DETECTING OF SOME POLLUTION COMPONENTS OF SURFACE WATER DISCHARGED FROM URBAN AND INDUSTRIAL PARK WITH SPOT-5 IMAGERIES

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Abstract: Remotely sensed imageries of high (very high) spatial resolution not only have been applied in the survey to establish and update topographic maps but also used in many other applications if we exploit the full potential of their radiance properties, as monitoring air and surface water quality etc. over the industrial zones and urban areas. Therefore, this article presents the first results of monitoring the state of surface water quality in the area of Dam Vac, Vinh Phuc province that is waste water basin from industrial zones by using SPOT-5 imageries. Three maps of polluted surface water components such as BOD5, COD, TSS have been established on ArcGIS after running especially radiometric processing on ENVI system of a scene SPOT-5. The results presented in this paper are a part of report belonging into the project nr 977/QĐ-BTNMT signed by Minister of MORE, Vietnam.

1. INTRODUCTION

Using satellite image data in monitoring water environment has been developed for many years. From the 70th – 80th of the 20th century in U.S, LANDSAT satellite image data has been employed to appreciate water quality of Michigan Lake, or Fox River. In Europe, in order to supervise from satellite image data, the river – lake – lagoon system substances such as Montocchio Lake (Italy), Mazury Lake (Poland) have divided into ecological areas depended upon geomorphology, vegetation cover, climate conditions that related to water quality parameters like cholorophyll concentration, cloudiness, suspended. With the boom of China economy in recent years, the environmental problems include water environment have been noticed and taken the remote sensing technology in monitoring water environment quality. Kwangtung (China) is one of the provinces has the high economical growth index; simultaneously involved the environmental pollution. With the help of remote sensing technology, some water pollutants like BOD5, COD were supervised in Shenzhen reservoir by using Landsat satellite image. Combining with field measurement data, remote sensing technology possibly oversees in the large systems of river – lake – lagoon, in industrial zones or in cities. Therefore, periodical monitoring data allows authorities and leaders making decisions suitable for the current condition and future to protect environment.
The results of SPOT5 satellite image process for Vinh Phuc industrial areas presented in this article authorize to expand remote sensing technology in Vietnam.

2. METHODS AND EQUATION

Technological Processing

The technological process can be generalized as in **Figure 1**. The above diagram has 2 major parts:
- Creating "real reflectance" images for objects in the ground through BRDF function.
- Creating "combination" images or building the transformation model to form the images for each pollutant.

Image Correction

The sun rays carry energy with five different routes, finally going on the satellite's sensor. **Figure 2** illustrates the paths of the sun's rays with the characteristic quantities back to sensor (*Jesen, 1996*). **Figure 2** clearly shows the DN values (Digital Number) of the scene with signal L which were recorded by sensor will be the sum of "real" signal, Ls (direct reflection from objects on ground surface to sensor) and the "noise" signal, Lp (the reflection, scattering by the surrounding environment).

$$L = Ls + Lp \quad \textbf{(Equation 1)}$$

The nature of the problem of radiometric correction of satellite image is removing the noise signal Lp. Assuming that the topography surface is Lambert surface (is the smooth surface, height difference is not significant), the radiometric correction should be done involved:

- Correction of spectrum sensor based on its calibrated parameters;
- Atmosphere correction.

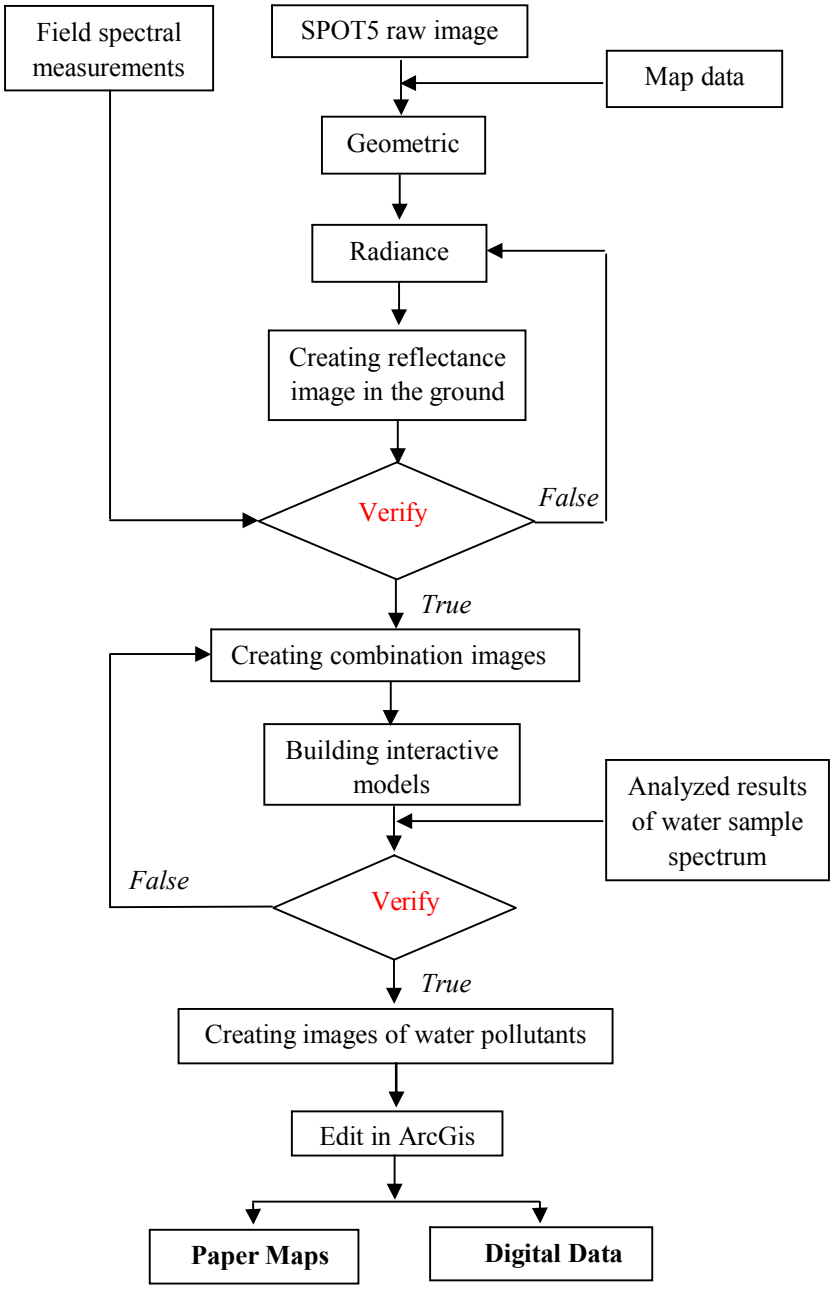

Figure 1: Technological process to create image – map of surface water pollutants

Relationship between radiance spectrum of the four image positions in the space of the same area is described in **Figure 3**. Four image positions are shown as follows:

- Image No.1 is the original (raw) image with pixel DN values (past-sensor image).
- Image No.2 is the result of sensor's spectrum correction; actually converting DN image (past-sensor image) into the radiance image L (at-sensor image).

$$L = DN*a + b \quad \textbf{(Equation 2)}$$

where: *a and b are the gain and offset values. Each spectral band has different gain and offset values.*
*The radiance value L given by such the **Equation 2** has units Watts per square meter per steradiance per micron ($Wm^{-2}sr^{-1}\mu m^{-1}$).*

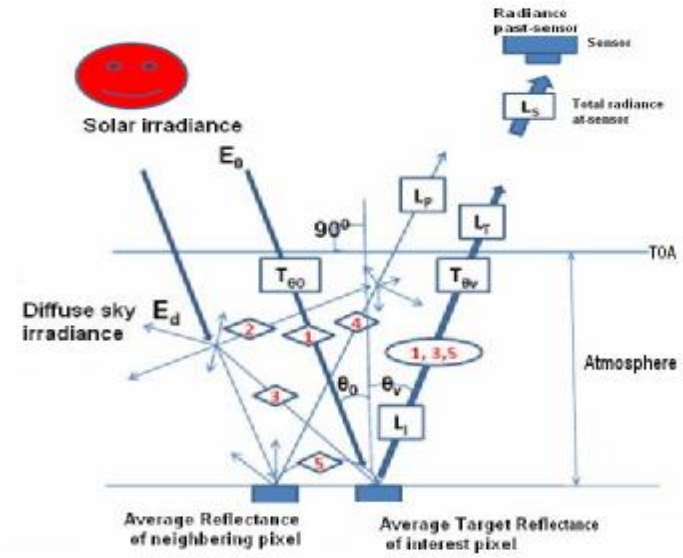

Figure 2: The paths of sun's rays on the sensor

- Image No.3 is the conversion result of radiance image R to reflected image at the top of atmosphere, (denote ρ_{TOA} image).
- Image No.4 is the result of a continuing conversion from ρ_{TOA} image to the reflected image at the surface (denote ρ_{SUR} image).

$$\rho_{sur} = \frac{\pi\left(L - L_p\right)}{T_v\left(E_0.Cos\theta.T_Z + E_d\right)} \qquad \textbf{(Equation 3)}$$

where: *L: radiance value; L_p: path radiance,*
T_v: atmospheric transmittance from Earth to Sensor; T_z: atmospheric transmittance from Sun to ground,
E_o : Solar irradiance; E_d: downewelling diffuse irradiance,
θ: sun zenith angle (or 90^0 – sun elevation angle),

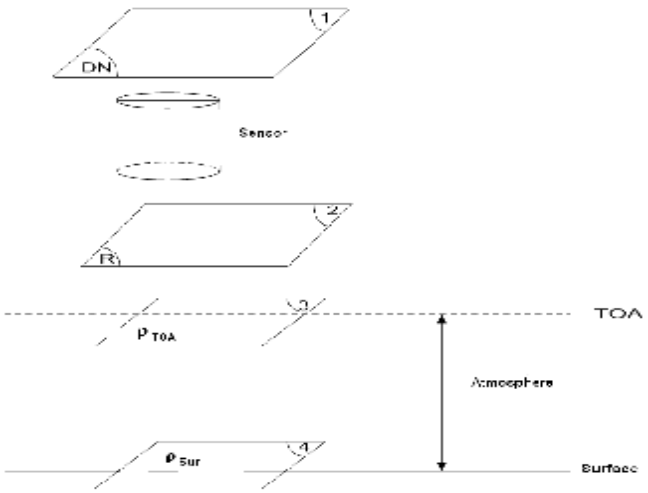

Figure 3: The process of transformation from DN image → R → ρ_{TOA} → ρ_{sur}

3. EXPERIMENT

Supervised Area

There are four operating industrial zones in Vinh Phuc, included 3 zones having waste water treatment centre: Khai Quang, Kim Hoa and Ba Thien industrial zones. Besides, a waste water treatment factory has been built in Binh Xuyen industrial zone.

Image and Map Data

Image Data

SPOT5 satellite image scene number 269-307, processing level 1A obtained on 02/11/2010 in Vietnam National Center for Remote Sensing. The experimental area included industrial zones are located by black boundary (in the right bottom of the scene) after georeferenced to the coordinate system VN-2000 (**Figure 4**). Dam Vac lagoon is specified as the waste water zone and need to be accessed the pollution level.

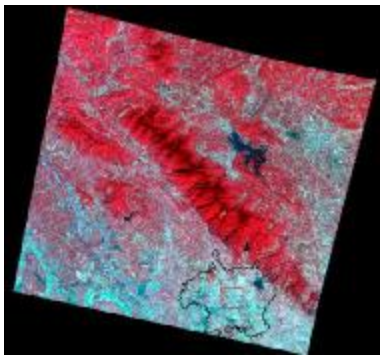

Figure 4: SPOT5269-307 (02/11/2010) – Georeferenced to VN2000

Parameters of SPOT5 scene 269307 obtained on 02/11/2010				
Instrument	Preprocessing Level	Number of spectral bands	Number of line/pixels per line	Corners Location
HRG 2	1A	4	6000/6000	1. N 21°5'0.24" - E 105°19'3" 2. N 21°4'2.49" - E 105°5'6.15" 3. N 21°11'1" - E 105°4'8.49" 4. N 21°1'8.36" - E 105°11'4.6"

Table 1: SPOT5 scene 269-307 parameters (02/11/2010)

Base Map Data

The maps in scale 1:25000 numbered FA67Bd, FA68Ac, FA68Ad, FA68Bc, FA68Cb had been revised in Vietnam National Center for Remote Sensing in 2004.

Field Measurement Data

Spectral Measurement Data for Surface Water

The field surveying group carried out to measure reflectance spectrum at 15 surface water sample points for 3 spectral bands Green–Red–Near Infrared distributed in the 3 industrial zones. The reflectance spectrum range for surface water objects measured in field corresponding to each SPOT5 spectral band Green–Red–Near Infrared in turn: 0.0077–0.2193 (G), 0.0060-0.2374 (R), 0.0043–0.0909 (NIR). The spectrometer used in field is **FieldSpec** ®3, (www.asdi.com).

Surface Water Pollution Components

After measured the reflectance spectrum, the field surveying group carried out to obtain water component concentration at 15 points that got spectrum values before (this work was undertaken by Institute of Environmental Technology belongs to Vietnam Academy of Science and Technology). Furthermore, the concentration of surface water components was specified after analyzed in laboratory. For applying satellite image data in monitoring water quality, we specially made some notes about pollution concentration of surface water components which exceed Vietnam Normatives 2009 (QCVN24-2009) such as: BOD5, COD, TSS (mg/l) (**Table 2**).

	Surface water concentration at sample points (mg/l)				
No.	BOD_5	COD	TSS	Point Information	
Point 1T	269	412	66	Waste water in tank before processing	Khai Quang Industrial Zone
Point 2T	43	68	36	Water after processed that directs to the detention reservoir	
Point 3T	66	114	30	Waste water at the drainage gate (before entering the city public drain)	
Point 4M	24	37	42	Water in the detention reservoir	
Point 5T	75	118	36	Waste water in the city drain	
Point 6M	22	34	64	Water in Dam Vac lagoon nearby the golf	
Point 7T	96	168	25	Waste water in the public drain (before entering Dam Vac lagoon)	
Point 8M	26	42	102	Water in Dam Vac lagoon nearby the city drain gate	
Point 9M	56	89	76	The mixing waste water point in the Binh Xuyen industrial zone	Binh Xuyen Industrial Zone
Point 10T	162	253	46	Waste water in the drain gate	
Point 11M	20	43	126	Water in Dam Khoang lagoon	
Point 12T	38	60	40	Waste water before entering the drain gate	
Point 13T	33	62	19	Waste water in the processing tank	Kim Hoa Industrial Zone
Point 14M	21	31	59	Water in Ca Lo river nearby the mixing waste water point	
Point 15T	32	58	29	Waste water in the drain before entering Ca Lo river	

Table 2: The pollution concentration of surface water components after analyzed sample water in field (include BOD5, COD, TSS)

4. RESULTS

Creating reflectance image

SPOT5 satellite image scene No. 269-307 obtained on 02/11/2010 at an altitude of 800km from the ground. The noise spectral signals (in form of Digital Number – DN) were caused by atmospheric environment following the geometric mechanism Sun – Earth – Sensor. The first important step is transform the image at an altitude of 800km to the image in the ground through spectrum calibration. That step means to get the "real" reflectance value of objects, in this case, is the reflectance spectrum in the ground. To execute this task, we used Bi-directional Reflected Distribution Function (BRDF).

The transformation results DN raw image to reflectance image at the surface (the ρ_{sur} image) represented in (**Figure 5** and **Figure 6**).

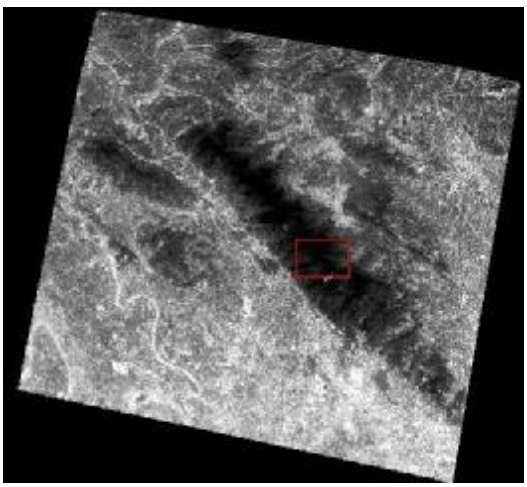

Figure 5: SPOT5 - DN image (band XS1)

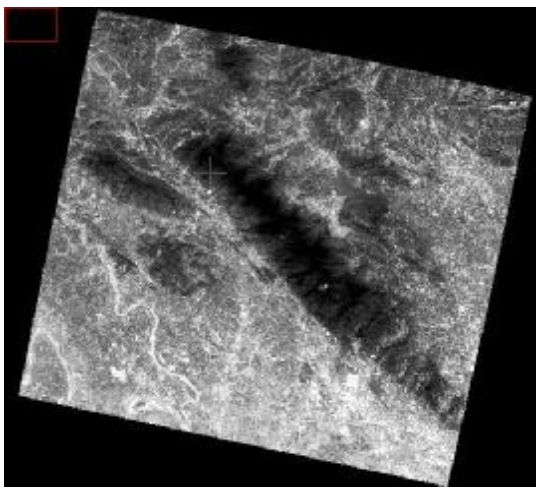

Figure 6: SPOT5 - ρ_{sur} image (band XS1)

To show more obviously the displayed difference, the spatial pixel value tables corresponding to each processing level are presented below (**Table 3** and **Table 4**).

	4033	4034	4035	4036	4037	4038	4039	4040	404
5286	173	156	148	150	188	164	162	166	167
5287	180	[illegible]	246	168	162	177	192	162	151
5288	185	162	189	194	146	160	148	151	154
5289	156	147	146	155	152	161	147	141	143
5290	145	149	141	142	146	149	142	143	137
5291	141	161	155	143	140	147	148	144	139
5292	144	158	166	146	155	162	169	147	138
5293	145	153	160	143	160	172	156	139	143
5294	159	146	140	150	148	147	147	144	152
5295	140	148	144	142	142	144	145	169	158
5296	140	158	171	167	162	160	170	179	166
5297	138	144	168	194	213	175	165	168	170
5298	136	143	152	211	183	175	176	186	156
5299	140	142	153	150	162	151	147	161	159

Table 3: SPOT5 269-307 spatial pixels of XS1 raw image

	4033	4034	4035	4036	
5286	0.126826	0.107355	0.0981922	0.146297	0.144
5287	0.134843	0.158898	0.210436	0.117863	0.114
5288	0.140570	0.114227	0.145151	0.150878	0.095
5289	0.107355	0.0970469	0.0959015	0.106210	0.102
5290	0.0947562	0.0993376	0.0901748	0.0913201	0.095
5291	0.0901748	0.113082	0.106210	0.0924655	0.089
5292	0.0936108	0.109646	0.118808	0.0959015	0.106
5293	0.0993376	0.103919	0.111936	0.0924655	0.111
5294	0.110791	0.0959015	0.0890294	0.100483	0.098
5295	0.0890294	0.0981922	0.0936108	0.0913201	0.091
5296	0.0890294	0.109646	0.124535	0.119954	0.114
5297	0.0867388	0.0936108	0.121099	0.150878	0.172
5298	0.0844480	0.0924655	0.102774	0.170349	0.138
5299	0.0890294	0.0913201	0.103919	0.100483	0.114

Table 4: SPOT5 269-307 spatial pixels of XS1 ρ_{sur} image

Point name	GPS Coordinates	Field Reflectance Spectrum Value			ρsurf Image Value			Real Error		
		G (0.5 - 0.578)	R (0.617 - 0.687)	NIR (0.78 - 0.893)	G	R	NIR	G	R	NIR
1T	[illegible]	0.0789	0.0624	0.0221	0.121099	0.116513	0.206434	-0.042199	0.054113	0.184334
2T	[illegible]	0.1397	0.1149	0.0772	0.0867388	0.0701683	0.0784586	0.0529612	-0.0446317	0.0012586
3T	[illegible]	0.0224	0.0202	0.0196	0.122244	0.123018	0.297364	-0.099844	0.102818	0.277764
4M	[illegible]	0.0157	0.0857	0.059	0.0993376	0.0872427	0.25695	-0.0836376	0.0015427	0.19795
5T	560478; 2353236	0.0106	0.0095	0.0129	0.137134	0.15554	0.304059	-0.126534	0.14604	0.291159
6M	562756; 2355223	0.1159	0.0957	0.0466	0.10621	0.0945603	0.1224	0.00969	0.0011397	0.07564
7T	563330, 2354732	0.0899	0.0956	0.029	0.10621	0.108382	0.130169	-0.01631	0.012782	0.101169
8M	563797; 2354727	0.2193	0.2374	0.0909	0.131407	0.128709	0.310835	0.087893	-0.108691	0.219935
9M	569685; 2351510	0.058	0.0539	0.0747	0.109646	0.106756	0.253583	-0.051646	0.052856	0.178883
10M	569706; 2351497	0.1339	0.103	0.0706	0.101628	0.0880557	0.19603	0.032272	0.0149443	0.12543
11M	569713, 2351497	0.0983	0.0877	0.0827	0.0970469	0.0864296	0.102003	0.0012531	-0.0012704	0.019303
12T	569608; 2351232	0.0077	0.006	0.0043	0.146297	0.140092	0.230008	-0.138597	0.134092	0.225708
13T	574952; 2348416	0.1375	0.122	0.0609	0.141715	0.133587	0.22664	-0.004215	0.011587	0.16574
14M	575767; 2348422	0.1902	0.2049	0.0748	0.119954	0.110822	0.310835	0.070246	0.094078	0.236035
15T	575737, 2348409	0.0604	0.0521	0.0274	0.121099	0.119765	0.357983	-0.060699	0.067665	0.330583
				RMSE	0.0717652865	0.0745489	0.2024813			
				BIAS = 1.5*RMSE	0.107629797	0.1118234	0.303867			

Table 5: Estimating the accuracy of ρ_{sur} image values

For evaluating the quality of ρ_{sur} image, we used field spectral measurement data at 15 sample points (**Table 5**). The result shows there was only 1 point exceeding RMS of bias value and was removed (The authorized limited error in a specific case is 1.5 times RMSE. In theory, the limited error can be 2 or 3 times RMSE). Therefore, we could have a conclusion that the applied correction models ensure the requirement and giving the high accuracy.

Creating Images for Surface Water Pollution Components

To create the images for a number of surface water pollution components, the process is shown below:

- Using the analyzed results of the surface water pollution components, namely: BOD5, COD, TSS.
- Forming image combinations or image transformation models.
- Evaluating to select the optimal model.

The analyzed sample water will provide the concentrations of pollution components. According to QCVN24-2009, we only paid attention to the concentration of components exceeding the threshold to form the images.

In the case of SPOT5 having 3 visible spectral bands (Red – Green – Near Infrared), we constructed the image combinations from the low to higher level for creating images of water pollution components such as: BOD5, COD, TSS. In the results we derived:

$$Ln(BOD5) = 0.533717*F1 + 0.466283*F2;$$
$$Ln(COD) = 0.531286*F3 + 0.468714*F4;$$
$$Ln(TSS) = 0.545459*F5 + 0.454542*F6.$$

Where: F_1 to F6 are the images in higher level combined from surface reflectance images XS_i (i = G, R, NIR).

After exporting images of water pollution components to ArcGIS, we only remained the surface water pollution objects and conducted to classify pollution concentration (measured in mg/l). The last step is displaying and editting following map regulations (**Figure 7**, **Figure 8** and **Figure 9**).

Another major step after obtaining images of some pollutants is assessing the quality of those. To carry out this work, we measured concentration of pollutants in images at 15 sample points. The results of limited error values were worked out as follow:

- The limited error for BOD5 pollutant concentration is: 26 (mg/l).
- The limited error for COD pollutant concentration is: 31 (mg/l).
- The limited error for TSS pollutant concentration is: 28 (mg/l).

5. CONCLUSIONS & RECOMMENDATIONS

Based on SPOT5 image and the analyzed results of pollutant, our research group created the products comprised of images and maps in the scale 1:25000 and a number of evaluating normatives. The products have the approved accuration compared with the field measurement and can attain those results completely by a secure processing. The outcome confirmed that with the current condition possibly to apply remote sensing and GIS technology for detecting and monitoring water environment quality in city – industrial zones. Concurrently, the requirement demands the association between inter-disciplinary organization in order to gain the high quality products.

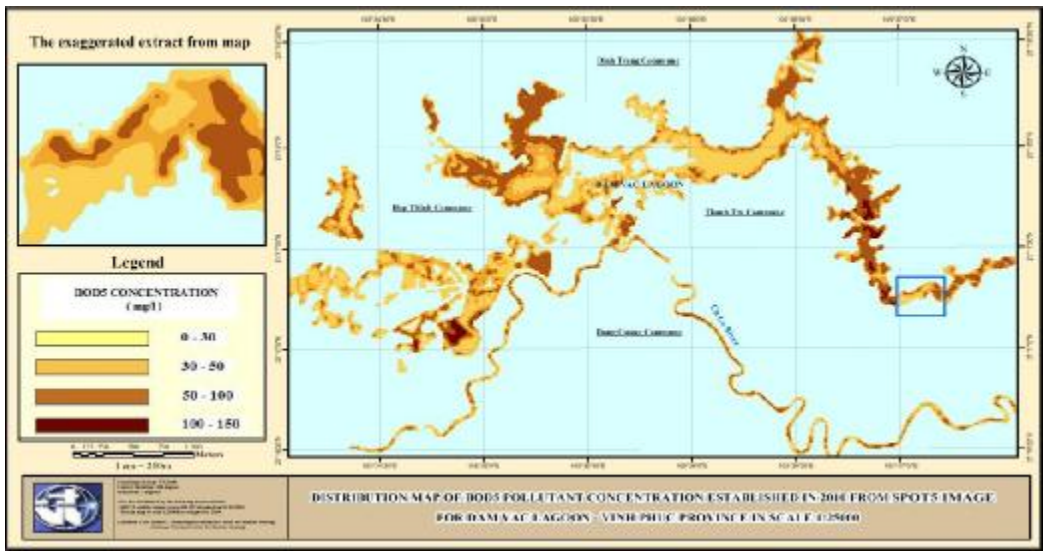

Figure 7: The map of BOD5 from SPOT5 image (02/11/2010) for Dam Vac lagoon, Vinh Phuc, scale 1:25000

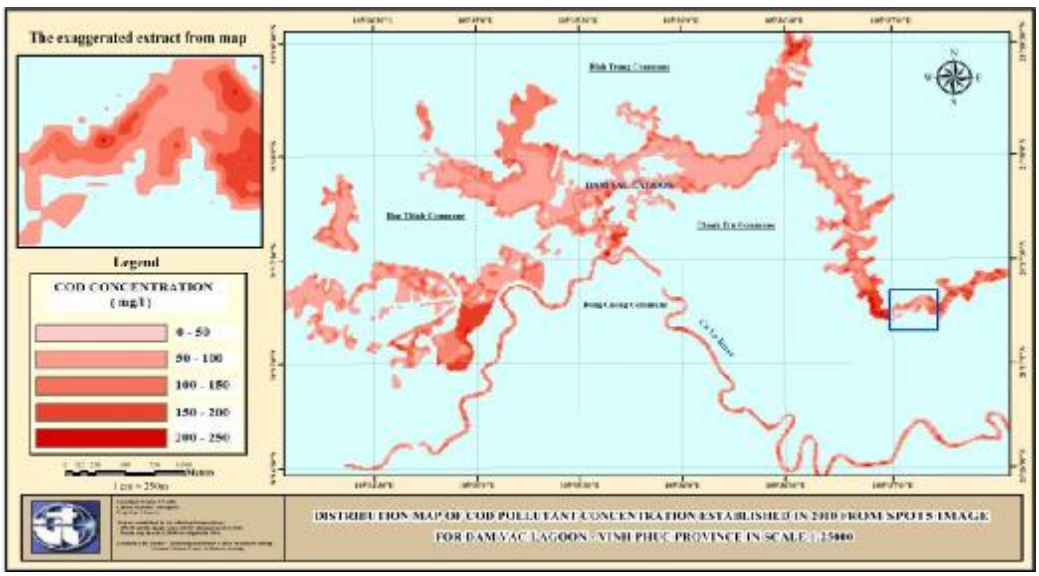

Figure 8 The map of COD from SPOT5 image (02/11/2010) for Dam Vac lagoon, Vinh Phuc, scale 1:25000

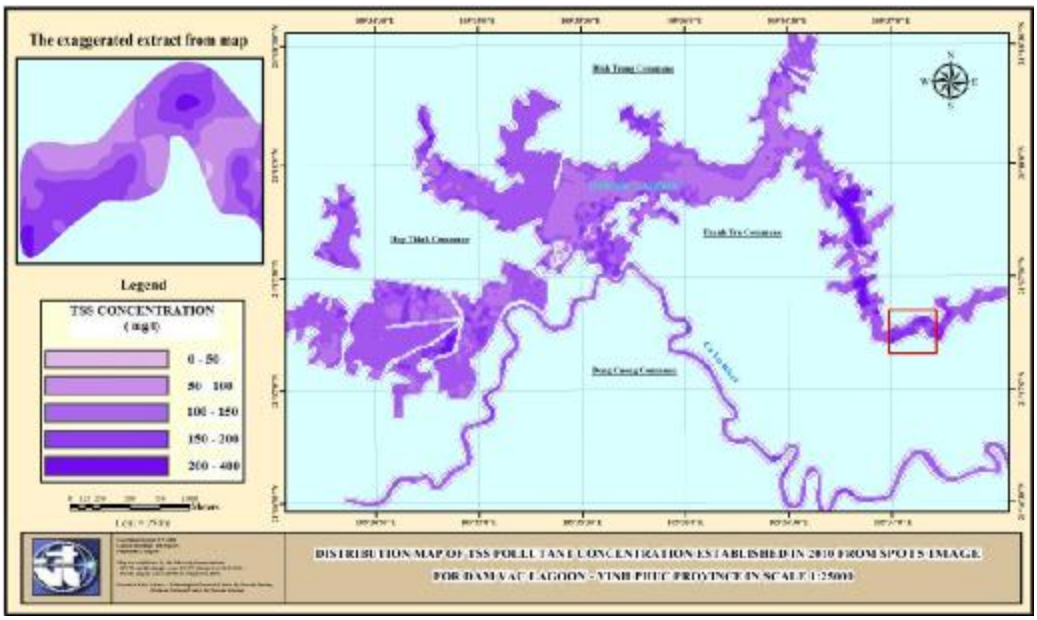

Figure 9: The map of TSS from SPOT5 image (02/11/2010) for Dam Vac lagoon, Vinh Phuc, scale 1:25000

REFERENCES:

Alparslan E, Coskun G, Alganci U., 2009, Water quality determination of Küçükçekmece Lake Turkey by using multispectral satellite data. Scientific World Journal (9), pp 1215-1229.

M. Kaiser, H. Aboulela, H. A. El-Serehy, H. Ezz Edin, 2008. Spectral Enhancement of the SPOT Imagery Data to Assess Marine Pollution near Port Said Egypt. PIERS Proceedings, Cambridge.

Ismail Mohd Hasmadi, Usali Norsaliza, 2010. Analysis of SPOT- 5 Data for Mapping Turbidity Level of River Klang Peninsular Malaysia. Applied Remote Sensing Journal.

Harma, P., Vepsalainen, J., Hannonena, T., Pyhalahti, T., Kamari, J., Kallio, K., Eloheimo, K., and Koponen, S., 2001. Detection of water quality using simulated satellite data and semi-empirical algorithms in Finland. The Science of the Total Environment, 268, pp.107-121.

Hu, C., Chen, Z., Clayton, T. D., Swarzenski, P., Brock, J. C., and Muller-Karger, F.E., 2004. Assessment of estuarine water-quality indicators using MODIS medium-resolution band: Initial results from Tampa Bay, FL. Remote Sensing of Environment., 93, pp.423-441.

Wu, C. I., 2001. The study of using satellite images to monitor the water quality of mountain Yonghe reservoir. Master Thesis of Chun-hwa University (Chinese), Taiwan, R.O.C.

Keith D. Hutchison, 2003. Applications of MODIS satellite data and products for monitoring air quality in the state of Texas. Atmospheric Environment 37, pp.2403–2412.

Hellweger, F. L., P. Schlosser, U. Lall, and J. K. Weissel, 2004. Use of satellite imagery for water quality studies in New York Harbor. Estuarine Coastal and Shelf Science, Vol. 61, pp.437–448.

APHA, 1992. Standard Methods for the Examination of Water and Wastewater (16th ed). American Public Health Association, Washington D.C.

Lillesand, T. M., R. W. Kiefer, and J. Chipman, 2004.Remote Sensing and Image Interpretation (5th ed.). John Wiley and Sons, New York.