ESTIMATION OF GROUNDWATER USE PATTERN AND DISTRIBUTION

in the coastal Mekong Delta, Vietnam

via socio-economical survey and groundwater modeling.

Present by:

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Introduction

Surface water resources in the Mekong Delta are under increasing strain due to unplanned extraction, pollution, salinization and climate change effects. In many provinces of Mekong delta, excessive **groundwater extraction** has resulted in many serious groundwater-related problems such as **groundwater depletion, saline intrusion, arsenic contamination and land subsidence**.

Groundwater abstraction has increased rapidly and **declining groundwater levels** now pose an immediate threat to drinking water supplies, livelihoods in the Mekong Delta (IUCN 2011). In addition, groundwater resources sustain a significant and increasing share of **irrigated agricultural production**. This proportion is much higher in **rural and coastal areas** where residents have great difficulty accessing fresh water during the dry season due to saline and/or polluted canal water (Danh 2008).

The increase in demands and the afore mentioned **negative effects of groundwater depletion** raise the urgent question: at **what time in future are the limits to local groundwater** use reached? Hence, there is a need to know **groundwater use pattern and distribution** in the study area for future groundwater management.

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Introduction

Today, one of the most serious problems in **Tra Vinh** as other coastal provinces in Mekong Delta is the exploitation of groundwater for **different purposes**. According to the report prepared by provincial Department of Natural Resources and Environment, there were only **121 abstraction wells** which have been reformed the abstraction license until May 2018 with total of abstraction rate about **61,620 m^3/d.**

So, the variable **patterns of groundwater use** and the varied services that aquifer systems provide do not form a clear aggregate picture or status of groundwater, nor do they present an opportunity for **systematic management** response to Tra Vinh province.

For that reason, the understanding about **pattern and distribution of groundwater use (GWU)** plays a key part in ground resources assessment and management at the Mekong Delta in general and Tra Vinh Province in particular.

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Objectives

The main objective of this study is to explore **groundwater use pattern/distribution** in coastal area via socio-economic survey and groundwater modelling.

The specified objectives are to:

1) Estimate the baseline of groundwater use (pattern).
2) Estimate spatial distribution of groundwater use (space and time)
3) Assess effect of groundwater use to groundwater budget

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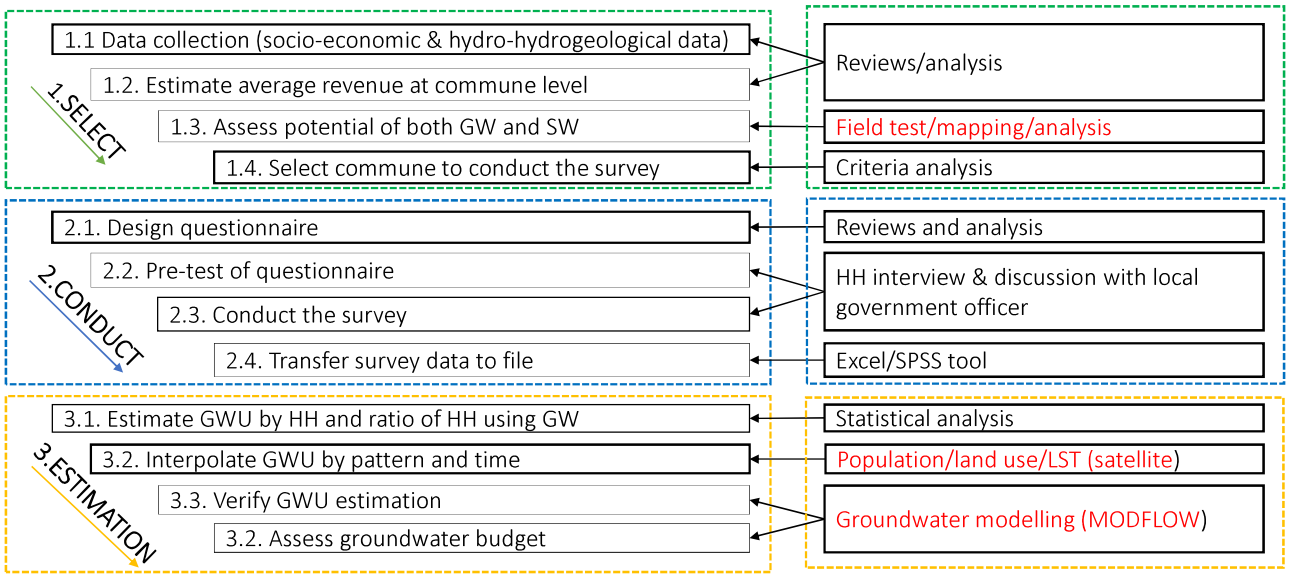
Methodologies



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Study area conditions

Location

The Tra Vinh province is situated southwest of Ho Chi Minh City and lies on the coastal plain of the Mekong Delta.

Topography includes coastal plain, alluvial deposits, hundreds of mounds and sand caves, a complex network of rivers and canals

Surrounded by Tien and Hau rivers and long coast, Tra Vinh 's economy base on agriculture, aquaculture, fish and shrimp breeding. The province is covered by verdant plants in the garden village along the bank of the river

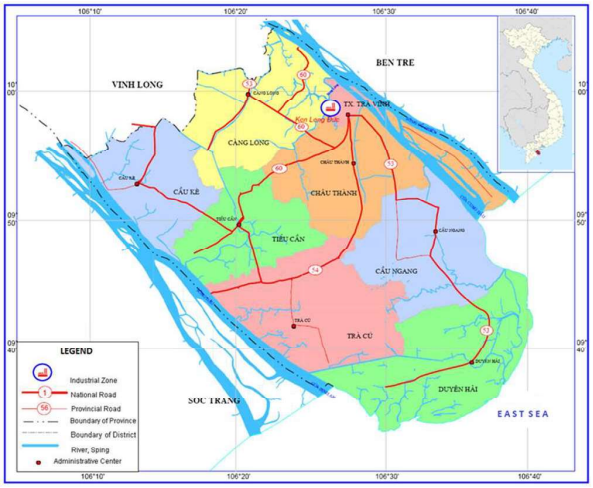

Figure 1 – Geographical location of Tra Vinh Province in the Mekong Delta, Vietnam (Peter P,2018).

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Study area conditions

Climate

Tra Vinh is on tropical monsoon region. The rainfall reduces gradually from North to South, highest in Cang Long, Tra Vinh and lowest in Cau Ngang and Duyen Hai. As for the duration of rain, up to 90% of rainfall occurs in the rainy season, starting from May to November

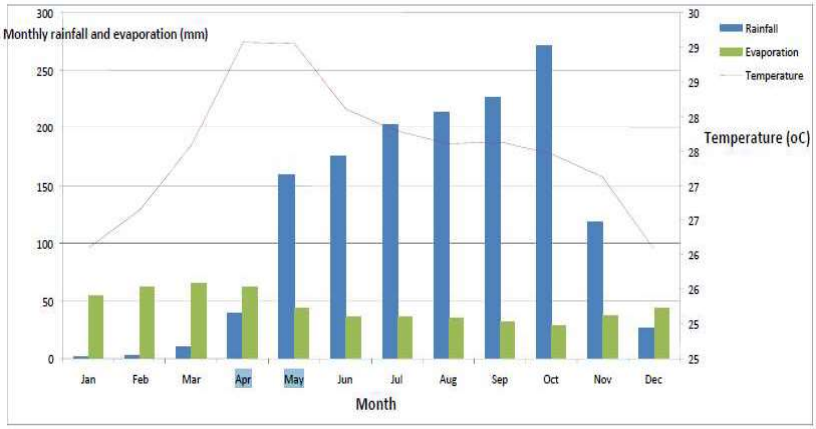

Figure 2 – Monthly average temperature (°C) and total monthly rainfall (mm) in Tra Vinh station
Source: Hydro-meteorological Station of South Vietnam

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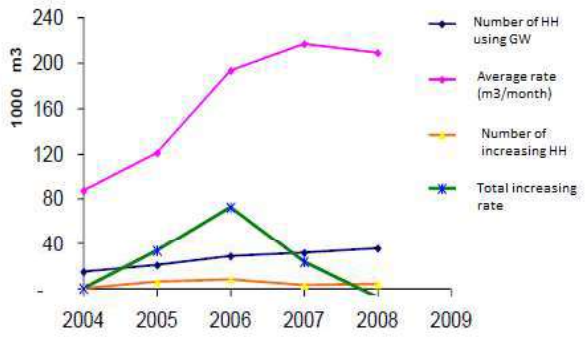
Study area conditions

Groundwater use status

Groundwater is partially used in aquaculture and annual crop irrigation is widely used for domestic and industrial purposes. It is reported that 224,773 m^3/day was abstracted in whole province of which, abstraction amount from wells with capacity ≥ 50m^3/day is 53,200 m^3/day and that of wells with capacity <50m^3/day is 200,720 m^3/day) (Vuong 2013).



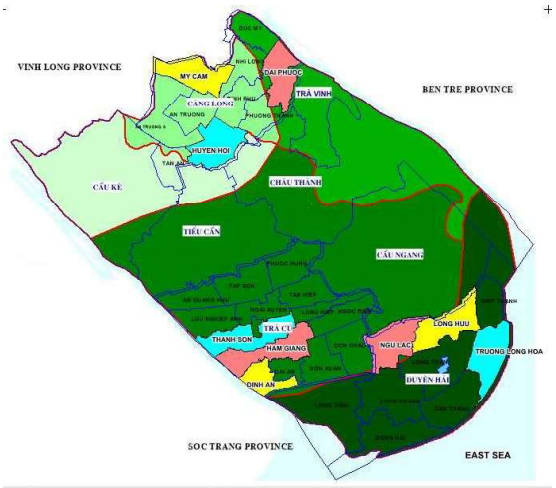
No	Aquifer	Groundwater abstraction (m^3/d)		
		Public well	HH well	Total
1	Holocene (qh)		7,800	7,800
2	Upper Pleistocene (qp_3)	0	73,920	73,920
3	Middle Pleistocene (qp_{2-3})	42,000	119,000	161,000
4	Lower Pleistocene (qp_1)	3,200	0	3,200
whole province		53,200	200,720	245,920

Results and discussion

Communes survey selection

Criteria selection

1. Saltwater distribution (both groundwater and surface water)
   - Easy to improve SW + Fresh GW (ESFG)
   - Easy to improve SW + Saline GW (ESSG)
   - Hard to improve SW + Fresh GW (HSFG)
   - Hard to improve SW + Saline GW (HSSG)
   - Saline SW all seasons + Fresh GW. (SSFG)
2. Average commune revenue (ACR) levels
   - high ACR (> 30 mil.dong/year),
   - moderate ACR (20 - 30 mil.dong/year)
   - low ACR (<20 mil.dong/year



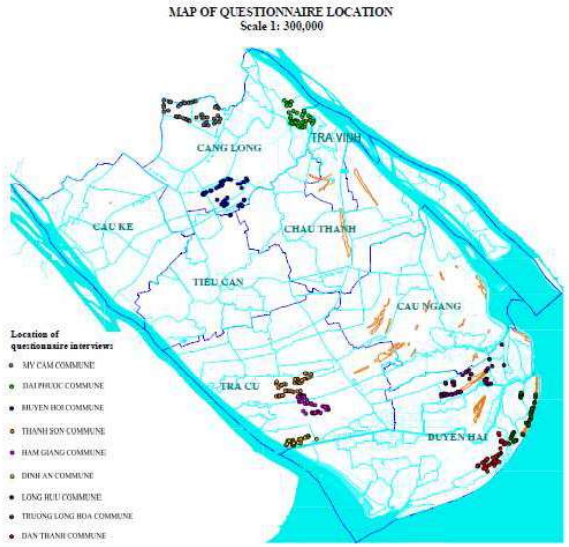
District	Commune	Population person	Area ha	Agriculture area (ha)			Income assessment	Potential of WR
				Paddy	Prenial crops	Aqualculture		
Cang Long	My Cam	11,832	2,298	1,006	1,053	0	High	ESSG
	Huyen Hoi	14,244	3,473	2,521	577	4	Moderate	ESFG
	Dai Phuoc	9,520	2,008	409	872	2	Low	HSSG
Tra Cu	Dinh An	5,444	592	168	19	4	High	HSFG
	Thanh Son	9,592	1,415	884	160	4	Moderate	HSFG
	Ham Giang	2,488	1,591	252	239	15	Low	HSFG
Duyen Hai	Long Huu	10,862	3,623	627	316	1,986	High	SSFG
	Truong Long Hoa	5,560	3,751	4	399	3,298	Moderate	SSFG
	Dan Thanh	7,069	4,134	1,230	408	1,248	Low	SSFG

Results and discussion

Household survey distribution for interviews

The questionnaire was used by the interviewer to collect (through face-to-face interview) information from interviewees

- 419 households from 9 communes of 3 districts in Tra Vinh were interviewed in total.
- Survey data was inputted to Excel and cleaned and analyzed by SPSS tool



Results and discussion

GWU pattern estimation from field survey in each communes

Commune	Aquaculture		Irrigation	
	RHHUG (%)	APR (m^3/ha/d)	RHHUG (%)	APR (m^3/ha/d)
My Cam	0	0	0	0
Dai Phuoc	0	0	0	0
Huyen Hoi	0	0	0	0
Thanh Son	0	0	93	24.84
Ham Giang	1.50	3.69	95	33.38
Dinh An	1.60	4.58	91	32.06
Long Huu	1.80	3.60	97	30.83
Truong Long Hoa	1.90	4.22	98	26.98
Dan Thanh	2.60	5.73	97	32.19
Average	**1.88**	**4.36**	**95**	**30.05**

Commune	Number of HH survey	Bottle water		In-house tap water		Own well	
		RHHUG (%)	APR m^3/HH/d	RHHUG (%)	APR m^3/HH/d	RHHUG (%)	APR m^3/HH/d
My Cam	47	0	0	0	0	0	0
Dai Phuoc	46	0	0	0	0	0	0
Huyen Hoi	47	23	0.007	49	0.191	87	1.05
Thanh Son	47	38	0.005	45	0.189	74	2.20
Ham Giang	45	45	0.003	47	0.374	84	1.87
Dinh An	47	17	0.005	74	0.503	43	1.80
Long Huu	47	72	0.006	45	0.297	91	3.42
Truong Long Hoa	48	79	0.004	43	0.256	85	3.74
Dan Thanh	45	89	0.007	38	0.617	84	4.38
Average	**46.6**	**40**	**0.004**	**38**	**0.270**	**61**	**2.05**

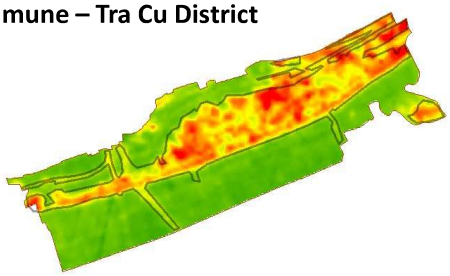
Results and discussion

GWU distribution from LST estimation from satellite image

HH distribution or area which concentrate agriculture activities such as vegetables or annual crops can be represented by land surface temperature (LST) distribution. GWU of each district can be estimated by statistical data (number of HH, land use) and interpolated to spatial distribution by apply LST distribution

HH, land use distribution
(Google Earth)

Ngoc Bien commune – Tra Cu District



LST distribution from Landsat 8 Image
(acquisition date 2-22-2014).

Results and discussion

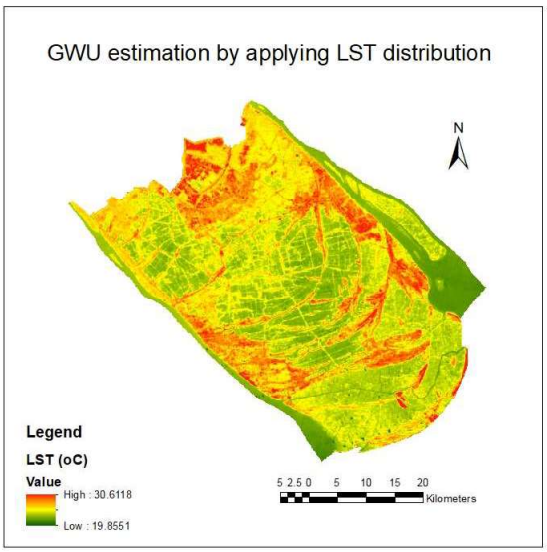
LST distribution estimate method and results

Convert the At-Satellite Brightness Temperature to Land Surface Temperature, using the following equation

$$T = TB/[1 + \left(\lambda \times \frac{TB}{c2}\right) \times \ln(e)]$$

Where:

- λ = wavelength of emitted radiance
- C2=h*c/s = 1.4388*10^{-2} m K = 14388 μm K
- H = Planck's constant = 1.38 * 10^{-23} J/K
- C = velocity of light = 2.998 * 10^{5} m/s

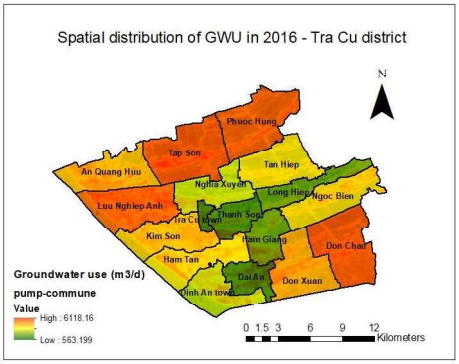


Satellite	Band	λ(μm)
Landsat 4,5&7	6	11.45
Landsat 8	10	10.8
Landsat 8	11	11.45

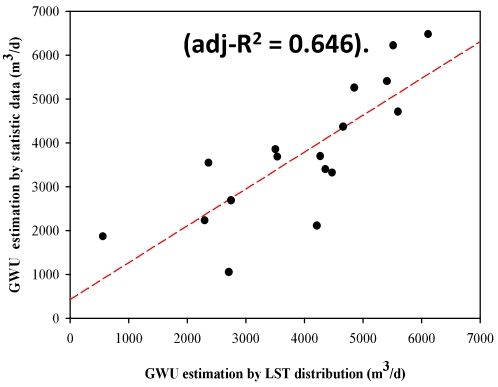
Results and discussion

Compare GWU estimations from LST distribution and statistics from authorities

The study investigated the correlation between the estimated GWU by statistic data including number of HH and land use of 17 communes in Tra Cu district and estimated GWU by LST from Landsat 8 Image (acquisition date 2-22-2014).

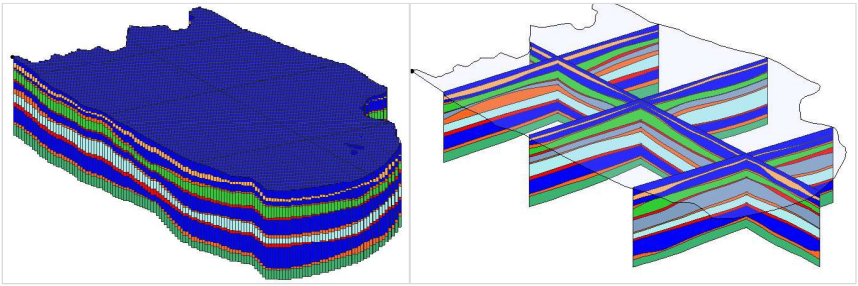


GWU estimation by applying LST distribution

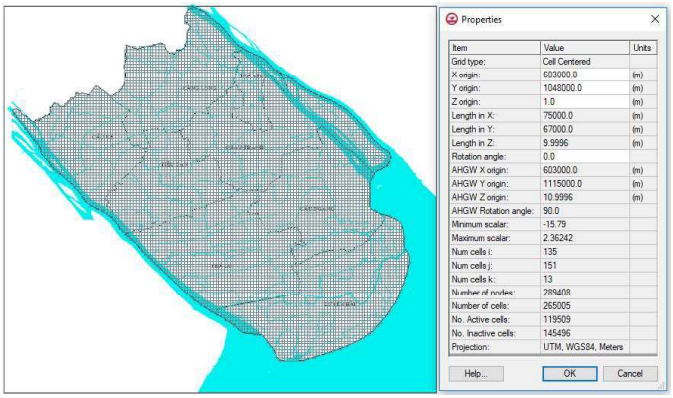


Results and discussion

Groundwater modelling



- The model grid consists of 135 rows and 151 columns with grid Size: 500 x 500m
- The model consists of 13 layers
  - Layers 1, 3, 5, 7, 9, 11, 13: aquifer;
  - Layers 2, 4, 6, 8, 10, 12: aquitard.
- General head and specify head boundary : apply from the regional model (Vuong 2013).
- The potential amount of recharge can vary from 8% to 12% of total annual precipitation (Silva 2018)
- The water levels were simulated by using MIKE11 (Tri 2016)
- The river conductance from previous model (Boehmer 2000)

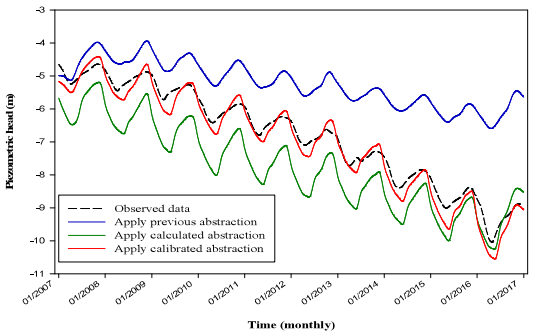


Results and discussion

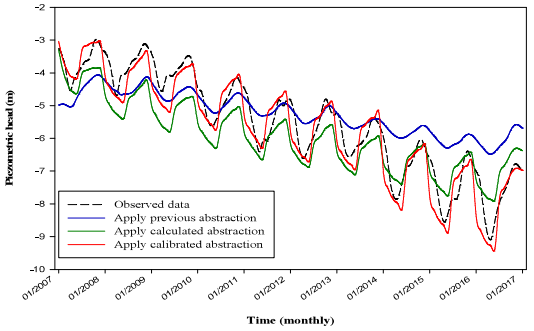
Verify GWU estimation (pattern and distribution)

Observed well	MAE	RMSE	R^2
Q404030			
Previous abstraction	1.560	1.793	0.89
Survey abstraction	-0.860	0.967	0.92
Calibrated abstraction	-0.049	0.221	0.98
Q217030			
Previous abstraction	0.263	0.970	0.85
Survey abstraction	-0.436	0.787	0.87
Calibrated abstraction	-0.204	0.503	0.92

Groundwater flow model was applied to compare change of piezometric head by using different abstraction.



Q404030 (qp_3 aquifer)



Q217030 (qp_{2-3} aquifer)

Results and discussion

Annual GWU pattern and distribution from GW model

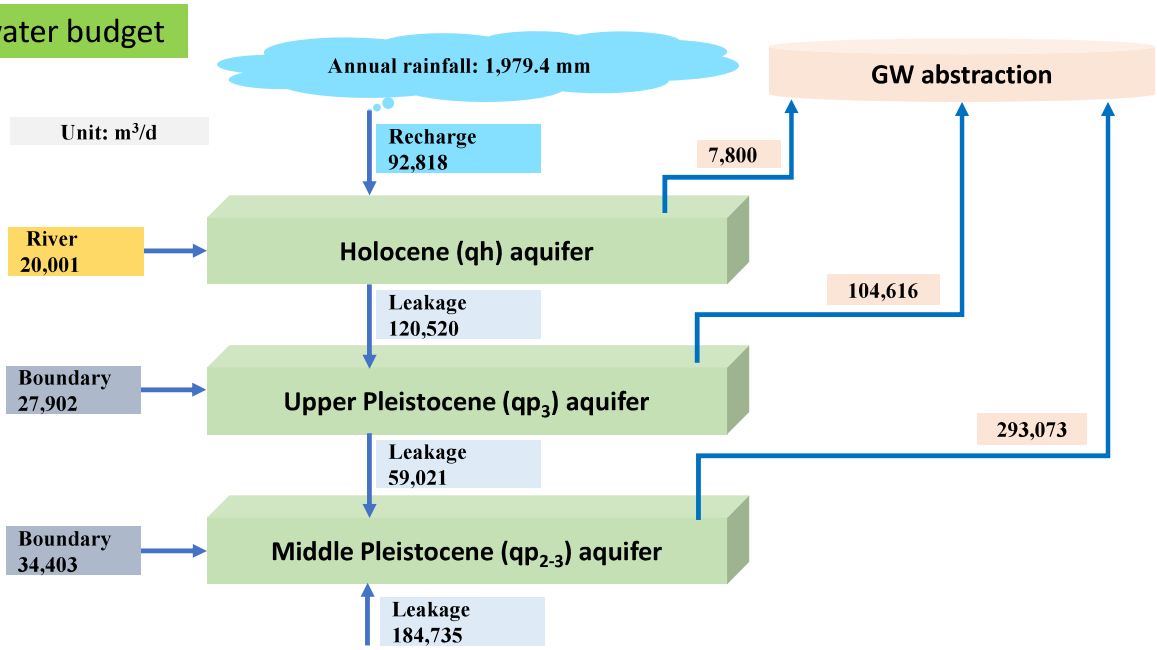
GWU concentrated mainly in coastal zone with over 67 percentages (234,476 m^3/d) of total GWU in Tra Vinh Province. From 2007 to 2016, GWU of Tra Cu and Duyen Hai increased rapidly from 48,200 m3/d and 51,127 m3/d to 94,648 m3/d and 90,903 m3/d respectively

Year	Number of HH	Ratio of HH using groundwater (%)							
		Cang Long	TP	Cau ke	Tieu Can	Chau Thanh	Cau Ngang	Tra Cu	Duyen Hai
2007	220,869	34%	6%	64%	43%	48%	33%	26%	40%
2008	221,665	42%	9%	73%	56%	58%	49%	33%	43%
2009	222,193	43%	8%	63%	55%	57%	43%	35%	39%
2010	222,789	43%	8%	58%	55%	57%	45%	37%	45%
2011	224,293	43%	7%	63%	55%	57%	45%	39%	56%
2012	225,590	45%	11%	62%	59%	60%	48%	37%	61%
2013	226,786	47%	8%	65%	62%	62%	53%	40%	60%
2014	228,004	49%	9%	68%	66%	65%	56%	48%	76%
2015	229,045	51%	10%	71%	70%	67%	59%	61%	69%
2016	231,238	53%	10%	73%	74%	70%	61%	83%	71%

Year	Number of HH	Annual groundwater use (m^3/d)								
		Tp. Tra vinh	Cang Long	Cau Ke	Tieu Can	Chau Thanh	Cau Ngang	Tra Cu	Duyen Hai	Total
2007	220,869	5,877	10,102	24,417	26,579	30,476	33,585	46,415	65,915	**243,365**
2008	221,665	6,419	10,599	26,745	27,351	34,175	34,994	51,073	69,714	**261,071**
2009	222,193	7,164	11,044	25,482	28,516	38,910	39,473	55,769	74,988	**281,346**
2010	222,789	7,752	11,686	25,368	29,384	40,652	41,409	59,804	77,164	**293,220**
2011	224,293	8,692	12,373	27,198	30,404	45,109	43,946	64,245	78,337	**310,305**
2012	225,590	8,704	13,019	27,765	31,250	46,532	46,770	70,862	82,060	**326,962**
2013	226,786	9,967	13,697	29,153	32,238	48,825	49,155	75,850	86,358	**345,243**
2014	228,004	10,665	14,359	30,523	33,084	52,009	52,009	81,039	90,313	**364,001**
2015	229,045	11,411	15,045	31,952	33,817	54,510	54,705	22,060	90,871	**314,371**
2016	231,238	12,146	15,745	34,428	34,735	55,776	57,936	89,819	96,221	**396,806**

Results and discussion

Groundwater budget



Conclusions

Groundwater use pattern

In northern part, where most groundwater is brackish and saline, the ratio of HH using groundwater is only **44 percent** at present. However, in middle part and coastal part, their ratios were **83 percent and 73 percent**, respectively. Average rate of GWU in coastal part also was **much higher** than the rate in northern part, particular is **3.78 m^3/HH/d and 1.05 m^3/HH/d**.

Groundwater use distribution

In 2016, annual GWA was estimated to be **347,793 m^3/d** in which sum of Duyen Hai, Tra Cu and Cau Ngang district occupied about 67 percent. **LST distribution** (produced by satellite image) presented a good correlation with GWU distribution with R^2 = 0.646. In future, it can be applied to estimate GWU in other area and in regional scale. **GW modelling** verified and corrected the estimated pumping pattern and distribution.

Effect of groundwater abstraction on groundwater budget

In qp_{2-3} aquifer (main abstracted aquifer), **82 percentage of inflow** was leakage flow with lower and upper aquifer. However, the over **GWA reduced the storage of aquifer** due to decline GWL significantly in the period of 10 years.

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Thank You

For Your Attention

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