Water turbidity mapping using Landsat-8 data in Mekong and Bassac Rivers, Vietnam

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Abstract

This study aims to investigate the applicability of Landsat-8 OLI data for water turbidity mapping in the Mekong and Bassac Rivers, Vietnam using Landsat data. The data processing consists of three steps: (1) atmospheric correction using FLAASH model, (2) model establishment using Bayesian Model Average (BMA), and (3) error verification. The results indicated that the higher correlations between Landsat bands and water turbidity were respectively observed for bands 3, 4, 5 and 7 (Bayesian Information Criterion - BIC = -64.37 and R^2 = 0.84). The results compared with the field survey data yielded a close agreement (R^2 of 0.83) and the root mean square error (RMSE) of 10.57 NTU.

Study area and data

- Mekong and Bassac Rivers located in South Vietnam are two main rivers that have the length of approximately 210 km and the width ranging from 500 m to 5 km (Fig. 1).

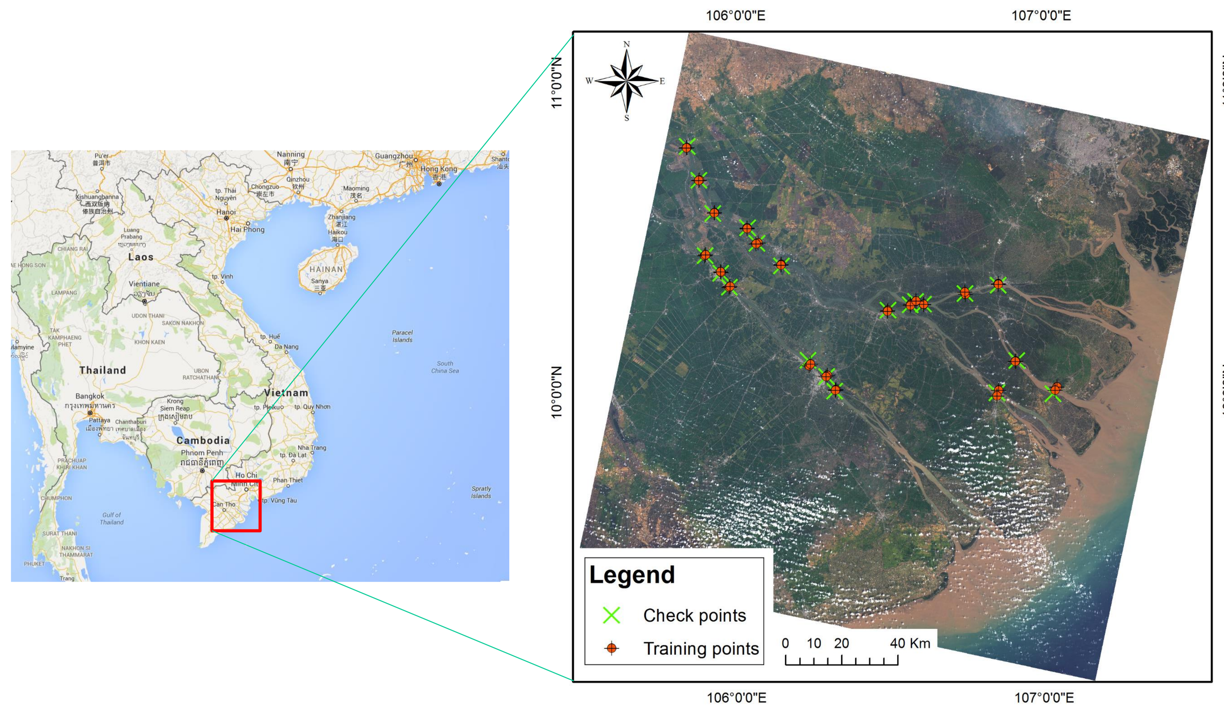

Fig. 1. Map of showing Mekong and Bassac Rivers and field survey locations. Landsat false-color composite (RGB = 4, 3, 2).

In-situ data

- The water turbidity data were collected in 24 January 2015 synchronizing with the Landsat 8 data acquisition time with 63 sites of 21 transects from upper to lower Mekong and Bassac Rivers (Fig.1).

Satellite data

- Landsat OLI data (path/row: 125/53) acquired in 24 January 2015 were used. The Landsat-8 OLI have 7 spectral bands with a spatial resolution of 30 m.

Methods

- The data were processed through 3 mains step (Fig. 2).

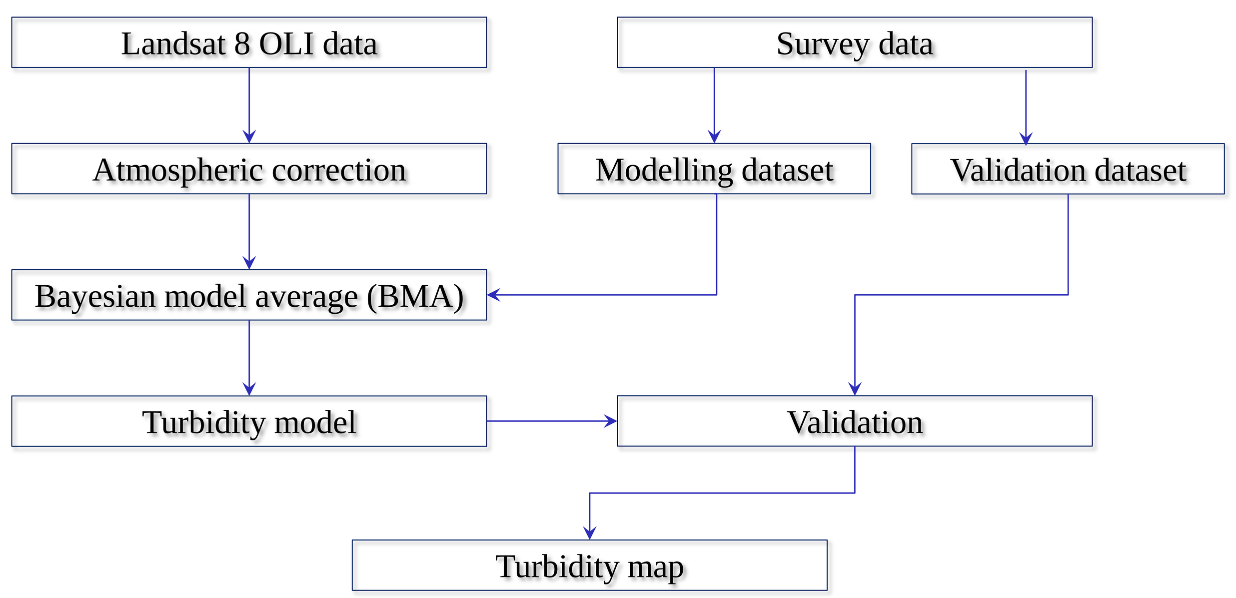

Fig. 2. Flow chart illustrating steps of data processing.

- The Landsat data from digital number (DN) were convert to TOA radiance L_λ (W.sr^{-1}m^{-2} μm^{-1}) by following equation:

$$L_\lambda = M_L Q_{cal} + A_L,$$

where L_λ = TOA spectral radiance (W.sr^{-1}m^{-2} μm^{-1}); λ = band wavelength; M_L = band-specific multiplicative rescaling factor from the metadata; A_L = band-specific additive rescaling factor from the metadata; Q_{cal} = quantized and calibrated standard product pixel values (DN).

- The TOA spectral radiance were applied for atmospheric correction by using FLAASH model in ENVI 5.1.
- Suppose dependent variable Y of turbidity and predictors X_1, X_2, . . . , X_7 corresponding to 7 bands of Landsat data. Then using variable selection methods to find the best model with the form:

$$Y = a_0 + \sum_{i=1}^{7} a_i X_i,$$

where a_i are model coefficients.

- In this study, Bayesian model average (BMA) was used to select parameters.
- Coefficients a_i of the model were indicated by least square method from modelling dataset. Then the model was verified by validation dataset.
- Finally, the model was applied to the Landsat image to generate the turbidity map in Mekong and Basaac Rivers.

Results and Discussions

- The survey data were separated into two parts: group-1 (70% samples) was used to model relationship between spectral bands and field data, and group-2 (30% samples) was used for validation of the modeling results.
- The modeling results are summarized in Table 1.

Table 1. Models obtained from BMA methods.

Best 5 models (cumulative posterior probability = 0.6918):

	p!=0	EV	SD	model 1	model 2	model 3	model 4	model 5
Intercept	100.0	-5.5771	29.42	7.951	-2.287	-48.692	34.445	-15.803
X1	11.0	0.5236	242.05	.	.	.	.	.
X2	16.7	-13.4901	381.23	.	.	.	.	-685.560
X3	73.9	-914.8746	726.86	-1222.114	-1001.108	.	-1772.031	.
X4	100.0	1157.6981	245.26	1275.828	1158.665	834.852	1516.598	932.216
X5	93.6	354.1824	157.63	264.328	406.282	554.532	.	447.025
X6	61.8	-333.9797	584.27	.	-675.566	-892.103	1114.113	-714.595
X7	50.6	-341.8307	496.05	-603.599	.	.	-1545.385	.
nVar				4	4	3	4	4
r2				0.842	0.842	0.821	0.832	0.830
BIC				-64.373	-64.205	-62.760	-61.681	-61.213
post prob				0.244	0.225	0.109	0.064	0.050

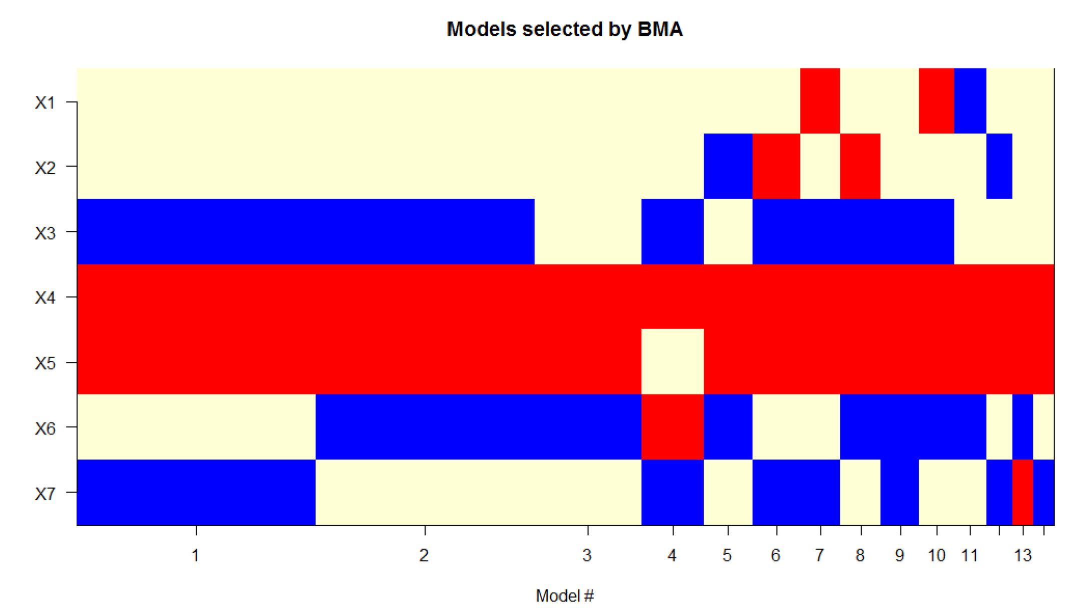

Fig. 3. BMA plot for14 selected models.

- The R^2 and BIC for best 5 models are comparable (Table 1). Model 1 has the highest posterior probability of 0.24, and is thus selected to model water turbidity. The model results presented as follows:

Turbidity = 7.95 – 1,222.11×B3 + 1,275.83×B4 + 264.33×B5 - 603.60×B7;

- The turbidity is sensitive to band 3, 4 and 5 (Table 1, Fig. 3). Band 4 is 100% appearing in all selected models, while band 5 and 3 are 93.6% and 73.9%, respectively. The positive correlation with the turbidity was observed for bands 4 and 5, while band 2 has the negative correlation to turbidity. These results are reasonable because bands 4 and 5 are red and near infrared bands that absorb turbid water. Band 3 is green band inferred to clear water opposite with turbid water.

Results and Discussions (cont.)

- The results indicated close correlation between the in-situ turbidity and Landsat data (Fig. 4a). The predicted results compared with the field data confirmed the validity of the model (Fig. 4b), with R^2 = 0.83 and RMSE = 10.57 (NTU).
- The turbidity concentration was lower in the upper part of the rivers, while it was relatively high in the lower part (Fig. 5). The higher turbidity is mainly attributed to sedimentation accumulation.

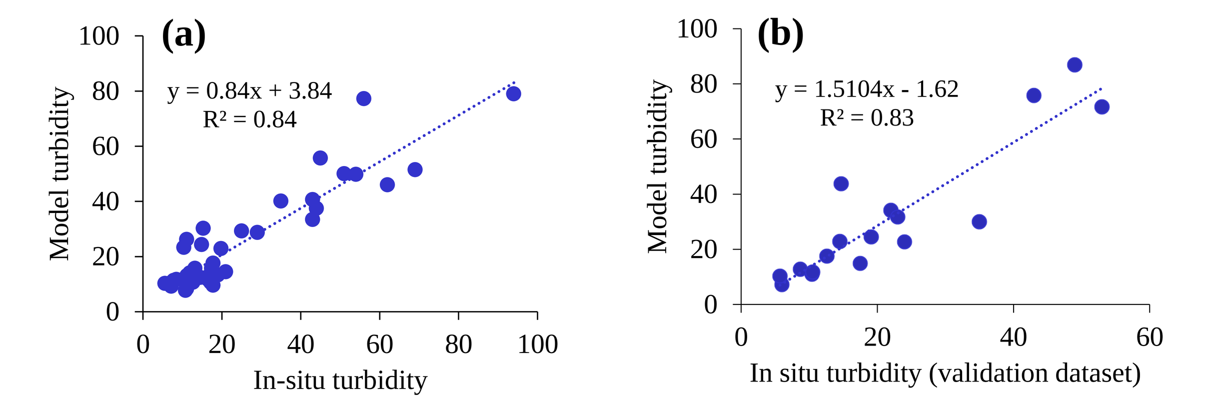

Fig. 4. (a) model and *in-situ* turbidity correlation from model dataset, and (b) model and *in-situ* turbidity correlation from validation dataset.

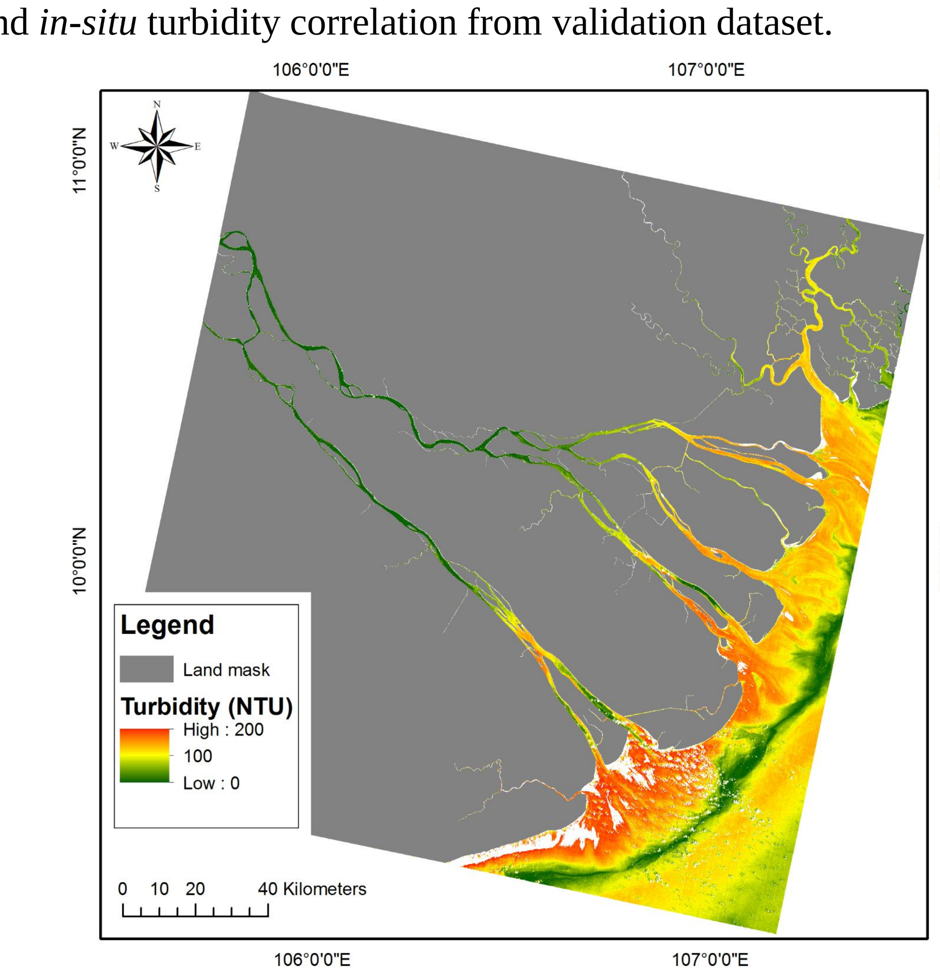

Fig. 5. Spatial distribution of the turbidity from Landsat-OLI data in Mekong and Basaac Rivers.

Conclusions

- This study demonstrates the applicability of Landsat-OLI for turbidity mapping in Mekong and Bassac Rivers.
- The results confirmed the validity of our approach for water turbidity mapping, with R^2 = 0.83 and RMSE = 10.57 NTU.
- The results could be useful for water turbidity monitoring in rivers and estuaries in Vietnam.

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