Report of Fuzzy Classification and Object Monitoring

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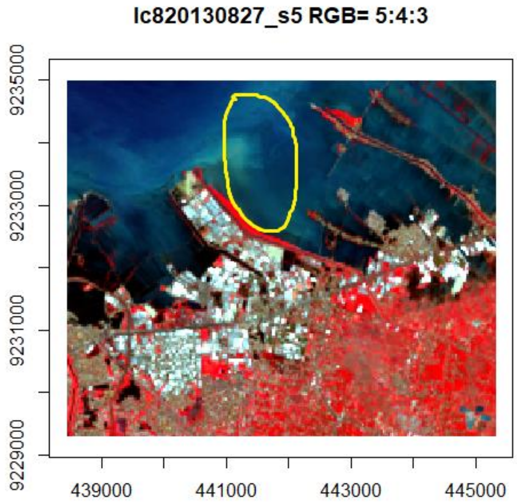
Question 1: In your subset several land cover classes are visible. Select one class which has fuzzy boundaries in geographic space, as well as a change between the two images, based on visual inspection of the two images. Motivate your choice and show a screenshot where you indicate that class and mark (a part of) the target fuzzy boundary. Include this annotated screenshot and motivation in your report (MS Word document).

The class that I select is water. It has a fuzzy boundary in the shore. This has been marked in the two RGB images (see bellow). This region is located between continental shelf and the sea. It is fuzzy, because it is difficult to label whether it belongs to land or sea. In the RGB=543 image, the fuzzy boundary goes gradually changes its color from light blue to dark blue and even to black. This region is shown in google earth as well. See the region circled by the yellow line.

This fuzzy boundary has a change in the two images. In the 2017, the light blue area increases a lot, compared with 2013. This increased area is located along the land.

I set RGB as 543. Because, in the feature space, among all the bands, these three bands provide the biggest differences from each other. Secondly, 543 is able to distinguish water from land. Thirdly, in ERDAS, 543 is able to show the color changes of water much more clearly than other band combinations.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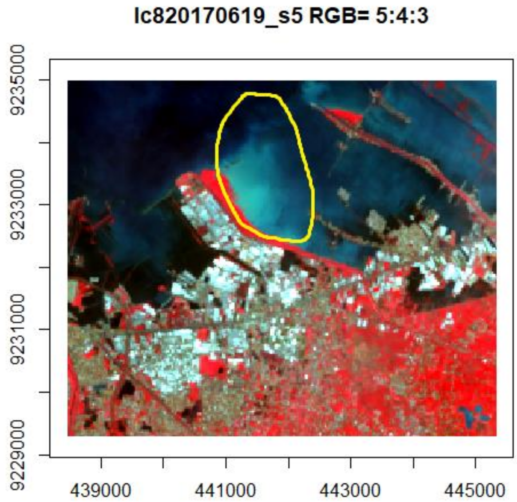
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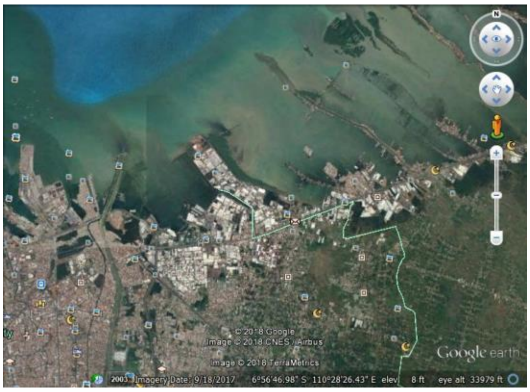
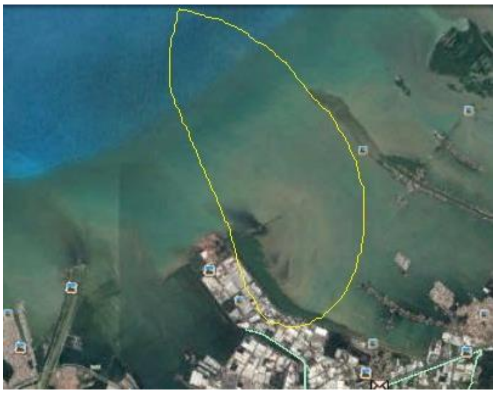
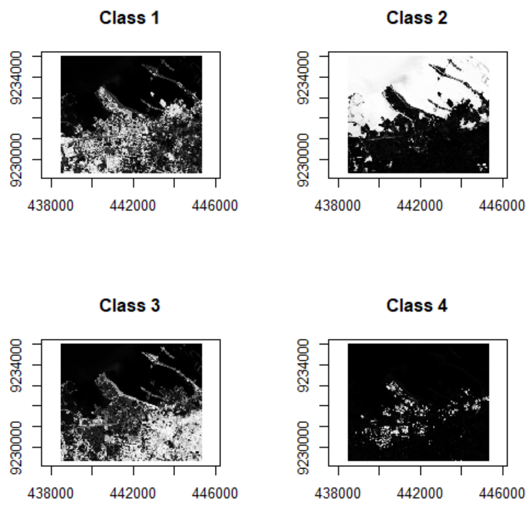
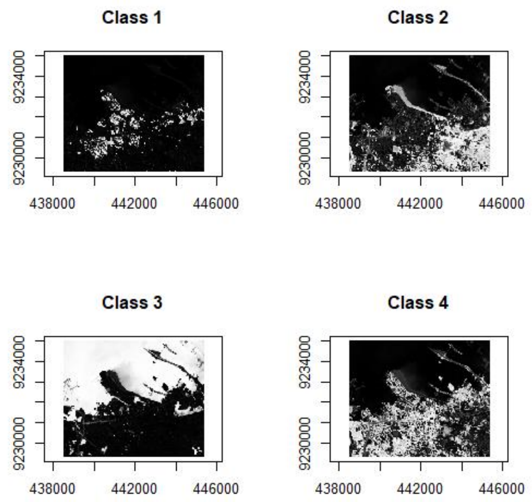
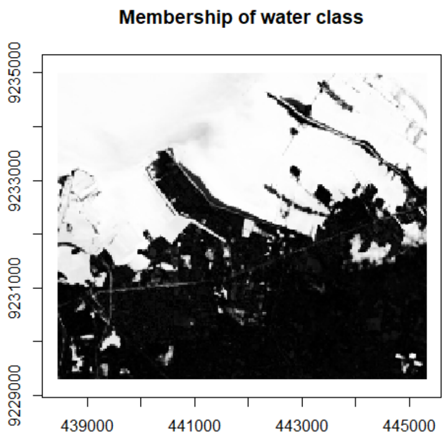
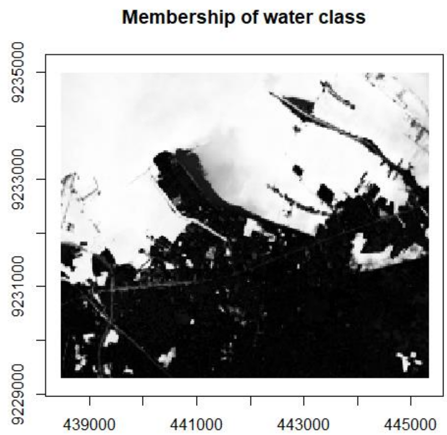

© 2018 Google
Image © 2018 CNES / Airbus
Image © 2018 TerraMetrics
Google earth



Question 2: Perform a fuzzy classification on provided images using R to map the class you have selected in Question 1. Store screenshots of your classifications (membership to the target class only) in your report. Specify and motivate your choices of the number of classes and of the parameter *m*. Also show a colour composite of the two membership images for your target class, make sure you specify which image is assigned in which colour. Remember that the aim of the classification is to detect changes in the surface area of the target class through time. If you decide to manipulate classes after the classification specify the image where this happens and how you did that.

Store screenshots of your classifications (membership to the target class only)

<table>
<tr><td></td><td>2013</td><td>2017</td></tr>
<tr><td>4 classes after iteration</td><td>
</td><td>
</td></tr>
<tr><td>Membership of my target class (water)</td><td>
</td><td>
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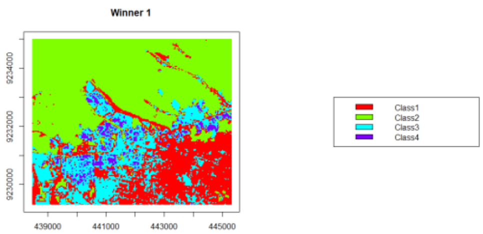
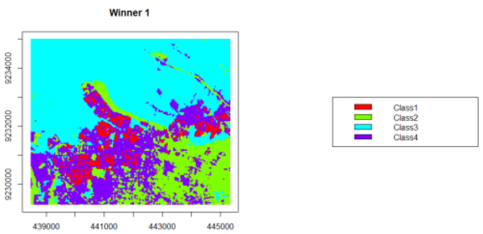
<tr><td>Winner 1</td><td>
</td><td>
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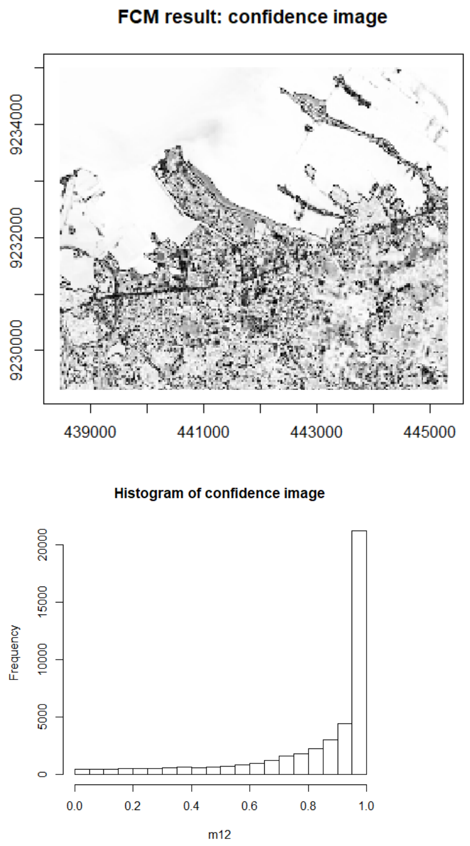
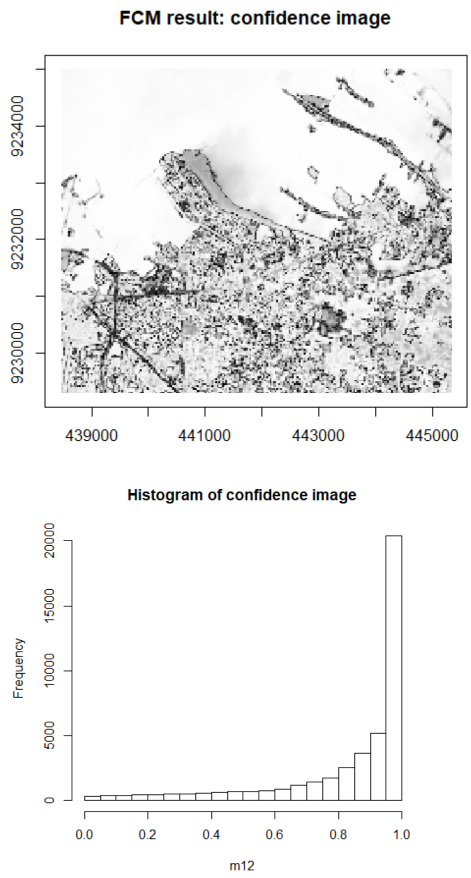
FCM confidence image		

Motivate your choices of the number of classes and of the parameter *m*.

Number of classes Ncl: 4. When Ncl is too big, we classify too many classes. Then there is a chance that 2 classes are very similar. If we are interested in one of the classes, then the other class which provides useful information will be ignored. The accuracy of the classification will be low. When Ncl is too small, Then there is a chance that 2 different classes are grouped into one class. Too much noise will be added into our target class.

The fuzzy parameter m: 2. When m is too big, fuzziness will be changed slightly. The degree of changes will be small. Thus, it is difficult to see the membership difference of two pixel values. When m is too small, fuzziness will be changed slightly drastically. The degree of changes will be large. Thus, some pixel values might not be covered or not be included in the fuzzy analysis.

4. Object based monitoring

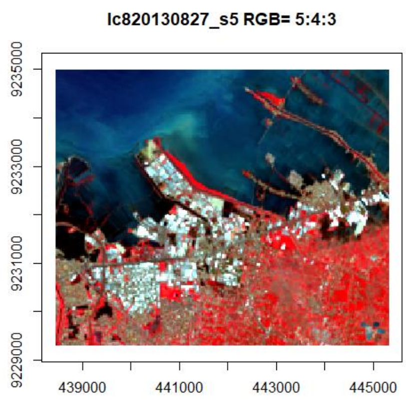
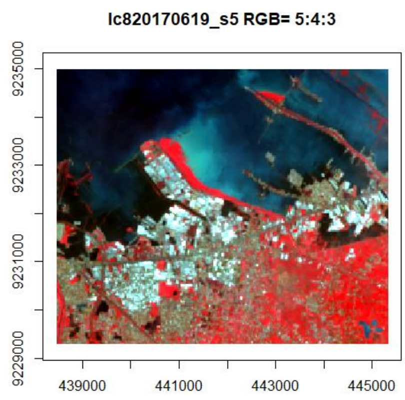
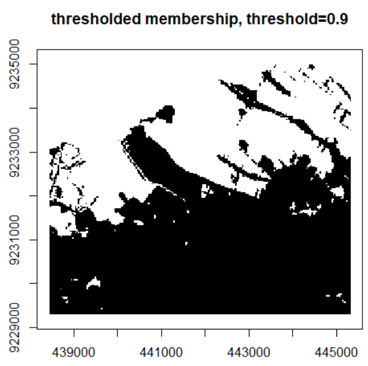
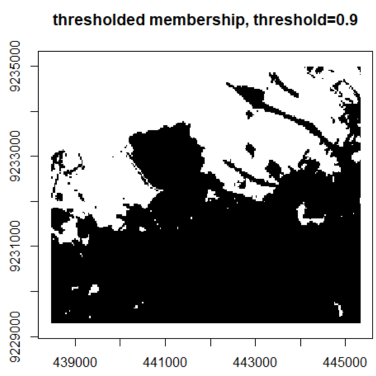
From the membership images of the target class, you need to group pixels to form the vague object. Then you can analyse changes in the target class.

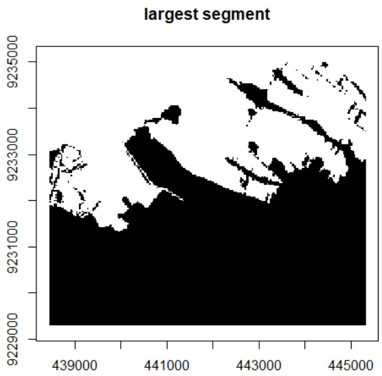
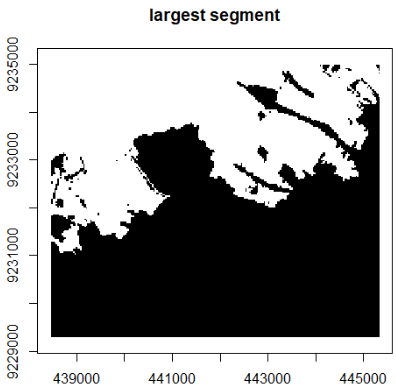
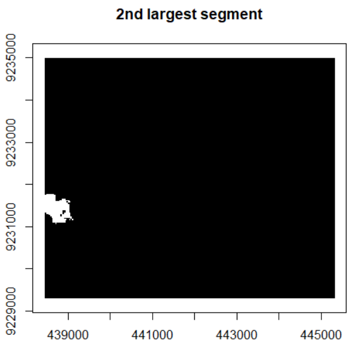
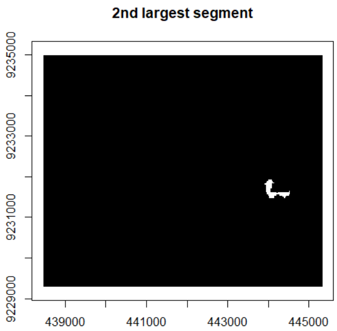
Question 3: For each of the membership images of the target class which you obtained, group the pixels belonging to the target class into one or more segments. Include screenshots of the segments in your report document. Explain and motivate how you obtained the segments. Do these segments coincide with (real-world) objects? Or in other words: has segmentation led to successful object detection? Please, motivate your answer in your report.

Explain and motivate how you obtained the segments.

In the membership image, each pixel has a value in the range from 0 to 1. This value is membership. Membership means how big the possibility is that this pixel belongs to my target class. In order to group the pixels into segments, a threshold need to be set. The pixels which have higher memerbership than the threshold will be considered as “belong to the target class”. The pixels which have lower memerbership than the threshold will be considered as “NOT belong to the target class”. Then the pixels that are “belong to the target class” will be grouped together to form the segments.

Threshold=0.9

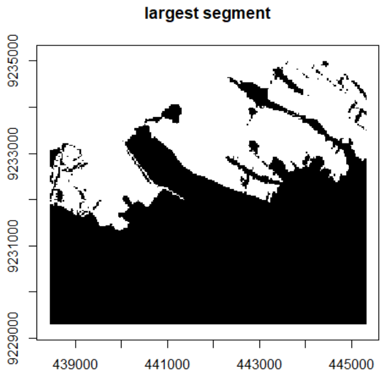
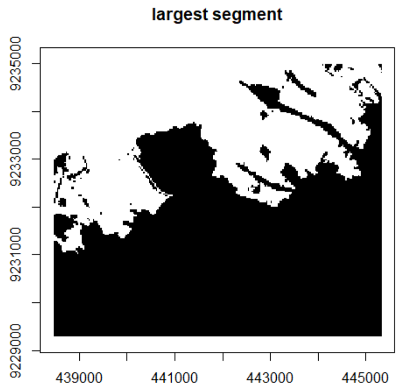
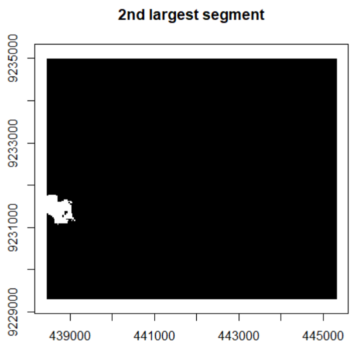
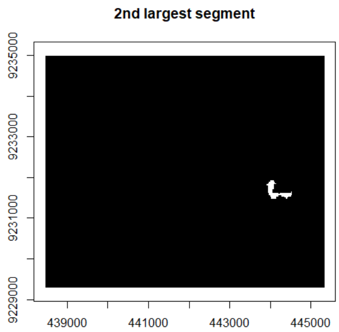
	2013	2017
Original RGB image		
Thresholded memebrship		

Largest segment (see white part)		
	Area of the largest segment is 16478100 m^2	Area of the largest segment is 15405300 m^2
Second largest segment (see white part)		
	Area of the 2nd largest segment is 298800 m^2	Area of the 2nd largest segment is 101700 m^2

Does segments coincide with (real-world) objects?

Yes, the segments coincide with (real-world) objects. I have selected water as the real-world object. In all the images above, the white areas are my segments. I compare the white area in the thresholded-membership image with the original image, they do locate on the same location. So the segmentation process is successful.

Question 4: Calculate the surface area of the largest matching segment for each date. Explain how you calculated the lake surface area and show the result for all images in a table.

	2013	2017
Largest segment		
Area of largest segment	Area of the largest segment is 16478100 m^2	Area of the largest segment is 15405300 m^2
Second largest segment		
Area of second largest segment	Area of the 2nd largest segment is 298800 m^2	Area of the 2nd largest segment is 101700 m^2

Explain how you calculated the lake surface area and show the result for all images in a table.

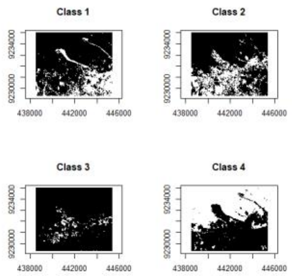
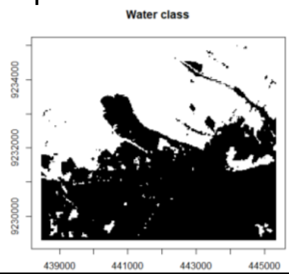
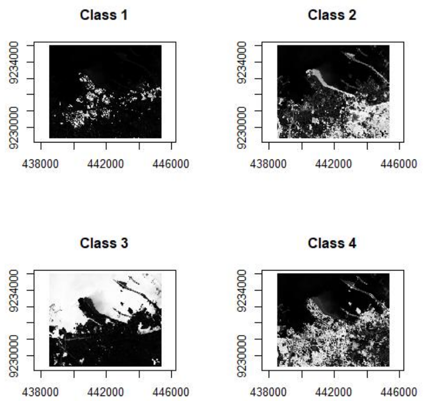
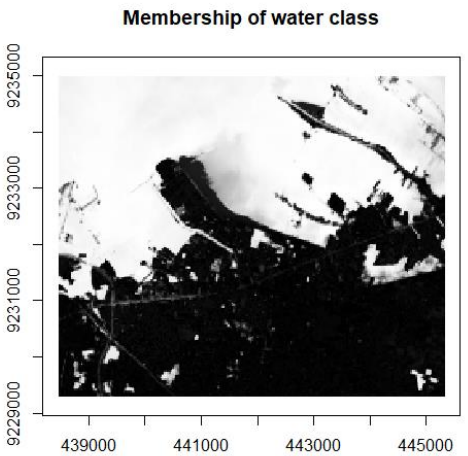
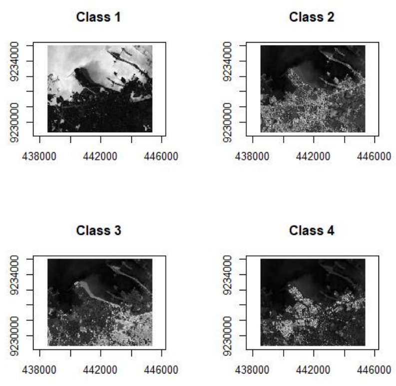
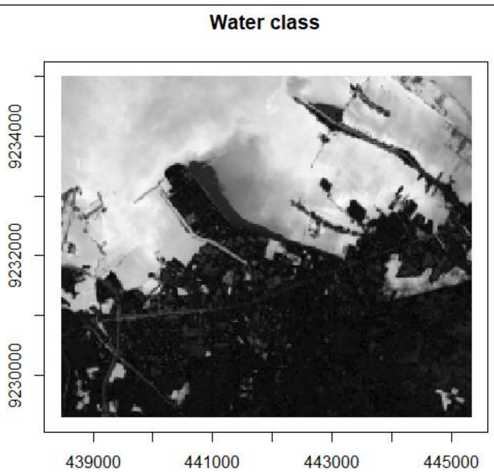
Largest segment means: a group of pixels which the sum of their area is the largest. Assume each pixel has an area A_i. Then we can calculate the total surface area of the largest segment:

$$\text{Total area} = A_1 + A_2 + ... + A_n \text{ .}$$

Question 5: Choose one image (specify which one) and estimate the uncertainty in area estimation due to the method used, i.e. due to the use of FCM and thresholding. Provide a numeric estimate of the uncertainty and an explanation how this was obtained.

I choose the image 2017.

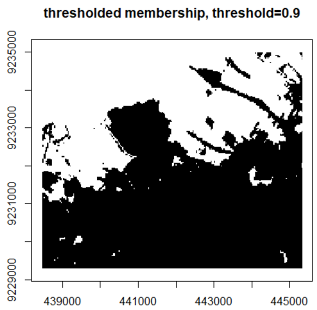
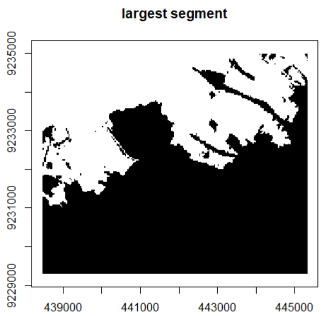
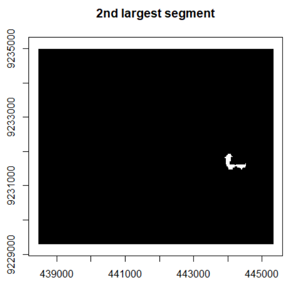
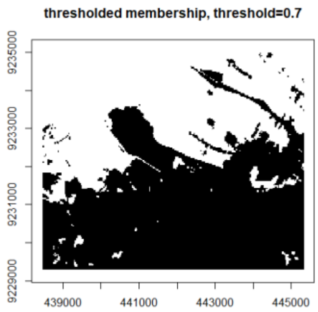
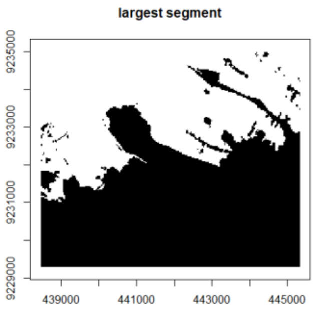
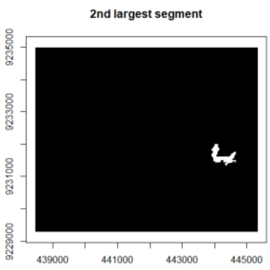
1) Fuzzy parameter has an influence on the uncertainty. Current fuzzy parameter m is 2. We can change m to 1 or 2. We recalculate the fuzzy-c-mean. Then the area result will be different. When m=1, it is not able to convergence. When m =3, it provide more degree of fuzziness than m=2. This is why we see more grey areas in the membership image of m=3. As I said in question 2 “When m is too big, fuzziness will be changed slightly. The degree of changes will be small. Thus, it is difficult to see the membership difference of two pixel values. When m is too small, fuzziness will be changed slightly drastically. The degree of changes will be large. Thus, some pixel values might not be covered or not be included in the fuzzy analysis.”

Fuzzy parameter	After computation, 4 classes	Water class
M=1		Not able to convergence! So this result is problematic 
M=2		
M=3		

2) Number of class has an influence on the uncertainty. We can set number of class Ncl as 4 or 8, or 10. Then werecalculate the fuzzy-c-mean. The area result will be different. As I said in question 2 “When Ncl is too big, we classify too many classes. Then there is a chance that 2 classes are very similar. If we are interested in one of the classes, then the other class which provides useful information will be ignored. The accuracy of the classification will be low. When Ncl is too small, Then there is a chance that 2 different classes are grouped into one class. Too much noise will be added into our target class.”

3) Thresholding has an influence on the uncertainty. Lowing down the thresholding will allow more pixels to be labeled as water class. So, when threshold is 0.70, the corresponding area is larger than the area when threshold is 0.90. Numerical calculation can be seen in the following table.

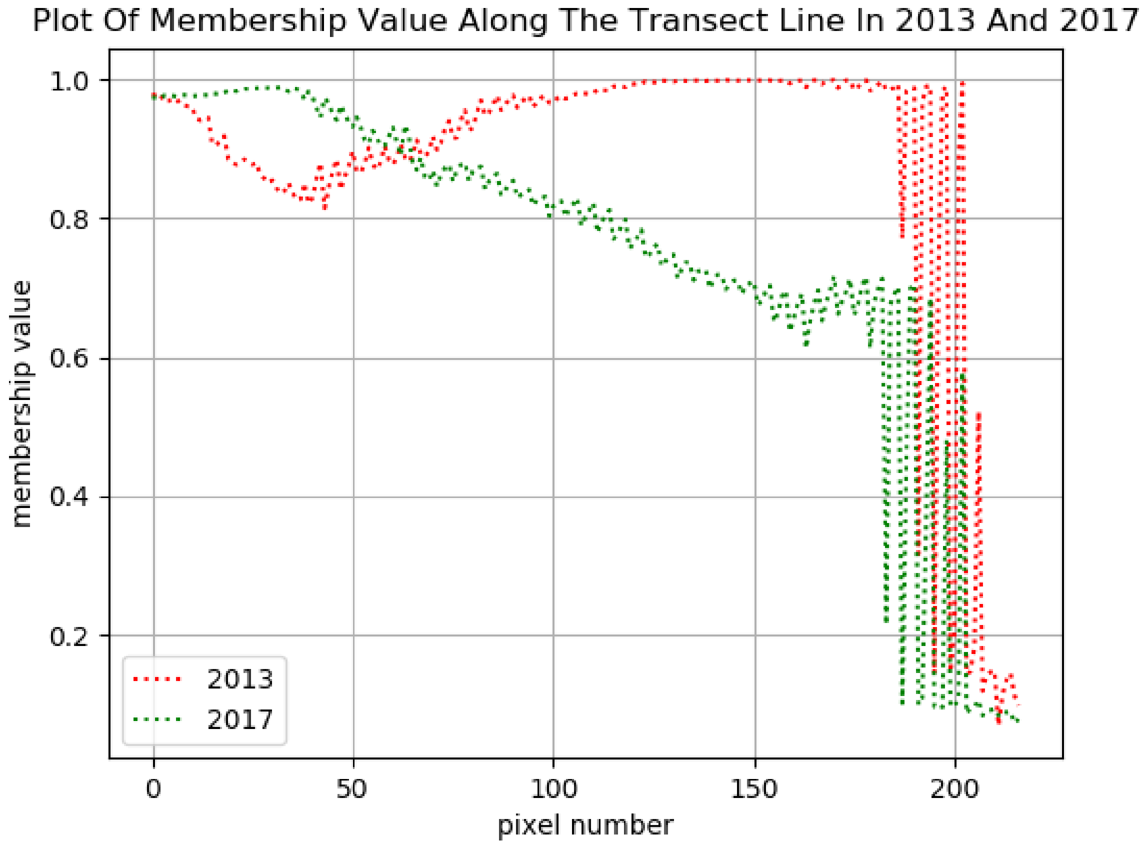
Assume: m and Ncl are both fixed (m=2 and Ncl=4), only change thresholding. The result are in the following table:

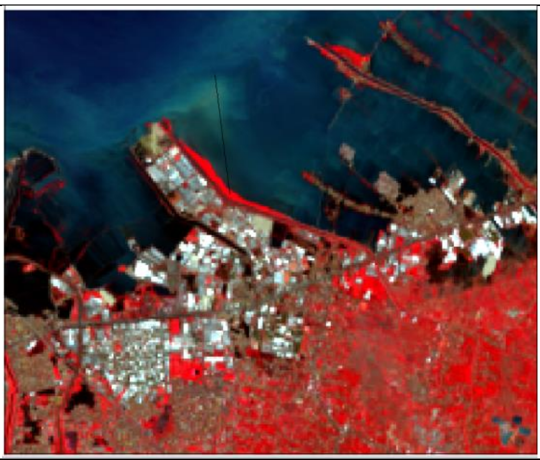
	2017 water object (thresholded membership)	2017 largest area	2017 second largest area
When threshold= 0.90			
		Area of the largest segm ent is 15405300 m^2	Area of the 2nd larges t segment is 101700 m^2
When threshold= 0.70			
		"Area of the largest seg ment is 17155800 m^2"	"Area of the 2nd large st segment is 198000 m^2"
Numerical difference between estimated area of		17155800 m^2-1540530 0 m^2 =1 750 500 m^2	198000 m^2-101700 m^2 =96 300 m^2

threshold 0.90 and threshold 0.70			

4) Even though the above 3 parameters are fixed, the fuzzy classification result could still be slightly different in different times of run. Because the initial mean values of the classes are randomly chosen. For each time of running, the initial mean will be different. This has an influence on the classification. Therefore, it has an influence on the uncertainty of area estimation.

Question 6: Reflect on obtained membership transect graphs. Do you observe a difference in the two graphs? Is this observation in agreement with the temporal change as determined by the analysis of the object area?



	2013	2017
Transection line overlapped with original image		

Transect line overlapped with membership image		

In the plot of membership value, both of lines (2013 and 2017) starts from 1 and ends at value which is close to zero. This means the transect line starts from “very likely to be water”, and then the possibility gradually decreases, finally ends with “very unlikely to be water”. The line 2017 shows much more fuzziness, compared with the line 2013.

This matches with my observation in the original images. It also agrees with membership images. In 2017, the light blue area along the coast is enlarged to a large extent. The reason could be the increasing amount of constructions along the coast. It also could be a result of increasing amount of river sediments and mangrove planting. So grey region in the membership image increases. The line 2017 shows much more fuzziness. When the pixel number is around 200, more membership values are close to zero. Because the transect line reaches the land.

However, there are some limitations on this transect line.

Firstly, the fuzzy zone in image 2013 locates leftwards to the transect line, while the fuzzy zone in image 2013 is located on right side of the transect line. If I draw a line that fit the fuzzy boundary of 2017 image very well, then its direction is somewhat different from the transect line that fits 2013 image. So I decided to draw a line that both fuzzy boundaries touches as much as possible. As a result, the direction of the transect lines does not fully perpendicular to any of the boundary. This influences the plot. It would be nice to draw a curved line, instead of a straight line.

Secondly, the length of the line also has and influence on the plot. The longer the length, the more information will show. However, if the line is too long, the fuzziness part will be squashed in the plot. It will not be shown well. If the line is too short, the fuzziness part will not be fully presented.

Thirdly, I set fuzzy parameter as 2. It shows less fuzziness, compared with m=3. So if I set m=3, the plot will show more fuzziness.

Question 7: Evaluate your result of changes in the target class surface area. Did the surface area change over time? What can you say about the uncertainties of the surface area estimates and the uncertainties in the changes in surface area?

Yes, the surface area changes over time. The amount of water pixels in 2017 is smaller than those in 2013. This means water surface area is decreasing. Answer of the uncertainty is the same as the answer of Question 5.