

# Comparing of Landsat 8 and Sentinel 2A using Water Extraction Indexes over Volta River

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## Abstract

Remote sensing data are most often used in water bodies' extraction studies and the type of remote sensing data used also play a crucial role on the accuracy of the extracted water features. The performance of the proposed water indexes among the various satellite images is not well documented in literature. The proposed water indexes were initially developed with a particular type of data and with advancement and introduction of new satellite images especially Landsat 8 and Sentinel, therefore the need to test the level of performance of these water indexes as new image datasets emerged. Landsat 8 and Sentinel 2A image of part Volta River was used. The water indexes were performed and then ISODATA unsupervised classification was done. The overall accuracy and kappa coefficient values range from 98.0% to 99.8% and 0.94 to 0.98 respectively. Most of water bodies enhancement indexes work better on Sentinel 2A than on Landsat 8. Among the Landsat based water bodies enhancement ISODATA unsupervised classification, the modified normalized water difference index (MNDWI) and normalized water difference index (NDWI) were the best classifier while for Sentinel 2A, the MNDWI and the automatic water extraction index (AWEI\_nsh) were the optimal classifier. The least performed classifier for both Landsat 8 and Sentinel 2A was the automatic water extraction index (AWEI\_sh). The modified normalized water difference index (MNDWI) has proved to be the universal water bodies enhancement index because of its performance on both the Landsat 8 and Sentinel 2A image.

**Keywords:** Water index, Landsat 8, Sentinel 2A, ISODATA unsupervised algorithm

## 1. Introduction

Water is an important component of human lives and without it the survival of living things on this planet would be impossible. The sources of water may include rivers, lakes, dams, rainfall, wells, sea and stream. Proper identification and management of these sources of water would be of great importance to wellbeing of human beings. Water from rivers and streams are normally processed to obtain drinking water for both urban and rural communities.

Identification of water bodies have been done through either field surveying or remote sensing techniques (Yang et al., 2017). Using remote sensing technique has numerous advantages over the field surveying methods because it is cost and time effective. Multispectral remote sensing technique in particular is being applied in the extraction and characterization of many cryospheric features like glaciers, sea ice, lakes and rivers, the extent of snow and ice, and icebergs (Jawak et al., 2015). Gao et al. indicated that remote sensing is an efficient and effective method for water extraction (Gao et al., 2016). Many researchers have utilized remote sensing in terms of its techniques and data to extract urban waters, rivers, coastal waters and lakes (Jiang et al. 2014b; Kaplan & Avdan, 2017; Du et al., 2016).

Researches are always ongoing on accurate identification and highlighting water features from remotely sensed imageries and as a result new and improved methods have being developed. Yang et al., classified the methods for extracting water as pixel-based approach, sub-pixel mapping with spectral mixture analysis and object-based approach (Yang et al., 2017). Jawak et al., however summarized the water bodies extraction methods as

pixel-based, object-based, hybrid, spectral index based, target and spectral matching methods (Jawak et al., 2015). For high accurate extraction of water bodies, combinations of these methods have been employed. There has been improvement in the identification of water bodies when object extraction techniques are combined with water indices (Jiang et al., 2014a). Kaplan and Avdan (2017) used object-based techniques such as image segmentation and pixel-based indexes, such as NDWI to extract water bodies and had improved kappa value of 0.5 than when only NDWI was used. Gao et al. (2016) could accurately extract small water bodies in mountainous areas and at the same time eliminate mountain shadow by combining several current water extraction methods.

The most commonly used multispectral data in water body extraction is Landsat imagery. As a result, most of the water extraction methods in literature were based on the usage of Landsat data (Feyisa et al., 2014). The free availability of Landsat data may account for its widely usage in water bodies extraction applications. The introduction of Sentinel 2A Multispectral Instrument (MSI) has provided another multispectral data option for mapping water bodies. The spectral bands of Sentinel 2A especially the near-Infra-Red (NIR) and Short-Wavelength Infra-Red (SWIR) bands provide some information about surface water (Yang et al., 2017).

The difference in performance of the proposed water indexes on different satellite data type is not normally researched by many authors (Zhou et al., 2017) and this gap of knowledge keeps widening as new and more satellite image datasets are being introduced. The proposed water extraction techniques were originally developed by using a satellite data type more especially Landsat imagery and with advancement in satellite remote sensing, more sensors have been developed. There is therefore, the need to investigate the performance of these proposed water extraction techniques on these sensors. The main aim of this paper is to determine which water enhancement techniques would provide optimal result on a satellite data type viz Landsat 8 and Sentinel 2A.

## 2. Methods and Materials

### 2.1 Study Area

Volta River was chosen because its importance to the people of Ghana. It provides electric power and serves as a source of transport for many communities in the northern and Volta regions of Ghana. The nature of the Volta River makes it more suitable for testing the water indexes because some parts of the Volta River are wide as lake while some parts are also narrow as river. High resolution image of Volta River in figure 1 was used as a reference image for visual comparison of the water indexed enhanced ISODATA unsupervised classified images.

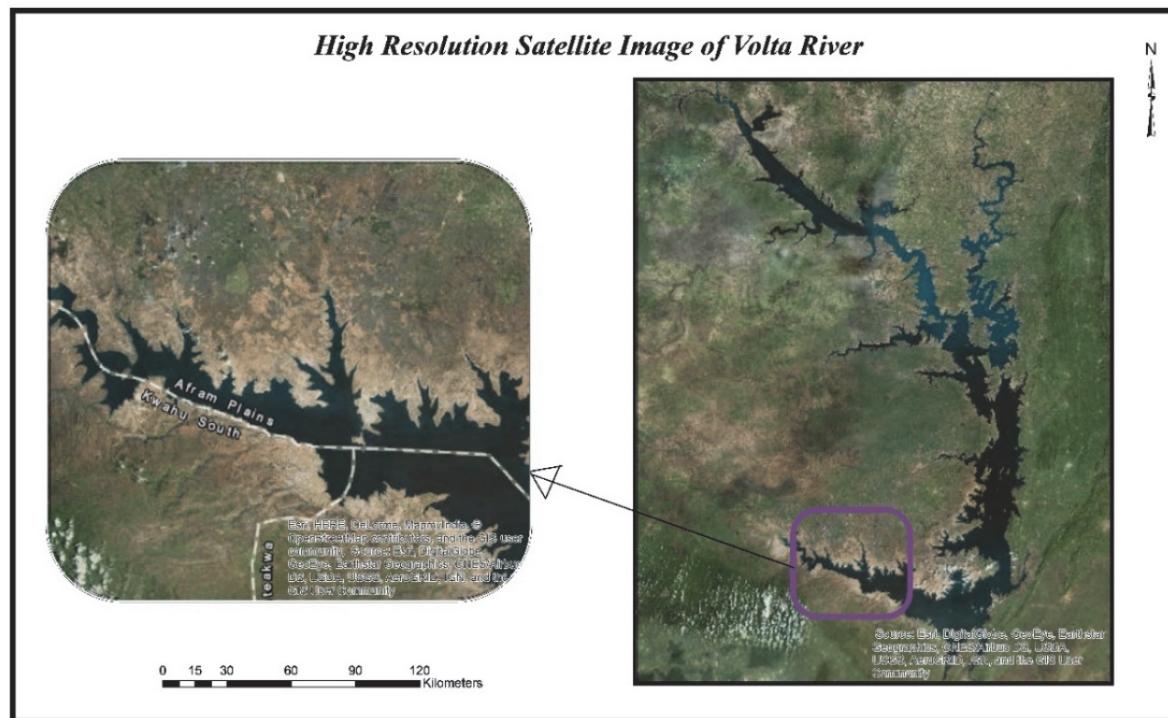


Figure 1. Satellite image of the Volta River

## 2.2 Materials Used

Table 1. Materials used and their sources

Data Type	Acquisition Date	Source
Landsat 8	25-01-2017	USGS explorer
sentinel-2A	27-01-2017	USGS explorer

## 2.3 Methods

The images of Landsat 8 and Sentinel were downloaded from the USGS explorer and some image preprocessing analysis such as layer stacking, subsetting and atmospheric and radiometric corrections were performed on the images before the water enhance indexes were then applied. The formula for water indexes were inputted into band math tool of ENVI 5.3 and applied on the images. The enhanced images were then classified using the ISODATA unsupervised classification algorithms to discrete the water bodies from non-water bodies. The confusion matrix for the water enhanced based ISODATA unsupervised classified images were constructed using known landcover types to assess the accuracy and performance of each water index on the different type on the classified images. Concept and principles of the water bodies enhancement indexes used in this research are explained below;

### 2.3.1 Normalized Difference Water Index (NDWI)

The normalized difference water index (NDWI) was the first water index to be proposed. The index was proposed by McFeeters to map and highlight open water features in remotely sensed data (McFeeters, 1996). He used the near-infrared (NIR) and green radiation as parameters in expressing his proposed water index. Mathematically, the normalized difference water index was expressed by McFeeters as;

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

The NDWI models reduces the non-water features such as vegetation and soil by supressing the low reflectance of NIR by water features and at the same time maximizing the reflectance of water by using green wavelengths (McFeeters, 1996). A threshold value of 0 was proposed by (McFeeters, 1996) stating that, positive values depict water bodies feature while negative values show areas of non-water features. The NDWI has the ability to detect water turbidity (McFeeters, 1996) but the main setback of the NDWI is its inability to separate built-up land from water bodies which lead to the overestimation of the extracted water features (Xu, 2006).

### 2.3.2 Modified Normalized Difference Water Index (MNDWI)

Xu modified McFeeters's normalized difference water index (NDWI) by substituting the near infrared band with a middle infrared band (Landsat TM band 5) to derive the modified normalized difference water index (Xu, 2006). According to Xu, the most preferred model for enhancing and extracting water features dominated by built-up land background is the MNDWI. The main purpose upon which MNDWI was developed was the reduction and removal of built-up land noise over the NDWI model. MNDWI was expressed by Xu (2006) as;

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

Three results are expected from using the MNDWI model; (1) greater positive values for water as water absorbs more MIR light than NIR light; (2) negative values for built-up land because of its higher reflectance in the MIR light than in NIR light and (3) soil and vegetation will still have negative values (Xu, 2006).

### 2.3.3 Automated Water Extraction Index (AWEI)

The automated water extraction index was proposed by Feyisa et al. (2014) for improving water bodies classification accuracy in areas that have shadow and dark surfaces and at the same time offers a stable threshold value for discriminating water features from other surface features. They used the five bands of Landsat in developing the AWEI. The AWEI aims at maximizing the enhancement of water from non-water features through band differencing, addition and application of different coefficients (Feyisa et al., 2014). They developed two automated water extraction indexes; one for effective elimination of shadow pixels and other one for removing only non-water pixels, including dark built surfaces in areas with urban background (Feyisa et al., 2014). The AWEI can be used to discriminate water features from non-water under different environmental

conditions (Jawak et al., 2015).

Mathematically, Feyisa et al. (2014) express AWEI as;

$$\text{AWEI\_nsh} = 4 \times (\text{Green} - \text{SWIR1}) - (0.25 \times \text{NIR} + 2.75 \times \text{SWIR2}) \quad (1)$$

$$\text{AWEI\_sh} = \text{Blue} + 2.5 \times \text{Green} - 1.5 \times (\text{NIR} + \text{SWIR1}) - 0.25 \times \text{SWIR2} \quad (2)$$

Feyisa et al. (2014) proposed some conditions under which AWEI can yield an effective and efficient results and these conditions are highlighted as follows; (1) in circumstances where the major issue is the shadow and other features such as snow, ice and high albedo built surface are of less concern, using AWEI\_sh alone would provide the best separability enhancement of water from non-water surfaces; (2) if shadows are not a main issue using AWEI\_nsh alone would yield the optimal separability enhancement of water bodies from other surfaces; (3) using both AWEI\_sh and AWEI\_nsh would provide the best separability of water when both high albedo surfaces and shadow/dark surfaces are present; (4) in situation where there are no shadows, no dark urban backgrounds and no high-albedo, using either AWEI\_sh or AWEI\_nsh is preferred (Feyisa et al., 2014).

### 3. Results and Discussion

Sentinel 2A is one of the recent satellite imageries available to users at no cost. The spatial and spectral resolutions of Sentinel 2A data is relatively better compared to other satellite imageries such as Landsat and ASTER.

The performance of the various water bodies enhancement techniques has not been fully explored on Sentinel data. Critical examination of the performance of these water bodies enhancement methods would provide a firsthand knowledge on which method would give the optimal results when performing water bodies enhancement studies. The results of the various water bodies enhancement techniques on Sentinel 2A imagery are illustrated in figure 2.

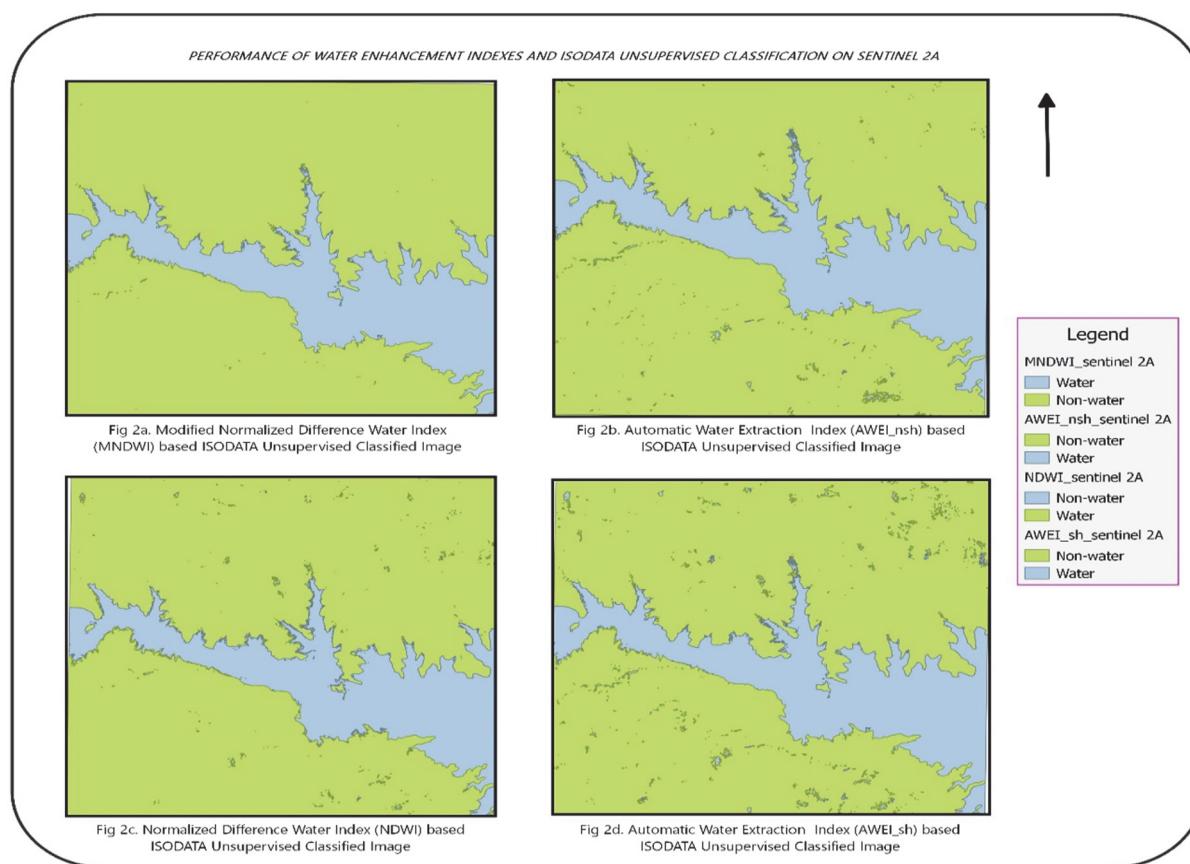


Figure 2. The performance of water index on Sentinel 2A imagery.

All the water bodies enhancement methods could define the outline of river being used for the experiment. The

levels of performance of the indexes were arranged from highest to lowest in figure 2. The best performance was obtained using MNDWI, followed by AWEI\_nsh. The lowest performance was however obtained using AWEI\_sh. The performance of NDWI did not yield the improved result as compared to MNDWI. There was overestimation of water bodies by the NDWI and AWEI\_sh because of mixed classification of non-water features.

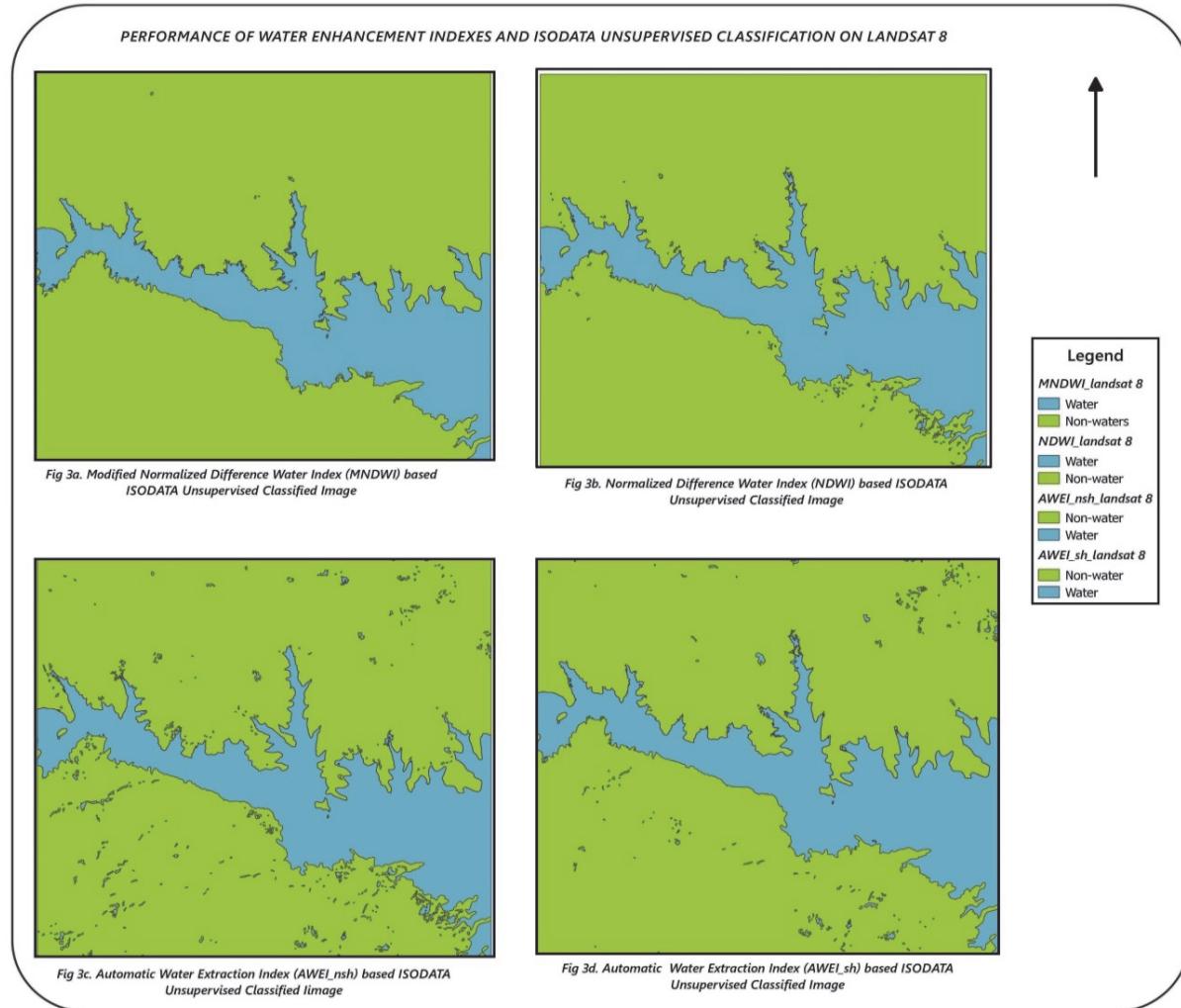


Figure 3. The performance of water index on Landsat 8 imagery

The water indexes were originally developed by using either Landsat TM or Landsat ETM+ but their performance on the newly improved Landsat 8 is well documented by researchers. The Landsat 8 offers surface reflectance without the need for performing atmospheric and radiometric corrections. They in way make the use of Landsat 8 quite easy and at the same time the accuracy of results is well reserved.

In figure 3, the performance of the most commonly used water indexes on Landsat 8 is demonstrated. The modified normalized difference water index (MNDWI) and the normalized difference water index (NDWI) provided the best results. The automatic water extraction index did not offer the best results because mixed classification of non-water features.

The assessment of water indexes on both Landsat 8 and Sentinel 2A were also compared to the overall accuracy and kappa values of the water index based ISODATA unsupervised classification results in figure 4 and 5.

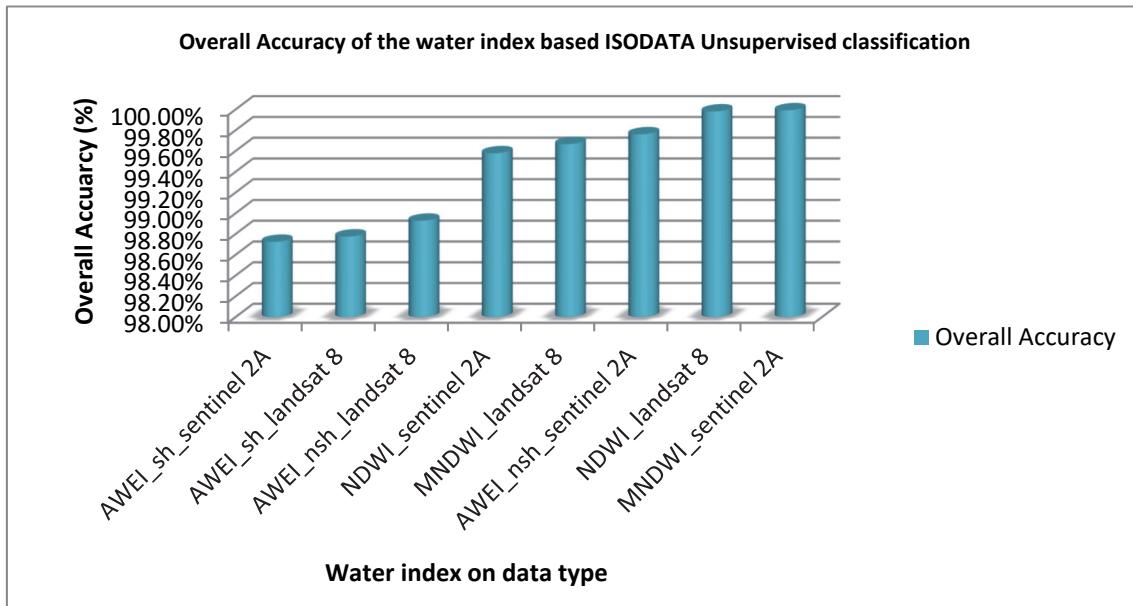


Figure 4. The overall accuracy results

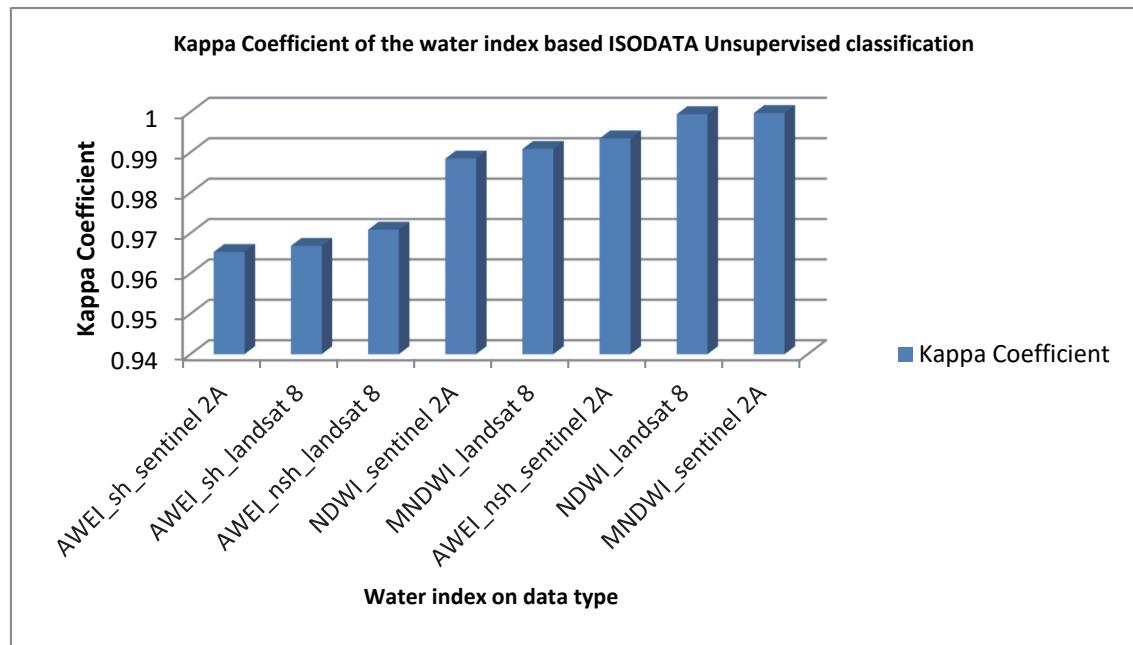


Figure 5. Kappa values of water index based ISODATA classification

According to the overall accuracy and kappa values, the modified normalized difference water index (MNDWI) based ISODATA unsupervised classification on Sentinel 2A provided the highest overall accuracy percentage. This means that this approach was able to classify water bodies with little or no mixed classifications. The normalized difference water index (NDWI) also works better on Landsat 8 rather than on Sentinel 2A. Automatic water extraction index (AWEI\_sh) provided the worst performance on Landsat 8 and Sentinel 2A. The results from the overall accuracy indicated one water index might not provide the optimal results on all the different types of satellite images.

Generally, the water indexes on Sentinel 2A offer the best results as compared to Landsat 8. The results from the Sentinel 2A image were the ones with the highest overall accuracy and kappa values apart from AWEI\_sh based classification. The spatial resolution of the Sentinel 2A image might be the reason why it provided the optimal water bodies extraction results. The resolution spatial of Sentinel 2A were all resampled to 15meters while that of Landsat 8 were 30meters.

#### 4. Conclusion

The performance of water enhancement based ISODATA unsupervised classification was quite good on both Landsat 8 and Sentinel 2A images. The overall accuracy and kappa coefficient values range from 98.0% to 99.8% and 0.94 to 0.98 respectively. Most of water bodies enhancement indexes work better on Sentinel 2A than on Landsat 8. The difference in spatial resolution may account for the difference in performance of water bodies enhancement index on Landsat 8 and Sentinel 2A.

Among the Landsat based water bodies enhancement ISODATA unsupervised classification, the modified normalized water difference index (MNDWI) and normalized water difference index (NDWI) were the best classifier while for Sentinel 2A, the MNDWI and the automatic water extraction index (AWEI\_nsh) were the optimal classifier. The least performed classifier for both Landsat 8 and Sentinel 2A was the automatic water extraction index (AWEI\_sh).

The modified normalized water difference index (MNDWI) has proved to be the universal water bodies enhancement index because of its performance on both the Landsat 8 and Sentinel 2A images. The modified normalized water difference index can be recommended to be used on either Landsat 8 or Sentinel 2A to other water indexes such as the normalized water difference index and the automatic water extraction indexes.

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