Spatial dynamics of the Coastal Eutrophication Analysis System by SPA Process Realization and Data Analysis

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Abstract

Coastal eutrophication phenomenon is one of the lists of Sustainable Development Goals (SDGs 14) life below water, which has the primary problem that facing the most of coastal water bodies in worldwide areas. It is crucial to have a flexible analysis system for analyzing the dynamic coastal water-quality. So, this paper presents a new analysis system with a mathematical equation for Metadata analysis and eutrophication classification, which created in the database. The essence of this paper is to illustrate the meta-level knowledge of database for coastal eutrophication analysis. For the implementation of the Mathematical Equation for Metadata analysis and eutrophication classification found that Oligotrophic had 71 times, Mesotrophic had 148 times, Lower-eutrophic had 154 times, Eutrophic had 100 times, Upper-eutrophic had 49 times, Seriously-eutrophic had 31 times, Hyper-eutrophic had 13 times.

This paper shows the effectiveness of SPA process to analyze and classify the coastal eutrophication phenomenon.

Keywords : Coastal Eutrophication Analysis System, SPA Process, Data Analysis

INTRODUCTION

Recently, biodiversity in the coastal and marine area being destroyed by pollution in the water body. In 2008 the biodiversity in the coastal and marine area is decreasing by more than 66 % from 1970. For Thailand coastal situation in 2012, the expansion impact to life underwater decreases at least 30 % of the primary production rate for fish (World Wildlife Fund, 2012)

Sustainable Development Goals (SDGs 14) in part of life below water addressed to coastal eutrophication. The one of advancing the sustainable use and conservation on SDGs 14 with coastal eutrophication is to studies global trends point of coastal waters due to pollution and eutrophication for expansion the protected areas for marine biodiversity and remain critically important to preserve marine resources (United Nations, 2015). Coastal water-quality is the key to maintaining coastal ecosystem function, which is essential to life below water and access to the coastal sustain-

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able development for societies (Srebotnjak et al., 2012). Coastal water-quality with enrichment in nutrients especially nitrogen compounds (N) and phosphate compounds (P) causes the growth of the aquatic plant as an algae or eutrophication phenomenon (Kong et al., 2017). Eutrophication crisis usually leads to a variety of impacts of coastal, such as 1) the depletion of dissolved oxygen (DO), 2) the reduction light transparency, 3) the occurrence of high levels of chlorophyll a or toxic algae bloom (Smayda, 2008), 3) the occurrence of anoxia and hypoxia (Gerlach, 1990), and 4) a biodiversity of marine ecosystem and environment loss (Xu et al., 2012).

In recent decades with the rapid growth of economic and industry, and population growth is effect to increasing eutrophication phenomenon in the coastal area. There are several existing significant research and implementations in water-quality analysis area for providing the eutrophication phenomenon. One of the most important in part of Environmental information technology is to deliver the meaning of the environmental phenomenon (eutrophication) to the society for protecting and preserving the coastal. So in this paper, we proposed a method for a spatial dynamic of the coastal eutrophication analysis system by SPA process realization and data analysis. The essence of this paper is to illustrate the meta-level knowledge of database for coastal eutrophication analysis.

PROPOSED METHOD

This research proposed an analysis system for analyzing and classification the coastal water-quality for eutrophication situation, which is realized SPA Process realization and Metadata Analysis.

In our proposed method consists of 3 parts: (1) SPA Process realization for Coastal water-quality analysis, (2) Eutrophication classification, and (3) Mathematical Equation for Metadata analysis. The outlined by the following;

A. SPA Process realization for Coastal water-quality analysis

Sensing Processing Actuation (SPA) process is an effective concept for supporting the definition of performing initial action according to an occurrence of real-time environmental evidence. (Kiyoki and Chen, 2014), (Kiyoki and Kawamoto, 2007) and (Kiyoki and Ishihara, 2003). rSPA Process was realized from SPA process, which is a tool to determine the critical and classification of single and muti-features in detail (Chalisa and Kiyoki, 2015).

In this paper, SPA Process is utilized to support the definition of rule in automatically performing initial action in response to the occurrence of real coastal eutrophication phenomenon. The Sensing (S) layer is sensing data from raw water-quality data, international standards of water feature and scientific statement, which is related eutrophication condition in coastal areas. The Processing (P) layer is a part of analysis data with logic test and knowledge of database. And the Actuation (A) layer is a part of the output to deliver the level of eutrophication situation. The system architecture of this research is shown in Figure 1.

The purpose of this part is to realize and create the automatic interpreting system for eutrophication situation for coastal water-quality analysis.

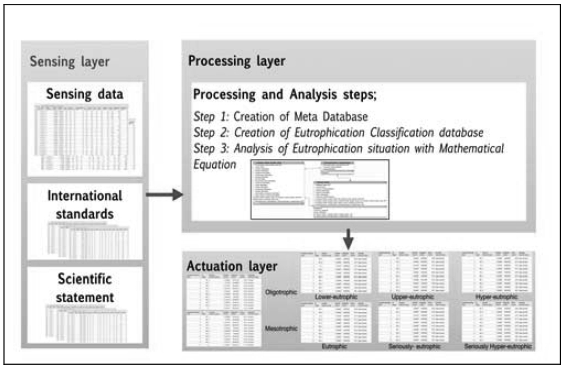

Figure 1 The system architecture of this research

B. Eutrophication classification

The eutrophication level related to 2 mainly pollutant features: phosphate (PO_4^{3-}) and Total nitrogen, which in total nitrogen in form of ammonia (NH_4^{3-}), nitrite (NO_2), and nitrate (NO_3). The mainly pollutant features used to determine the level of eutrophication situation in the coastal area.

The purpose of this part is to establish the database of eutrophication classification.

The number of levels is different depending on the level (C), which is represented as

$C_i = \{C_1, C_2, C_3, ..., C_i, C_q\}$

$$f_{eutro}(PO_4^{3-},TN) = \begin{cases} C_{1,} & \{(PO_4^{3-},TN) \in R^2 : 0.0 < PO_4^{3-} < 4.6 : 0.0 < TN < 300.0\} \\ C_{2,} & \{(PO_4^{3-},TN) \in R^2 : 4.6 \le PO_4^{3-} < 10.0 : 300.0 \le TN < 600.0\} \\ C_{3,} & \{(PO_4^{3-},TN) \in R^2 : 10.0 \le PO_4^{3-} < 23.0 : 600.0 \le TN < 1000.0\} \\ C_{4,} & \{(PO_4^{3-},TN) \in R^2 : 23.0 \le PO_4^{3-} < 50.0 : 1000.0 \le TN < 1500.0\} \\ C_{5,} & \{(PO_4^{3-},TN) \in R^2 : 50.0 \le PO_4^{3-} < 110.0 : 1500.0 \le TN < 2000.0\} \\ C_{6,} & \{(PO_4^{3-},TN) \in R^2 : 110.0 \le PO_4^{3-} < 250.0 : 2000.0 \le TN < 3000.0\} \\ C_{7,} & \{(PO_4^{3-},TN) \in R^2 : 250.0 \le PO_4^{3-} < 550.0 : 3000.0 \le TN < 4600.0\} \\ C_{8,} & \{(PO_4^{3-},TN) \in R^2 : 550 \le PO_4^{3-} : 4600.0 \le TN\} \end{cases}$$

Where

$f_{eutro}(PO_4^{3-}, TN) = \{C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8\}$ ← {Oligotrophic, Mesotrophic, Lower-eutrophic, Eutrophic, Upper-eutrophic, Seriously- eutrophic, Hyper-eutrophic, Seriously Hyper-eutrophic},

$PO_{4\,obs}^{3-}$ = the observation value of conductivity parameter,

TN_{obs} = the observation value of total dissolved solid parameter,

C. Mathematical Equation for Metadata analysis

The decreasing factor (F) is a mathematic equation used for aggregating several decreasing water-quality parameters into a single score. The decreasing factor calculated by the sum of several sub-factor (P_i) with their weight (W_i) and the scale of each sub-factor (P_i) is in the range of 0 to 100 (Yan and Feng, 2015 and Veesommai and Kiyoki, 2018).

The purpose of this part is to realize the decreasing factor (F) for dealing with the coastal water-quality analysis.

Sub-factor (P_i) calculation

The method for calculating the Sub-factor (P_i) is represented as Eq. 1

$P = \{P_1, P_2, P_3, . . . P_i, P_r\}$, when the number of sub-factor is r

$$f_{(i)} = \begin{cases} 100, & if\ X_i > C_{i0} \\ \frac{100(k-j)}{k} + \frac{100}{k}\frac{C_{ij}-X_i}{C_{ij}-C_{i(j-i)}}, & if\ C_{ij} < X_i \le C_{i(j-1)} \\ 0, & if\ X_i \le C_{ik} \end{cases}$$

Eq. 1

Where

P_i is a sub-factor of parameter,

X_i is the value of the observation parameter data,

k is a total number of level (class) in a context,

j is a level (class) of observation data,

C_{i0} is the minimum value of level of class (for case a) and the maximum value of j th level (for case b),

C_{ij} is the upper limit (for case a) and the lower limit (for case b) of the j class,

C_{ik} is the maximum value (for case a) and the minimum limit of level

I. Weight sub-factor

The weight of the assessment sub-factors is calculated based on their relative significance to overall in water-quality.

The method for calculating the weight of sub-factor is Eq. 2

$$W_i = \frac{q_i}{\sum_{i=1}^{n} q_i} \quad \text{Eq. 2}$$

Where

W_i is the weight of sub-factor value P_i,

q_i is a level of sub-factor value P_i

Factor (F) calculation

The method for calculating the total value F is represented as Eq. 3

$$F = \sum_{i=1}^{n} P_i W_i \quad \text{Eq. 3}$$

Where

F is a factor's total value, which is calculated as a summation of the sub-factor value P_i with weighting.

IMPREMENTATION

A. The study area and description

The collected coastal water-quality data in this research is utilizing open data of the coastal water-quality in Chonburi Province, Thailand, which provided by Institute of marine science, Burapha University. The data set consisted of 10 location of water-quality sampling points and 12 water-quality features.

The water-quality sampling points is 10 points: A: is the Chonburi bay (CH1), B is the corner of rong payaban kao road-south (CH2), C is the wat komut pier (AS1), D is the prong canal (AS2), E is the laem tan (LT), F is the bangsaenheritahe hotel (BS1), G is the bangsaen circle (BS2), H: is the wonnapha piea (WP), I is the bang phra piea (BP), and J is the ko loi (SR).

The location of water-quality sampling points is shown on the map in Figure 2 and location name, geographical information (according to google map) are listed in Table 1.

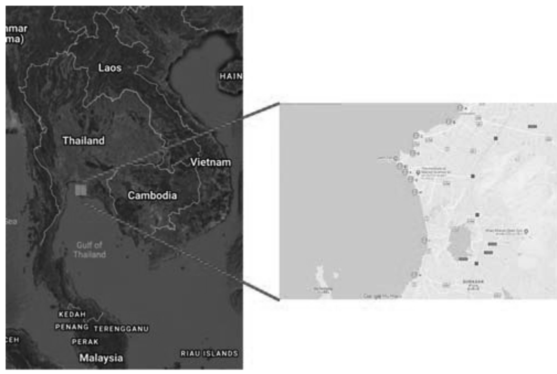

Figure 2 The location of water-quality sampling points: a is the water-quality sampling points on Thailand map (according to map data2018 ⓒ SK telecom imagery, USGS) and b is the water-quality sampling points on ChonBuri and Golf of Thailand map (according to according to map data 2018 ⓒ Google)

Sampling point	Location	
	Latitude Longitude	Latitude Longitude
A	13.36849	100.97573
B	13.35180	100.96174
C	13.33510	100.92182
D	13.31415	100.91774
E	13.29845	100.90187
F	13.29147	100.90826
G	13.28261	100.91537
H	13.26783	100.92005
I	13.21035	100.93214
J	13.16881	100.91985

Table 1 The name and geographical information of water-quality sampling points.

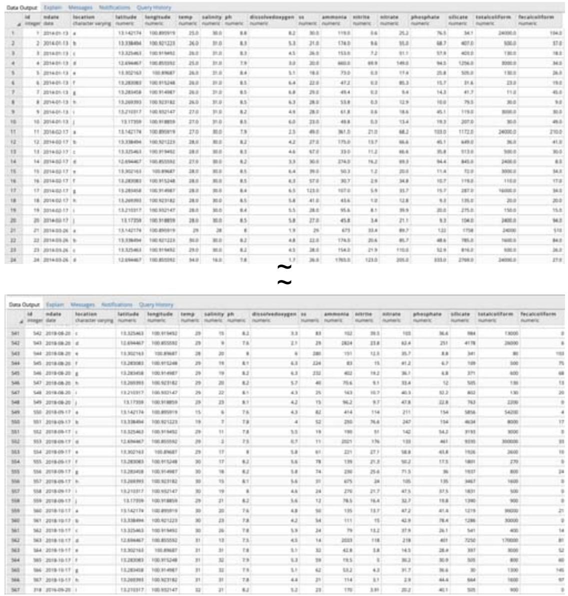

Figure 3 The 10 sampling points with spatiotemporal metadata.

B. Data preparation

The data preparation of this research collected several water-quality features such as temperature, pH, Dissolved Oxygen (DO), Salinity, Suspended Solids (SS), Total ammonia (Total-NH_3), Nitrite (NO_2^-), Nitrate (NO_3^-), Phosphate (PO_4^{3-}), Silica, Total Coliform bacteria, and Fecal Coliform bacteria. The 10 sampling points from Jan 2014 to October 2018 with spatiotemporal metadata such as date, location, latitude, and longitude of each data set are shown in Figure 3.

Then the dataset with spatiotemporal metadata created in the database by programming language (PostgreSQL) for analyzing coastal eutrophication condition in details.

C. System Design

The system design is comprised of the processing process, which is consist of 3 procedures (1) to create the data structure in the database, (2) to create the eutrophication classification the data structure in the database, and (3) to analysis the eutrophication class by using the mathematical calculation in the database. The database architecture for processing and analyzing of this research is shown in Figure 4.

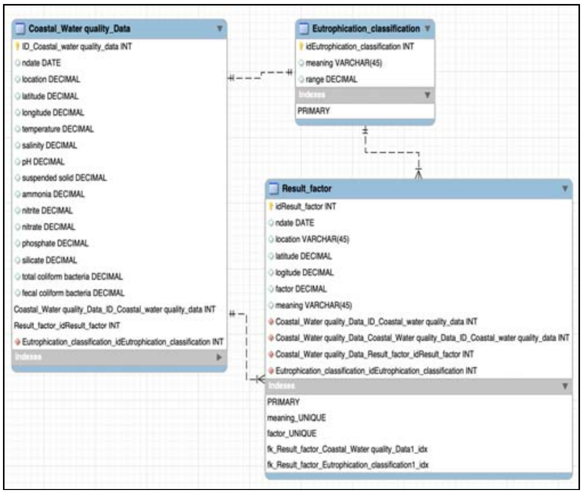

Figure 4 The database structure for processing and analyzing eutrophication in coastal area.

RESULT

In term of the coastal water-quality features, the specific characteristic of water-quality features for Eutrophication was selected by the system to analyze and classify the Eutrophication situation. There are 4 specific characteristic features; (1) total ammonia (Total-NH_3), (2) Nitrite (NO_2^-), (3) Nitrate (NO_3^-), and (4) Phosphate (PO_4^{3-}) in this analysis system. The result from implementation is defined in the following:

A. The result of Eutrophication classification

As the result from Mathematical Equation for Metadata analysis and eutrophication classification, the system calculates and classifies the class according to the standards and scientific statement (from processing layer *step* 2-3 in the database of the system).

The results of implementation found that Oligotrophic had 71 times, Mesotrophic had 148 times, Lower-eutrophic had 154 times, Eutrophic had 100 times, Upper-eutrophic had 49 times, Seriously- eutrophic had 31 times, Hyper-eutrophic had 13 times, and Seriously Hyper-eutrophic hadn't found. The results in detail shown as Figure 5-12 and each Figure of Figure 5-12 had shown the result by the class of eutrophication (column 7), the decreasing factor (column 6), and spatiotemporal metadata of points.

Data Output Explain Messages Notifications Query History

	id integer	location character varying	latitude numeric	longitude numeric	factor numeric	meaning character varying
1	36	f	13.283083	100.915248	88.82	Oligotrophic
2	37	g	13.283458	100.914987	88.90	Oligotrophic
3	46	g	13.283458	100.914987	96.94	Oligotrophic
4	48	j	13.17359	100.918859	93.93	Oligotrophic
5	77	i	13.210317	100.932147	88.93	Oligotrophic
6	128	j	13.17359	100.918859	87.97	Oligotrophic
7	138	j	13.17359	100.918859	88.10	Oligotrophic
8	144	f	13.283083	100.915248	91.77	Oligotrophic
9	145	g	13.283458	100.914987	90.66	Oligotrophic
10	146	h	13.269393	100.923182	89.42	Oligotrophic
11	150	e	13.302163	100.89687	89.02	Oligotrophic
12	151	f	13.283083	100.915248	90.50	Oligotrophic
13	152	g	13.283458	100.914987	90.48	Oligotrophic
14	153	h	13.269393	100.923182	91.72	Oligotrophic
15	159	f	13.283083	100.915248	90.45	Oligotrophic
16	160	g	13.283458	100.914987	90.52	Oligotrophic
17	161	h	13.269393	100.923182	89.44	Oligotrophic

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Data Output Explain Messages Notifications Query History

	id integer	location character varying	latitude numeric	longitude numeric	factor numeric	meaning character varying
55	389	j	13.17359	100.918859	88.17	Oligotrophic
56	431	b	13.338494	100.921223	94.96	Oligotrophic
57	432	c	13.325463	100.919492	88.19	Oligotrophic
58	434	e	13.302163	100.89687	97.04	Oligotrophic
59	435	f	13.283083	100.915248	94.57	Oligotrophic
60	436	g	13.283458	100.914987	93.11	Oligotrophic
61	437	h	13.269393	100.923182	92.08	Oligotrophic
62	438	i	13.210317	100.932147	95.84	Oligotrophic
63	439	j	13.17359	100.918859	98.86	Oligotrophic
64	522	c	13.325463	100.919492	88.18	Oligotrophic
65	525	f	13.283083	100.915248	88.25	Oligotrophic
66	527	h	13.269393	100.923182	89.79	Oligotrophic
67	528	i	13.210317	100.932147	91.55	Oligotrophic
68	529	j	13.17359	100.918859	91.48	Oligotrophic
69	537	h	13.269393	100.923182	94.58	Oligotrophic
70	538	i	13.210317	100.932147	96.81	Oligotrophic
71	539	j	13.17359	100.918859	93.09	Oligotrophic

Figure 5 The results of Eutrophication classification in the class of Oligotrophic (C_1)

Data Output | Explain | Messages | Notifications | Query History

	id integer	location character varying	latitude numeric	longitude numeric	factor numeric	meaning character varying
1	6	f	13.283083	100.915248	75.76	Mesotrophic
2	7	g	13.283458	100.914987	77.53	Mesotrophic
3	8	h	13.269393	100.923182	82.40	Mesotrophic
4	15	e	13.302163	100.89687	79.50	Mesotrophic
5	16	f	13.283083	100.915248	80.03	Mesotrophic
6	17	g	13.283458	100.914987	75.61	Mesotrophic
7	18	h	13.269393	100.923182	83.62	Mesotrophic
8	20	j	13.17359	100.918859	83.44	Mesotrophic
9	27	g	13.283458	100.914987	78.05	Mesotrophic
10	28	h	13.269393	100.923182	80.53	Mesotrophic
11	30	j	13.17359	100.918859	76.62	Mesotrophic
12	35	e	13.302163	100.89687	85.39	Mesotrophic
13	38	h	13.269393	100.923182	80.02	Mesotrophic
14	40	j	13.17359	100.918859	85.76	Mesotrophic
15	63	e	13.302163	100.89687	75.62	Mesotrophic
16	64	f	13.283083	100.915248	76.88	Mesotrophic
17	69	a	13.142174	100.895919	80.20	Mesotrophic

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Data Output | Explain | Messages | Notifications | Query History

	id integer	location character varying	latitude numeric	longitude numeric	factor numeric	meaning character varying
132	429	j	13.17359	100.918859	81.60	Mesotrophic
133	430	a	13.142174	100.895919	77.68	Mesotrophic
134	444	e	13.302163	100.89687	77.52	Mesotrophic
135	445	f	13.283083	100.915248	77.76	Mesotrophic
136	447	h	13.269393	100.923182	79.39	Mesotrophic
137	449	j	13.17359	100.918859	78.52	Mesotrophic
138	477	h	13.269393	100.923182	78.51	Mesotrophic
139	487	h	13.269393	100.923182	79.76	Mesotrophic
140	499	j	13.17359	100.918859	75.58	Mesotrophic
141	519	j	13.17359	100.918859	77.11	Mesotrophic
142	524	e	13.302163	100.89687	85.29	Mesotrophic
143	526	g	13.283458	100.914987	86.43	Mesotrophic
144	536	g	13.283458	100.914987	81.50	Mesotrophic
145	544	e	13.302163	100.89687	82.42	Mesotrophic
146	545	f	13.283083	100.915248	86.49	Mesotrophic
147	546	g	13.283458	100.914987	81.68	Mesotrophic
148	547	h	13.269393	100.923182	78.63	Mesotrophic

Figure 6 The results of Eutrophication classification in the class of Mesotrophic (C_2)

Data Output | Explain | Messages | Notifications | Query History

	id integer	location character varying	latitude numeric	longitude numeric	factor numeric	meaning character varying
1	5	e	13.302163	100.89687	68.21	Lower-eutrophic
2	10	j	13.17359	100.918859	73.88	Lower-eutrophic
3	13	c	13.325463	100.919492	64.34	Lower-eutrophic
4	19	i	13.210317	100.932147	69.91	Lower-eutrophic
5	25	e	13.302163	100.89687	68.76	Lower-eutrophic
6	26	f	13.283083	100.915248	68.13	Lower-eutrophic
7	29	i	13.210317	100.932147	69.38	Lower-eutrophic
8	32	b	13.338494	100.921223	69.72	Lower-eutrophic
9	39	i	13.210317	100.932147	74.90	Lower-eutrophic
10	44	e	13.302163	100.89687	68.30	Lower-eutrophic
11	45	f	13.283083	100.915248	74.88	Lower-eutrophic
12	47	h	13.269393	100.923182	70.50	Lower-eutrophic
13	50	b	13.338494	100.921223	63.28	Lower-eutrophic
14	53	e	13.302163	100.89687	67.79	Lower-eutrophic
15	55	g	13.283458	100.914987	74.84	Lower-eutrophic
16	56	h	13.269393	100.923182	74.90	Lower-eutrophic
17	57	i	13.210317	100.932147	65.64	Lower-eutrophic

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Data Output | Explain | Messages | Notifications | Query History

	id integer	location character varying	latitude numeric	longitude numeric	factor numeric	meaning character varying
138	518	i	13.210317	100.932147	65.36	Lower-eutrophic
139	534	e	13.302163	100.89687	66.57	Lower-eutrophic
140	535	f	13.283083	100.915248	71.12	Lower-eutrophic
141	542	c	13.325463	100.919492	62.93	Lower-eutrophic
142	548	i	13.210317	100.932147	64.81	Lower-eutrophic
143	549	j	13.17359	100.918859	70.42	Lower-eutrophic
144	554	e	13.302163	100.89687	64.32	Lower-eutrophic
145	555	f	13.283083	100.915248	73.65	Lower-eutrophic
146	556	g	13.283458	100.914987	66.44	Lower-eutrophic
147	558	i	13.210317	100.932147	65.81	Lower-eutrophic
148	559	j	13.17359	100.918859	72.85	Lower-eutrophic
149	562	c	13.325463	100.919492	67.77	Lower-eutrophic
150	564	e	13.302163	100.89687	67.49	Lower-eutrophic
151	565	f	13.283083	100.915248	66.62	Lower-eutrophic
152	566	g	13.283458	100.914987	64.22	Lower-eutrophic
153	568	i	13.210317	100.932147	63.17	Lower-eutrophic
154	569	j	13.17359	100.918859	71.53	Lower-eutrophic

Figure 7 The results of Eutrophication classification in the class of Lower-eutrophic (C_3)

Data Output | Explain | Messages | Notifications | Query History

	id integer	location character varying	latitude numeric	longitude numeric	factor numeric	meaning character varying
1	1	a	13.142174	100.895919	52.73	Eutrophic
2	2	b	13.338494	100.921223	53.43	Eutrophic
3	3	c	13.325463	100.919492	55.49	Eutrophic
4	4	d	12.694467	100.855592	50.31	Eutrophic
5	9	i	13.210317	100.932147	61.14	Eutrophic
6	11	a	13.142174	100.895919	51.04	Eutrophic
7	12	b	13.338494	100.921223	59.69	Eutrophic
8	14	d	12.694467	100.855592	53.40	Eutrophic
9	22	b	13.338494	100.921223	58.18	Eutrophic
10	23	c	13.325463	100.919492	55.84	Eutrophic
11	31	a	13.142174	100.895919	55.33	Eutrophic
12	33	c	13.325463	100.919492	60.64	Eutrophic
13	42	b	13.338494	100.921223	56.37	Eutrophic
14	60	b	13.338494	100.921223	58.65	Eutrophic
15	61	c	13.325463	100.919492	57.43	Eutrophic
16	71	c	13.325463	100.919492	51.36	Eutrophic
17	79	a	13.142174	100.895919	61.06	Eutrophic

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Data Output | Explain | Messages | Notifications | Query History

	id integer	location character varying	latitude numeric	longitude numeric	factor numeric	meaning character varying
84	462	c	13.325463	100.919492	55.02	Eutrophic
85	465	f	13.283083	100.915248	53.55	Eutrophic
86	470	a	13.142174	100.895919	50.78	Eutrophic
87	480	a	13.142174	100.895919	56.50	Eutrophic
88	492	c	13.325463	100.919492	52.93	Eutrophic
89	494	e	13.302163	100.89687	61.69	Eutrophic
90	496	g	13.283458	100.914987	62.02	Eutrophic
91	498	i	13.210317	100.932147	62.16	Eutrophic
92	502	c	13.325463	100.919492	53.10	Eutrophic
93	504	e	13.302163	100.89687	52.95	Eutrophic
94	507	h	13.269393	100.923182	61.28	Eutrophic
95	508	i	13.210317	100.932147	52.15	Eutrophic
96	516	g	13.283458	100.914987	50.98	Eutrophic
97	552	c	13.325463	100.919492	59.10	Eutrophic
98	560	a	13.142174	100.895919	61.55	Eutrophic
99	561	b	13.338494	100.921223	52.23	Eutrophic
100	567	h	13.269393	100.923182	61.07	Eutrophic

Figure 8 The results of Eutrophication classification in the class of Eutrophic (C_4)

Data Output | Explain | Messages | Notifications | Query History

	id integer	location character varying	latitude numeric	longitude numeric	factor numeric	meaning character varying
1	21	a	13.142174	100.895919	47.24	Upper-eutrophic
2	34	d	12.694467	100.855592	39.36	Upper-eutrophic
3	43	c	13.325463	100.919492	47.53	Upper-eutrophic
4	52	d	12.694467	100.855592	48.07	Upper-eutrophic
5	54	f	13.283083	100.915248	45.18	Upper-eutrophic
6	59	a	13.142174	100.895919	40.46	Upper-eutrophic
7	91	c	13.325463	100.919492	41.71	Upper-eutrophic
8	156	c	13.325463	100.919492	45.35	Upper-eutrophic
9	186	d	12.694467	100.855592	44.77	Upper-eutrophic
10	203	a	13.142174	100.895919	46.96	Upper-eutrophic
11	206	d	12.694467	100.855592	45.54	Upper-eutrophic
12	213	a	13.142174	100.895919	41.89	Upper-eutrophic
13	223	a	13.142174	100.895919	47.46	Upper-eutrophic
14	226	d	12.694467	100.855592	39.66	Upper-eutrophic
15	233	a	13.142174	100.895919	48.25	Upper-eutrophic
16	236	d	12.694467	100.855592	49.38	Upper-eutrophic
17	243	a	13.142174	100.895919	42.69	Upper-eutrophic

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Data Output | Explain | Messages | Notifications | Query History

	id integer	location character varying	latitude numeric	longitude numeric	factor numeric	meaning character varying
33	412	c	13.325463	100.919492	46.35	Upper-eutrophic
34	420	a	13.142174	100.895919	43.27	Upper-eutrophic
35	451	b	13.338494	100.921223	46.23	Upper-eutrophic
36	460	a	13.142174	100.895919	44.76	Upper-eutrophic
37	463	d	12.694467	100.855592	44.16	Upper-eutrophic
38	471	b	13.338494	100.921223	45.70	Upper-eutrophic
39	472	c	13.325463	100.919492	49.44	Upper-eutrophic
40	481	b	13.338494	100.921223	47.49	Upper-eutrophic
41	490	a	13.142174	100.895919	47.51	Upper-eutrophic
42	500	a	13.142174	100.895919	40.29	Upper-eutrophic
43	510	a	13.142174	100.895919	46.78	Upper-eutrophic
44	520	a	13.142174	100.895919	42.36	Upper-eutrophic
45	521	b	13.338494	100.921223	44.21	Upper-eutrophic
46	532	c	13.325463	100.919492	49.08	Upper-eutrophic
47	550	a	13.142174	100.895919	45.93	Upper-eutrophic
48	551	b	13.338494	100.921223	44.20	Upper-eutrophic
49	557	h	13.269393	100.923182	46.39	Upper-eutrophic

Figure 9 The results of Eutrophication classification in the class of Upper-eutrophic (C_5)

Data Output | Explain | Messages | Notifications | Query History

	id integer	location character varying	latitude numeric	longitude numeric	factor numeric	meaning character varying
1	24	d	12.694467	100.855592	28.37	Seriously eutrophic
2	49	a	13.142174	100.895919	32.47	Seriously eutrophic
3	66	h	13.269393	100.923182	33.74	Seriously eutrophic
4	68	j	13.17359	100.918859	31.54	Seriously eutrophic
5	216	d	12.694467	100.855592	35.61	Seriously eutrophic
6	275	d	12.694467	100.855592	26.20	Seriously eutrophic
7	283	b	13.338494	100.921223	30.28	Seriously eutrophic
8	290	a	13.142174	100.895919	31.45	Seriously eutrophic
9	303	d	12.694467	100.855592	32.14	Seriously eutrophic
10	313	d	12.694467	100.855592	27.70	Seriously eutrophic
11	320	a	13.142174	100.895919	32.62	Seriously eutrophic
12	340	a	13.142174	100.895919	33.34	Seriously eutrophic
13	363	d	12.694467	100.855592	28.09	Seriously eutrophic
14	373	d	12.694467	100.855592	32.92	Seriously eutrophic
15	393	d	12.694467	100.855592	36.67	Seriously eutrophic
16	400	a	13.142174	100.895919	26.30	Seriously eutrophic
17	413	d	12.694467	100.855592	33.20	Seriously eutrophic

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Data Output | Explain | Messages | Notifications | Query History

	id integer	location character varying	latitude numeric	longitude numeric	factor numeric	meaning character varying
15	393	d	12.694467	100.855592	36.67	Seriously eutrophic
16	400	a	13.142174	100.895919	26.30	Seriously eutrophic
17	413	d	12.694467	100.855592	33.20	Seriously eutrophic
18	423	d	12.694467	100.855592	27.64	Seriously eutrophic
19	453	d	12.694467	100.855592	29.28	Seriously eutrophic
20	473	d	12.694467	100.855592	33.27	Seriously eutrophic
21	483	d	12.694467	100.855592	29.39	Seriously eutrophic
22	491	b	13.338494	100.921223	34.30	Seriously eutrophic
23	501	b	13.338494	100.921223	32.42	Seriously eutrophic
24	511	b	13.338494	100.921223	36.07	Seriously eutrophic
25	530	a	13.142174	100.895919	28.69	Seriously eutrophic
26	531	b	13.338494	100.921223	33.16	Seriously eutrophic
27	533	d	12.694467	100.855592	28.12	Seriously eutrophic
28	540	a	13.142174	100.895919	34.09	Seriously eutrophic
29	541	b	13.338494	100.921223	28.52	Seriously eutrophic
30	543	d	12.694467	100.855592	25.50	Seriously eutrophic
31	563	d	12.694467	100.855592	25.25	Seriously eutrophic

Figure 10 The results of Eutrophication classification in the class of Seriously eutrophic (C_6)

Data Output | Explain | Messages | Notifications | Query History

	id integer	location character varying	latitude numeric	longitude numeric	factor numeric	meaning character varying
1	41	a	13.142174	100.895919	21.57	Hyper-eutrophic
2	51	c	13.325463	100.919492	18.18	Hyper-eutrophic
3	284	c	13.325463	100.919492	20.43	Hyper-eutrophic
4	293	d	12.694467	100.855592	13.87	Hyper-eutrophic
5	323	d	12.694467	100.855592	19.68	Hyper-eutrophic
6	343	d	12.694467	100.855592	21.12	Hyper-eutrophic
7	383	d	12.694467	100.855592	20.73	Hyper-eutrophic
8	403	d	12.694467	100.855592	24.96	Hyper-eutrophic
9	493	d	12.694467	100.855592	18.80	Hyper-eutrophic
10	503	d	12.694467	100.855592	17.08	Hyper-eutrophic
11	513	d	12.694467	100.855592	20.90	Hyper-eutrophic
12	523	d	12.694467	100.855592	18.61	Hyper-eutrophic
13	553	d	12.694467	100.855592	24.13	Hyper-eutrophic

Figure 11 The results of Eutrophication classification in the class of Hyper eutrophic (C_7)

Data Output | Explain | Messages | Notifications | Query History

id integer	location character varying	latitude numeric	longitude numeric	factor numeric	meaning character varying

Figure 12 The results of Eutrophication classification in the class of Seriously Hyper-eutrophic (C_8)

CONCLUSION

This paper has presented a spatial dynamic of the Coastal Eutrophication Analysis System by SPA Process realization and Functional Data Analysis for determination and classification of coastal water-quality features in Chonburi bay area.

The significant analysis system is to evaluate the class (level) of coastal water-quality eutrophication and can get a better understanding of eutrophication situation in Chonbuti bay by mathematical calculation and automatic classification in the database.

This analysis system will be an extension by integrating climate change factor and deep learning method for making a deep interpretation as a progress.

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