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WATER-TABLE DYNAMICS AND TREND IN THREE UPAZILAS OF RAJSHAHI DISTRICT (BARIND AREA), BANGLADESH

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Abstract

Groundwater is an essential input for increasing crop production as well as for the sustainable agricultural development in Bangladesh. Availability of groundwater for irrigation has contributed to manifold increase in crop productivity of Bangladesh, particularly in the north-west region. This study was conducted on three Upazilas of Rajshahi District: Tanore, Godagari and Charghat. This part of the country is notable for water scarcity and almost dependent on groundwater resources. This study presents the trend of groundwater-table (25 years data) using the MEKESENS trend model. It reveals that the depth to groundwater level of almost all the monitoring wells is declining slowly. The trend of groundwater level in most of monitoring wells of Godagari and Charghat upazilas indicates that the aquifer became fully recharged every year. The groundwater level of Tanore upazila shows decreasing trend, implying that the aquifer was continuously depleting. Forecasting of groundwater level shows that in many cases, severe depletion of groundwater level will occur by 2030 if the present trend of groundwater extraction continues. If the decline of the water-table is allowed to continue in the long run, the result could be a serious threat to the ecology and to the sustainability of food production. The main source of recharging groundwater aquifer in the study area is rainfall, which is also decreasing in the area. Therefore, necessary measures should be taken to sustain water resources and thereby agricultural production. Demand-side management of water and the development of alternative surface water sources may be a viable strategy for the area. Such strategy could be employed to reduce pressure on groundwater and thus maintain the sustainability of the resource.

Keywords: Groundwater trend, aquifer recharge, sustainability, water-table

1 INTRODUCTION

Bangladesh contains world's one of the largest deltas and is, therefore, heavily depends on rivers originating in other countries and rainfall for its water supply. Climate change (rise in temperature and changing rainfall patterns), deforestation and construction of dams in common rivers have led to a reduced amount of water entering into Bangladesh. Of the 147 billion cubic meters water required in the country during dry season, only 90 billion cubic meters are available. This 40% deficit leads to drought in some regions. Most Bangladesh neighbors, including India and China, have embarked on building dams for using waters originating from Himalayas Mountains. In the last 3-4 decades when climate change began to be observed in the north-west region of Bangladesh, the situation has progressively become worse. All the rivers and canals of the area dry up during the dry season and make the people completely dependent on groundwater. The area is also highly prone to droughts because of high rainfall variability (Ali et al., 2005; Shahid, 2008; Shahid and Behrawan, 2008). Agriculture is the main sector of water use, especially in the north-west region of Bangladesh. Use of groundwater for irrigation is continuously increasing for increased agricultural production. About 75% water for irrigation in the north-west region comes from groundwater (Bari and Anwar, 2000). Adequate rainfall and reasonable river flow is necessary for recharging the local aquifer. The availability of both surface water and groundwater is therefore very critical for the habitation of this area. The over exploitation has caused the groundwater level falls to the extent of not getting fully replenished in the recharge season. Some other parts of Bangladesh are experiencing the over exploitation problem (Ali et al., 2012). In dry season, the groundwater-table depleted down to 14-20 meter in Nachole and Gomastapur upazila (Nawabgonj), whereas 6-10 meter in Porsha and Sapahar upazila (Naogaon)(Ahmed and Chowdhury, 2006). In Dhaka city, over-extraction has caused the water-table to fall by as much as 40 m in some places (Sarkar and Ali, 2009). A study on North-eastern region of Bangladesh revealed that the depth to water-table of almost all the wells is increasing slowly (Ali *et al.,* 2011). The climate change issue can also worsen the situation (Ali et al., 2007)

The groundwater-based irrigation system in the area has reached a critical phase as the phreatic water level has dropped below the suction limit of pumps in many places. It is a common concern that groundwater-table in the northwest region is gradually declining, causing anxiety for the expanded irrigation system in the area. So, for sustainable use of groundwater and its development, analysis of long-term groundwater level fluctuation and prediction of groundwater availability are important.

The specific objectives of the study were:

- to evaluate the dynamic nature of the annual minimum and maximum groundwater level in the study area using the recent past data,
- to quantitatively assess the trends in water level depths and predict the future scenario,
- to predict the availability of groundwater in terms of the maximum depth of groundwater level for next 20 years.

2 METHODOLOGY

2.1 Site description

Three upazilas namely Tanore, Godagari and Charghat of Rajshahi district (24.3667° N, 88.6^0 E, 18m above mean sea level) were selected as study area (Fig.1., Map showing location). Charghat is on the bank of river Padma. Godagari is the place where Mahananda river falls to Padma.

2.2 Data collection and processing

The water-table data of 22 observation wells, from the year 1985 to 2009, were collected from Bangladesh Water Development Board (BWDB), which is the department responsible for most water related records. From the weekly records, the maximum and minimum depths of water-table of a year were sorted out for analysis. Rainfall data of the study period (1985-2009) were collected from Bangladesh Meteorological Department (BMD). Table-1 shows the number of observation wells.

Table 1. No of observation wells in study area.

Upazila	Number of wells	Well no.
Charghat	8	RSS24, RSS26, RS34, RS97, RS98, RS99, RS102, RS116
Godagari	9	RS42, RS80, RS81, RS91, RS92, RS93, RS104, RS123, RS124
Tanore	5	RSS32, RS27, RS39, RS40, RS136

2.3 Data analysis

Trend analysis

The maximum depth to water-table in a particular year was used in trend analysis. The model "MAKESENS" was used for detecting and estimating trends. The model is based on the non-parametric Mann-Kendall test for trend and non-parametric Sen's method for the magnitude of the trend (Salmi *et al.*, 2002). The advantage of non-parametric method is that it is applicable for both monotonic and non-monotonic trend, and there is no problem with the missing data. The model also exploits both the so-called S-statistics and Z-statistics (the normal approximation) given by Gilbert (1987). For time series with less than 10 data points, the S-test is used and for time series with 10 or more data points, the Z-test is used.

Prediction for the future

The WT depths were predicted for the year 2020, 2025 and 2030. The depths of groundwater level were computed by using the following equation

GWL depth (m) = B + Q*(Simulated year - Base year) …………………… (1)

where, B is the intercept and Q is the slope of trend line. Base year is first year (1985) of the collected data and simulated year is the desired year for prediction.

3 RESULTS AND DISCUSSION

3.1 Dynamics of groundwater level

Seasonal fluctuation of groundwater level in 2009 of some study wells is shown in Figure 2. Groundwater level fluctuates annually in response to groundwater extraction, subsurface inflow and outflow, recharge from precipitation and infiltration of applied irrigation water. Groundwater level is usually the highest in September to October and the lowest in April to June. Longer-term fluctuation of groundwater level occurs when discharge exceeds or is less than recharge over several seasons.

The maximum and minimum depths of groundwater level in different observation wells of Charghat, Godagari, Tanore upazila are shown in Figure 3, 4 and 5. It is observed from the minimum and maximum depths of groundwater level that the water level fluctuated within 7 m in Charghat, 4 to 16 m in Godagari and 1 to 7 m in Tanore during the study period (1985 –

2009). The maximum fluctuation occurred in well RS42. However, during the peak time of recharge, groundwater-table of Charghat and Godagari reached almost to its previous year's positions except in some years. In case of wells RS91 and RS92, the difference between the maximum and minimum depths of groundwater level was becoming narrower, implying that there was inadequate recharge in the aquifer. Groundwater levels in four of the five observation wells in Tanore upazila did not regain their previous levels through recharge. The withdrawal of water from the aquifer was higher than the recharge in the aquifer.

3.2 Effects of rainfall on the depth of minimum groundwater level

The effects of rainfall on the depth of minimum groundwater level of the observation wells of Tanore, Charghat and Godagari upazila are illustrated in Figure 6. It is observed that the annual minimum depth of groundwater level responded to the rainfall of that year in case of most of the observation wells of Charghat and Godagari upazilas, and well RS40 of Tanore upazila. Higher amount of rainfall lowered the minimum depth of groundwater level in those study wells, entailing that the higher amount of rainfall replenished the aquifer completely. After the year 2006, well RS97 of Charghat upazila did not show the effect of rainfall on the minimum water level. Continuous increase in the minimum depth of groundwater level was observed in the well RS91 of Godagari upazila, and in the wells RS27, RSS32, RS39 and RS136 of Tanore upazila after the year 2000 without any recharge from rainfall.

3.3 Trend of minimum groundwater level

Charghat upazila

The trend of minimum groundwater level in Charghat upazila is illustrated in Figure 7. A rising trend of the minimum groundwater level was found in well RS34, which indicated that the replenishment of the aquifer of that area in any year from recharge was more than that of the previous year. A slightly increasing trend (lowering) of the water level was noticed in well RS97, RS98, RS99 and RS102 during the study period. So, in those areas, full recharge of the aquifer did not occur. No significant trend was found in the minimum groundwater level in the wells RS116, RSS24 and RSS26 since the observed data were scattered to give any definite trend. Also the statistical calculations giving a high level of significance with narrow angles between the confidence lines confirmed that there was no trend.

Godagari upazila

Figure 8 illustrates the trend of minimum groundwater level in Godagari upazila. Except observation well RS42 and RS81, a rising trend in groundwater level was found in all the observation wells, revealing incomplete replenishment of the aquifer in those areas. Groundwater levels of the wells RS42 and RS81 showed a constant trend (horizontal trend line), representing the attainment of previous year's position through recharge.

Tanore upazila

The trend of minimum groundwater level in Tanore upazila is illustrated in Figure 9. The minimum groundwater level continuously dropped in all the wells except well RS40. The declining trend of the minimum groundwater level implies that recharge was inadequate to replenish the aquifer completely.

3.4 Trend of maximum groundwater level

Charghat upazila

The trend of maximum groundwater level in Charghat upazila is shown in Figure 10. It is observed that the annual maximum groundwater level remained mostly unchanged in the observation wells RS99, RS116, RSS24 and RSS26. This result revealed that the groundwater in those areas remained in dynamic equilibrium under the combined action of recharge and abstraction. In case of the other wells, the maximum groundwater level showed a light declining trend.

Godagari upazila

The trend of maximum depths of groundwater level in Godagari upazila is illustrated in Figure 11. The depth of maximum groundwater level is steadily increasing in all the wells. The increasing trend of the maximum groundwater level implies that the amount of extraction of groundwater increased in the study area during the study period.

Tanore upazila

Figure 12 shows the trend of the maximum depth of groundwater level in Tanore upazila. A smooth increasing trend of the annual maximum depth of groundwater level was noticed in all observation wells except well RS40. Well RS40 showed slightly declining trend in the maximum groundwater level. The increasing trend of the maximum groundwater level entailed that the amount of extraction of groundwater increased in the study area over the period of study.

3.5 Trend of maximum groundwater level fluctuation

The fluctuation of the maximum groundwater level was obtained from the difference of the yearly minimum and maximum depths of groundwater level.

Charghat upazila

The trend of the maximum fluctuation of groundwater level in Charghat upazila is shown in Figure 13. The maximum fluctuation of groundwater level continuously increased in the observation wells RS34, RS98, RS102 and RS97. This increasing trend in the maximum fluctuation indicated that the extraction of groundwater increased over the time in the study area. The decreasing trend in the maximum annual fluctuation was observed in the wells RS99, RS116, RSS26 and the fluctuation was constant over time in well RSS24. The decreasing of groundwater level fluctuation implies the lower extraction of groundwater.

Godagari upazila

Figure 14 illustrates the trend of maximum fluctuation of groundwater level in Godagari upazila. An increasing trend of the maximum fluctuation of groundwater level was found only in well RS42 and a decreasing trend was found in the wells RS80, RS91, RS92 and RS93. A gradual decreasing of groundwater level fluctuation revealed a lower extraction of groundwater. The unchanged trend in the fluctuation observed in well RS104, RS123 and RS124 implies dynamic equilibrium of the aquifer under annual recharge and extraction of groundwater.

Tanore upazila

The trend of maximum fluctuation of groundwater level in Tanore upazila is depicted in Figure 15. A decreasing trend of the fluctuation was found in the wells RS27, RS39, RS40 and RS136. Such trend entails the incomplete recharge of the aquifer. Well RSS32 also showed a decreasing trend of the maximum fluctuation of groundwater level but the broad angle between the confidence lines made the trend less significant.

3.6 Future trend of groundwater level

The predicted maximum depth of groundwater level for the year 2020, 2025 and 2030 under different observation wells are summarized in Table 2. A negative trend obtained in the wells RS99, RS116 and RSS26 of Charghat upazila indicates more replenishment of the aquifer in any year than the previous year. The depth to groundwater level in all other wells is expected to increase if the present trend of groundwater extraction continues. The worst scenario of groundwater level is expected to appear in well RS91 of Godagari and RS40 of Tanore upazila as its depth will be tripled in 45 years.

Table 2. Maximum depth of groundwater level in 1985 and 2009, and simulated scenario of the maximum depth of groundwater level for the future (Q is the Sen's slope and B is the intercept).

Upazila	Well no.	Depth of GWL (m) in		Q (m/year)	B (m)	Simulated depth of GWL (m) in		
		1985	2009			2020	2025	2030
Charghat	RS34	5.87	7.33	0.059	5.86	7.95	8.24	8.54
	RS97	5.87	8.80	0.089	6.01	9.14	9.59	10.04
	RS98	5.46	9.40	0.174	5.24	11.33	12.20	13.07
	RS99	9.76	9.51	-0.009	9.33	8.99	8.94	8.89
	RS102	5.05	9.70	0.177	5.45	11.65	12.53	13.42
	RS116	6.99	6.30	-0.100	7.56	4.06	3.56	3.06
	RSS24	6.30	6.90	0.017	6.53	7.14	7.23	7.32
	RSS26	7.39	7.56	-0.019	7.98	7.31	7.22	7.12
Godagari	RS42	13.84	20.30	0.239	14.80	23.17	24.36	25.56
	RS80	7.90	10.70	0.100	7.88	11.38	11.88	12.38
	RS81	13.46	17.00	0.061	13.30	15.43	15.73	16.04
	RS91	10.00	20.05	0.425	10.10	24.98	27.10	29.23
	RS92	7.70	11.35	0.120	7.49	11.69	12.29	12.89
	RS93	10.29	12.95	0.063	10.50	12.69	13.01	13.33
	RS104	8.27	10.40	0.055	8.48	10.41	10.68	10.96
	RS123	6.82	8.70	0.124	6.77	11.11	11.73	12.35
	RS124	11.50	13.25	0.047	11.50	13.13	13.36	13.59
Tanore	RS27	10.49	17.20	0.250	9.90	18.65	19.90	21.15

	RS39	7.52	12.19	0.261	5.94	15.08	16.38	17.69
	RS40	6.91	13.09	0.155	8.67	14.09	14.87	15.65
	RS136	18.65	21.93	0.042	18.2	19.68	19.89	20.10
	RSS32	7.93	12.40	0.175	7.22	13.35	14.22	15.09

4 CONCLUSIONS AND RECOMMENDATIONS

Continuous declining trend of groundwater level was found in most of the observation wells of one upazila during the study period. Adequate replenishment of the aquifer was observed in most of the observation wells of two upazilas (Charghat and Godagari). Mining of the aquifer was observed in Tanore upazila. Extraction of groundwater increased in the study area over the study period. Prediction of water levels in the observation wells RS99, RS116 and RSS26 of Charghat upazila forecasted more replenishment of the aquifer in any year than the previous year and depth of the other wells will be doubled within 2030. So for sustainable groundwater management, law and long-term policy need to be enacted to prevent groundwater mining. Engineering and agronomic measures need to be adopted to reduce the extraction of groundwater.

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Fig. 1. Map of Rajshahi district indicating study area

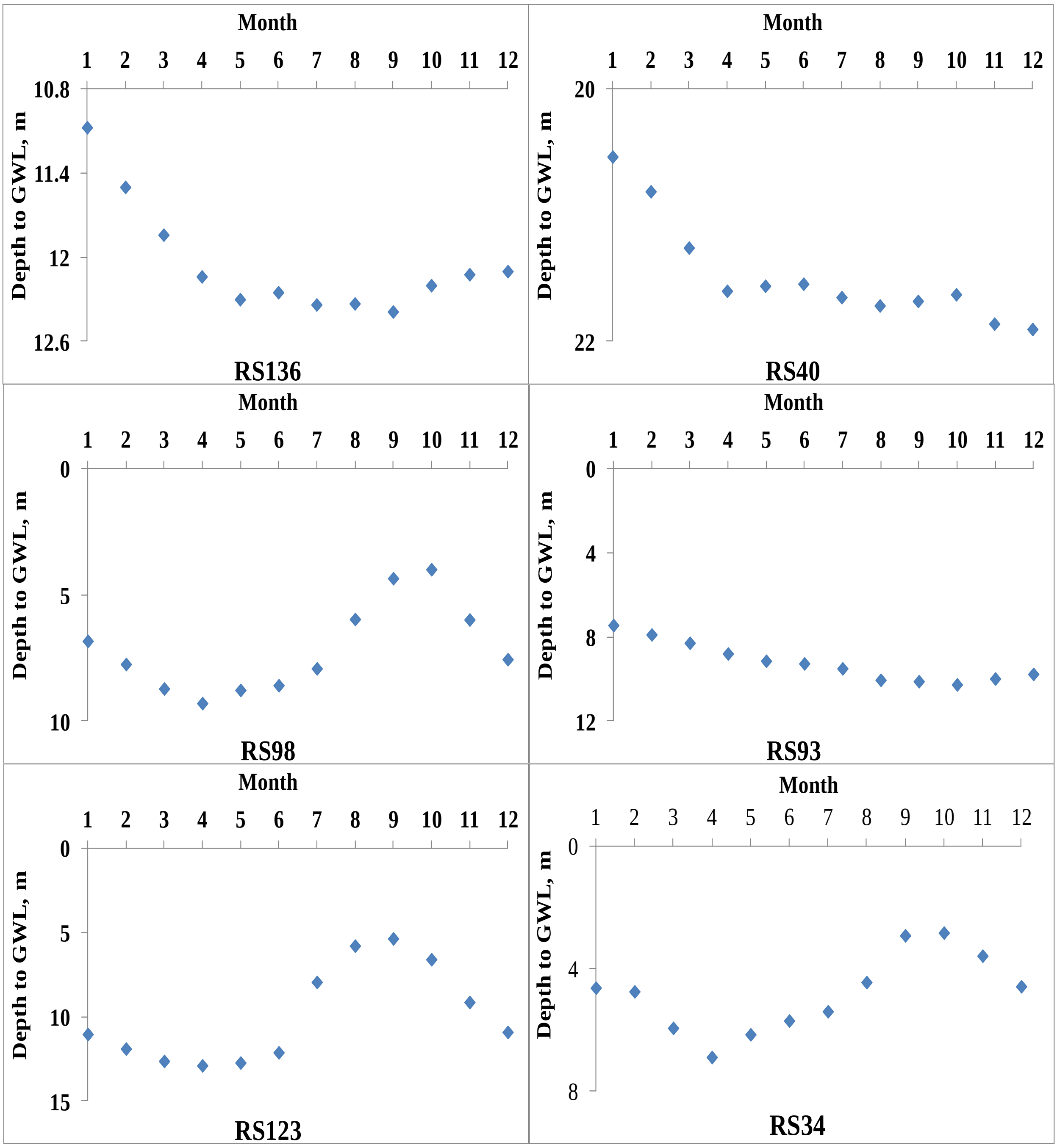

Fig. 2. Seasonal fluctuation of ground water level (GWL) in 2009

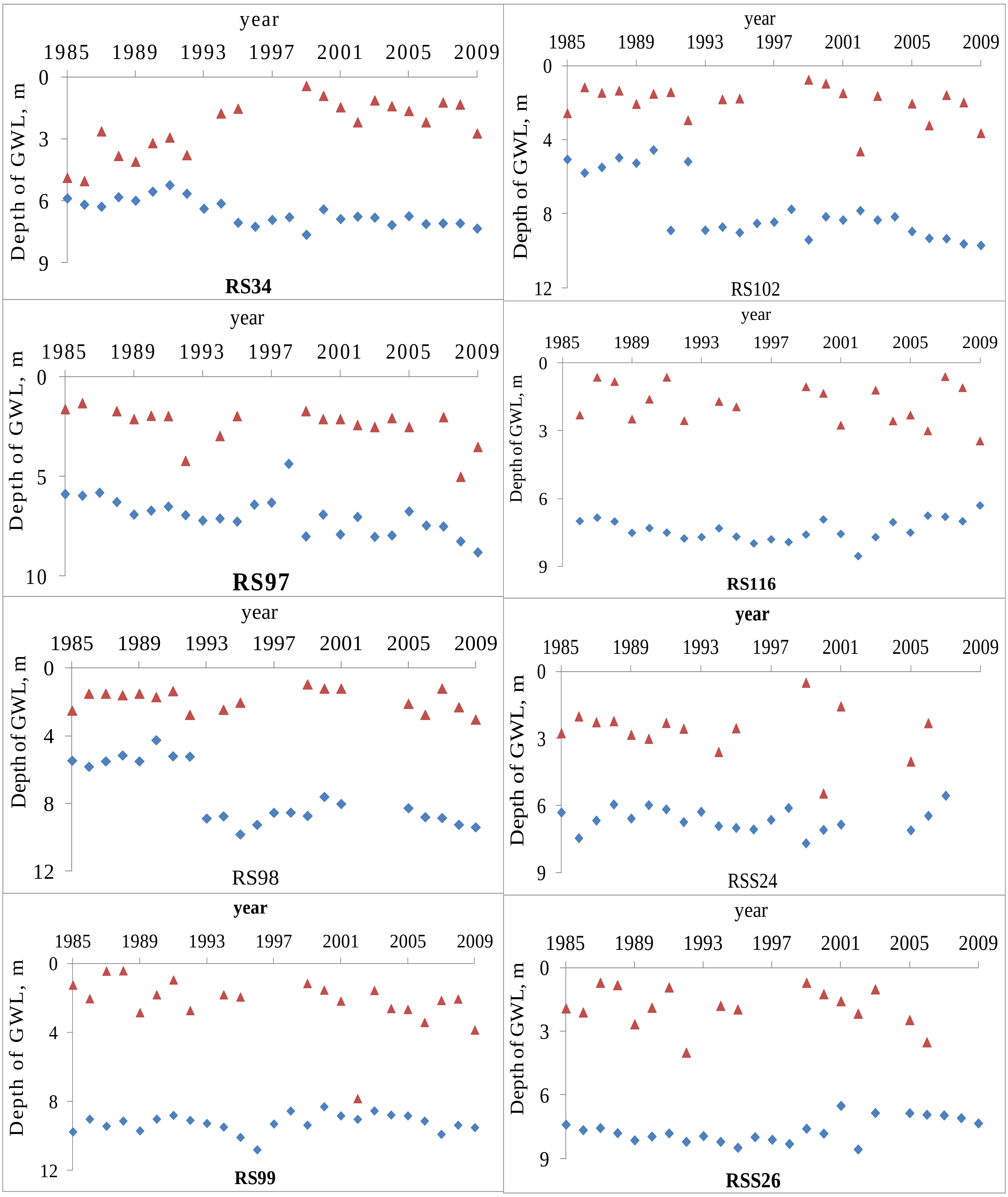

Fig. 3. Depth of maximum and minimum groundwater levels (GWL) in different observation wells of Charghat upazila during 1985 to 2009 (Legend: ▲ = minimum depth of GWL, ♦ = maximum depth of GWL).

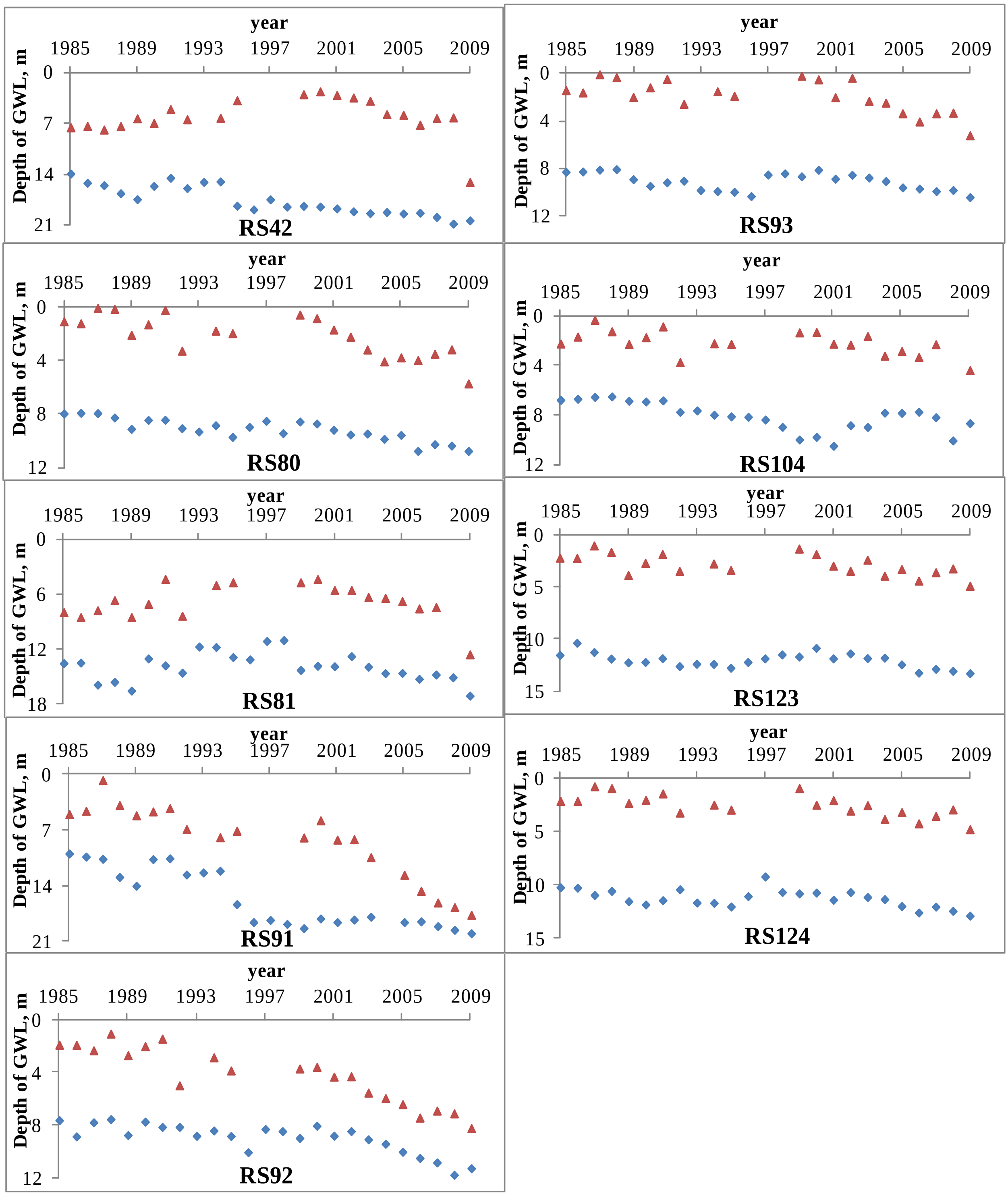

Fig. 4. Depth of maximum and minimum groundwater levels (GWL) in different observation wells of Godagari upazila during 1985 to 2009 (Legend: ▲= minimum depth of GWL, ♦ = maximum depth of GWL).

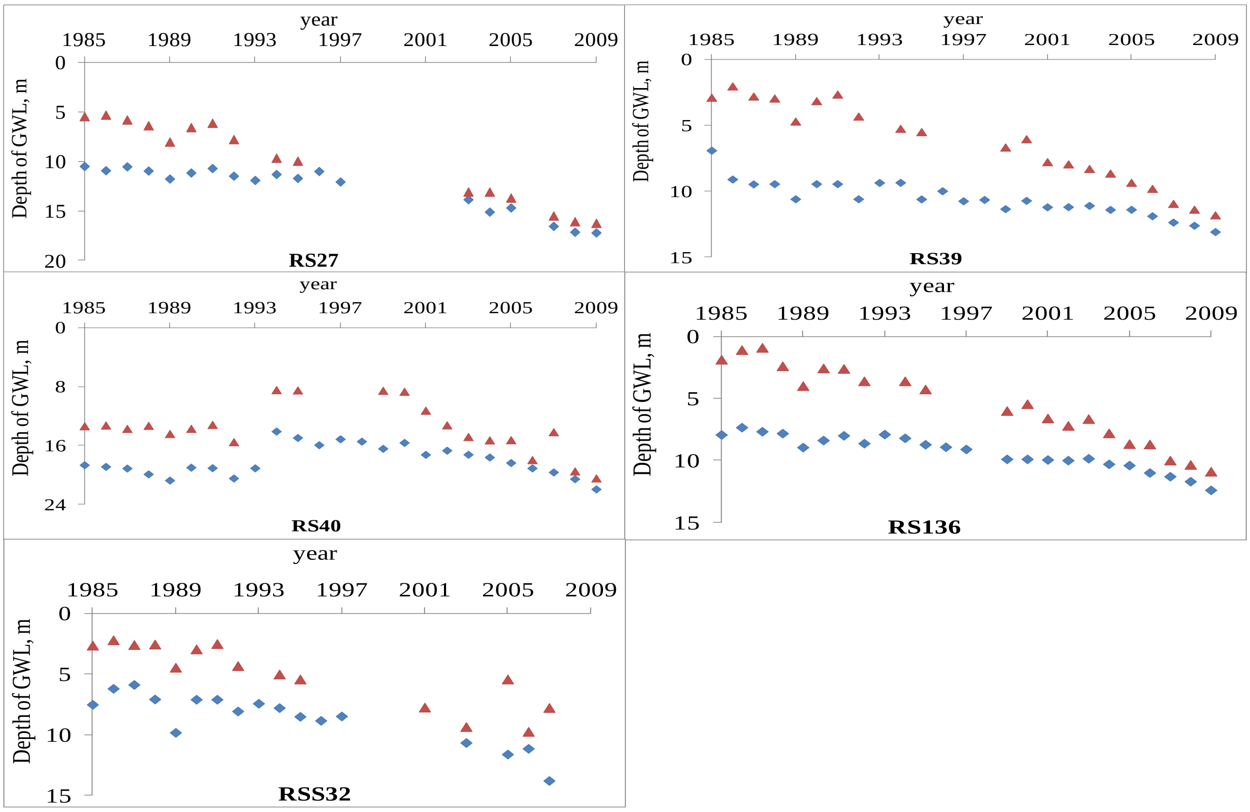

Fig. 5. Depth of maximum and minimum groundwater levels (GWL) in different observation wells of Tanore upazila during 1985 to 2009 (Legend: ▲= minimum depth of GWL, ♦ = maximum depth of GWL).

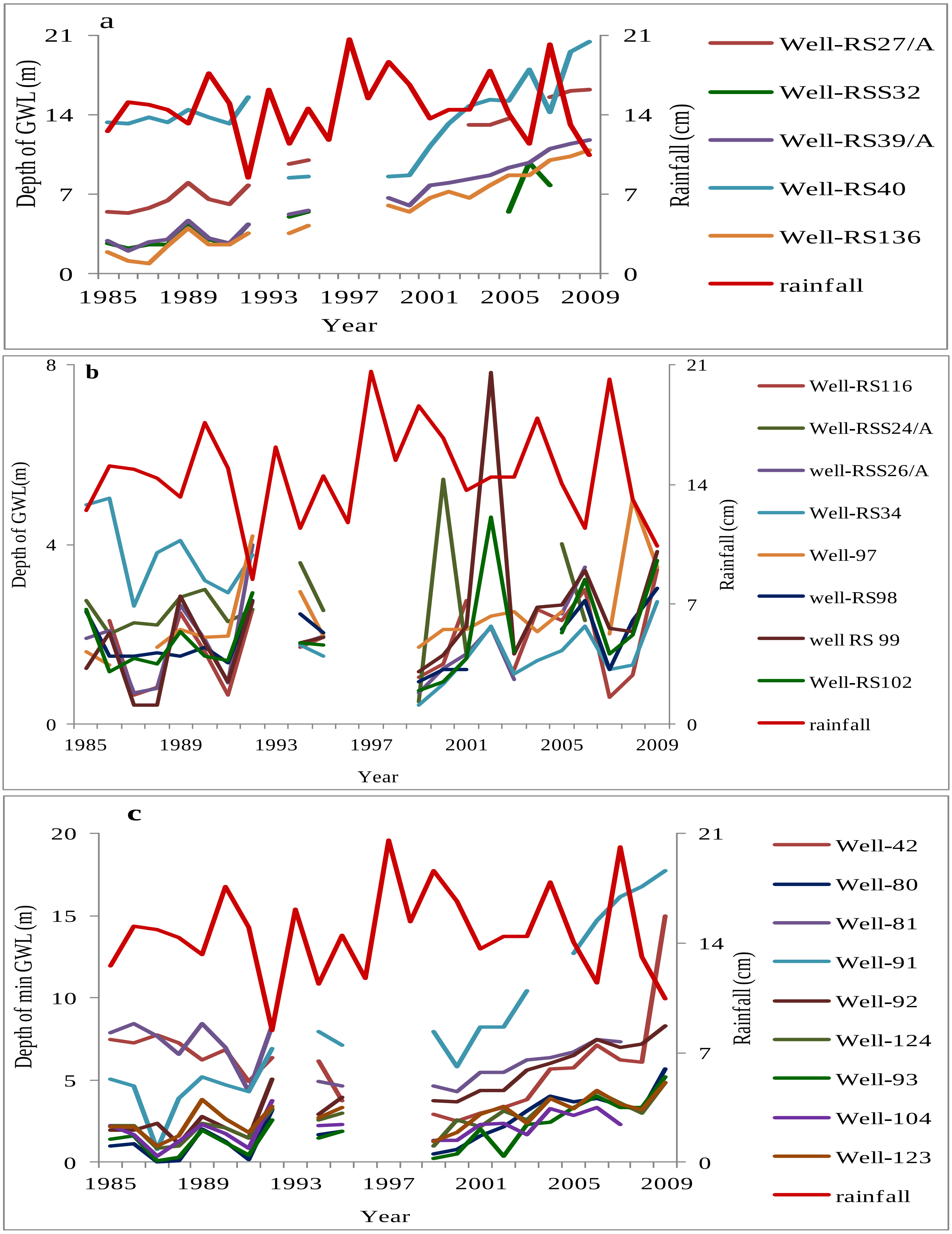

Fig. 6. Effects of rainfall on the depth of minimum groundwater level (GWL) in Tanore (a), Charghat (b) and Godagari (c) upazila

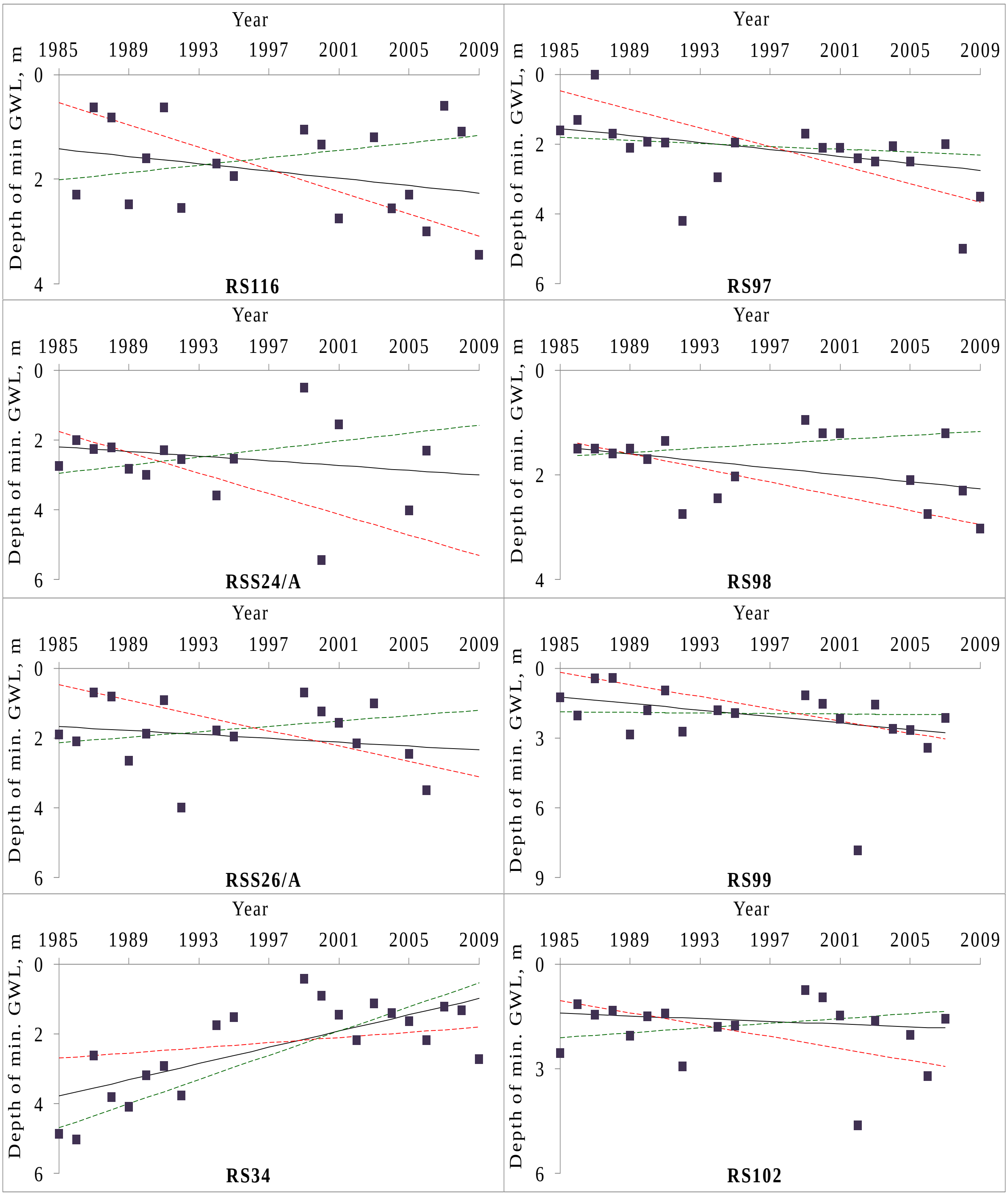

Fig. 7. Trend of minimum depths of groundwater level in Charghat Upazila

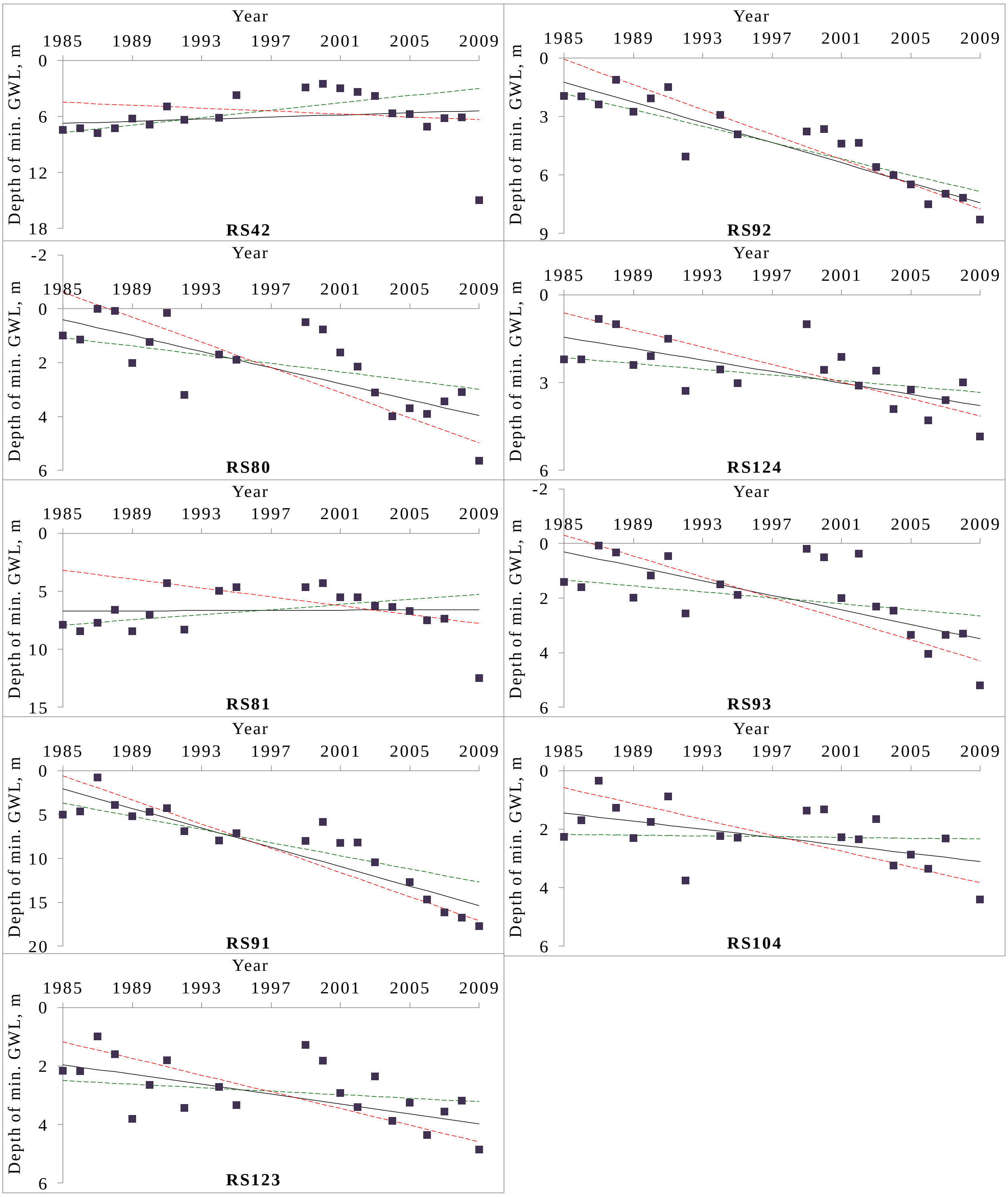

Fig. 8. Trend of minimum depths of groundwater level in Godagari upazila

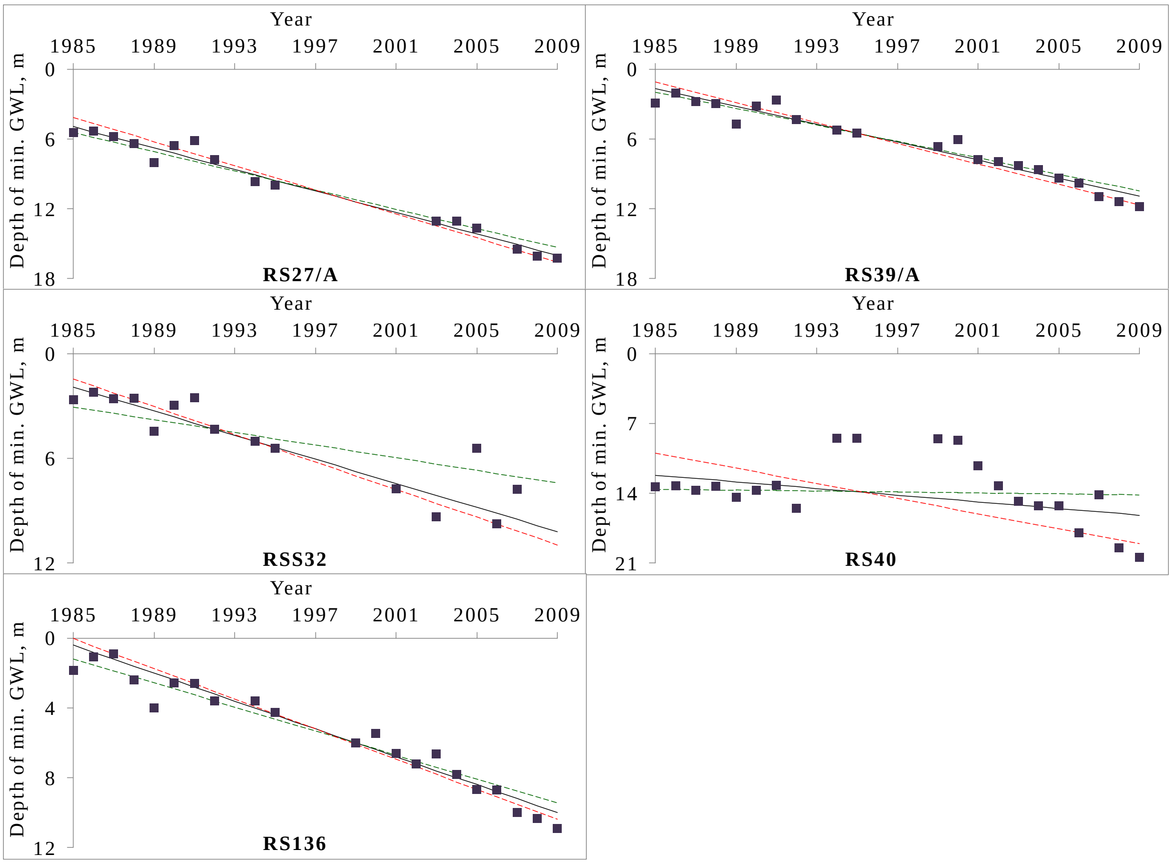

Fig. 9. Trend of minimum depths of groundwater level in Tanore upazila (Legend: ♦ = depth of GWL, — = max depth of GWL at 95% conf., — = min depth of GWL at 95% conf., — = Sen's estimate)

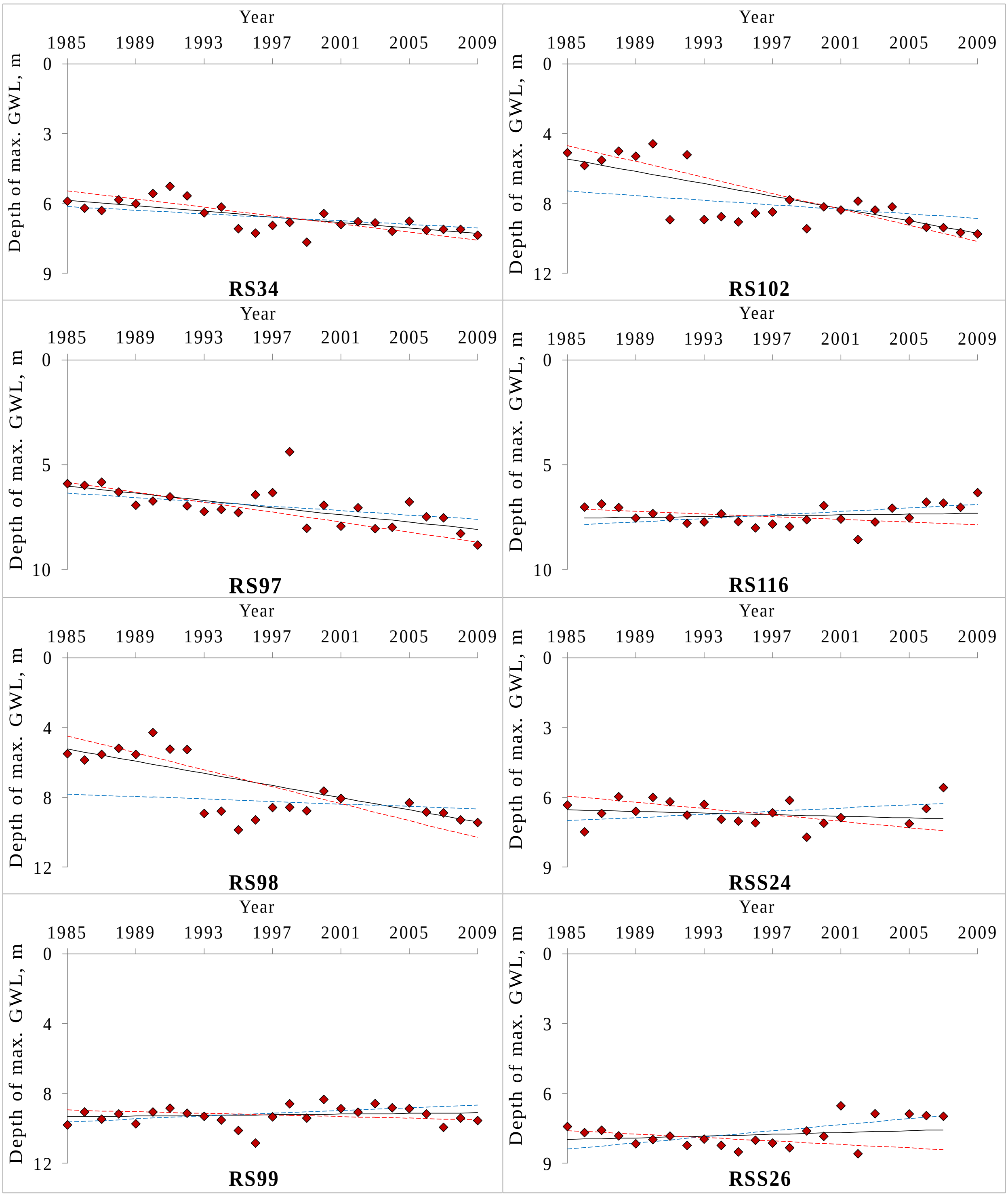

Fig. 10. Trend of maximum depths of groundwater level (GWL) of Charghat upazila

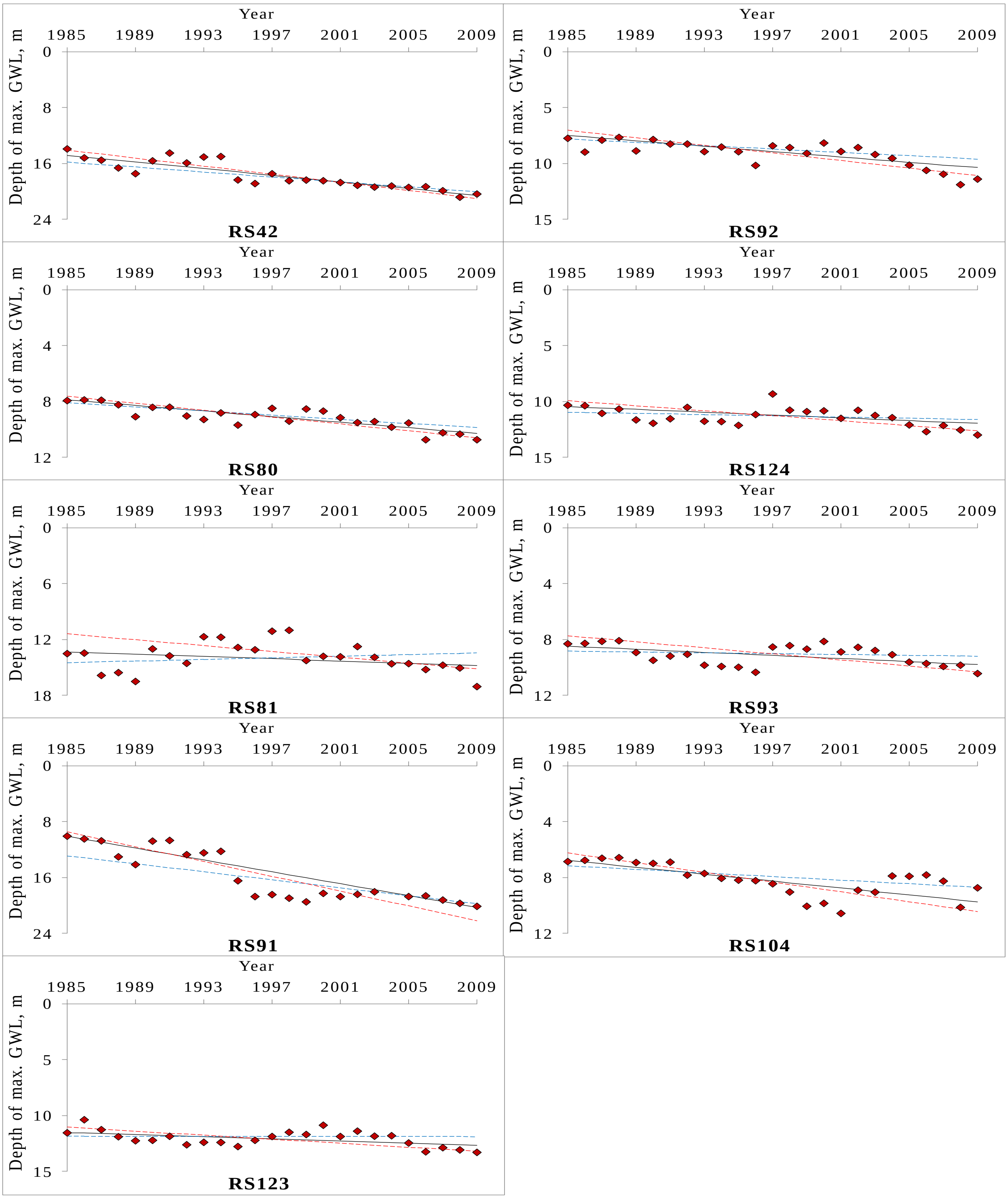

Fig. 11. Trend of maximum depths of groundwater level (GWL) of Godagari upazila

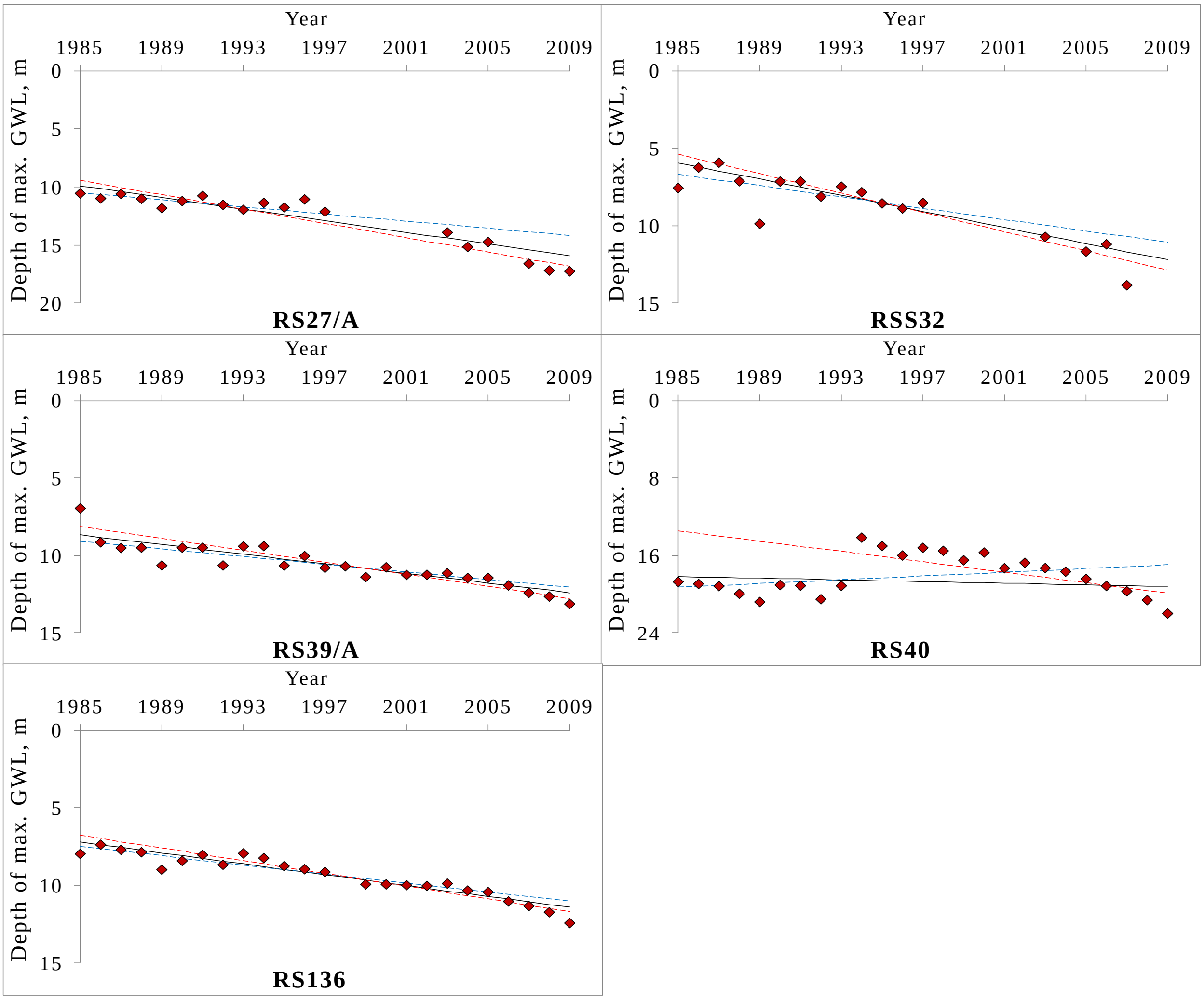

Fig.12. Trend of maximum depths of groundwater level (GWL) of Tanore upazila (Legend: ♦ = depth of maximum GWL, — = max depth of GWL at 95% conf., — = min depth of GWL at 95% conf., — = Sen's estimate)

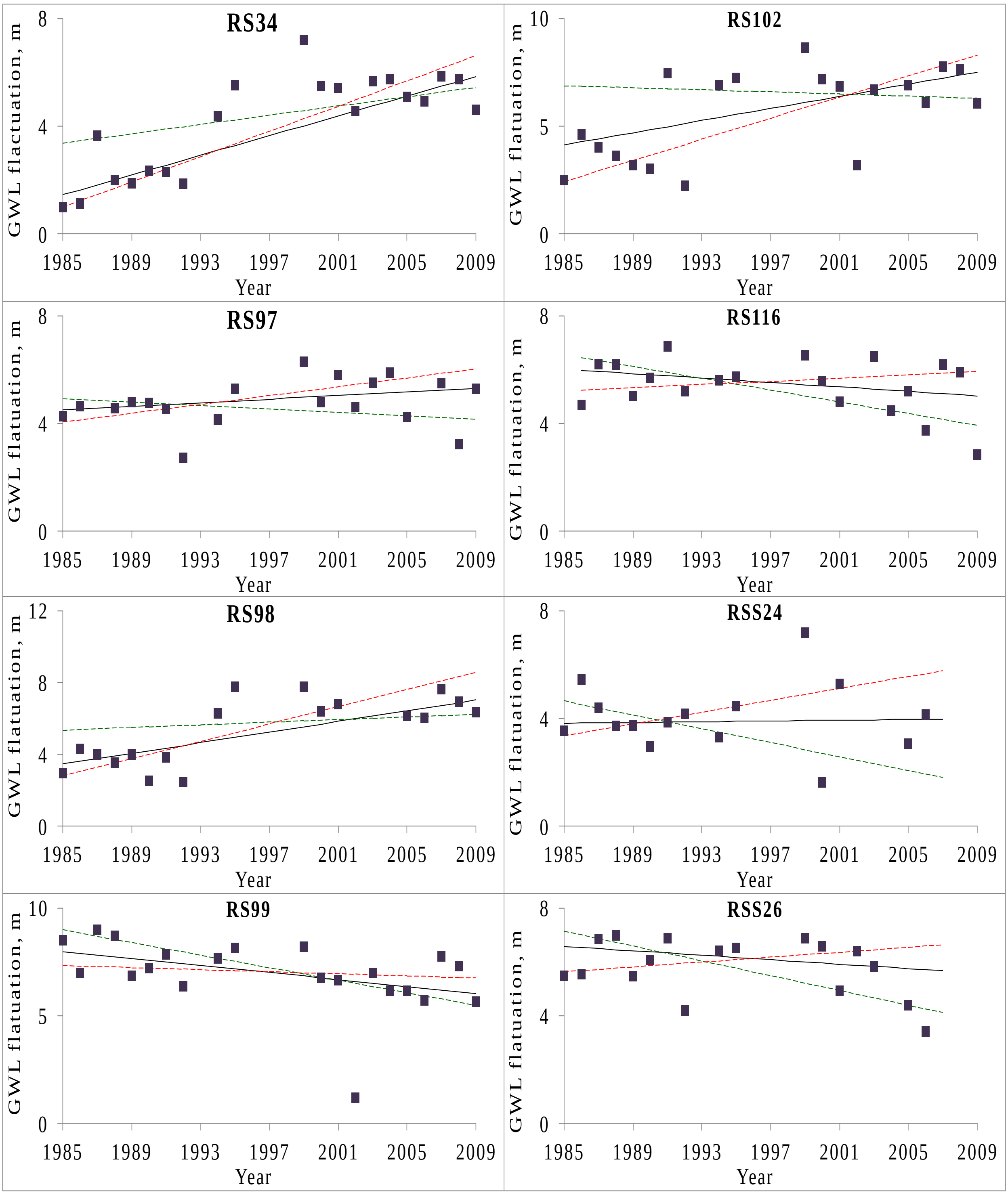

Fig. 13. Trend of maximum fluctuation of groundwater level (GWL) in Charghat upazila

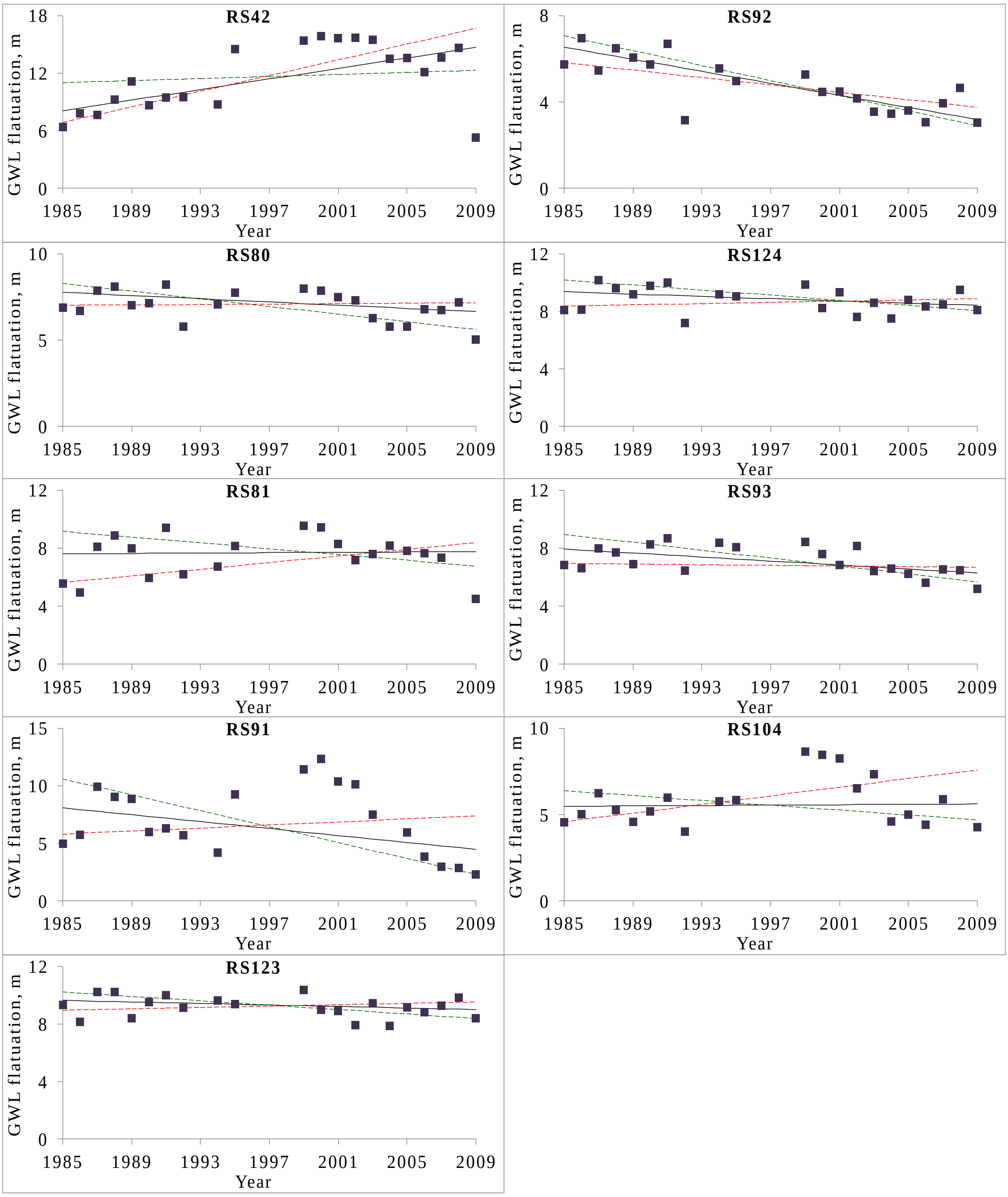

Fig. 14. Trend of maximum fluctuation of groundwater level (GWL) in Godagari upazila

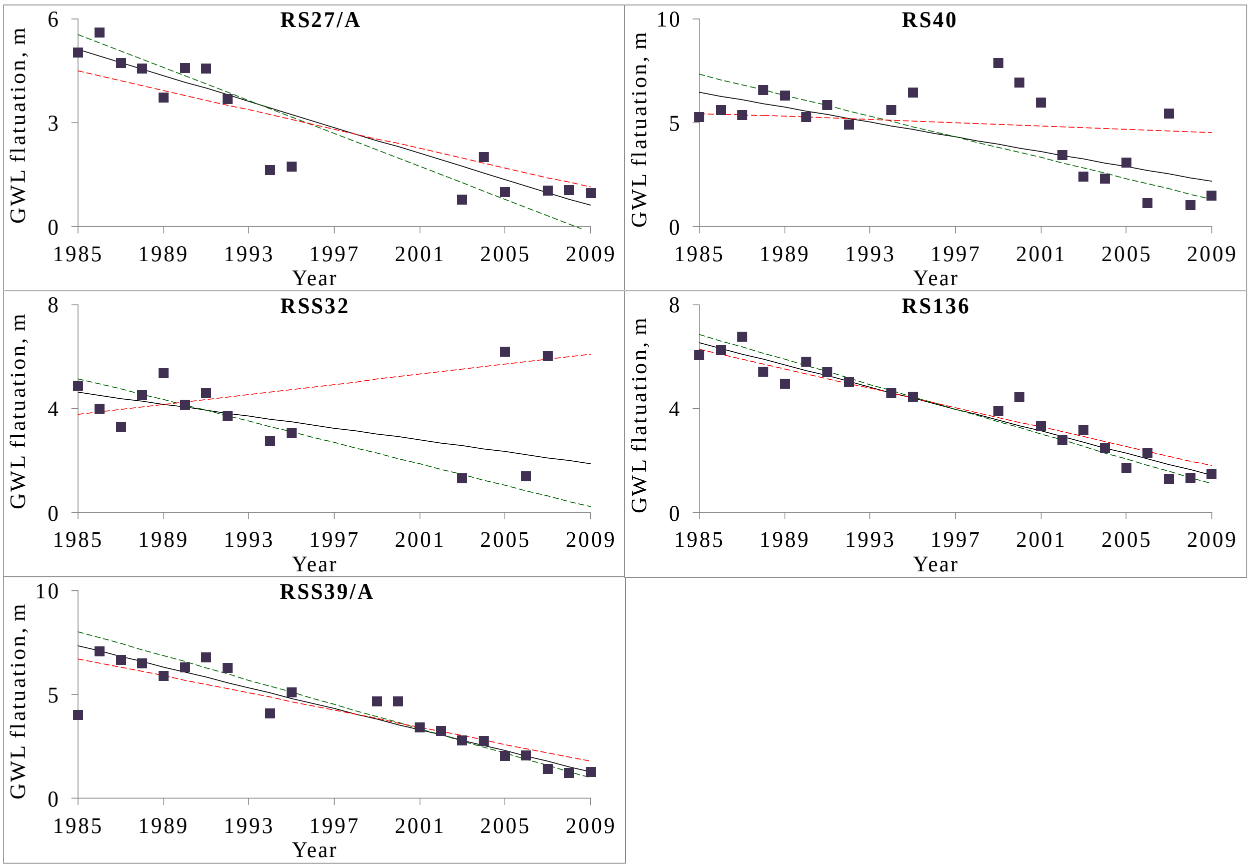

Fig. 15. Trend of maximum fluctuation of groundwater level (GWL) in Tanore upazila (Legend: ■ = depth, — = max depth of GWL at 95% conf., — = min depth of GWL at 95% conf., — = Sen's estimate)