Use of Landsat-8 imagery to estimate depth and clarity in nearshore coastal waters: Feasibility study- Chabahar Bay, Iran

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Abstract

This study examined the advantages of incorporating the new band of Landsat-8 OLI imagery (band 1: Coastal/Aerosol, 435-451 nm) to a model for estimation of Secchi disk depth (SDD) values (as an indicator for transparency) in near-shore coastal waters using multispectral bands. In doing so, Chabahar Bay in the southern part of Iran (north of Gulf of Oman) was selected as the study area. Two approximately four-hour in-situ observations (including 48 and 56 field measured SDD values for each date respectively) were performed in the study area using Secchi disk; this was designed to start about two hours before and end about two hours after the time of satellite overpasses. Thereafter, a model was formed for estimation of SDD values based on the terms including all possible linear and mutual ratio values of Coastal/Aerosol (B1), Blue (B2), Green (B3), and Red bands (B4). In the first step, the correlation between reflectance/ratio reflectance values of these bands and $\ln(SDD)$ values were calculated to indicate higher correlated bands/band ratios with the first field measured SDD values. Consequently, 17 combinations of highest correlated bands/band ratios were selected to estimate SDD values. In this
regard, 32 points among the 48 field observations were selected to determine unknown coefficients of models using a multiple linear regression, and the rest 16 points were designated for accuracy assessment the results. Eventually, the measured SDD values in second field observations were utilized for validating the results. On the other hand, the improvement in the capabilities of Landsat-8 imagery to retrieve bathymetric information in shallow coastal waters was examined. The selected Landsat-8 operational land image (OLI) acquired on February 2014 in calm weather and relatively low turbidity. Precise and high resolution bathymetric data from the study area, produced by field surveys using a single beam echo-sounder, were selected for calibrating the models and validating the results. Three methods, including traditional linear, and ratio transform techniques as well as a novel proposed integrated method, were used to determine depth values. All possible combinations of first the three bands have been considered (11 options) using the traditional linear and ratio transform techniques, together with five model options for the integrated method. The accuracy of each model was assessed by comparing the determined depth values with field measured values. The standard error of the estimates, correlation coefficients ($R^2$) for both calibration and validation points, and root mean square errors (RMSE) were calculated for all model options.

Final results demonstrated that combination of linear terms including B1, B2 and B3 bands and band ratio terms including ratio reflectance values of B4/B3, B3/B1, and B2/B1 has led to obtain the highest accuracy ($R^2=0.866$ and $RMSE=0.919$, SVM feature
weight= 4.294). This was in agreement with the results obtained from the second observations. Finally, by applying the entire 104 field observed SDD values, the model in form of \( SDD = 0.077 \exp (1.209 \frac{R_{B1}}{R_{B1}} - 1.739 \frac{R_{B2}}{R_{B1}} + 5.198 \frac{R_{B3}}{R_{B1}} + 10.408 \frac{R_{B2}}{R_{B1}}) \) can be used to determine SDD values in near-shore coastal waters of Chabahar Bay using atmospherically corrected reflectance values of Landsat-8 OLI bands. In case of depth estimation, when compared with the ratio transform method, the method employing linear transformation with a combination of CB, B, and G bands yielded more accurate results (standard error = 1.712 m, \( R^2_{\text{calibration}} = 0.594 \), \( R^2_{\text{validation}} = 0.551 \), and RMSE = 1.80 m). Adding the CB band to the ratio transform methodology also dramatically increased the accuracy of the estimated depths, whereas this increment was not statistically significant when using the linear transform methodology. The integrated transform method in form of \( \text{Depth} = b_0 + b_1 X_{CB} + b_2 X_B + b_3 \ln \left( \frac{R_{CB}}{R_G} \right) + b_4 \ln \left( \frac{R_B}{R_G} \right) \) yielded the highest accuracy (standard error= 1.634 m, \( R^2_{\text{calibration}} = 0.634 \), \( R^2_{\text{validation}} = 0.595 \), and RMSE= 1.71 m), where \( R_i \) (i=CB, B, or G) refers to atmospherically corrected reflectance values in the \( i^{th} \) band \([X_i=\ln(R_i-R_{\text{deep water}})]\).

**Keywords:**
Remote sensing; Turbidity; Clarity; Secchi disk depth (SDD); Bathymetry; Coastal area