Determining the Most Appropriate Classification Methods for Water Quality

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Abstract. Assessing water resources’ quality and also monitoring them have attracted lots of attention in the recent years. Remote sensing has been growing widely in the last decade and its resources are very usable when it comes to water resources management. In this study, by using remote sensing technology, satellite images that have 350 to 1050 nanometres wavelength band sensors are used to determine the quality of the Kizilirmak River’s water. Through the river’s resources, ground based spectral measurements are made to identify the quality differences of the water at the test spots that have been determined before. In this context at Imranli, where the river contacts civilization for the first time, which is located in Sivas city of Turkey, samples are gathered in order to do ground based spectroradiometer measurements. These samples are gathered simultaneously with the image acquiring time of CHRIS Proba satellite. Spectral signatures that are obtained from ground measurements are used as reference data in order to classify CHRIS Proba satellite’s hyperspectral images over the study area. Satellite images are classified based on Chemical Oxygen Demand (COD), Turbidity and Electrical Conductivity (EC) attributes. As a result, interpretations obtained from classified CHRIS Proba satellite hyperspectral images of the study area are presented. Spectras are readied for Matched Filtering and Spectral Angle Mapper methods for determining the best classification method.

1. Introduction

Remote sensing techniques provide fast and reliable information about the water quality variables which includes the hydro-physical, biological and biochemical attributes [1, 2, 3].

By using satellite based imagery, water surface reflectance is measured from a water resource in order to obtain attributes like chlorophyll-a (CHL_A), chemical oxygen demand (COD), Turbidity etc. Remote sensing of water quality started in 1978 when Coastal Zone Colour Scanner (CZCS) sensor was launched in 1978. The spatial resolution of CZCS was not suitable for monitoring small and moderately sized water resources. Through advancing years the spatial resolutions of other satellite sensors like Sea-Viewing Wide Field-of-view Sensor (SeaWiFS), Moderate Resolution Imaging Spectroradiometer (MODIS) or Medium Resolution Imaging Spectrometer (MERIS) are improved in order to work on small study areas [1, 4, 5]. In this study, by using remote sensing technology, satellite images that have 350 to 1050 nanometres wavelength band sensors (e.g. CHRIS Proba) are used to determine the quality of the Kizilirmak River's water. Through the river's resources, ground based spectral measurements are made to identify the quality differences of the water at the test spots that have been determined before. In this context at Imranli, where the river contacts civilization for the first time, which is located in Sivas city of Turkey, samples are gathered in order to do ground based spectroradiometer measurements. These samples are gathered simultaneously with the image acquiring time of CHRIS Proba. Spectral
signatures that are obtained from ground measurements are used as reference data in order to classify CHRIS Proba’s hyperspectral images over the study area. Satellite images are classified based on Chemical Oxygen Demand (COD), Turbidity and Electrical Conductivity attributes [2].

1.1. Study Area
Kizilirmak River is born and also pours out to sea in country limits of Turkey. It is the longest river of the country by the length of 1355 kilometres. The study area consists one town named Imranli, which is located in Sivas city of Turkey (Figure 1). This town is the first place where the river meets civilization after it is born in Kizildag town of Sivas. The study also consists Imranli Dam which is fed by Kizilirmak river’s streams throughout the region [2].

![Figure 1. Study area (Green markers indicate locations where the water samples are taken)](image)

1.2. Water Quality Assessment
Field work is specified on gathering the water samples in the study area that were decided beforehand. FieldSpec 4 Spectroradiometer was used to obtain the spectras from the water samples. These spectras have been organized in ViewSpecPRO software provided by ASD. CHRIS Proba images (CHRIS_IM_140830_OC61_41), which has 18 bands and 17 m ground sampling distance, were corrected in atmospheric and radiometric level in BeamVISAT software (Figure 2). These images then have been georeferenced, layer stacked and then clipped to the region of interest by the shape files provided by General Directorate of State Hydraulic Works of Turkey in order to reduce image size and make it easy to interpret on them [2].

In terms of COD, 1,2,3,4,6,7 and 10 water samples in the sample points was found to be I. Water Quality Class, 5 and 8 samples were quality in the II. Water Quality class. There are also some variations amongst other physical parameters EC and turbidity. EC is a parameter based on how much the water can conduct electricity through and signifies substances dissolved in water. When the sample gathering points are analysed at 1, 2, 3, 4, 5, 6, 7 and 8th points (except 10th which is located at Imranli Dam) EC attributes are increasing according to the flow direction of the river (Table 1).
Water samples are evaluated on the basis of water quality class of Turkish Directive on Water Pollution Control. This basis consists of four water quality classes that are lining up from I to IV, making IV. Quality class the dirtiest and the I. Quality is the cleanest water resource, [8]

This might be caused because of the dissolution of rocks where the dam water flows through or the discharge from the settlements nearby. At gathering point 10 (where the dam resides) EC parameter is 371 µs/cm [2].

Table 1. Attributes of water sample locations [2].

| Locations | Chemical Oxygen Demand | Electrical Conductivity (µs/cm) | Turbidity (NTU) |
|-----------|------------------------|-------------------------------|-----------------|
| 1         | 10                     | 423                           | 1.82            |
| 3         | 17                     | 430                           | 1.09            |
| 4         | 8                      | 399                           | 1.73            |
| 5         | 32                     | 419                           | 3.07            |
| 6         | 8                      | 420                           | 1.17            |
| 7         | 6                      | 506                           | 0.94            |
| 8         | 35                     | 530                           | 1.16            |
| 10        | 19                     | 371                           | 1.65            |

2. Classification of the Images
To make spectral classification of Chris Proba image, spectroradiometer measurements which are used as endmember were done. Afterwards, resampling of spectroradiometer measurements of the Water quality-I and Water quality-II to Chris Proba bands was made. The resampled (Figure 3) spectra of Water quality-I and Water quality-II were averaged for determining general spectra of endmember.
As classification method, spectral angle mapper was used. SAM is among the most popular spectral classification method utilizing spectral vectors where the degree of similarity between two endmembers changes on the basis of the number of bands used in the processed image [2, 5]. The two endmember spectra were classified by accepting the thresholds for Water quality-I and Water quality-II as 0.025 radian determining the angular similarity value used in the endmember collection (Figure 4).

Another supervised classification method for determining water quality, Matched filtering (MF) is used. MF is used for finding the abundances of user-defined end members using a partial unmixing (Figure 5). MF maximizes the response of the known end member and suppresses the response of the composite unknown background, thus “matching” the known signature [6, 7]. It has been developed a RGB band combination that includes the result of endmember 5 (collected at the place 5 on the river and assigned quality-II) in the red filter, the result of endmember 6 (collected at the place 6 on the river and assigned quality-I) in the blue filter and the result of endmember 8 (collected at the place 8 on the river and assigned quality-II).

3. Results and Discussion
By interpreting the result classification images (Figs. 4, 5), we can understand that water quality assessment of water bodies can be easily carried out by gathering the water sample spectra with a spectroradiometer and then applying them to high resolution hyperspectral imagery.
Figure 4. SAM results: second quality water areas in red and first quality water areas in blue

Also according to the figure 5, MF supervised classification result shows the extent of the water in quality-I and quality-II. MF and SAM results are compatible dispersion.

Figure 5. Matched filtering

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