A New Combination of Water Index Model Based on TM Image

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Keywords: Remote sensing, Water extraction, Water index, Contrast, NCWI.

Abstract. A new water index is proposed for the problem that the normalized difference vegetation index and the modified normalized difference water index cannot suppress bare land information in the process of extracting water. Using the reflectance difference between the green and mid-infrared bands as the molecule and the reflectance and value of the near-infrared and red bands as denominators, a new combined water index was constructed. The index not only effectively suppress vegetation and building noise, but also further widen the contrast between water and bare land, reducing the interference of bare ground information on water extraction.

Introduction

Remote sensing technology has the characteristics of large scale, low cost, high speed, etc. It can accurately and quickly extract water information and become an important means for long-term monitoring of rivers, lakes and oceans [1]. The commonly used methods of water extraction include single-wavelength method, spectral correlation method, difference method, ratio method, vegetation index method, and water index method. Huafang Chen used the single-band threshold method and the difference method to extract water from the mountain plateau [2]. Qingqing Wang constructed a Simple Ratio of Water Index (SRWI) using TM2 and TM5 to extract water [3]. Huan Yu used the Normalized Difference Vegetation Index (NDVI) to extract wetland water [4]. Inspired by NDVI, the Normalized Difference Water Index (NDWI), the Modified Normalized Difference Water Index (MNDWI), and the Automated Water Extraction Index (AWEI) were proposed [5-7]. In this paper, after studying the NDVI and MNDWI water extraction methods, we use the MNDWI molecule as a new index molecule and the NDVI denominator as the denominator of the new index to build a New Combination of Water Index (NCWI) that can suppress bare land information.

Water Extraction Principle and Method

In the wavelength range of most satellite sensors, the reflection ability of the water is weak, and the reflectivity tends to decrease as the wavelength increases. The reflectivity of the clear water in the blue-green band (480nm-580nm) is between 4%-5%. In the red band (580nm), the reflectivity dropped to 2%-3%. When the wavelength exceeds 740nm, especially in the near-infrared and mid-infrared bands (740nm-2500nm), the reflectivity of the clear water falling to the bottom. Vegetation, buildings, and bare land have high reflectivity in the near-infrared and mid-infrared bands, which provides a basis for distinguishing between water bodies and background features.

Some scholars found that the reflectivity of water gradually weakened from the red band to the near-infrared band, and the reflectance of vegetation suddenly increased from the red band to the near infrared band. Using these two bands to construct the NDVI can distinguish between water and vegetation. Hanqiu Xu found that the reflectivity of water in TM images continuously weakens from the green band to the mid-infrared band, and has the strongest absorption characteristics in the mid-infrared band, while the reflectance of buildings rapidly increases from the near-infrared band to the mid-infrared band. Therefore, the MNDWI was constructed using the green band and the mid-infrared band, which increased the contrast between the water and the building.

In this paper, the NDVI and MNDWI have been improved and the NCWI has been constructed. As can be seen from Figure1 and Figure2, the reflectivity of the bare land has a minimum in the green band and a maximum in the mid-infrared band. If the two bands perform a difference
operation, a negative value can be obtained. The reflectivity and value of bare land in the near-infrared and red bands are smaller than those in the green and near-infrared bands (Table 1-3). Therefore, when the MNDWI molecule is invariant, the denominator of the MNDWI is replaced by the denominator of the NDVI. In other words, the reflectance and value of the near infrared band and the red band are used to replace the reflectance of the green band and the middle infrared band. The value of the calculated bare land index will be significantly reduced. Correspondingly, the reflectivity of the water in the green band is high, the reflectivity in the mid-infrared band is low, and the two bands perform a positive value after the difference operation; and the reflectivity and value of the water in the near-infrared band and the red band. It is larger than the reflectance and value in the green band and the mid-infrared band. Therefore, after replacing the denominator of the MNDWI, the index of the water will also be reduced. However, the decrease in the value of the bare land index is much greater than the decrease in the value of the water index, so that the contrast between the water and the bare land will be considerably enhanced. The formulas for the three methods are as follows:

\[ \text{NDVI} = \frac{(\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red})} \]  

(1)

\[ \text{MNDWI} = \frac{(\text{Green} - \text{MIR})}{(\text{Green} + \text{MIR})} \]  

(2)

\[ \text{NCWI} = \frac{(\text{Green} - \text{MIR})}{(\text{NIR} + \text{Red})} \]  

(3)

In the formula (3): Green, Red, NIR, and MIR are green, red, near-infrared, and mid-infrared bands, respectively, corresponding to the second, third, fourth, and fifth bands of the TM image.

Experiments and Analysis

The experiments were conducted using Landsat TM images from February 26, 2011, August 19, 2010, and August 3, 2010 from Kunming, Maanshan, and Dalian respectively. The image has been corrected for system radiation, ground control point geometry, and DEM topography. Using NDVI, MNDWI, and NCWI to extract water from lake, river, and ocean areas, the extraction threshold was chosen to be 0.4. The contrast value is used to describe the separability of water and background features. The greater the contrast, the better the separability. The formula is as follows:

\[ C = |W - B| \]  

(4)

In the formula (4): C is the contrast value, W is the mean value of NDVI, MNDWI or NCWI in the water, and B is the average value of NDVI, MNDWI or NCWI of the background feature.

(1) Lake area

The lake area selected Dianchi Lake in Kunming City (Figure 3(a)), with the majority of vegetation and buildings in the background. From the results of each index, although NDVI suppressed the vegetation disturbance well (Figure 3(b)), the average NDVI value of both water and buildings was negative (Table 1), so a lot of building noise is confused with water. The mean value
of MNDWI in water is positive, and the mean value of MNDWI in other features is negative. Therefore, the interference of background features can be well suppressed. However, the MNDWI still lacks in the separation of water and bare land. As shown in Figure 3(c), part of the bare ground is mistaken for water. After the NCWI replaced the denominator of the MNDWI with the sum of the near-infrared and red-light bands, the average NCWI (-0.85) in the bare land was smaller than the average of the MNDWI in the bare land (-0.56). Continuing to study the contrast between water and bare land, we can see that the $C_{NCWI}$ value (1.25) is 26.26% higher than the $C_{MNDWI}$ value (0.99). The increase in contrast value indicates that the separation effect between water and bare land has been strengthened. See Figure 3(d), it can also be found that most of the bare information is suppressed.

![Image](image.png)

Figure 3. Lake area water extraction.

Table 1. Mean Brightness, NDVI Mean, MNDWI Mean, NCWI Mean of Lake area features.

<table>
<thead>
<tr>
<th>Feature</th>
<th>band1</th>
<th>band2</th>
<th>band3</th>
<th>band4</th>
<th>band5</th>
<th>band7</th>
<th>NDVI</th>
<th>MNDWI</th>
<th>NCWI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>57</td>
<td>26.5</td>
<td>24</td>
<td>16.5</td>
<td>10.5</td>
<td>6</td>
<td>-0.19</td>
<td>0.43</td>
<td>0.40</td>
</tr>
<tr>
<td>Vegetation</td>
<td>71.5</td>
<td>35</td>
<td>38</td>
<td>75.5</td>
<td>68</td>
<td>34</td>
<td>0.33</td>
<td>-0.32</td>
<td>-0.29</td>
</tr>
<tr>
<td>Building</td>
<td>124</td>
<td>71</td>
<td>88</td>
<td>76</td>
<td>126.5</td>
<td>81.5</td>
<td>-0.07</td>
<td>-0.28</td>
<td>-0.33</td>
</tr>
<tr>
<td>Bare land</td>
<td>72</td>
<td>38.5</td>
<td>52</td>
<td>64.5</td>
<td>138</td>
<td>74</td>
<td>0.11</td>
<td>-0.56</td>
<td>-0.85</td>
</tr>
</tbody>
</table>

$C(Water, Veg)_{NDVI}=0.52$
$C(Water, Veg)_{MNDWI}=0.75$
$C(Water, Veg)_{NCWI}=0.69$
$C(Water, Building)_{NDVI}=0.12$
$C(Water, Building)_{MNDWI}=0.71$
$C(Water, Building)_{NCWI}=0.73$
$C(Water, Bare land)_{NDVI}=0.30$
$C(Water, Bare land)_{MNDWI}=0.99$
$C(Water, Bare land)_{NCWI}=1.25$

(2) River area

In the river area, the lower reaches of the Yangtze River with a high degree of vegetation coverage (Figure 4(a)), about 70% of the background land is vegetation. Comparing Figure 4(b), Figure 4(c) and Figure 4(d), it is easy to see that the extraction effect of MNDWI and NCWI is better than that of NDVI. The main reason is that the water extracted by NDVI is not complete enough. And NDVI also failed to eliminate the interference of buildings and bare land. In addition, there is still a small amount of bare land identified as water in the MNDWI, while the NCWI further eliminates the interference from bare land. Examining the contrast between water and bare land can also find that the $C_{NCWI}$ value (0.73) is 0.02 higher than the $C_{MNDWI}$ value (0.71).

![Image](image.png)

Figure 4. River area water extraction.

Table 2. Mean Brightness, NDVI Mean, MNDWI Mean, NCWI Mean of River area features.

<table>
<thead>
<tr>
<th>Feature</th>
<th>band1</th>
<th>band2</th>
<th>band3</th>
<th>band4</th>
<th>band5</th>
<th>band7</th>
<th>NDVI</th>
<th>MNDWI</th>
<th>NCWI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>84.5</td>
<td>38.5</td>
<td>38.5</td>
<td>35</td>
<td>18.5</td>
<td>6</td>
<td>-0.05</td>
<td>0.35</td>
<td>0.27</td>
</tr>
<tr>
<td>Vegetation</td>
<td>79</td>
<td>37.5</td>
<td>28.5</td>
<td>123.5</td>
<td>86.5</td>
<td>25.5</td>
<td>0.63</td>
<td>-0.40</td>
<td>-0.32</td>
</tr>
<tr>
<td>Building</td>
<td>97.5</td>
<td>48.5</td>
<td>56</td>
<td>52.5</td>
<td>67</td>
<td>41</td>
<td>-0.03</td>
<td>-0.16</td>
<td>-0.17</td>
</tr>
<tr>
<td>Bare land</td>
<td>106</td>
<td>54.5</td>
<td>66</td>
<td>70</td>
<td>117</td>
<td>62</td>
<td>0.03</td>
<td>-0.36</td>
<td>-0.46</td>
</tr>
</tbody>
</table>
### Ocean area

The ocean area was selected in the coastal waters of Dalian. The background features include vegetation, buildings, and bare land. The results of water extraction with three indices are shown in Figure 5. When NDVI divides the coast boundary, some of the exposed tidal flats are mistaken for seawater, and in the densely-constructed areas and in the vegetation coverage areas, bare land is also mistakenly divided into water. Although the MNDWI has a good effect in suppressing building noise, it also appeared that the bare land was mistaken for the water, and the NCWI solved this problem well, not only inhibiting the interference of vegetation and buildings, but also further eliminate the bare land misplacement. The contrast between bare land and water reached 0.89.

![Dalian coastal area image](image1) ![NDVI image](image2) ![MNDWI image](image3) ![NCWI image](image4)

Figure 5. Ocean area water extraction.

<table>
<thead>
<tr>
<th>Band</th>
<th>NDVI</th>
<th>MNDWI</th>
<th>NCWI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>0.68</td>
<td>0.75</td>
<td>0.59</td>
</tr>
<tr>
<td>Vegetation</td>
<td>0.17</td>
<td>0.51</td>
<td>0.44</td>
</tr>
<tr>
<td>Bare land</td>
<td>0.08</td>
<td>0.87</td>
<td>0.73</td>
</tr>
</tbody>
</table>

### Conclusion

By using the reflectance and value of NDVI formula in the near infrared band and red band to replace the reflectance and value of the green band and middle infrared band in the MNDWI formula, the NCWI constructed can quickly and comprehensively extract water. Compared with NDVI and MNDWI, NCWI not only can effectively suppress vegetation and building noise, but also can further reduce the interference of bare information. Especially in areas with moderate or low vegetation coverage, such as cities and coasts, NCWI has better extraction results.

### Acknowledgement

This research was financially supported by the National Natural Science Foundation of China (Project No. 41206078).

### References


