Preliminary Groundwater Quality Assessment under Groundwater Banking Project for Agricultural Uses in Tung Kula Rong Hai

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Abstract

Tung Kula Rong Hai, Roi Et is one of the key player in the global food supply chain and a major jasmine rice production area in Thailand. However, dough, flood and water management are the big problems in this area, resulting in low rice yield compared with other regions. Groundwater banking projects were established to enhance water supply reliability and resolve flood problem, but groundwater quality from banking is unclear. So, this paper aims to examine the groundwater quality assessment for agricultural uses in terms of physical and chemical properties and map it using Geographic Information System. Based upon the groundwater flow direction, groundwater samples were collected from the shallow monitoring wells and deep ponds, covering the area of 4.8 km^2. The results showed that groundwater from deep pond is weakly acidic with mean acidity being from 5 to 5.8 and high level of turbidity (67% of samples), whereas, other measured parameters were lower than the standard, which showed suitability for agriculture uses. Also, 30% of samples from shallow wells showed, good or permissible water quality for agricultural and irrigation uses according to pH, total dissolve solid (TDS), conductivity, salinity, sodium adsorption rate (SAR) and hardness. However, more than 30% of samples of shallow wells were observed with very low quality of water due to high level of salinity (>1.5 g/L), conductivity (>2250 us/cm), SAR (>26 SAR), TDS (>2000 mg/L), which showed shallow groundwater as less suitable for agricultural uses and irrigation and plot it on Geographic Information System.

Keywords: Tung Kula Rong Hai, groundwater quality, groundwater banking, and agriculture

Introduction

Rice is a major food for the world's population, especially in Asia. Thailand is the second highest worldwide rice production with fifth largest amount of land under rice cultivation. Top rice countries consist of India, Thailand, Pakistan, United States, Vietnam, Uruguay, Brazil and China [1]. Thailand has produced 25 million tons of paddle rice in 2016-2017 crop year, value of 168 billion baht in 2017 [2]. Tung Kula Rong Hai is one of the main export jasmine rice products. It is the most famous premium rice which has a unique sweet-scented aroma, softness and tender texture [3]. Tung Kula Rong Hai cover twelve districts with five provinces which consisted of Pathum Rat, Suwannapoom, Kaset Wisai, Phon Sai, and Nong Hee of Roi Et (45.13% of total area), Sila Lat and Rasi Salai of Srisaket (13.74%), Kho Wang and Maha Chana Chai of Yasothon (2.71%), Chumphon Buri and Tha Tum of Surin (29.93%) and Phayakkhaphum Phisai of Mahasarakham (8.42%) [4]. However, dough, flood, water management and lacking irrigation system are the big problems in this area, resulting in low rice yield compared with other regions. Therefore, water management is one factor that important for improve the rice cultivation.

From situation of this area, Groundwater banking projects were established to enhance water supply reliability and resolve flood problem in this area. Groundwater Banking is water management mechanism designed to increase water usage, water supply reliability. It can be created by dewatered aquifer space to save water during years when is abundant rainfall. Moreover, this water can be pump and used during dry season and all years that do not have a surplus of water [5]. Groundwater is one of earth's most vital renewable and widely distributed resources as well as an important source of water supply throughout the world due to it is much clean and free from pollution [6]. However, groundwater quality from groundwater banking is still unclear. Water quality are important factor for regular monitoring and to understand the environmental conditions. The different propose require different criteria of water quality as well as standard methods such as drinking water, industrial and agricultural uses [7]. The contamination of groundwater can result in poor drinking water quality, less of crop production and lost of water supply, high cost for treatment and potential health problem.

This study aims to examine the groundwater quality assessment for agricultural uses in terms of physical and chemical properties and map it using Geographic Information System. Moreover, the demonstration of groundwater bank quality was also investigated. The study area covered the area of 4.8 km^2 of rice cultivation in Suwannaphum at Roi Et Province.

Materials and methods
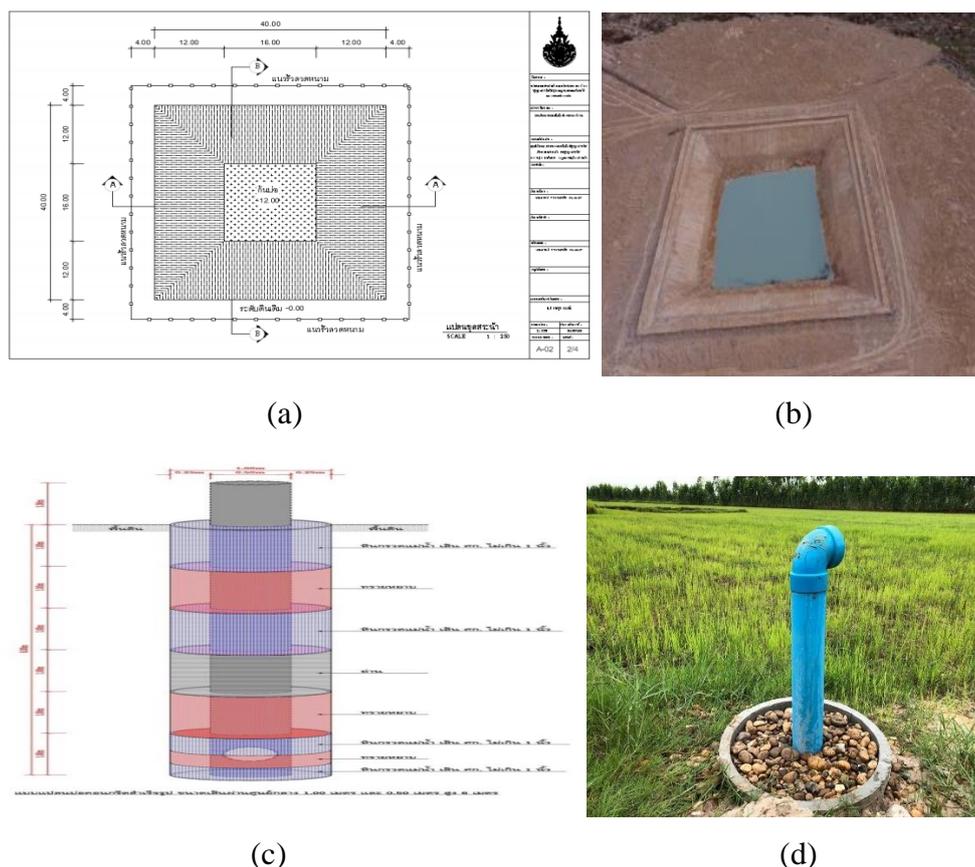
Study area and groundwater bank

The study area is located in Suwannaphum, Roi Et province which is one part of Tung Kula Rong Hai in northeastern Thailand. It is one of the key players in the global food supply chain and a major jasmine rice production area in Thailand. Jasmin rice is main rice production in this study area. However, dough, flood, water management and lacking irrigation system are the big problems in this area. Therefore, groundwater banking projects were established to enhance water supply reliability and resolve flood problem in this study. Groundwater banking has two types which are constructed that are shallow wells and deep ponds (as shown in Figure. 1). It was covered an area of 4.8 km^2 with coordinate extending from 15.59889167 to 15.55927249 latitude and from 103.69811978 to 103.74334694 longitude based on groundwater flow direction. The study area for groundwater banking project is shown in Figure. 2.

### Sampling collections and analysis

Water sampling was collected based upon the groundwater flow direction as illustrate in Figure 2. A total of 10 samples from the shallow monitoring wells (10 samples from 40 shallow monitoring wells) and 6 samples from deep ponds (6 samples from 6 deep ponds), covering the area of 4.8 km^2 in groundwater banking area during July 2018 were collected. The detail of sampling location are shown in Figure 2 and Table 1). Groundwater was pump out at least 3 min period to sampling the shallow monitoring wells collection. The groundwater was collected and analyzed in physical and chemical characteristic such as pH, temperature, color, turbidity, conductivity, salinity, total dissolve solid (TDS) and sodium adsorption ratio (SAR). The pH and temperature were

measured in situ immediately at sampling point using colorimetric method and thermometer, respectively. The analysis of conductivity, salinity, total dissolve solid (TDS) were measure using EC300 conductivity meter. The color and turbidity were analyses by spectrophotometer, respectively. For sodium adsorption ratio (SAR) was measure and calculate ratio based on this equation 1 [8]. Prior to transportation, the groundwater samples were preserved in an ice box (temperature lower than 4 ℃). The samples were then transported to Rajamangala University of Technology Isan and stored below 4 ℃ in a refrigerator until analyze. All analysis data in both of physical and chemical characteristics were summarized. Arc GIS software (version 10.0) was applied for developing map.

$$\text{Sodium adsorption rate (SAR)} = \frac{Na^+}{\sqrt{\frac{1}{2}(Ca^{2+}+Mg^{2+}}} \qquad (1)$$

(a)   (b)

(c)   (d)

Fig. 1 Types of groundwater bank, (a) drawing figure from top view of deep pond, (b) real photo of deep pond, (c) drawing figure of shallow well and (d) real photo of shallow well

(a)   (b)
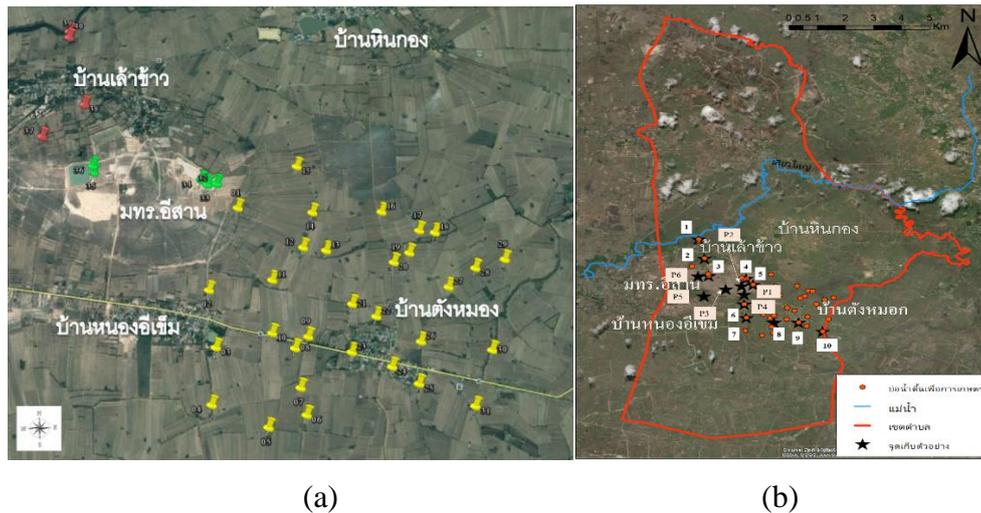
Fig. 2. Map of study area and groundwater sampling point from the shallow monitoring wells and deep ponds; (a) All of study area with 40 shallow monitoring wells and 6 deep ponds, (b) sampling location in both of shallow monitoring wells and deep ponds.

Table 1. Station number, Sampling location, Number in map, Latitude, Longitude and Type of the source

Station No.	No. in map	Location	Latitude	Longitude	Type of the source
1	40	Ban Lao Khao	15.59889167	103.70027220	Shallow monitoring well
2	38	Ban Lao Khao	15.59094167	103.70215560	Shallow monitoring well
3	35	RMUTI	15.58384717	103.70335781	Shallow monitoring well
4	32	RMUTI	15.58260901	103.71549623	Shallow monitoring well
5	1	Ban Hin Kong	15.58015000	103.71755000	Shallow monitoring well
6	2	Ban Nong I Khem	15.57207663	103.71480316	Shallow monitoring well
7	3	Ban Nong I Khem	15.56660440	103.71545727	Shallow monitoring well
8	9	Ban Tang Mong	15.56745847	103.72431534	Shallow monitoring well
9	24	Ban Tang Mong	15.56464798	103.73211938	Shallow monitoring well
10	31	Ban Tang Mong	15.56094107	103.73976513	Shallow monitoring well
P1	P1	RMUTI	15.57972222	103.70888889	Deep pond
P2	P2	RMUTI	15.57833333	103.70888889	Deep pond
P3	P3	RMUTI	15.57555556	103.70194444	Deep pond
P4	P4	RMUTI	15.57611111	103.71472222	Deep pond
P5	P5	RMUTI	15.57555556	103.70194444	Deep pond
P6	P6	RMUTI	15.58611111	103.70000000	Deep pond

Note : RMUTI is Rajamangala University of Technology Isan

Data analysis and Statistic analysis

All analysis data in both of physical and chemical characteristics were summarized. The one-way ANOVA was applied to detect significant in data from different sampling point among shallow monitoring wells and deep ponds. Lastly, Arc GIS software (version 10.0) was applied for developing map from all data.

Results and discussion

Physio-chemical properties of groundwater

Various physio-chemical parameters like pH, TDS, Turbidity, Salinity, Conductivity, SAR were analyzed in the groundwater samples used for agricultural and their levels in different locations of the study area and developing map by GIS. The spatial distributions from each parameter were shown in Figure 3(a)-3(f) by (a) pH, (b) conductivity, (c) total dissolve solid, (d) turbidity, (e) salinity and (f) sodium adsorption rate and deeply detail are summarized in Table 2.

pH

The spatial distribution of pH between shallow monitoring wells and deep ponds were illustrate in Figure 3(a). The average value of pH in shallow monitoring wells were found in the range of 7.5 to 8 (blue dot in GIS map). On the other hand, the average value of pH from deep ponds samples were found weakly acidic with mean acidity being from 5 to 5.8 which was located in RMUTI area. However, all samples from both sources were meet the water quality standard of pH for agriculture uses which are in the range of 5 to 8 (The criteria of water quality for agricultural used is shown in Table 3).

Conductivity

The analysis of water sample collected from shallow monitoring wells and deep ponds indicated that the average of conductivity ranges from 20.1 µs/cm to 7920 µs/cm in shallow monitoring wells and 9.8 µs/cm to 126.7 µs/cm from deep pond samples. Groundwater samples of shallow monitoring wells from station No. 6 (Ban Nong I Khem), 7 (Ban Nong I Khem) and 10 (Ban Tang Mong) were found higher than 2250 µs/cm which indicated that it was very low quality of groundwater (as compared with standard value from Table 3). However, groundwater samples of deep ponds from station No. P1 to P2 found in the range of 9.8 µs/cm to 126.7 µs/cm which was lower than the standard for agriculture uses (as compared in Table 3). The spatial distribution of conductivity was shown in Figure 3(b).

Total dissolve solid

Figure 3 (c) shows the spatial distribution of total dissolve solid (TDS) from two types of sampling sources. The values of TDS were found from 17.5 mg/L to 5720 mg/L in shallow monitoring wells. Station No. 6 (3895 mg/L), 7 (5720 mg/L) and 10 (3365 mg/L) were higher than 2000 mg/L which indicated that it was very low quality of groundwater. Instead, the average TDS value from deep pond were found suitable for agriculture uses with 0.05 mg/L to 90.5 mg/L which indicated in no effect to agriculture uses (according to Table 3). High value of TDS influences the taste, hardness, and corrosive property of the water. TDS value more than 1000 mg/L is disagreeable taste or makes the water unsuitable in other respects. This indicated TDS value from shallow monitoring wells are not suitable for used (Table 3), which should be treated before used it [10-11].
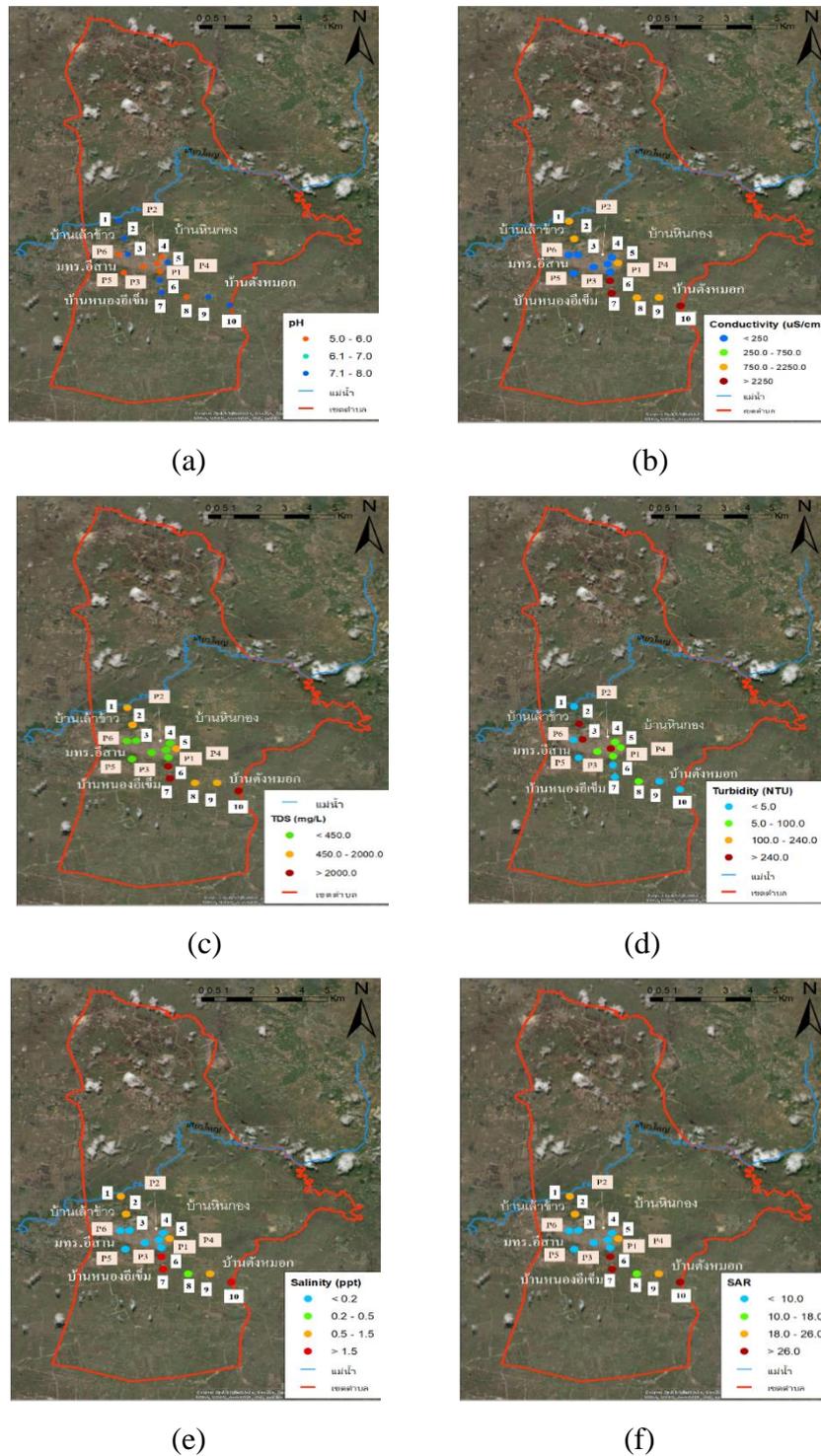
Turbidity

Figure 3 (d) presents the spatial distribution of turbidity in shallow monitoring wells and deep ponds through map. In the shallow monitoring wells were found turbidity values from lower than 5 NTU to more than 240 NTU. It was calculated to 40% of total sampling number found high turbidity (more than 90 NTU) due to groundwater structure collapses. Furthermore, the average value of turbidity was found from lower than 5 NTU to more than 240 NTU, 50% of total samples were found high turbidity (more than 65 NTU). However, turbidity parameter is not too much effect to agricultural uses but too much effect for drinkable uses (Table 3).

Salinity

The concentration of salinity in shallow monitoring wells were found 0 g/L to 4.9 g/L and 0 g/L to 0.1 g/L from deep ponds. Salinity has significant effect to agricultural uses. The groundwater samples at No. 6 (Ban Nong I Khem), 7 (Ban Nong I Khem) and 10 (Ban Tang Mong) were found very high salinity (more than 4.9 g/L) as compared with other sampling point which is due to effluent coming from groundwater flow and soil structure. These points are not recommended for agriculture used due to high concentration of salt which can affect to rice uses (according to the standard in Table 3). However, the groundwater samples at No.3 (RMUTI), 4 (RMUTI) from shallow well were found good

quality for agriculture due to low salinity which was lower than 0.1 g/L (Table 3). The spatial distribution of salinity was shown in Figure 3 (e).

(a)

(b)

(c)

(d)

(e)

(f)

Fig. 3. Spatial distribution of (a) pH, (b) Conductivity ($\mu s/cm$), (c) Total dissolved solid; TDS (mg/L), (d) Turbidity (NTU), (e) Salinity (mg/L) and (f) Sodium adsorption rate; SAR

Sodium adsorption rate (SAR)

Lastly, the concentration of sodium adsorption rate from shallow monitoring wells and deep ponds were analyzed in the groundwater samples and plot it in map as shown in Figure 3(f). The groundwater sample from shallow monitoring wells were found SAR in the range of 0 to more than 26. The highest SAR value was found No. 6, 7 and 10 in the shallow well (more than 26) and No. P4 in the deep pond sample. The effect of SAR on infiltration rate is mainly a soil surface phenomenon. High concentration of SAR can significant effect to toxic concentration of sodium adsorption by crop which effect to rice production (Table 3).

Table 2. Descriptive statistics of physical and chemical properties of groundwater from both of shallow monitoring wells and deep ponds in this study area

Station No.	Location	Type of the source	Temperature (°C)	pH	TDS (mg/L)	Conductivity (μs/cm)	Turbidity (NTU)	Salinity (g/L)	SAR	Color
1	Ban Lao Khao	Shallow monitoring well	31	8.0	1026.0	1115.0	< 5	0.8	20	Clear gray
2	Ban Lao Khao	Shallow monitoring well	32	7.5	728.0	1026.0	>240	0.6	19	gray
3	RMUTI	Shallow monitoring well	32	7.5	144.9	201.6	> 240	0.1	5	Cloudy white
4	RMUTI	Shallow monitoring well	32	5.6	17.5	20.1	90	0.0	0	Dark orange
5	Ban Hin Kong	Shallow monitoring well	34	7.6	1150.0	1315.0	37	0.9	21	Cloudy white
6	Ban Nong I Khem	Shallow monitoring well	33	7.7	3895.0	4501.0	< 5	3.3	>26	Clear
7	Ban Nong I Khem	Shallow monitoring well	32	7.6	5720.0	7920.0	< 5	4.9	>26	Clear
8	Ban Tang Mong	Shallow monitoring well	31	5.7	579.0	816.0	100	0.4	14	Cloudy white
9	Ban Tang Mong	Shallow monitoring well	30	7.6	1285.0	1778.0	< 5	1.0	22	Clear
10	Ban Tang Mong	Shallow monitoring well	30	7.5	3365.0	3924.0	< 5	2.8	> 26	Clear
P1	RMUTI	Deep pond	30	5.1	18.0	24.0	> 240	0.0	2	Brown
P2	RMUTI	Deep pond	31	5.0	11.2	15.4	65	0.0	3	Brown
P3	RMUTI	Deep pond	32	5.6	0.07	9.8	< 5	0.0	2	Clear
P4	RMUTI	Deep pond	31	5.3	90.5	126.7	14	0.1	5	Cloudy white
P5	RMUTI	Deep pond	30	5.8	0.05	62.3	> 240	0.0	1	Brown
P6	RMUTI	Deep pond	31	5.4	0.06	81.1	< 5	0.0	3	Clear

Table 3. Criteria for water quality for agricultural uses [9]

S/No.	Parameters	Rank	Criteria	Remark
1	Total dissolved solid (TDS)	A	< 450 mg/L	No effect
		B	450 – 2000 mg/L	Middle
		C	> 2000 mg/L	Strength
2	Conductivity	A	0-250 mg/L	Good quality
		B	250-750 mg/L	Middle
		C	>2250 mg/L	Very low quality
3	Salinity	A	< 0.2	Good quality
		B	0.2-0.5	Middle
		C	0.5-1.5	low quality
		D	>1.5	very low quality
4	SAR	A	0-10	Good quality
		B	18-26	Low quality
		C	>26	Very low quality

Conclusions

Preliminary groundwater quality under groundwater banking were analyzed in both of physical and chemical properties. The shallow monitoring wells and deep pond under groundwater banking were examine the water quality. The groundwater from deep pond found weakly acidity (pH from 5 to 5.8) and high level of turbidity (as calculated as 67% of total samples). Other parameters were found lower than the standard such as TDS (< 90.5 mg/L), salinity (< 0.1 g/L), conductivity (126.7 µs/cm) and SAR (< 5) which was suitable for agriculture uses. In the other hand, the groundwater samples from shallow monitoring wells found very high saline (> 4.9 g/L), at station number of 6, 7 and 10 which are not suitable for agriculture uses. Moreover, other parameters also were found higher than the standard for agriculture and irrigation uses such as conductivity (> 7920 µs/cm), TDS (> 5720 mg/L) and SAR (> 26). Moreover, groundwater sample from station number 3 and 4 were found good quality for agriculture due to low salinity (< 0.1 g/L), conductivity (< 200 µs/cm), TDS (<145 mg/L) and SAR (<5) but high value of turbidity (> 90 NTU). Therefore, groundwater Banking is suitable for water management mechanism designed to increase water supply reliability and can solve rice cultivation problems such as drought, flood and water management. The groundwater quality from deep pond and some point of shallow monitoring wells were found suitable for agriculture and irrigation uses (water quality meet to standard value for agriculture uses).

Acknowledgements

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