

Fast and Automatic Data-Driven Thresholding for Inundation Mapping with Sentinel-2 Data

Georgios A. Kordelas, Ioannis Manakos, David Aragonés, Ricardo Díaz-Delgado and Javier Bustamante

This supplementary material supports the main text as follows:

Supplementary 2. Accuracy Assessment Results for Iap Situation

1. Accuracy Assessment per date

The results for IAP (Including Boundary Ambiguous pixels) situation are given in Table 1, Table 2, Table 3, Table 4, and Table 5. The accuracy estimation results include the estimation of Producer's Accuracy (PA), User's Accuracy (UA), Overall Accuracy (OA), and kappa coefficient (k). The confusion matrices, based on which the results of Tables 1-5 are produced, are included in Supplementary 3. A detailed insight in the results is given in the following.

Table 1 presents the accuracy assessment for the complete buffered Biosphere Reserve area. Part A of Table 1 indicates that the PA of Water class is over 79.84% for all dates. The UA of water class is low for two dates during the summer period; on 16/07/2016 (64.57%) and 25/08/2016 (63.16%), while for the rest of the dates UA is over 89.86%. On the other hand, Part B of Table 1 indicates that the PA and UA of water class are over 90.75% and 72.40% for all dates, respectively. For both approaches, k is over 0.7.

Table 1. Part A and Part B show for the complete area the accuracy assessment results for the unsupervised and supervised approaches, respectively.

Part A		Unsupervised – Complete area													
Date \ Class	29 Dec. 2015		6 June 2016		16 July 2016		25 Aug. 2016		4 Oct. 2016		23 Dec. 2016		1 June 2017		
	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	
Water class	87.28%	90.10%	87.40%	89.86%	84.94%	64.57%	90.76%	63.16%	79.84%	93.51%	81.19%	93.03%	88.78%	92.32%	
Non-water class	98.74%	98.34%	98.74%	98.39%	95.64%	98.55%	95.06%	99.10%	99.82%	99.33%	98.26%	94.81%	98.50%	97.74%	
OA	97.42%		97.45%		94.72%		94.70%		99.17%		94.47%		96.86%		
k	0.8721		0.8718		0.7050		0.7163		0.8571		0.8323		0.8864		

Part B		Supervised – Complete area													
Date \ Class	29 Dec.2015		6 June 2016		16 July 2016		25 Aug.2016		4 Oct.2016		23 Dec.2016		1 June 2017		
	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	
Water class	96.77%	84.71%	95.89%	84.95%	94.24%	83.18%	4.56%	72.40%	90.75%	87.74%	96.68%	83.92%	97.45%	88.31%	
Non-water class	97.71%	99.57%	97.83%	99.47%	98.22%	99.45%	96.64%	99.48%	99.58%	99.69%	94.70%	99.01%	97.38%	99.47%	
OA	97.60%		97.61%		97.88%		96.46%		99.29%		95.14%		97.40%		
k	0.8898		0.8873		0.8720		0.8008		0.8885		0.8668		0.9108		

Accuracy assessment results for each type of wetland: (a) seasonal marshes, (b) cultivated rice-paddies, and (c) temporary ponds, are presented in the following.

Table 2 presents the accuracy assessment for the marshland area. Part A of Table 2 indicates that the PA of water class is low for one date; on 04/10/2016 (52.82%), while for the rest of the dates it is over 66.41%. The UA of water class is low for one date during the summer period; on 25/08/2016 (53.55%), while for the rest of the dates UA is over 64.29%. On the other hand, Part B of Table 2 indicates that the PA and UA of water class are over 71.03% and 56.77%, respectively. For the unsupervised approach k is over 0.7146, with the exception of 25/08/2016 and 04/10/2016, where k is around 0.58. For the supervised approach k is over 0.8184, with the exception of 25/08/2016 and 04/10/2016, where k is 0.718 and 0.6303, respectively.

Table 3 presents the accuracy assessment for the rice-paddies. Part A of Table 3 indicates that the PA of Water class is very low on 04/10/2016 (34.80%), while for the rest of the dates is over 80.61%. The UA of water class is over 63.83%. On the other hand, Part B of Table 3 shows that the PA and UA of water class are over 69.82% and 63.20%, respectively. For the unsupervised approach k is over 0.4694, while for the supervised approach k is over 0.6249.

Table 4 presents the accuracy assessment for the temporary ponds areas. Part A of indicates that the PA ranges from 40.27% to 75.79%, while the UA ranges from 19.03% to 81.22%. Part B of Table 4 indicates that the PA ranges from 53% to 80.77%, while the UA ranges from 16.20% to 59.56%. For the unsupervised approach, k ranges from 0.2886 to 0.6897, while for the supervised approach k ranges from 0.2565 to 0.6716.

Table 2. Part A and Part B show for the marshland, the accuracy assessment results for the unsupervised and supervised approaches, respectively.

Part A		Unsupervised – Marshland													
Class \ Date	29 Dec. 2015		6 June 2016		16 July 2016		25 Aug. 2016		4 Oct. 2016		23 Dec. 2016		1 June 2017		
	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	
Water class	79.36%	90.57%	83.87%	94.79%	73.91%	74.75%	66.41%	53.55%	52.82%	64.29%	90.25%	98.78%	83.84%	97.27%	
Non-water class	99.68%	99.20%	98.47%	94.86%	99.83%	99.82%	99.82%	99.90%	99.94%	99.91%	97.33%	80.67%	98.11%	88.32%	
OA	98.91%		94.84%		99.66%		99.72%		99.85%		92.33%		91.76%		
k	0.84030		0.8565		0.7416		0.5916		0.5791		0.8261		0.8308		

Part B		Supervised – Marshland													
Class \ Date	29 Dec. 2015		6 June 2016		16 July 2016		25 Aug. 2016		4 Oct. 2016		23 Dec. 2016		1 June 2017		
	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	
Water class	91.83%	78.45%	95.57%	88.30%	84.18%	79.87%	78.84%	66.08%	71.03%	56.77%	98.19%	92.96%	97.13%	92.24%	
Non-water class	99.01%	99.68%	95.81%	98.49%	99.86%	99.89%	99.88%	99.94%	99.89%	99.94%	82.23%	94.99%	93.44%	97.60%	
OA	98.74%		95.75%		99.75%		99.81%		99.83%		93.48%		95.09%		
k	0.8396		0.8893		0.8184		0.7180		0.6303		0.8369		0.9010		

Table 3. Part A and Part B show for the rice-paddies, the accuracy assessment results for the unsupervised and supervised approaches, respectively.

Part A		Unsupervised – Rice-paddies													
Class \ Date	29 Dec. 2015		6 June 2016		16 July 2016		25 Aug. 2016		4 Oct. 2016		23 Dec. 2016		1 June 2017		
	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	
Water class	91.13%	97.41%	90.18%	93.21%	82.69%	64.17%	93.75%	63.83%	34.80%	79.23%	80.61%	96.32%	94.04%	97.60%	
Non-water class	95.90%	86.48%	96.11%	94.30%	66.04%	83.84%	60.24%	92.79%	99.88%	99.18%	94.19%	72.01%	95.55%	89.26%	
OA	92.90%		93.91%		73.10%		74.58%		99.07%		85.31%		94.55%		
k	0.8514		0.8687		0.4694		0.5098		0.4797		0.6974		0.8809		

Part B		Supervised – Rice-paddies													
Class \ Date	29 Dec. 2015		6 June 2016		16 July 2016		25 Aug. 2016		4 Oct. 2016		23 Dec. 2016		1 June 2017		
	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	
Water class	99.21%	93.10%	96.79%	88.15%	94.85%	85.23%	95.14%	70.44%	69.82%	63.20%	97.97%	88.29%	99.06%	95.44%	
Non-water class	87.56%	98.50%	92.29%	97.98%	87.90%	95.87%	70.10%	95.07%	99.49%	99.62%	75.45%	95.16%	90.88%	98.05%	
OA	94.88%		93.97%		90.85%		80.82%		99.12%		90.17%		96.27%		
k	0.8879		0.8734		0.8154		0.6249		0.6590		0.7718		0.9155		

Table 4. Part A and Part B show for the temporary ponds, the accuracy assessment results for the unsupervised and supervised approaches, respectively.

Part A		Unsupervised – Temporary Ponds													
Class	Date	29 Dec. 2015		6 June 2016		16 July 2016		25 Aug. 2016		4 Oct. 2016		23 Dec. 2016		1 June 2017	
	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	
Water class		55.88%	73.87%	73.33%	65.22%	75.79%	42.04%	71.79%	31.19%	59.98%	19.03%	40.27%	81.22%	69.08%	58.26%
Non-water class		99.97%	99.93%	99.92%	99.95%	99.89%	99.97%	99.92%	99.99%	99.92%	99.99%	99.96%	99.72%	99.87%	99.92%
OA		99.90%		99.87%		99.87%		99.91%		99.91%		99.68%		99.79%	
k		0.6358		0.6897		0.5402		0.4345		0.2886		0.5370		0.6311	

Part B		Supervised – Temporary Ponds													
Class	Date	29 Dec. 2015		6 June 2016		16 July 2016		25 Aug. 2016		4 Oct. 2016		23 Dec. 2016		1 June 2017	
	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	
Water class		61.06%	55.41%	77.19%	59.56%	80.77%	41.55%	79.84%	30.18%	62.02%	16.20%	53.00%	57.95%	77.86%	59.14%
Non-water class		99.92%	99.94%	99.90%	99.96%	99.88%	99.98%	99.91%	99.99%	99.90%	99.99%	99.82%	99.78%	99.86%	99.94%
OA		99.86%		99.85%		99.86%		99.90%		99.89%		99.61%		99.80%	
k		0.5803		0.6716		0.5481		0.4376		0.2565		0.5517		0.6712	

2. Combined Accuracy

The rows in Table 5 provide the PA, UA, OA, and k , which are estimated when the number of true positive pixels of water class, false positive pixels of water class, true positive pixels of non-water class, and false positive pixels of non-water class are added for all 7 dates per approach and examined study area (information about the approach and the study area is given in the second column).

Table 5. Combined accuracy assessment for 7 different dates.

Approach and Study area	Measure	Water Class		Non-Water Class		OA	k
		PA	UA	PA	UA		
		1	Unsupervised (MCET): Complete area	85.78%	83.94%		
2	Supervised: Complete area	96.04%	83.73%	97.51%	99.46%	97.34%	0.8795
3	Unsupervised: Marshland	86.72%	97.14%	99.33%	96.63%	96.72%	0.8961
4	Supervised: Marshland	97.11%	91.33%	97.59%	99.23%	97.49%	0.9254
5	Unsupervised: Rice-paddies	88.46%	84.92%	86.94%	90.07%	87.63%	0.7514
6	Supervised: Rice-paddies	97.40%	87.14%	88.06%	97.60%	92.30%	0.8461
7	Unsupervised: Temporary Ponds	57.97%	57.13%	99.92%	99.92%	99.85%	0.5747
8	Supervised: Temporary Ponds	66.45%	50.83%	99.88%	9.94%	99.82%	0.5751
9	Unsupervised (Otsu): Complete area	90.83%	72.23%	95.35%	8.73%	94.82%	0.7753

For the complete buffered Biosphere Reserve area, by comparing the 1st and 2nd rows of Table 5 it is estimated that for the water class the PA of the unsupervised approach is **10.26%** lower than the supervised approach, while the UA of the unsupervised approach is **0.21%** higher. k of the supervised approach is about **6.02%** higher than the unsupervised approach. For the marshland area, by comparing the 3rd and 4th rows of Table 5 it is estimated that for the water class the PA of the unsupervised approach is **10.39%** lower than the supervised approach. In contrast, the UA of the

unsupervised approach is **5.81%** higher than the supervised approach. k of the supervised approach is about **3.22%** higher than the unsupervised approach. For the rice-paddies, by comparing the 5th and 6th rows of Table 5 it is estimated that for the water class the PA and UA of the unsupervised approach are **8.94%** and **2.22%** lower than the supervised approach, respectively. k of the supervised approach is about **11.86%** higher than the unsupervised approach. For the temporary ponds, by comparing 7th and 8th rows of Table 5 it is estimated that for the water class the PA of the unsupervised approach is **8.48%** lower than the supervised approach. In contrast, the UA of the unsupervised approach is **6.30%** higher than the supervised approach. k of the supervised approach is about **0.07%** higher than the supervised approach. Summarizing, the combined accuracy assessment results, the PA of the unsupervised approach is **8.48%-10.39%** lower than that of the supervised approach, while the UA of the unsupervised approach can be lower or higher than that of the supervised approach, with a fluctuation ranging from **0.21% to 6.30%**. k is higher for the supervised approach for all study areas, except for the temporary ponds.

The 9th row of Table 5 provides PA, UA and the OA derived from the inundation maps estimated for the Complete area relying on the unsupervised approach and the Otsu method (see subsection 3.3.2 in the main manuscript). The 9th row is compared to the 1st row to evaluate how the performance of the unsupervised approach is affected when Otsu method is used instead of MCET for estimating splitting thresholds. Though, PA of the unsupervised approach with MCET is 5.05% lower than PA of the unsupervised approach with Otsu, UA of the unsupervised approach with MCET is 11.71% higher than UA of the unsupervised approach with Otsu. Additionally, when using Otsu in the unsupervised approach, PA is significantly higher than the UA (the difference between them is 18.6% for EAP). On the contrary, when MCET is used in the unsupervised method the difference between PA and UA is limited to 1.84%. k is about 6.59% higher when using MCET than Otsu.