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AUTOMATIC WATER FEATURE EXTRACTION FOR DIGITAL MAPPING

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ملخص البحث :

تهدف هذه الدراسة إلى تحديد أفضل تقنية لاستنباط المسطحات المائية من بيانات صور الاقمار الصناعية باختبار سبع تقنيات باستخدام صور (Landsat 8) و (sentinel 2B) و تقييم أدائها في استنباط المسطحات المائية . تشمل الأساليب السبعة تقنيات تصنيف الصور الخاضعة للإشراف وغير الخاضعة للإشراف و (NDWI) و (MNDWI) و (SWI) و (WRI) و (AWEI) وتشير النتائج إلى تفوق تقنية التصنيف غير الخاضعة للاشراف نتيجة الجمع بين النطاقات (من 1 الى 7) و (MNDWI) والتي تبلغ دقتها 96.67٪ مقارنة بالتقنيات الأخرى لاستنباط أسطح المياه من بيانات لاندسات . كما تتراوح دقة الطرق الأخرى من 68.33٪ إلى 93.33٪ للقمر (Landsat 8) و من 80٪ إلى 85٪ للقمر (Sentinel 2B) ، و ان (NDWI) يعمل أيضًا بشكل أفضل لبيانات القمر (Sentinel 2B) عن بيانات القمر (Landsat 8) . وقد أشارت نتائج الدقة إلى أن مؤشر مياه واحد قد لا يوفر النتائج المثلى لمختلف أنواع صور الأقمار الصناعية.

Abstract :

The presented paper aims to determine the best technique for water surfaces extraction through two sensors with different resolution, seven techniques are tested using (Sentinel-2B) and (Landsat-8) satellite images and their performances in extracting the water surfaces are evaluated. The seven techniques include supervised and unsupervised image classification techniques, Normalized Difference Water Index (NDWI), Modified Normalized Difference Water Index (MNDWI), Sentinel water index (SWI), Water Ratio Index (WRI) and Automated Water Extraction Index (AWEI). The results showed that the unsupervised classification for combination (bands 1:7 and MNDWI) has greater performance when compared to other techniques for extracting water surfaces from Landsat data, with an accuracy of 96.67%. On Landsat data accuracy ranges from 68.33 % to 93.33 %, while on Sentinel-2B, accuracy ranges from 80 % to 85 %. According to these accuracy results, one water index may not provide the best results on all types of satellites [1].

Key words: Water extraction, NDWI, MNDWI, SWI, WRI and AWEI.

1.Introduction

Water is the main component of human lives, the main water sources include rivers, lakes, rainfall, sea and stream. Proper identification and water management of these sources would be of great importance for human beings. Water areas have been identified using either field surveying or remote sensing techniques [2]. The use of remote sensing technique provides various advantages over traditional field surveying methods, including cost and time saving. Many water surfaces, such as lakes and rivers, are extracted and characterised using multispectral remote sensing techniques.

One of the most important applications in spatial data management is the use of satellite images to update Geographic Information System (GIS) databases. It has been widely made by visual interpretation or automatic classification. Many studies have been presented to extract features in semi-automatic methods. Currently, there is a need for more investigations focusing in automatic approach of natural and man-made features extraction. Automatic water extraction provides a quick process for extracting object from remote sensing data which help GIS users in saving time and effort spend in digitizing many features manually. It also facilitate and accelerate updating process for several data layers.

2. Studying Area

The portion of Nile River in Egypt bound by 24° 22\ N to 24° 33\ N and 32° 48\ E to 32° 58\ E. Figure 1 shows a high resolution image of the Nile River that was utilized as a reference image for visual comparison of water extraction techniques.

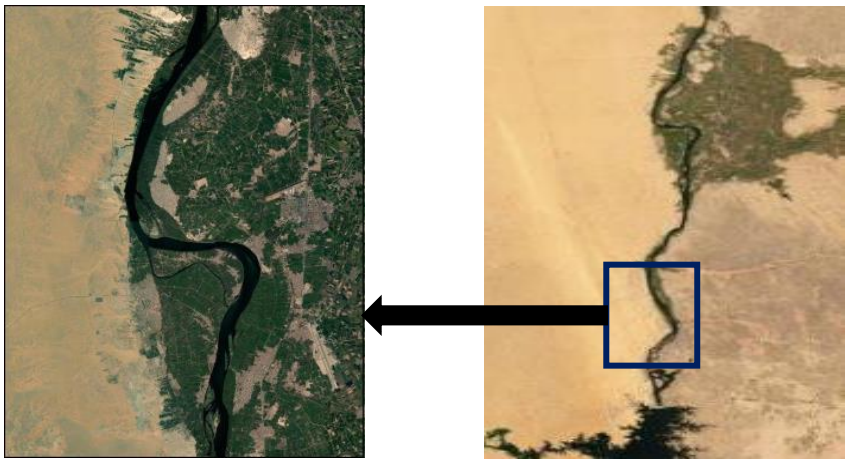

Figure 1. Location of the study area in high resolution satellite image.

3.Data and Methodology

The objective of this research is to extract and mapping the open water areas using satellite data, Landsat-8 and Sentinel-2 satellite images had been used, and these images were downloaded from USGS for Landsat-8 and from the European Space Agency for Sentinel-2B. Spectral bands comparison between these sensors is shown in Figure 2. ArcGIS software are used for image interpretation, processing and analysis. Figure 3. shows a flowchart for the applied techniques in this study to extract the water bodies.

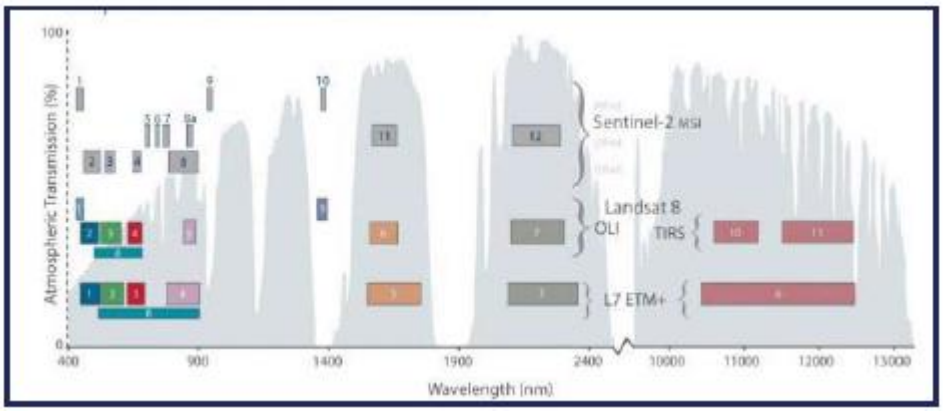

Figure 2. Spectral bands comparison between Sentinel-2 and Landsat-8, [3].

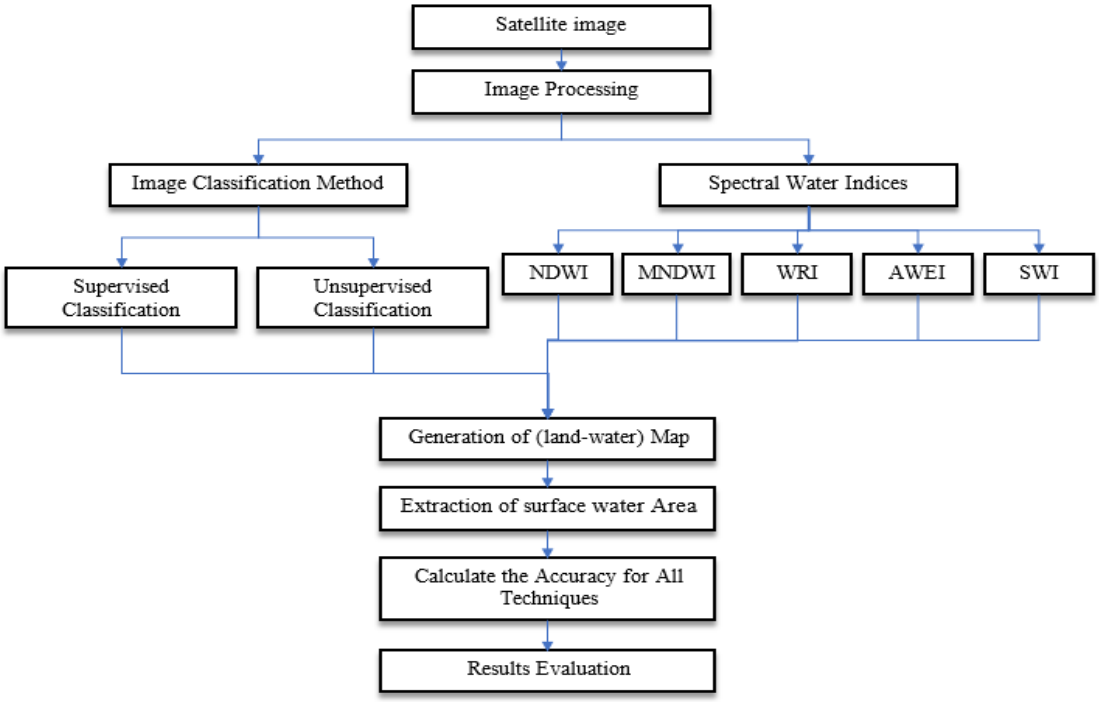

Figure 3. Flowchart for the applied techniques to extract the water bodies.

3.1. Applied image classification techniques

Two techniques of image classification are applied and can be summarized as follows:

Supervised classification is regularly used in the conditions that the study area is known. During the supervised classification process, first select the pixels that can be identified and the water types that can be determined to create classification models, and using this model to enable computer systems to recognize pixels with the same features automatically.

Unsupervised classification generally applies cluster Analysis, while cluster is to put pixels into several classes with the similarity of the pixels. The aim is to verify distance between pixels in the same class is as small as possible, and distance between pixels from different classes is as large as possible.

3.2.Computation of Spectral Water Indices

The spectral water indices applied in this study for the extraction of water areas as well as their equations and ranges are listed below:

- **Normalized Difference Water Index (NDWI) [4]**

$$NDWI = \frac{(Green - NIR)}{(Green + NIR)} \quad (1)$$

Where water bodies have positive values;

- **Modified Normalized Difference Water Index (MNDWI) [5]**

$$MNDWI = \frac{(Green - MIR)}{(Green + MIR)} \quad (2)$$

Where water bodies have positive values;

- **Sentinel water index (SWI)**

$$SWI = \frac{VRE\ 1 - SWIR\ 2}{VRE\ 1 + SWIR\ 2} \quad (3)$$

- **Water Ratio Index (WRI) [6], [7]**

$$WRI = \frac{(Green + Red)}{(NIR + MIR)} \quad (4)$$

Where water body value is greater than 1;

- **Automated Water Extraction Index (AWEI) [8]**

$$AWEI = 4(Green - SWIR1) - (0.25 \times NIR + 2.75 \times SWIR2) \quad (5)$$

Where water bodies have positive values.

Where water bodies have positive values;

The above mentioned Water Indices are computed to detect water surfaces using ArcGIS Software.

4.Accuracy Assessment

Visual interpretation and the quantitative accuracy index are used to conduct accuracy verification, the first procedure is to examine the performance of extracted water bodies by judging visual effects such as degree of continuousness and smoothness of the boundaries. The quantitative accuracy index is a common method that uses random check points and high resolution images to extract detailed variations in water body extraction processes. High resolution images were used as a reference data source to verify and test the randomly selected check points. Number of detected points were sixty check points were distributed randomly as shown in figure 4:

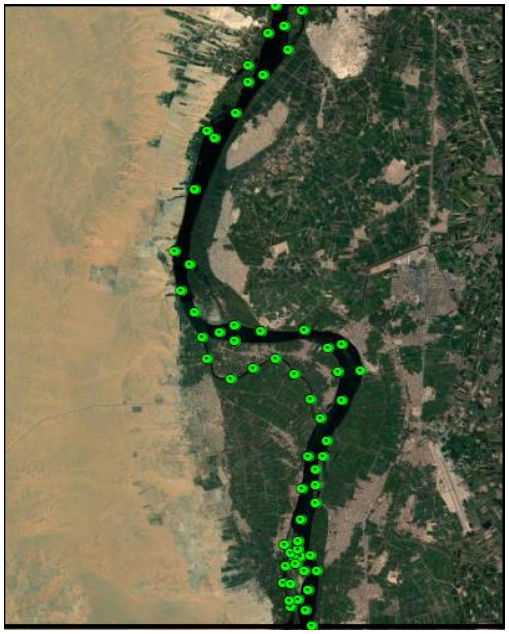

Figure 4. Distribution of check points.

- 14 points over the main Stream
- 25 points on the edge
- 21 points on the narrow branches

By using random check points and by comparing them with all extracted water from applied techniques. The accuracy of extracted water can be evaluated quantitatively.

5.Result and Analysis

Different techniques including supervised classification, unsupervised classification, NDWI, MNDWI, WRI, SWI and AWEI are used to extract the surface water from the Landsat-8 and Sentinel-2B images. The results are tested to assess the efficiency of the used methods. Figures 5 and 6 show the reference image and the derived land-water maps from the above mentioned techniques. The Accuracy of the extracted water bodies of the study area are presented in Table 1. Moreover, the accuracy of each studied technique was indicated in Figure 7.

In this study, after comparing the extracted water surface accuracy for the two combination (4, 5, 6) and (1:7) bands of Landsat-8 Data by using unsupervised

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classification technique. It's noted that the accuracy of combination bands (1:7) (95%) is better than the accuracy of combination bands (4, 5, 6) (93.33%).

The unsupervised classification technique performed significantly better compared with other techniques for surface water extraction. The accuracy of the unsupervised algorithm is about 95%. The visual comparison and the random check points show that the boundaries of the mapped water surfaces match the actual boundaries of the water in the reference image very closely. However, some mistakes and omissions occurred, as shown in Figures 5 and 6 respectively, which considered the primary cause of errors in the results. These omissions affect the values of the accuracy of all techniques.

Table 1. The Accuracy of the extracted water surfaces for all used techniques

Satellite	Applied techniques	Water points		Accuracy
		Correct	Wrong	
Landsat 8 OLI	NDWI	42	18	70 %
	MNDWI	53	7	88.33 %
	WRI	41	19	68.33 %
	AWEI	56	4	93.33 %
	Unsupervised-Isocluster bands (4,5,6)	56	4	93.33 %
	Unsupervised-Isocluster bands (1:7)	57	3	95 %
	Unsupervised-Isocluster bands (1:7), MNDWI	58	2	96.67 %
	Supervised Classification bands (1:7), MNDWI	56	4	93.33 %
Sentinel 2B	NDWI	49	11	81.67 %
	SWI	48	12	80 %
	unsupervised-Isocluster bands (5,6,7,8a,11,12) (Res20m)	51	9	85 %

The performance of the different commonly used water indices is demonstrated for Landsat-8 data, the automatic water extraction index (AWEI) (Accuracy equal to 93.33%) and the modified normalized difference water index (MNDWI) (Accuracy equal to 88.33%) provided the best results between the water indices. The normalized difference water index (NDWI) (Accuracy equal to 70%) and Water Ratio Index (WRI) (Accuracy equal to 68.33%) did not offer the best results because mixed classification of non-water features.

Hoping to improve the results, the surface water was extracted using unsupervised classification after the composition between (1:7) Landsat-8 bands and The modified normalized difference water index (MNDWI) map, it's gave accuracy about 96.67%.

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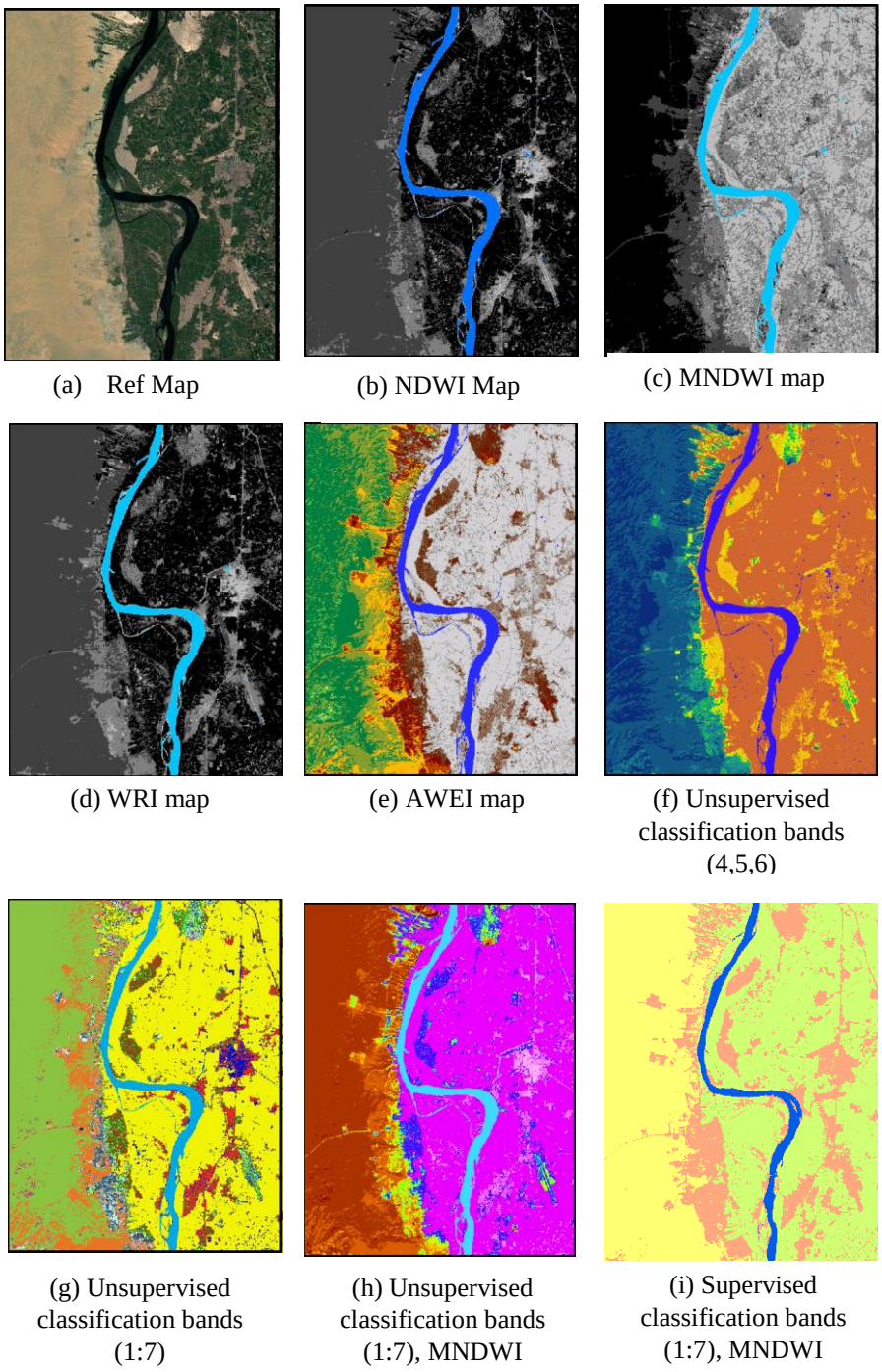
The Accuracy of supervised classification technique and the automatic water extraction index (AWEI) are equal to 93.33%. But the visual comparison shows that the boundaries of the Extracted water surfaces from supervised classification match the actual boundaries of the water in the reference image more than the automatic water extraction index (AWEI).



(a) Ref Map (b) NDWI Map (c) MNDWI map

(d) WRI map (e) AWEI map (f) Unsupervised classification bands (4,5,6)

(g) Unsupervised classification bands (1:7) (h) Unsupervised classification bands (1:7), MNDWI (i) Supervised classification bands (1:7), MNDWI

Figure 5. The reference and the resulting land-water maps from Landsat 8 image.

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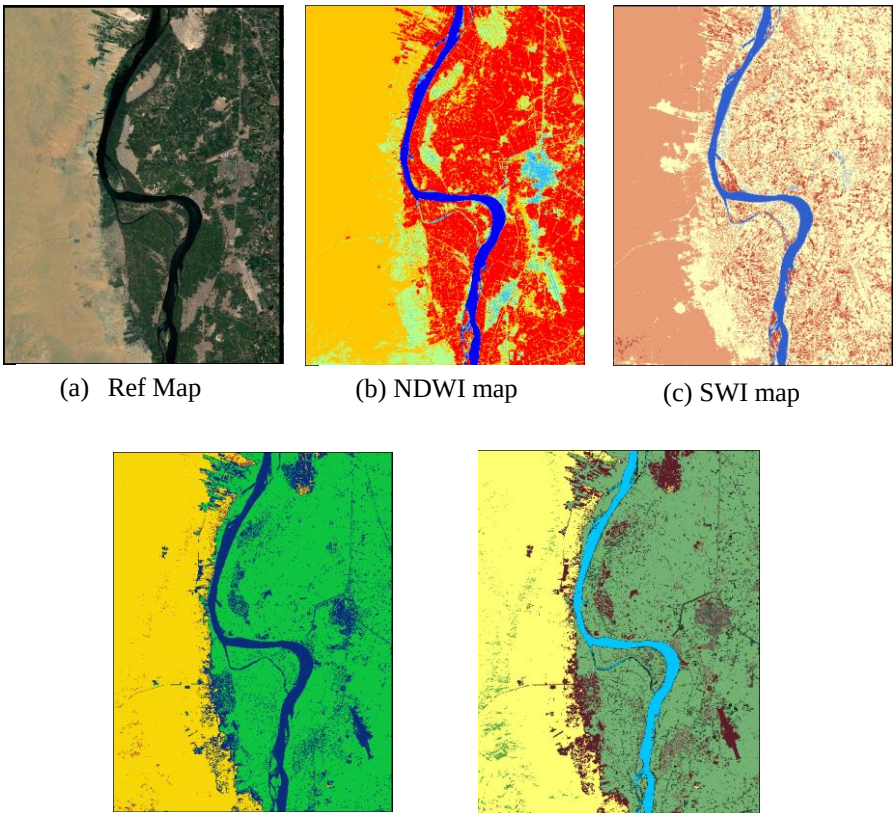
The performance of the different applied water indices are demonstrated for Sentinel-2 data. The unsupervised classification for bands (5,6,7,8a,11,12) with spatial resolution 20m performed significantly better compared with other techniques for surface water extraction with Accuracy 85%. NDWI and SWI are close in accuracy 81.67% and 80% respectively. But the land-water map from unsupervised classification of bands (2,3,4,8) with spatial resolution 10m was considered unacceptable and unreliable map which contain an unrealistic distribution of water surface and it classed the urban areas like building and roads as a water area through the study area as shown in Figure 6.(d). Therefore, the unsupervised classification technique for bands with spatial resolution 10m is not evaluated and is considered a disqualified method for extracting the water surface of the study area.



(a) Ref Map (b) NDWI map (c) SWI map

(d) Unsupervised classification bands (2,3,4,8) (e) Unsupervised classification bands (5,6,7,8a,11,12)

Figure 6. The reference and the resulting land-water maps from Sentinel 2 image.

According to the accuracy and visual comparison, the unsupervised classification after the composition between bands (1:7) and MNDWI on Landsat-8 provided the highest accuracy percentage (96.67%). This means that this approach was able to classify water surfaces with little mixed classifications. NDWI also works better on Sentinel rather than

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on Landsat, and WRI provided the least accuracy on Landsat and unsupervised classification of bands (2, 3, 4, 8) provided the least accuracy on Sentinel.

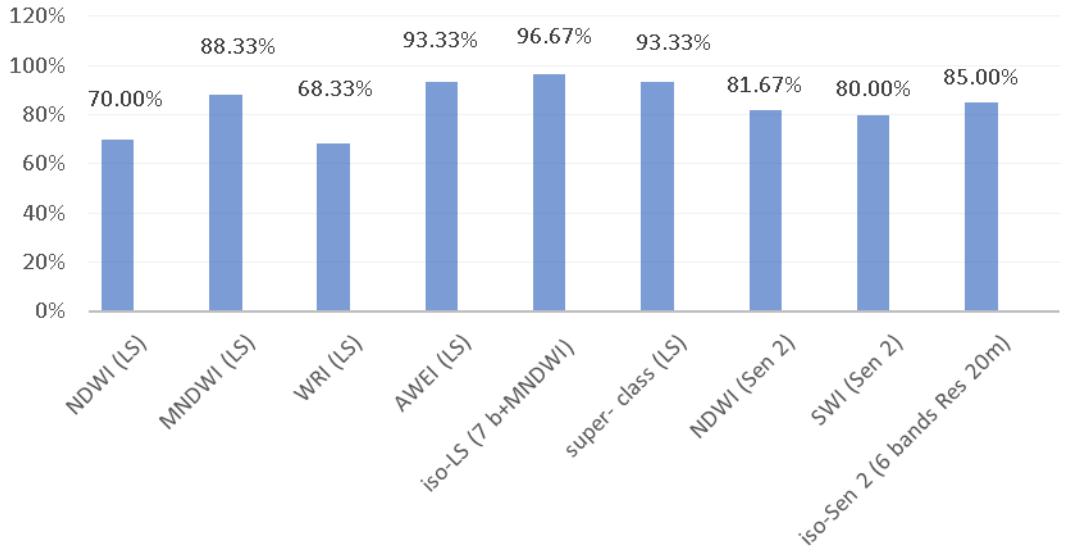

Figure 7. The Accuracy of water surface extraction techniques.

6.Conclusions

The investigation presented in the paper was on the performance evaluation for the extraction of water surfaces process based on using Landsat-8 and Sentinel-2 images. The results showed that the unsupervised classification for combination (bands 1:7 and MNDWI) has greater performance when compared to other techniques for extracting water surfaces from Landsat data, with an accuracy of 96.67%. On Landsat data accuracy ranges from 68.33 % to 93.33 %, while on Sentinel-2B, accuracy ranges from 80 % to 85 %. It should be noted that the mistakes in the water surface extraction method are mostly because of the omission of water pixels near the Nile River's boundaries.

NDWI also works better on Sentinel-2B rather than on Landsat-8, and WRI provided the worst performance on Landsat 8 and unsupervised classification of bands (2, 3, 4, 8) with resolution 10m provided the least accuracy on Sentinel-2. The results from these accuracy indicated that one water index might not provide the optimal results on all the different types of satellite images [1].

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