BUILDING FORECAST MAPS OF WATER QUALITY FOR MAIN RIVERS AND CANALS IN TIEN GIANG PROVINCE, VIETNAM

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Abstract

This study aims to enhance the mapping of forecast for water quality assessment in Mekong Delta provinces. The data from 32 sites from main rivers and canals in an area of around 2,482 km^2 in Tien Giang Province, Vietnam, were used for calculation and mapping. The ArcGIS 9.3 software, Inverse Distance Weighting (IDW) interpolation method, hydrologic data, and water quality parameters in March (2010-2014) were applied to build the maps showing 2020 water quality predictions for main rivers and canals in Tien Giang Province. The estimation was based on the Water Quality Index (WQI) with 6 parameters such as pH, total suspended solid (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), total nitrogen (T_N), and coliform. The results showed that water quality in the studied area in dry season will not be improved by the year 2020. The finding could be a scientific reference for the selection of effective approaches to improve water quality in main rivers and canals in Tien Giang Province.

Keywords: ArcGIS software, main rivers and canals, maps of forecasting, water quality, Water Quality Index (WQI).

1 INTRODUCTION

Tien Giang Province is located to the North of the Mekong Delta with an area of around 2,482 km^2, along the North of Tien River, Long An Province, and shares the border with Long An Province and Hochiminh City in the north, Dong Thap Province in the west, East Sea in the east, and Ben Tre Province in the south (*Fig. 1*) [1]. The Tien and Vam Co Tay rivers with Soai Rap, Tieu, Dai river mouths offer good and favourable conditions for the aquaculture. The terrain is divided into three distinct regions: fruit gardens along the bank of the River Tien, a plain and seaside. The area has two distinct seasons: rainy season (from May to November) and dry season (from December to April of next year) with average rainfall of 1,210-1,424 mm per year and an average temperature of 27-27.9^{0}C. The policies for socio-economic development and land-use change have stimulated the economic growth of Tien Giang, but the water pollution has a tendency to increase. Nowadays, Tien Giang has become an industrial province with many industrial parks, industrial clusters such as: My Tho IP, Tan Huong IP, Long Giang IP, Xoai Rap IP... and many industrial clusters with an area over 100ha: Tan My Chanh, Binh Duc, An Thanh….[1] These consequences of environmental pollution are thus far from inevitable. According to the Tien Giang Natural Resources and Environment Department, the TSS, COD, BOD_5, oil, *E. coli* parameters in 2011 exceeded the allowed levels (the National Technical Regulation for Surface Water Quality of levels A1 and A2) [1].

In order to contribute to the water resources management and improve water quality monitoring for main rivers and canals in Tien Giang Province, the ArcGIS 9.3 software, Inverse Distance Weighting (IDW) interpolation method, hydrologic data, and water quality parameters in March (2010-2014) were applied to build the maps showing 2020 water quality predictions for main rivers and canals in Tien Giang Province.

The objectives of the research were to: (1) Evaluate the properties of water quality for main rivers and canal in Tien Giang Province; and, (2) Apply the GIS technology for forecasting 2020 water quality for main rivers and canals in Tien Giang Province.

2 METHODS

2.1 Study sites

Based on the characteristics of socio-economic development, water bodies, flows, environmental variables, and ecological conditions, 32 sampling sites for main rivers and canals in Tien Giang Province were pointed out and were representative for a sampling program (*Fig. 1*).

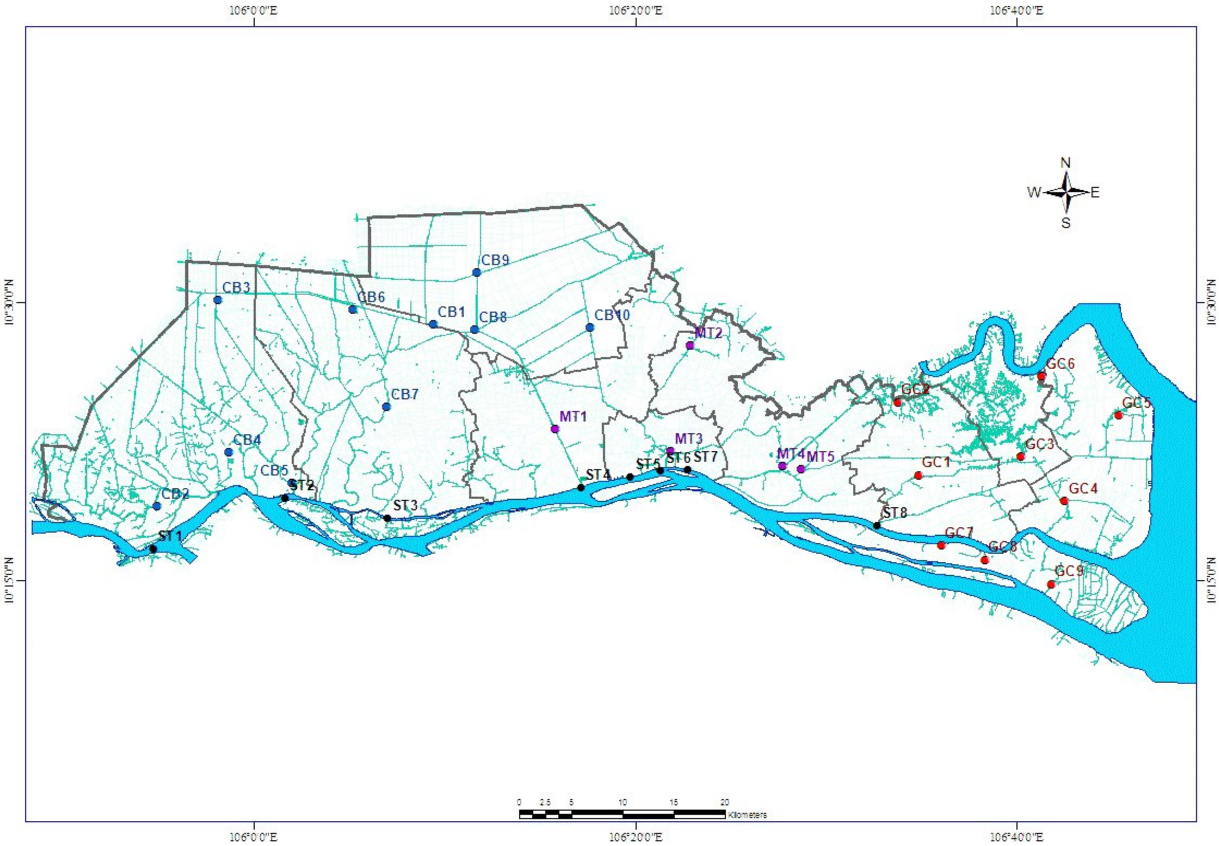

Fig. 1 Map of sampling sites.

2.2 Sampling Processing

The samples for water quality analyses in the field were collected according to the Operational Guide (3rd Ed.), UN Environment Programme (1992) [2]. The samples were taken in March in the period 2010-2014. Sample locations at each site were taken in the middle of the river with a depth layer of surface water of 30-40 cm. The water samples were collected in 2 litre plastic bottles and kept at 2^0C temperature [2].

2.3 Laboratory analysis

The aquatic environmental parameters (pH, TSS, DO, BOD_5, T_N and coliform) were analysed according to standard methods (APHA-AWWA-WEF, 1998). [3]

2.4 Calculation of Water Quality Index (WQI)

The WQI Calculation for building the forecast maps was implemented according to Ton That Lang et al [4]. The WQI was based on 6 parameters pH, TSS, DO, BOD, T_N, and coliform. The classification of water quality was presented in Tab. 1.

Tab. 1 Classification of water quality [4]

No.	WQI	Ranking	Color Indicators
1	9,0 – 10	Very light pollution	Blue
2	7,0 – 8,9	Light pollution	Green
3	5,0 – 6,9	Low moderate pollution	Yellow
4	3,0 – 4,9	High moderate pollution	Orange
5	1,0 – 2,9	Heavy pollution	Red
6	< 1,0	Very heavy pollution	Brown

2.5 Map Building Procedures

Inverse Distance Weighting (IDW) estimated cell values by averaging the values of sample data points in the vicinity of each cell. The closer a pint was to the centre of the cell being estimated, the more influence, or weight, it had in the averaging process. This method assumed that the variable being mapped decreases depending on the distance from its sampled location. The interpolation function is as follows [5]:

$$\lambda i = \frac{\sum_{j=1}^{G} \lambda j / D_{ij}^{p}}{\sum_{j=1}^{G} 1 / D_{ij}}$$

Where λ_i is the property at location i; λ_j is the property at location j; D_{ij} is the distance from i to j; G is the number of sampled locations; and p is the inverse-distance weighting power. The weights were proportional to the inverse distance raised to the power p. The decrease of weights depends on the value p. If $p = 0$, there was no decrease with distance, and because each weight λ_i is the same, the prediction is the mean of all the measured values. As p increased, the weights for distant points influenced the prediction. $P = 2$ was used as a result value [6].

The characteristics of the interpolated surface could also be controlled by applying a search radius, fixed or variable, which limited the number of input points that could be used for calculating each interpolated cell [7], [8].

3 RESULTS AND DISCUSSION

3.1 Characteristics of Water Quality

In March from 2010 to 2014, the results of water quality for main rivers and canals in Tien Giang Province are shown in Tab. 2. The results of water quality parameters at many sites did not meet the National Technical Regulation for Surface Water Quality of levels A1 (good quality for water supply) and A2 (good quality for aquatic communities reservation), especially the values of DO, BOD_5, coliform [9].

Table 2. Water quality parameters (min-max, mean) for main river and canals in Tien Giang Province, 2010-2014.

Sites	pH	TSS (mg/L)	DO (mg/L)	BOD5 (mg/L)	T_N (mg/L)	Coliform (MPN/100mL)
ST1	6.0–7.5 (6.9)	6–28 (12)	1.6–3.9 (2.9)	3–14 (6)	0.41–1.13 (0.73)	1500–15000 (5100)
ST2	6.6–7.5 (7.0)	8–23 (16)	2.2–6.0 (3.3)	1–8 (4)	0.48–1.12 (0.65)	2300–23000 (4000)
ST3	6.5–7.2 (7.0)	11–18 (15)	2.2–5.2 (3.4)	3–11 (6)	0.45–1.15 (0.66)	530–9100 (6000)
ST4	6.8–7.4 (7.1)	13–45 (24)	2.2–3.7 (2.9)	2–6 (4)	0.95–1.55 (1.28)	100–6000 (2500)
ST5	6.6–7.7 (7.1)	16–59 (33)	1.9–6.0 (3.2)	3–7 (4)	0.60–1.01 (0.81)	900–530000 (75000)
ST6	6.9–7.9 (7.2)	19–70 (32)	1.8–4.6 (2.9)	3–8 (5)	0.51–1.62 (1.17)	2100–9300 (5100)
ST7	6.7–8.2 (7.3)	13–58 (28)	2.3–6.1 (3.6)	4–7 (5)	0.72–1.65 (0.98)	110–750000 (370000)
ST8	7.0–7.8 (7.4)	14–108 (46)	2.1–5.7 (3.2)	8–16 (12)	0.45–0.86 (0.62)	9000–5300000(4900000)
CB1	6.2–7.2 (6.6)	13– 8 (20)	1.9–6.2 (3.5)	3–8 (5)	0.50–1.25 (0.92)	1400–11000 (2300)
CB2	6.1–7.4 (6.9)	8–26 (15)	1.8–4.9 (3.2)	3–9 (5)	0.22–1.15 (0.61)	200–2900 (1400)
CB3	6.2–7.1 (6.6)	14– 0 (22)	2.1–3.3 (2.5)	9–12 (10)	0.86–1.73 (1.23)	3000–75000 (32000)
CB4	6.2–7.4 (6.9)	9–31 (19)	2.4–3.9 (3.1)	3–14 (7)	0.56–1.01 (0.81)	390–12000 (6100)
CB5	6.5–7.2 (6.9)	10–26 (15)	2.2–5.4 (3.3)	2–6 (4)	0.45–0.76 (0.59)	600–70000 (12000)
CB6	6.5–7.5 (6.8)	12–47 (28)	1.3–5.7 (3.0)	5–12 (9)	0.81–1.47 (1.22)	900–70000 (33000)
CB7	6.5–7.1 (6.8)	21–31 (25)	1.9–5.6 (3.2)	3–8 (5)	0.84–1.15 (0.97)	1100–20000 (12000)
CB8	6.4–7.3 (6.8)	18–41 (27)	2.0–5.8 (3.2)	3–10 (7)	0.83–3.43 (1.51)	4000–120000 (79000)

Sites	pH	TSS (mg/L)	DO (mg/L)	BOD5 (mg/L)	T_N (mg/L)	Coliform (MPN/100mL)
CB9	3.7–6.9 (5.8)	15–85 (36)	2.3–6.0 (3.3)	2–11 (8)	0.34–1.41 (0.97)	2300–90000 (70000)
CB10	6.9–7.3 (7.1)	19–31 (25)	2.3–3.8 (3.0)	5–7 (6)	0.52–1.20 (0.76)	900–750000 (370000)
MT1	6.2–7.1 (6.6)	8–57 (24)	2.3–5.6 (3.4)	4–7 (5)	0.15–2.14(1.08)	100–23000 (4500)
MT2	6.4–7.1 (6.7)	5–33 (18)	1.7–3.5 (2.7)	4–8 (6)	1.06–2.66 (1.62)	120–640000 (7000)
MT3	6.5–7.3 (6.8)	13–62 (29)	1.9–5.6 (3.3)	3–7 (6)	0.65–1.14 (0.90)	2300–21000 (9800)
MT4	6.5–7.4 (7.0)	17–197 (100)	1.1–5.0 (2.7)	10–101 (32)	0.70–3.57 (1.89)	1100–90000 (51000)
MT5	6.2–9.1 (7.6)	11–87 (32)	1.6–5.9 (3.2)	5–15 (8)	0.87–3.79 (1.97)	110–3100000 (15000)
GC1	6.5–7.5 (7.1)	17–103 (51)	2.3–5.2 (3.3)	5–70 (21)	0.73–1.21 (0.85)	2000–1100000 (9000)
GC2	6.7–7.7 (7.2)	8–68 (28)	1.8–5.1 (3.1)	14–36 (20)	0.31–1.57 (0.86)	400–3900000 (30000)
GC3	6.9–7.4 (7.1)	15–51 (30)	1.9–6.1 (3.4)	6–37 (16)	0.27–1.25 (0.75)	10000–60000 (40000)
GC4	6.6–7.5 (7.0)	7–33 (22)	2.5–6.0 (3.6)	5–33 (12)	0.41–1.12 (0.69)	5300–140000 (60000)
GC5	6.8–7.6 (7.1)	19–58 (32)	1.5–5.5 (2.8)	5–21 (10)	0.10–1.82 (0.61)	700–3900000 (5300)
GC6	6.5–7.7 (7.0)	5–39 (19)	2.4–5.2 (3.4)	6–22 (10)	0.05–1.52 (0.49)	400–530000 (6000)
GC7	7.1–7.3 (7.2)	22–147 (58)	2.3–3.9 (3.0)	10–41 (20)	0.98–3.52 (1.82)	24000–7500000(460000)
GC8	7.2–7.4 (7.3)	25–132 (61)	2.2–3.6 (2.9)	8–38 (18)	0.38–1.77 (0.89)	6000–4000000 (600000)
GC9	5.5–7.3 (6.7)	5–140 (43)	2.3–6.0 (3.7)	5–59 (22)	0.61–3.50 (2.18)	46000–5400000 (93000)

Generally, the analysis results of environmental variables at 32 sites sampled from 2010 to 2014 showed that the water quality in the study area was quite good. The pollution level tended to increase on the urban and industrial sites (ST7, ST8, CB10, GC7, GC8).

3.2 Water Quality Index (WQI)

In March from 2010 to 2014, the values of WQI at 32 sites for main rivers and canals in Tien Giang Province were presented in Tab. 3. Based on the values of WQI, the water quality assessment was classified in Fig. 2.

Tab. 3 WQI values for main rivers and canals in Tien Giang Province in March, 2010-2014

No.	Sites	2010	2011	2012	2013	2014	Mean
1	ST1	7.3	7.8	7.4	6.5	6.3	7.1
2	ST2	7.8	7.5	7.3	6.5	6.5	7.1
3	ST3	7.8	7.9	7.0	6.5	6.3	7.1
4	ST4	7.9	7.0	8.1	6.2	6.6	7.2
5	ST5	6.7	6.5	7.6	6.4	6.0	6.6
6	ST6	7.1	6.6	7.2	6.3	6.5	6.7
7	ST7	8.0	6.4	6.9	6.4	6.0	6.7
8	ST8	6.8	5.2	6.3	6.2	5.1	5.9
9	**CB1**	7.2	7.3	7.3	6.9	6.6	7.1
10	**CB2**	7.8	7.9	8.2	6.7	6.5	7.4
11	**CB3**	7.2	6.7	7.2	5.6	5.9	6.5
12	**CB4**	6.9	7.8	7.7	6.5	6.2	7.0
13	**CB5**	7.2	7.5	7.8	6.5	6.6	7.1
14	**CB6**	8.0	6.8	6.5	6.1	6.1	6.7
15	**CB7**	7.4	7.2	7.0	6.5	6.6	6.9

No.	Sites	2010	2011	2012	2013	2014	Mean
16	**CB8**	7.6	6.8	6.8	5.7	5.8	6.5
17	**CB9**	6.0	6.6	6.3	6.0	5.9	6.2
18	**CB10**	7.5	6.7	6.5	6.9	5.9	6.7
19	**MT1**	7.5	7.7	8.4	5.8	6.1	7.1
20	**MT2**	7.9	6.6	7.1	6.2	6.2	6.8
21	**MT3**	7.2	6.6	7.7	6.2	6.6	6.9
22	**MT4**	3.6	5.4	7.3	5.7	5.0	5.4
23	**MT5**	7.0	5.9	7.6	5.8	6.1	6.5
24	**GC1**	7.1	5.6	7.5	6.4	3.4	6.0
25	**GC2**	6.5	6.3	7.6	6.1	5.0	6.3
26	**GC3**	6.6	6.2	7.2	6.3	5.2	6.3
27	**GC4**	7.4	6.8	7.4	6.1	5.2	6.6
28	**GC5**	7.6	6.2	7.4	6.3	5.0	6.5
29	**GC6**	8.1	6.3	7.8	6.2	5.5	6.8
30	**GC7**	5.1	5.3	6.1	5.6	5.3	5.5
31	**GC8**	5.2	5.2	7.2	6.1	4.8	5.7
32	**GC9**	7.2	5.6	6.3	5.5	3.8	5.7

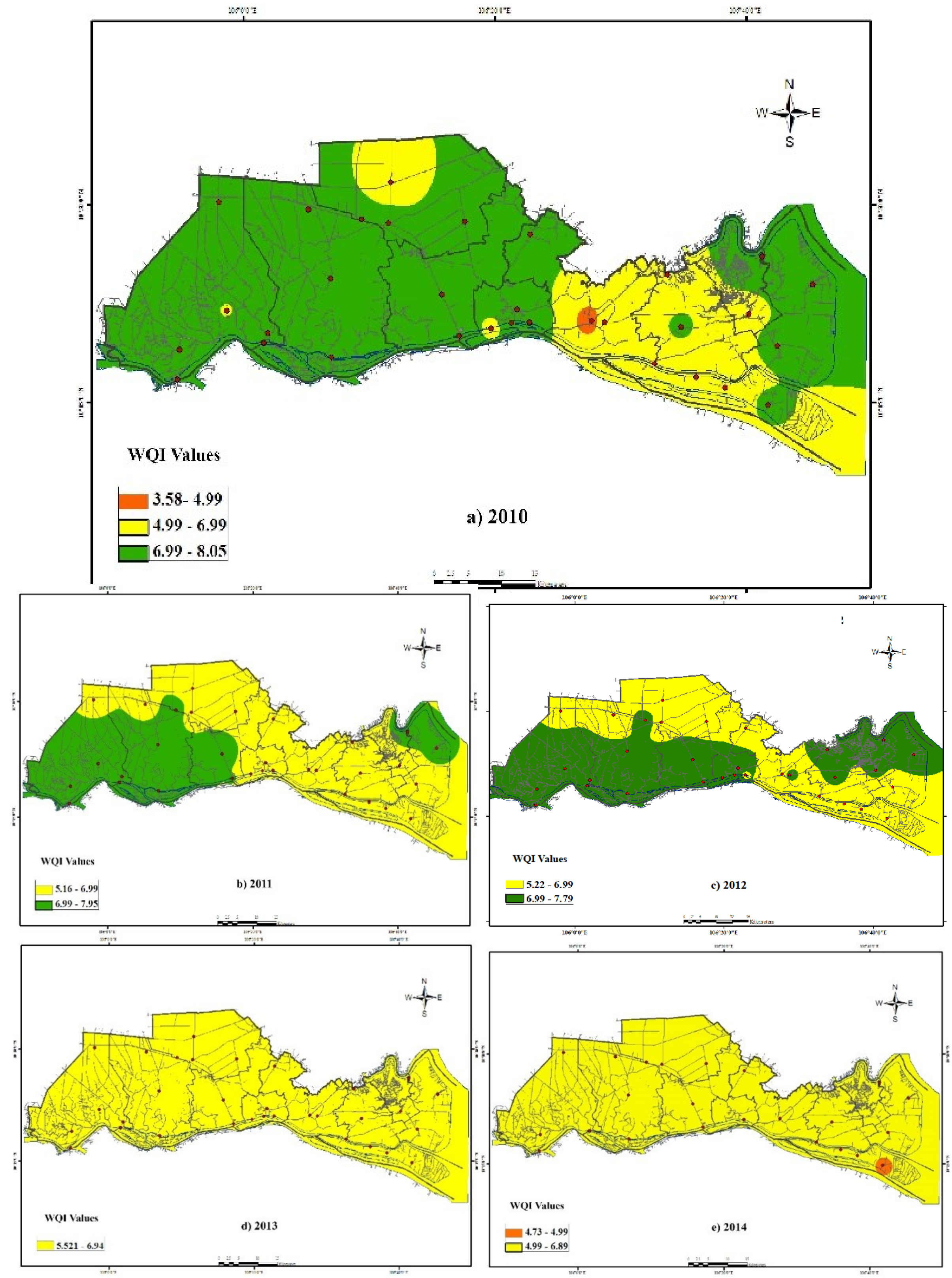

Fig. 2 Maps of water quality classification for main rivers and canals in Tien Giang Province in March, 2010-2014.

The water quality at 32 sites in the studied area was divided to 3 levels: (1) Very light pollution; (2) Light pollution; and, (3) Low moderate pollution. The water quality tended to reduce from the West (upper sites) to the South (lower sites). The WQI of water bodies in Tien Giang province was better compared to Vam Co Dong River and Saigon River.

During the period 2010-2013, water quality was better than that in 2013-2014. This could be a result of the strong industrial development of Tien Giang Province in the period of 2011-2015 while the approaches to environmental protection have not appropriately been controlled yet [10]. These water quality based on the physiochemical parameters were in agreement with the water quality assessment using benthic macro-invertebrates in water bodies, Tien Giang province [11].

3.3 Maps Forecasting 2020 Water Quality

The maps predicting water quality for main rivers and canals in Tien Giang Province from 2015 to 2020 were presented in Fig. 3. The 2020 water quality at 32 sites was divided to 5 levels: (1) Very light pollution; (2) Light pollution; and, (3) Low moderate pollution; (4) High moderate pollution; and, (5) High pollution. These results corresponded to the characteristics of socio-economic development in this study.

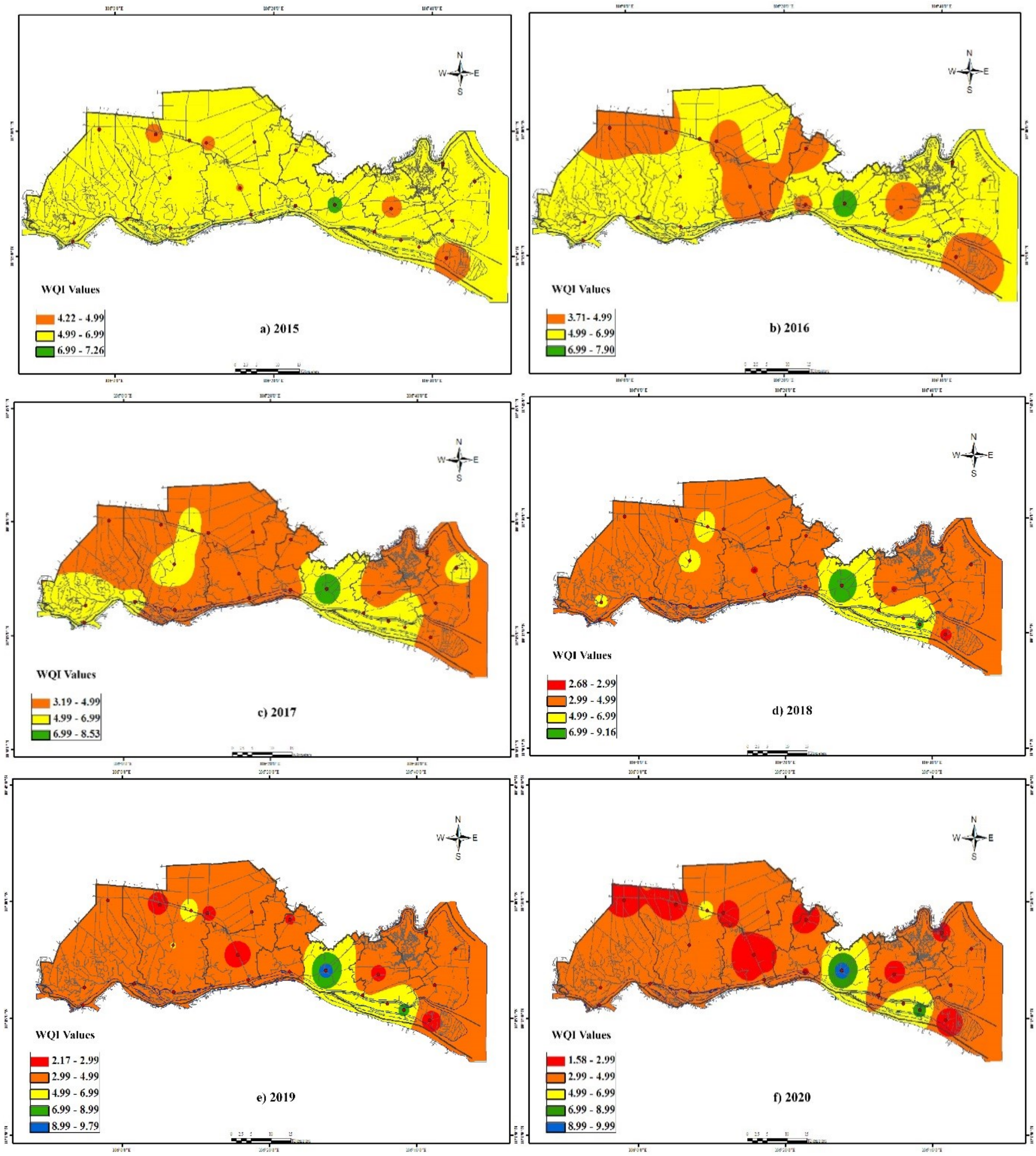

Fig. 3. Forecast Maps of 2020 water quality for main rivers and canals in Tien Giang Province.

Generally, 2020 water quality had a decreasing tendency at most sampling sites, except the sites in Chau Thanh and Go Cong Tay districts. These results showed that 2020 water quality at many sites cannot meet the demands for drinking water supply of Tien Giang Province [9].

4 CONCLUSION

The forecast maps of 2020 water quality for main rivers and canals in Tien Giang were built based on the WQI with the parameters pH, TSS, DO, BOD_5, T_N, and coliform in combination with GIS technology. Water quality at many sites had a decreasing tendency, and it could not meet the demands for potable water supply of Tien Giang Province.

Additionally, the properties of water quality for main rivers and canals were presented. The findings could be a scientific reference in selecting effective approaches to water quality management in Tien Giang Province.

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