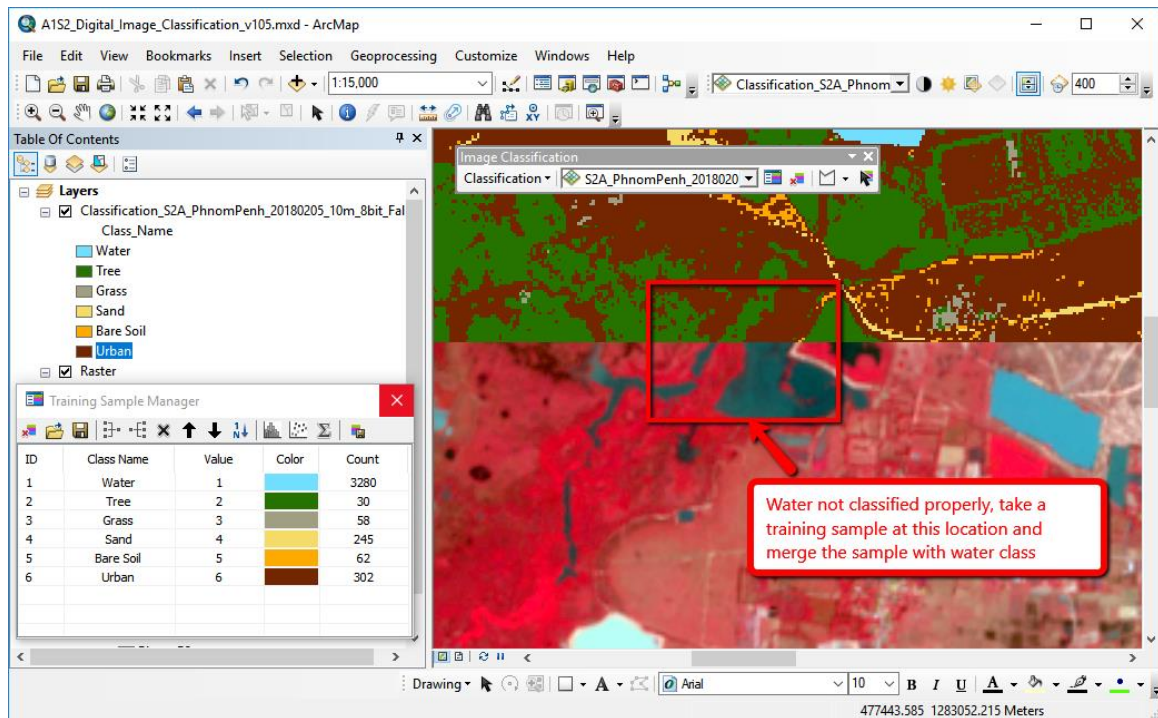
⇒ Which pair of two bands would you take to separate the landcovers?

⇒ Which landcover class has the most mixed pixels?

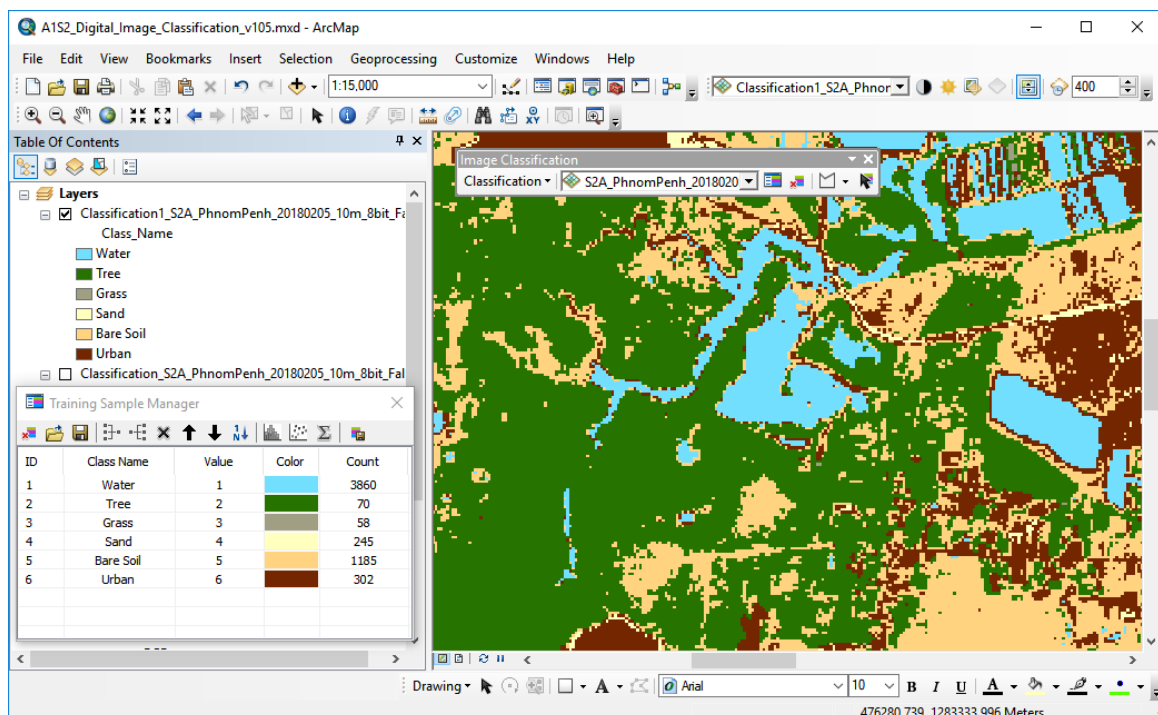
⇒ How would you overcome the mixed pixel problem?

Image classification

- From the classification toolbar > Run interactive supervised classification. You are going to have a temporary result based on the training you have performed.



- Use swipe tool to look for the areas of misclassification and try to incorporate them in correct group training new samples.
- Save the training sample as a new file with version info (S2A_PhnomPenh_6Cv2.shp)
- Run interactive supervised classification again. Observe the change.
- Repeat this process until you are happy with the result.



- One you obtain satisfactory results, search for copy raster toolbar
- Save the output the classified raster "S2A_PhnomPenh_6C_Final.tif" to the following location

X:\AGIT4DrRM\Training_Material\ModA1\s2-s3\Practical\Data_Output\Raster

Answer the following questions –

⇒ *Which classification is faster? Explain your thoughts.*

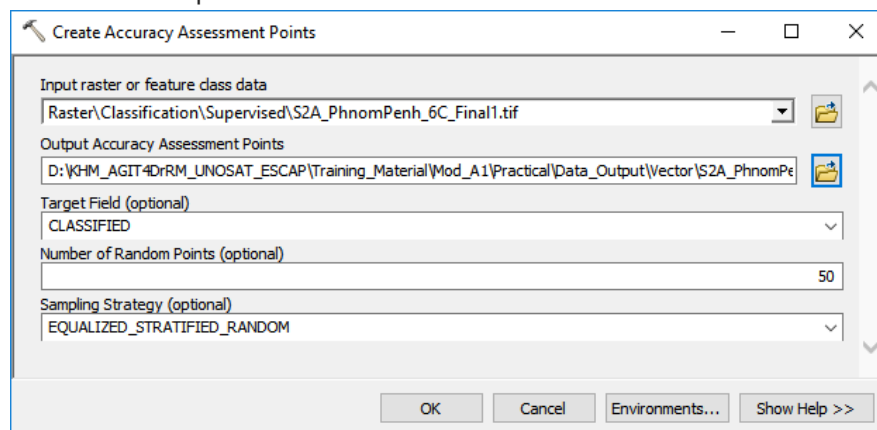
⇒ *Which classification is more accurate apparently? Explain your thoughts.*

⇒ *If you want to assess the accuracy of these image classification what can you do?*

Section D: Ground Truth Collection

Accuracy assessment is an important part of any classification project. It compares the classified image to another data source that is considered to be accurate or ground truth data. Ground truth data are traditionally collected using GPS devices and directly going to the field. Alternatively, experts also utilise information from high resolution imagery from google earth and Bing map. Even though these higher details in observation but these are still views from the top and there is no control over the observation time and date. However, a novel approach is to combine high resolution satellite base maps and street view imagery to make a robust assessment of ground-truth. This approach allows a user to collect sample from vast geographical area without having to travel to the field.

- Open the Create Accuracy Assessment Points tool and
 - Target Field = Classified
 - Input Raster = S2A_PhnomPenh_6C_Final
 - Sampling strategy = Equalized Stratified Random—Generates a set of accuracy assessment points where each class has the same number of points.
 - Number of points to 50

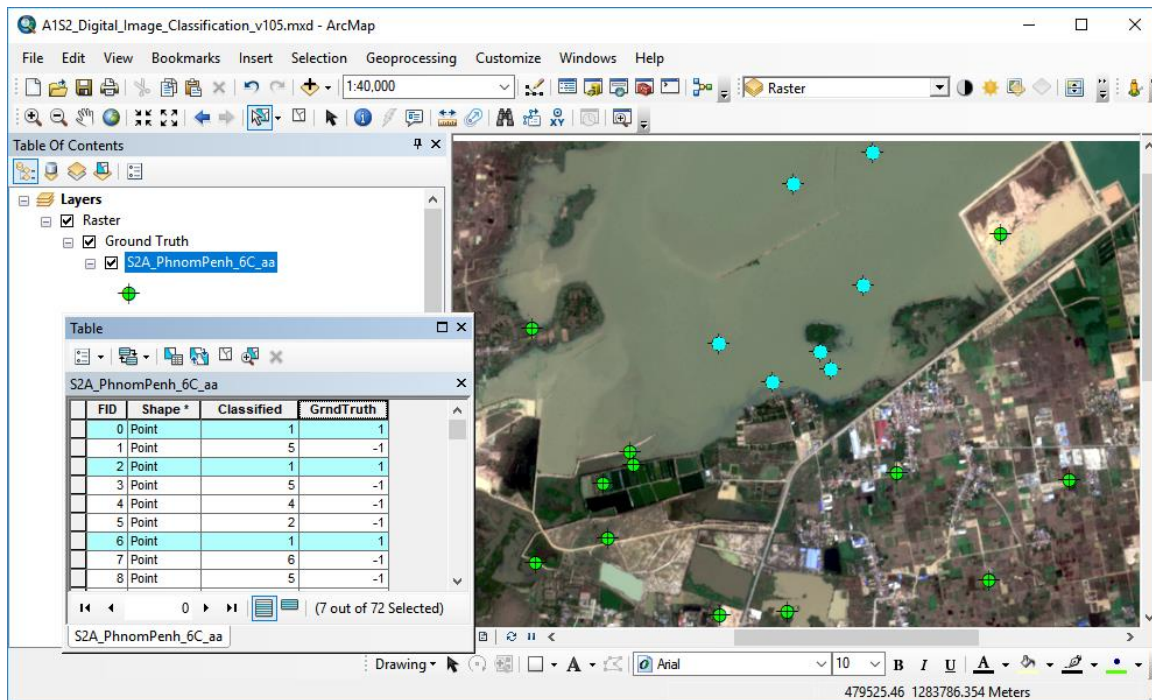


Now you are going to find 50 ground truth point has been created by ArcMap where values from the classified image is already inserted. But ground truth values are kept as -1 or missing values.



Table				
S2A_PhnomPenh_6C_aa				
FID	Shape *	Classified	GrndTruth	
0	Point	1	-1	
1	Point	5	-1	
2	Point	1	-1	
3	Point	5	-1	
4	Point	4	-1	
5	Point	2	-1	
6	Point	1	-1	
7	Point	6	-1	
8	Point	5	-1	

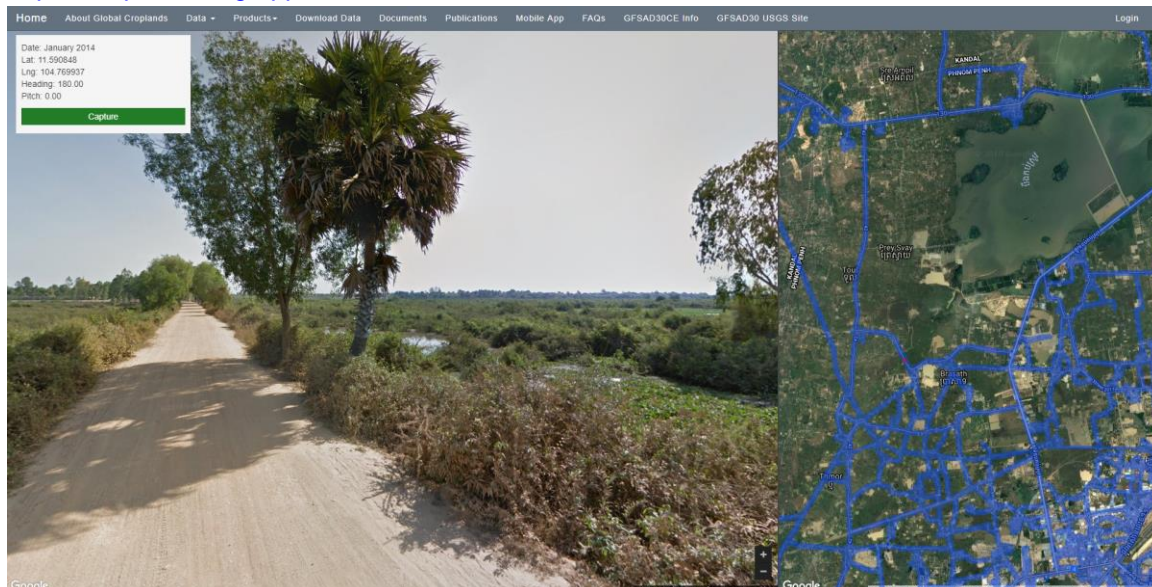
- Select the points inside water body and right click on GrndTruth column of the attribute table of S2A_PhnomPenh_6CAA file > Calculate Field and fill the values with 1.



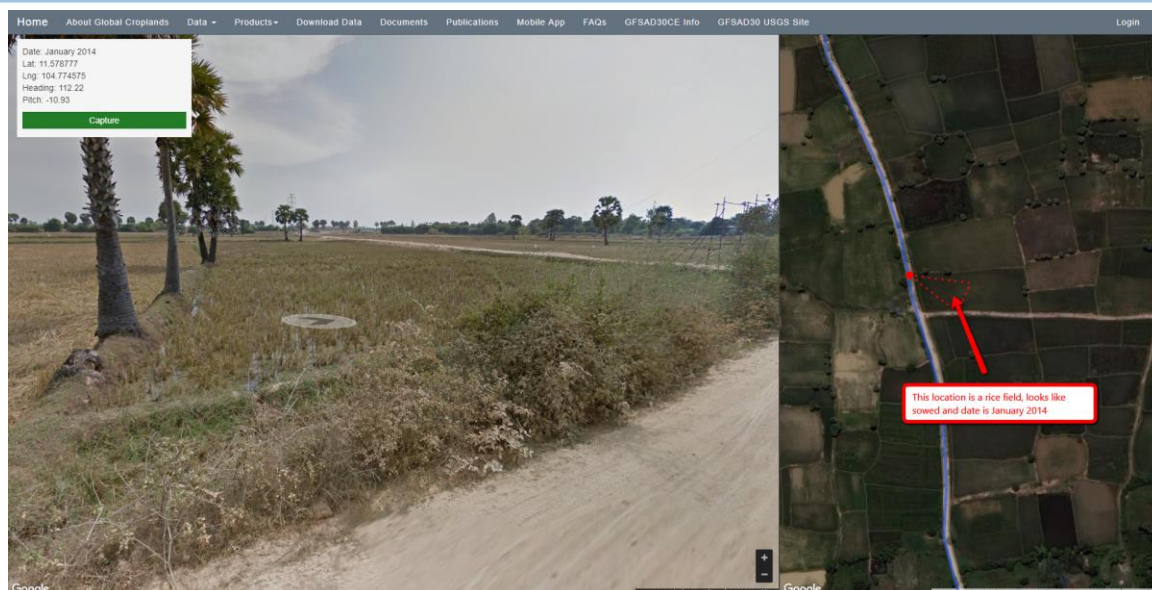
For uncertain areas and classes, we are going to use google street view from croplands

- Click the following link to access the croplands street view application

<https://croplands.org/app/data/street>



- Browse to your location of interest



- Fill in the correct class for GrndTruth S2A_PhnomPenh_6CAA
- Take at least 5 observations per landcover category and enter in the excel sheet

Section E: Accuracy Assessment (Your Turn)

⇒ Use Compute Confusion Matrix tool from Spatial Analyst toolbox > Segmentation and Classification toolset to conclude about the accuracy of your classification

⇒ Which indicator of value is most robust for understanding the accuracy of classification?

⇒ What is the difference between user's and producer's accuracy?

Confusion matrix example						
	c_1	c_2	c_3	Total	U_Accuracy	Kappa
c_1	49	4	4	57	0.8594	0
c_2	2	40	2	44	0.9091	0
c_3	3	3	59	65	0.9077	0
Total	54	47	65	166	0	0
P_Accuracy	0.9074	0.8511	0.9077	0	0.8916	0
Kappa	0	0	0	0	0	0.8357

[END OF EXERCISE]

Chapter 2 – Landcover change detection analysis

Introduction

Change detection is a type of analysis that intends to measure the change in some specific attribute of a specific area between two or more time periods. One of the most common change detection is based on the landcover of different time periods. The first step of such analysis is to categorise or classify each of the time period satellite image or areal image using same classification scheme and then compare to detect the change. The change in landcover can be detected from change due seasonality of landcover from same year and change in landcover from different year but same season. In this exercise we are going to investigate the landcover change and urbanisation in Cambodia from 2010 and 2015.

Learning Objectives

By going through this exercise, you will familiarize with techniques of landcover change detection using ArcMap and you will be able to:

- Compare multi-temporal landcover data
- Create summary of changes
- Detect spatial change pattern and investigate contributing factors

Data Inputs

X:\AGIT4DrRM\Training_Material\ModA2\s2\Practical\Data_Input\

File Name	Data Type
Raster\ESACCI-LC-L4-LCCS-300m-P1Y-2010-KHM-6C.tif	Single band Raster
Raster\ESACCI-LC-L4-LCCS-300m-P1Y-2015-KHM-6C.tif	Single band Raster

Section A: Symbolise the landcover dataset

- Open the workspace “A2S2_Landcover_Change_Detection_v10.mxd” from the following location –

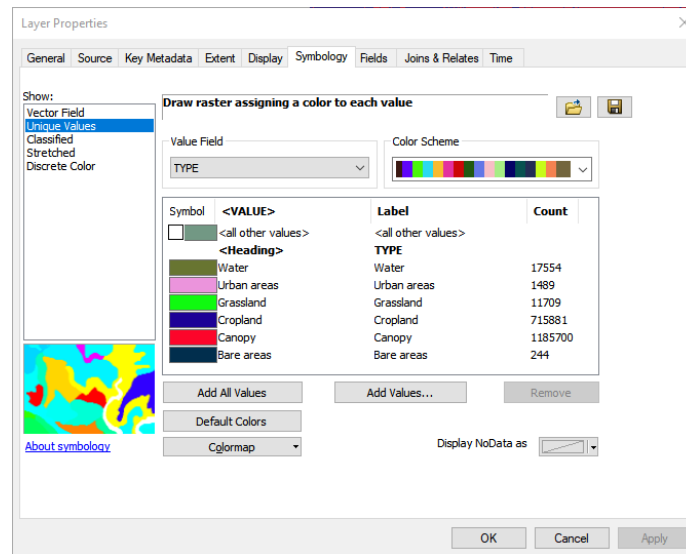
X:\AGIT4DrRM\Training_Material\ModA2\s2\Practical\Workspace

- Right click on the Landcover\2010 group layer > Click Add data > Add the raster named “ESACCI-LC-L4-LCCS-300m-P1Y-2010-KHM-6C.tif” from the following location

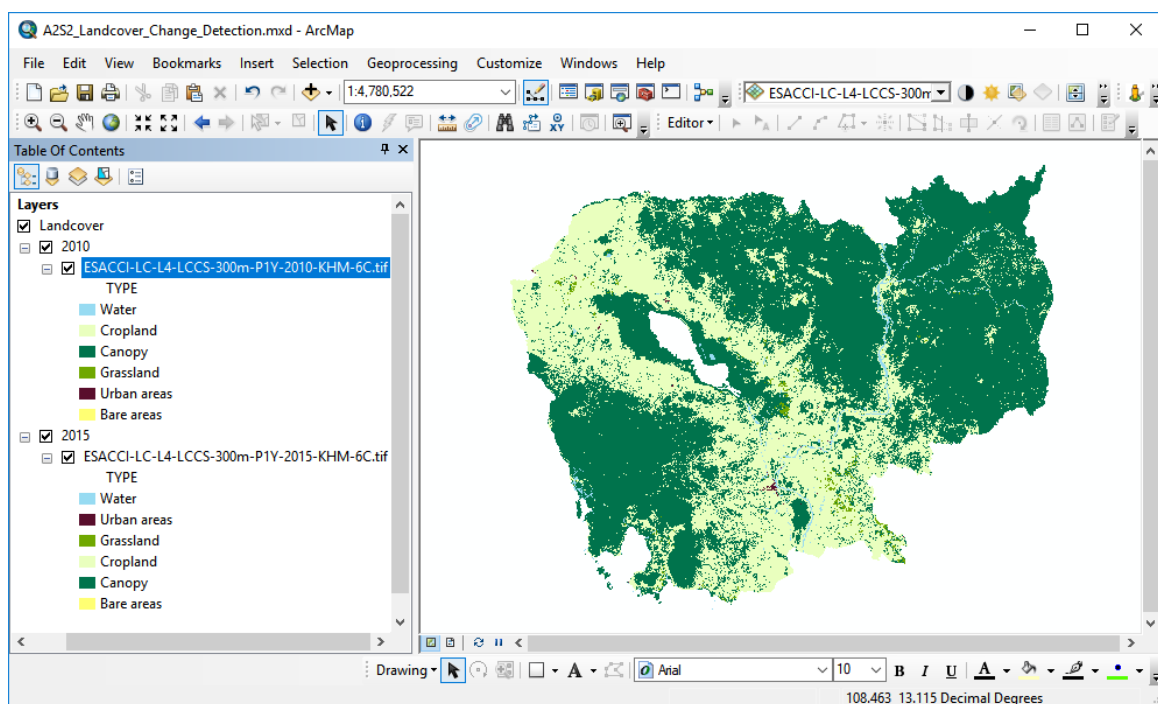
X:\AGIT4DrRM\Training_Material\ModA2\s2\Practical\Data_Input\Raster

This is the landcover dataset for the year 2010. Once this dataset is added by default it is visualised in a random colour palette from which it is quite impossible to understand the different landcover classes.

- Right click on the “ESACCI-LC-L4-LCCS-300m-P1Y-2010-KHM-6C.tif” > Properties > Symbology > Apply appropriate colour to different landcover classes



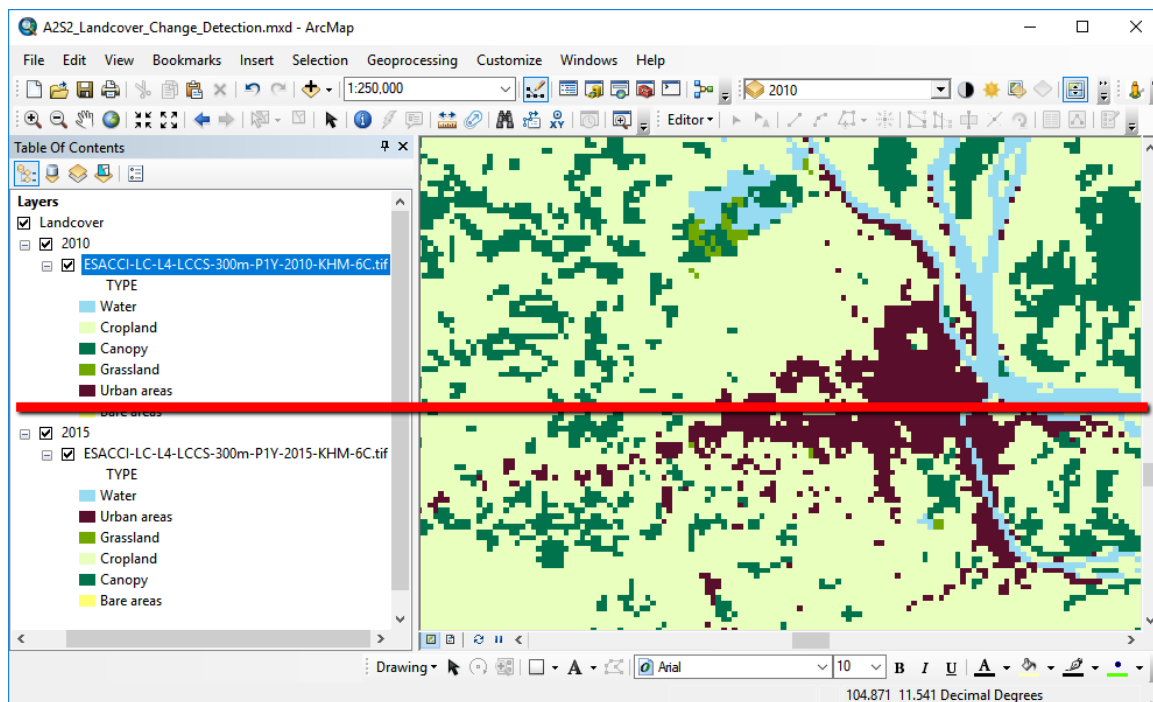
- Click apply ok



- Add the “ESACCI-LC-L4-LCCS-300m-P1Y-2015-KHM-6C.tif” under 2015 group layer.
- Click on the import symbology button > import the symbology from the “ESACCI-LC-L4-LCCS-300m-P1Y-2010-KHM-6C.tif” dataset

This process can import the symbology from the other dataset given the raster codes are same for both classifications.

- Use effects toolbar for comparing the two landcover dataset from the year 2010 and 2015.



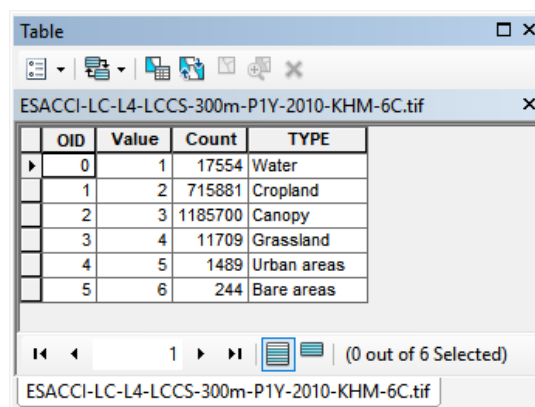
- *Comment on the change in and around Phnom Penh.*

Section B: Calculate summary statistics of changes

For change detection analysis it is important to determine the amount of land area is under each landcover type for each period. Then a comparative plot can help to visualise and determine percentage of change in landcover.

To do this we are going to take help of raster attribute table. For integer raster, for example an 8-bit unsigned raster it's possible to build an attribute table as only 256 numbers are possible. The attribute table hence provides the raster values and count for each value, which is somewhat different from the attribute table of vector.

Here we can see each individual value are listed with their corresponding counts as number of pixels. Each pixel has a spatial area from which we can calculate total land area per landcover.



OID	Value	Count	TYPE
0	1	17554	Water
1	2	715881	Cropland
2	3	1185700	Canopy
3	4	11709	Grassland
4	5	1489	Urban areas
5	6	244	Bare areas

⇒ From the attribute table calculate the land area for each landcover type for both 2000 and 2014 and fill-up the table.

Value	Class	Area in 2010 (km2)	Area in 2015 (km2)
1	Water		
2	Cropland		
3	Canopy		
4	Grassland		
5	Urban areas		
6	Bare areas		

⇒ Which landcover has undergone the maximum change? What can be the factors?

⇒ Are you able tell from this table which landcovers are under pressure from rapid urbanisation of PhnomPenh city?

Note:

By default, the landcover raster may not have attribute table. You can easily develop raster attribute table from Data Management Tools.

Section C: Investigate change factors

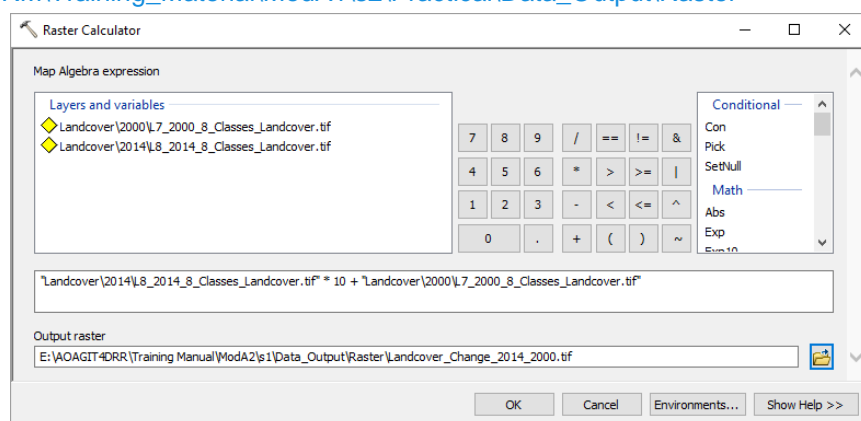
From the summary table it is really difficult to pinpoint which landcover transformed into what type of landcovers with the change of time. For this we usually employ a mathematical trick which is able to separate all the different 36 (6X6) different change combinations.

For this we are going to create a new raster from the formula –

Landcover 2015 *10 + Landcover 2010

- ⇒ Use raster calculator to a new raster data employing the above formula
“Landcover_Change_2015_2010.tif” in the following location

X:\AGIT4DrRM\Training_Material\ModA1\s2\Practical\Data_Output\Raster



If we obtain a value of 12, that means, now the landcover is Water, previously it used to be cropland.

- ⇒ Please fill up the following table with appropriate interpretation and total land area on each

Class in 2015	Class in 2010	Landcover 2015 *10 + Landcover 2010	Interpretation of value	Total Area Km ²
Urban (5)	Water (1)	51	Water in 2010, Urban in 2015⇒ Urbanisation on water buffer	
Urban (5)	Cropland (2)			
Urban (5)	Canopy (3)			
Urban (5)	Grassland (4)			
Urban (5)	Urban areas (5)			
Urban (5)	Bare areas (6)			

- ⇒ Describe the effect of urbanisation of different other landcover categories and please explain what kind of risk rapid urbanisation may increase?

[END OF EXERCISE]