Supplement of Hydrol. Earth Syst. Sci., 22, 4213–4228, 2018
https://doi.org/10.5194/hess-22-4213-2018-supplement
© Author(s) 2018. This work is distributed under
the Creative Commons Attribution 4.0 License.

Hydrology and Earth System Sciences
Open Access

Supplement of

Modeling the changes in water balance components of the highly irrigated western part of Bangladesh

A. T. M. Sakiur Rahman et al.

Correspondence to: A. T. M. Sakiur Rahman (shakigeo@gmail.com)

The copyright of individual parts of the supplement might differ from the CC BY 4.0 License.

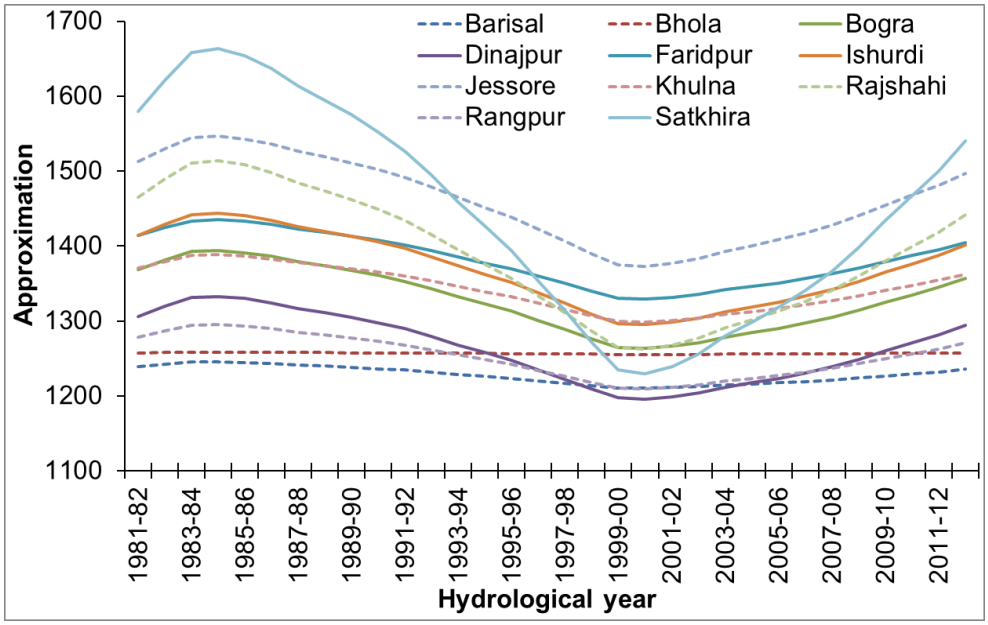

Figure S1. Approximation time series of P_{ET} obtained from DWT for the hydrological period of 1981-82 to 2012-13

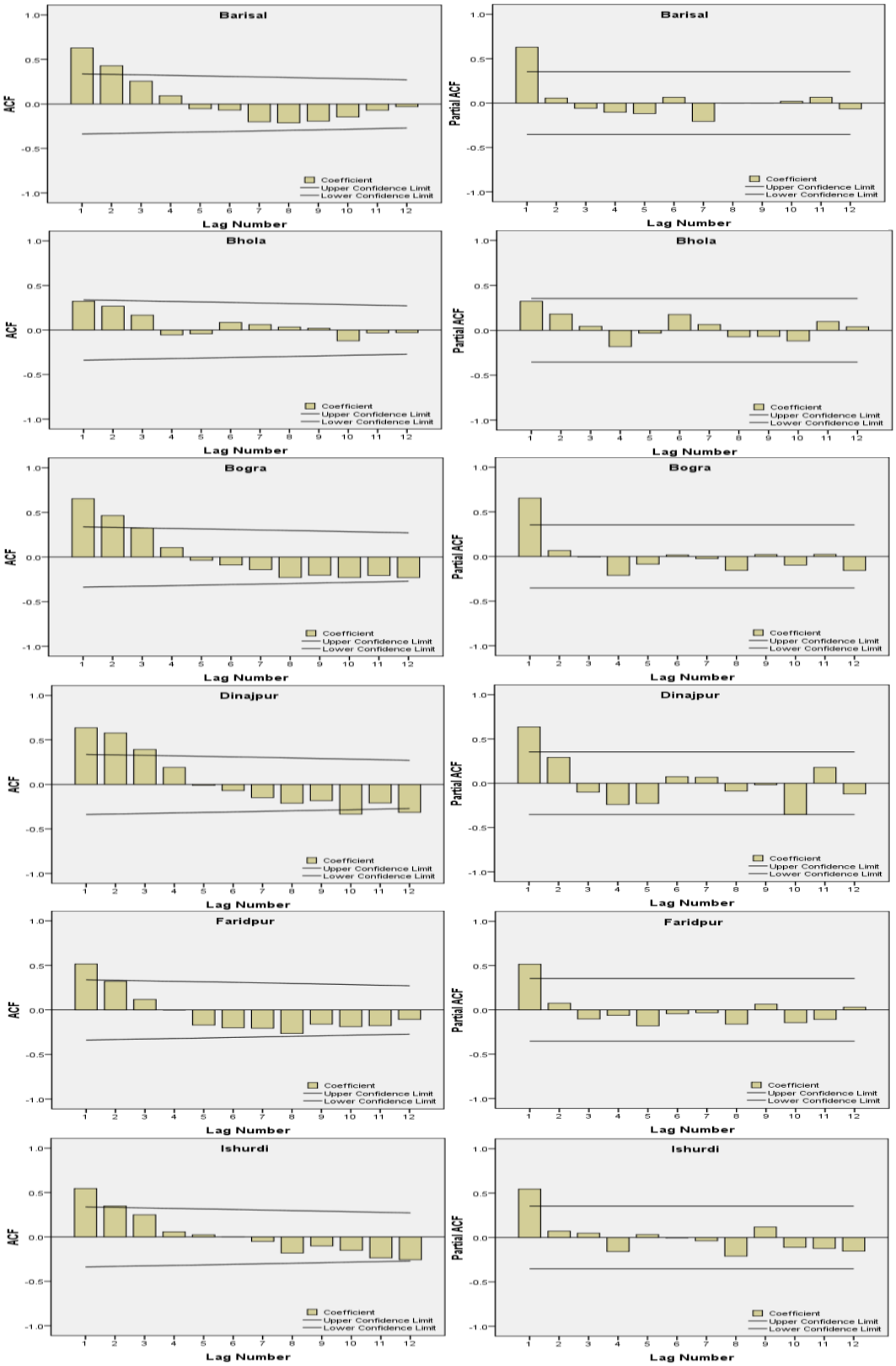

Figure S2. (a) Plot of auto-correlation function (ACF) and partial auto-correlation function (PACF) of actual P_{ET} data time series data that are used to identify order (p, d, q) of ARIMA model. The solid lines represent the 95% confidence intervals.

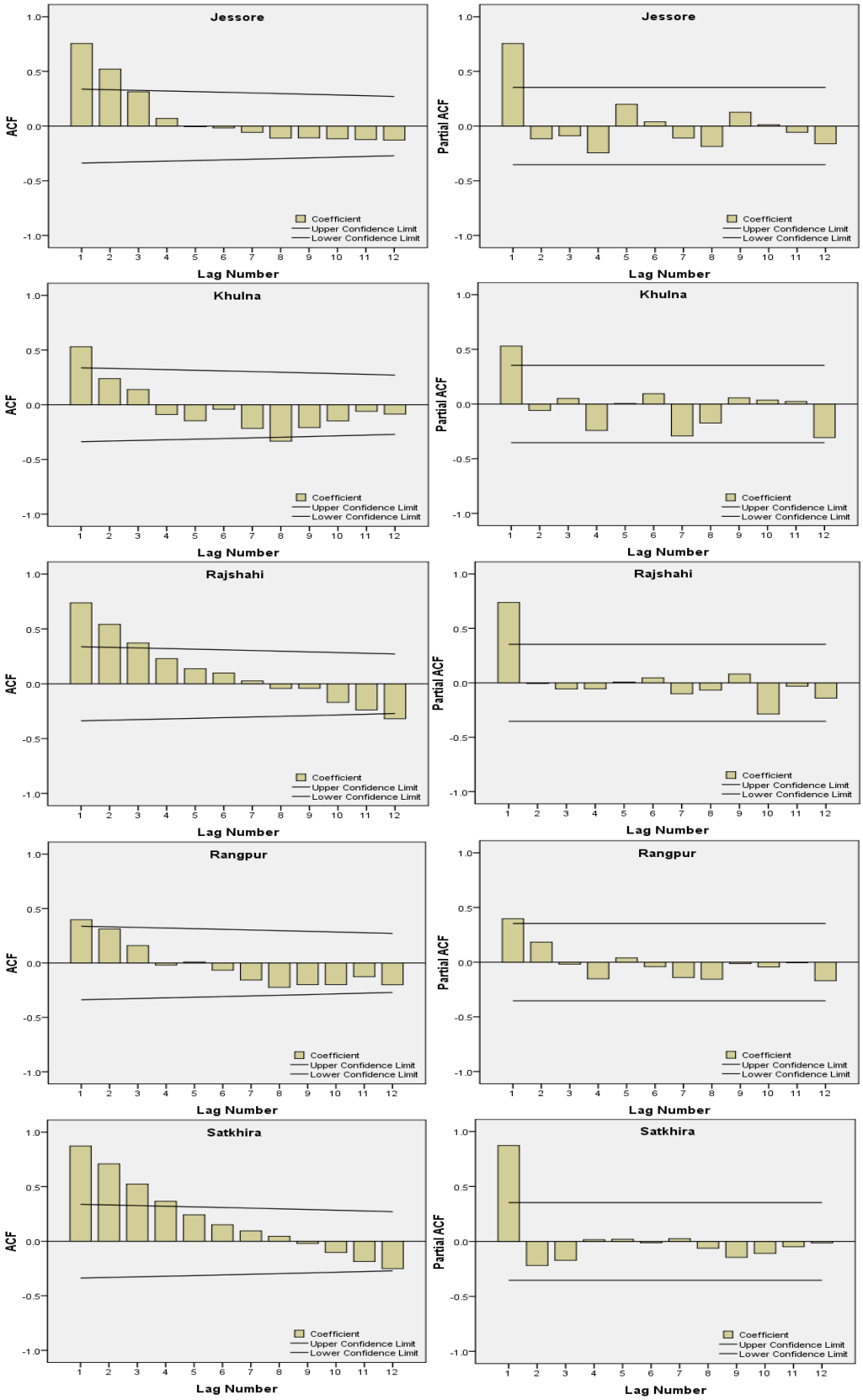

Figure S2. (a) (Continued)

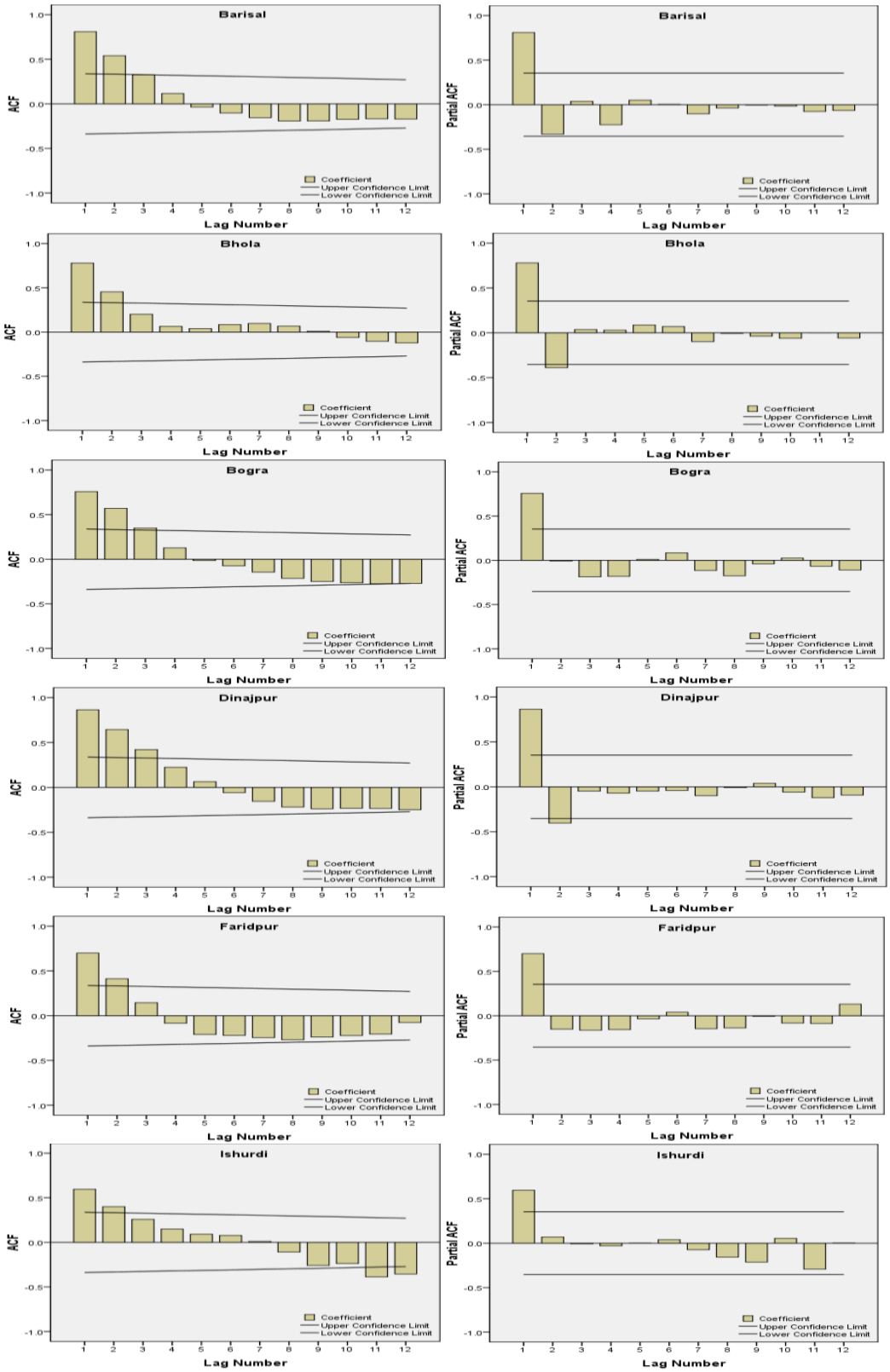

Figure S2. (b) Plot of auto-correlation function (ACF) and partial auto-correlation function (PACF) of DWT denoised P_{ET} time series data that are used to identify order (p, d, q) of ARIMA model. The solid lines represent the 95% confidence intervals. It is notable that lag-1 auto-correlation is higher than actual (See Fig. S2.a) data that also satisfy the condition of denoising.

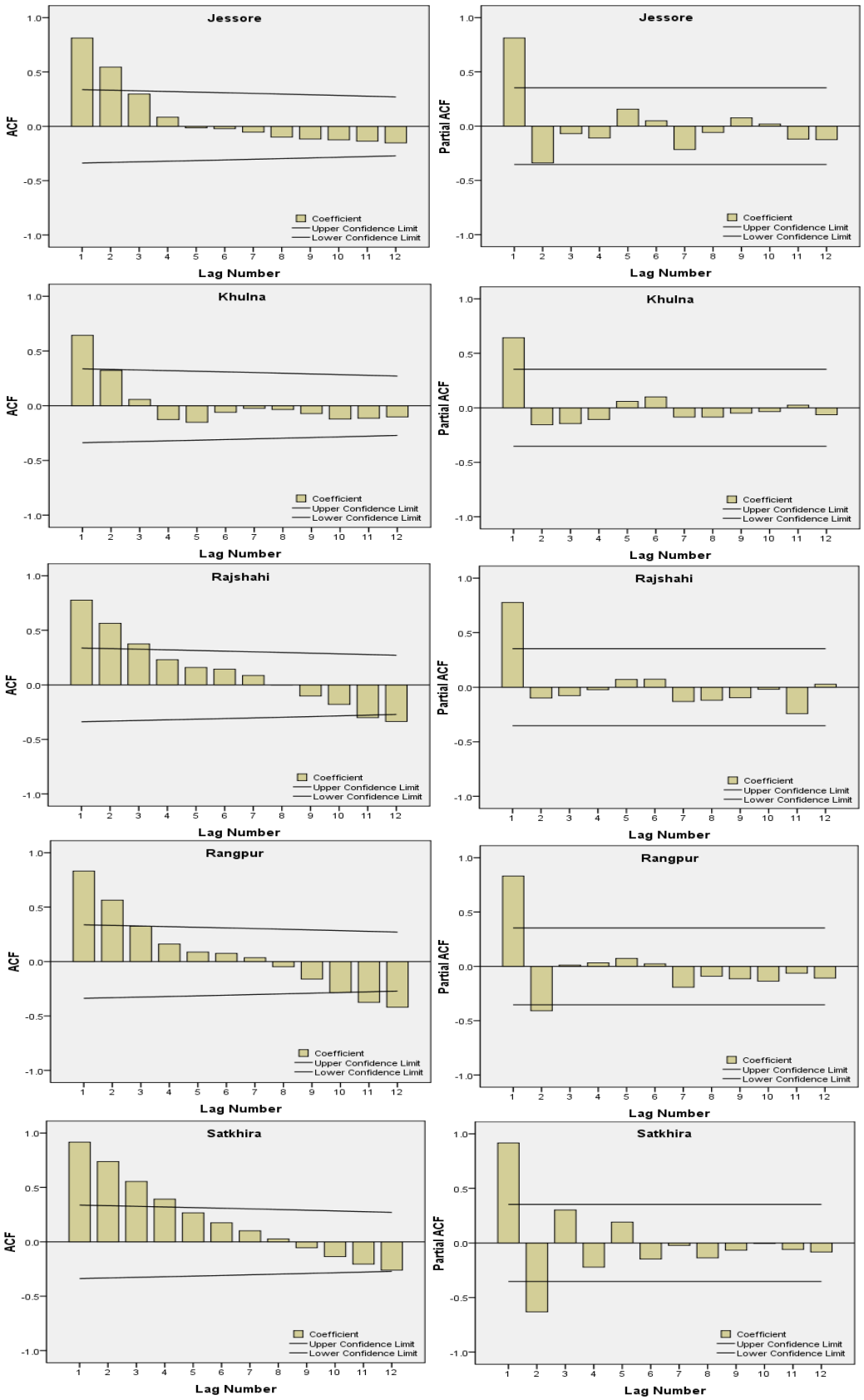

Figure S2. (b) (Continued)

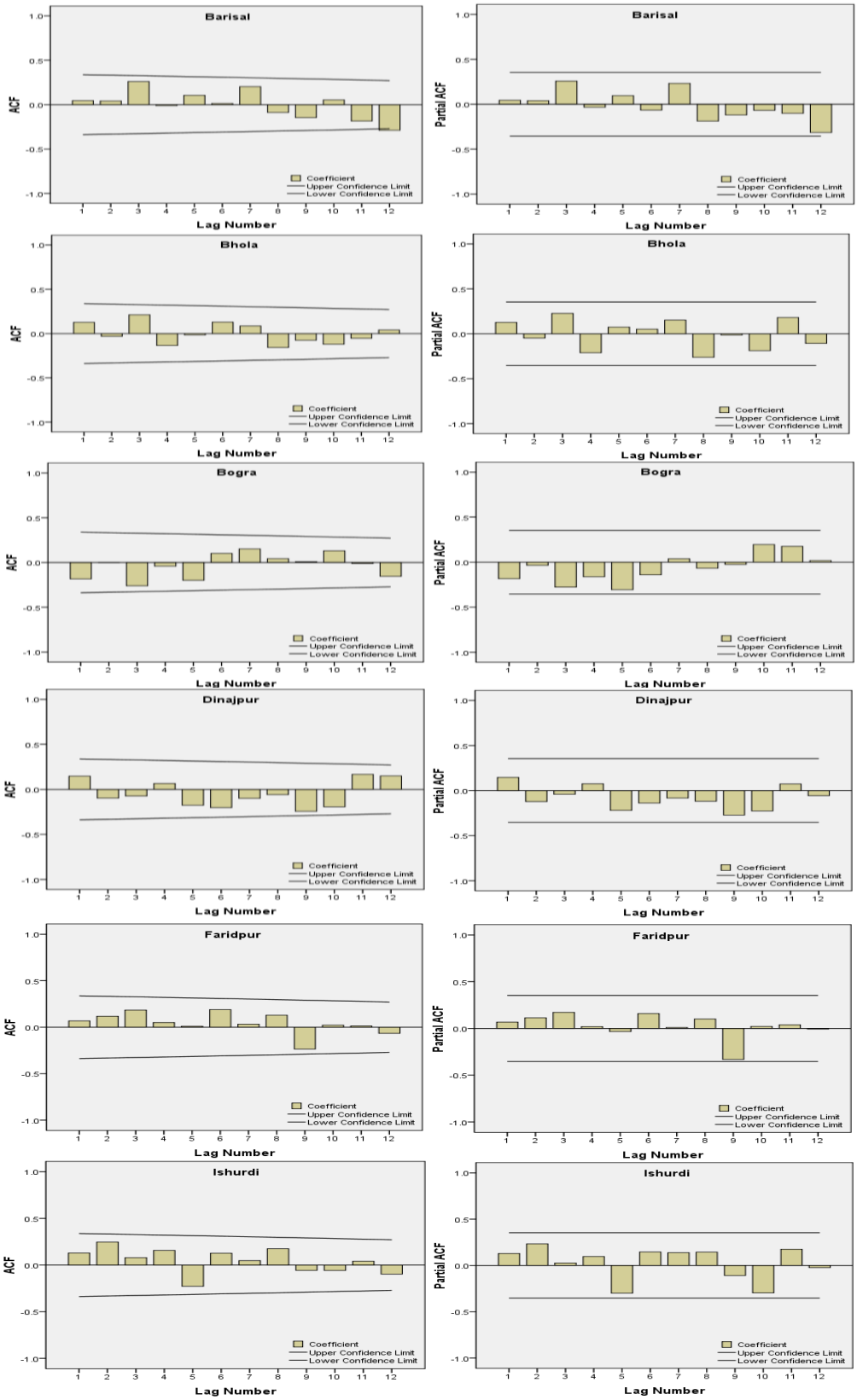

Figure S3. (a) Plot of auto-correlation function (ACF) and partial auto-correlation function (PACF) of actual A_{ET} data. It is observed that there is no spike that cross the solid lines (represent the 95% confidence intervals). Therefore, classical ARIMA model is not suitable for modeling the A_{ET}.

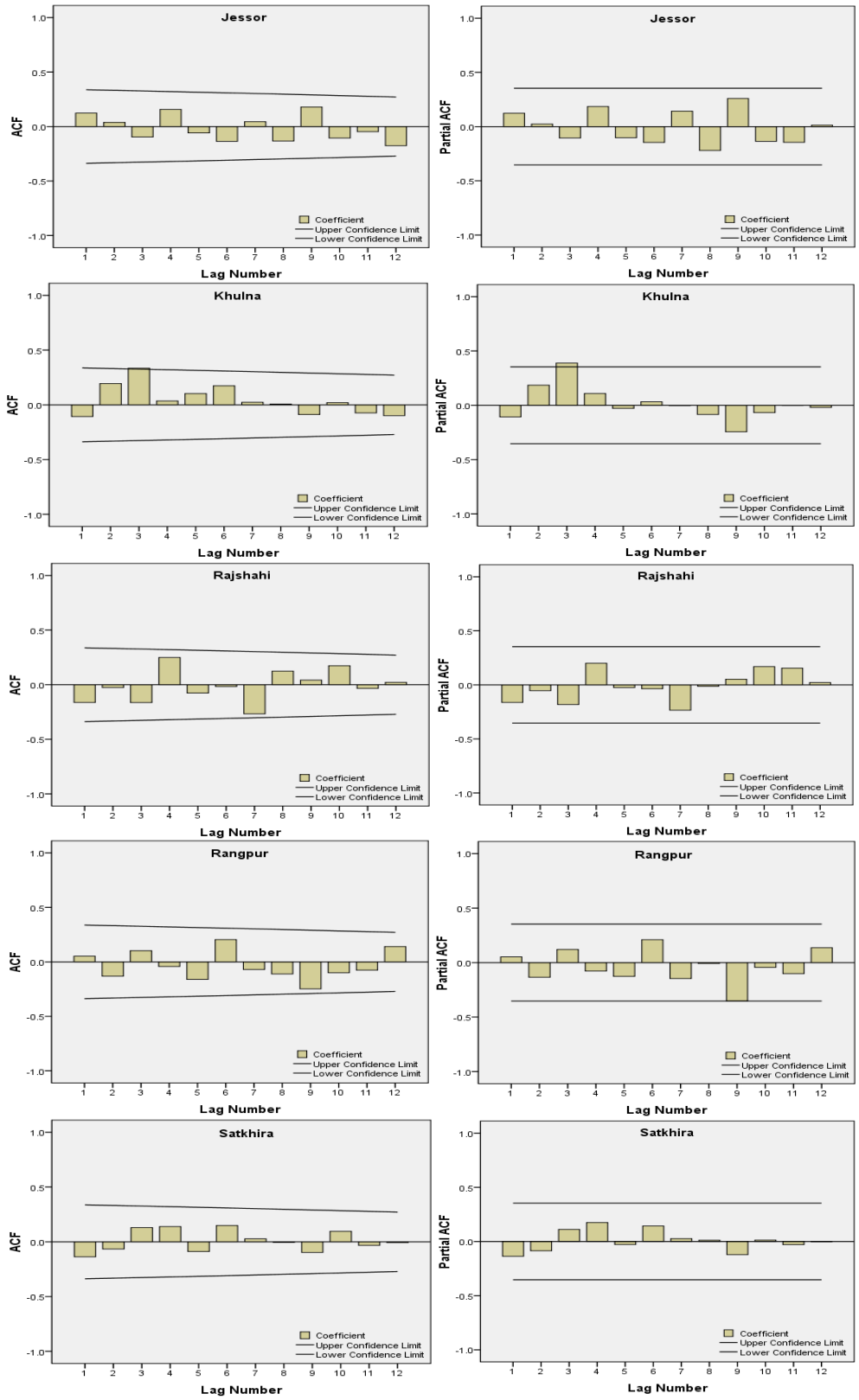

Figure S3. (a) (Continued) it is observed that there is no spike that cross the solid lines (represent the 95% confidence intervals) except Khulna station. Therefore, classical ARIMA model is not suitable for modeling the A_{ET}.

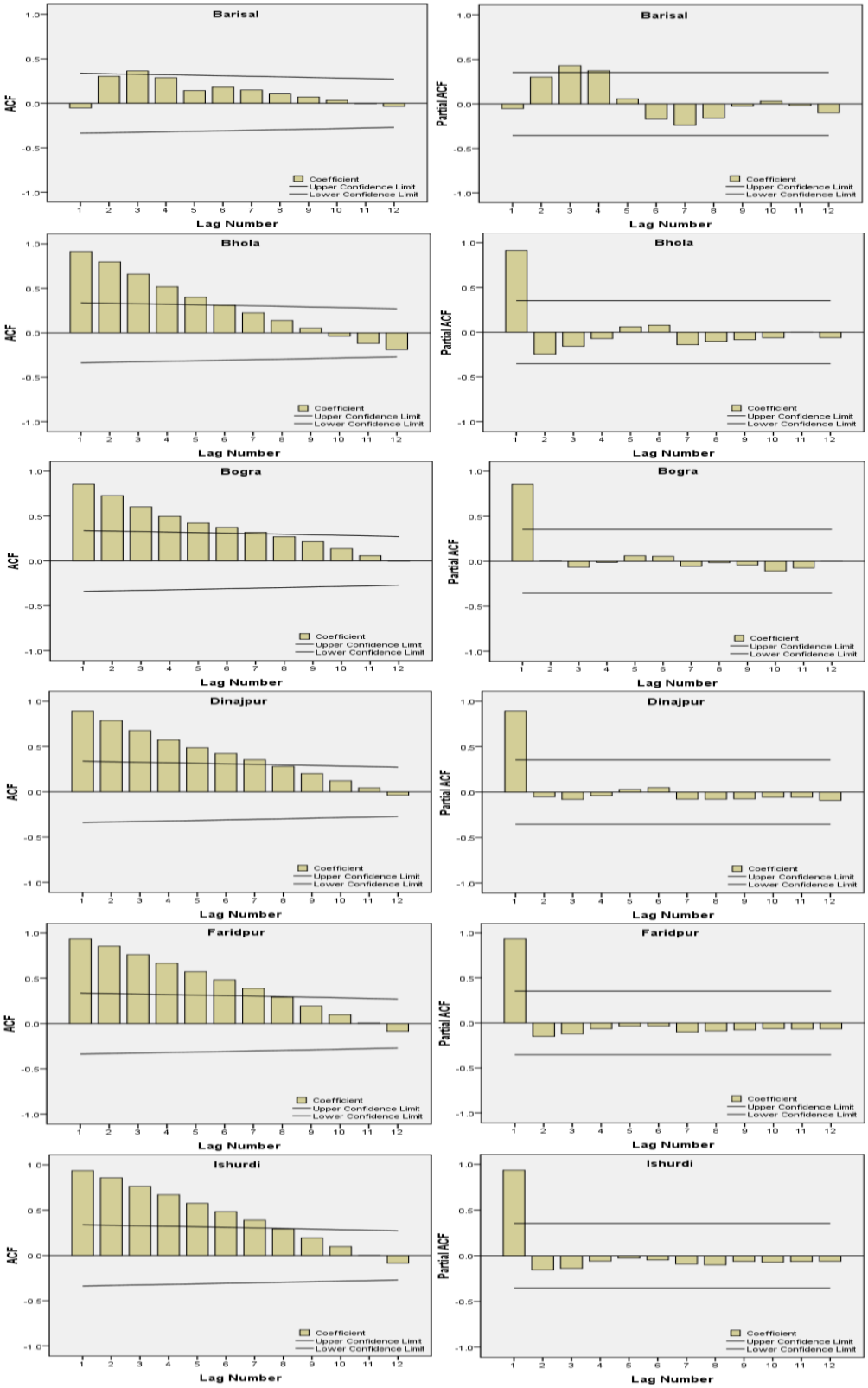

Figure S3. (**b)** Plot of auto-correlation function (ACF) and partial auto-correlation function (PACF) of DWT denoised A_{ET} time series data. It is observed that there are spike at different lags that cross the solid lines (represent the 95% confidence intervals). Therefore, ARIMA model is suitable for modeling the denoised A_{ET} time series data. It is also seen that lag-1 auto-correlation is higher than the figures in Fig. S3 (a) that also satisfy the condition of denoising.

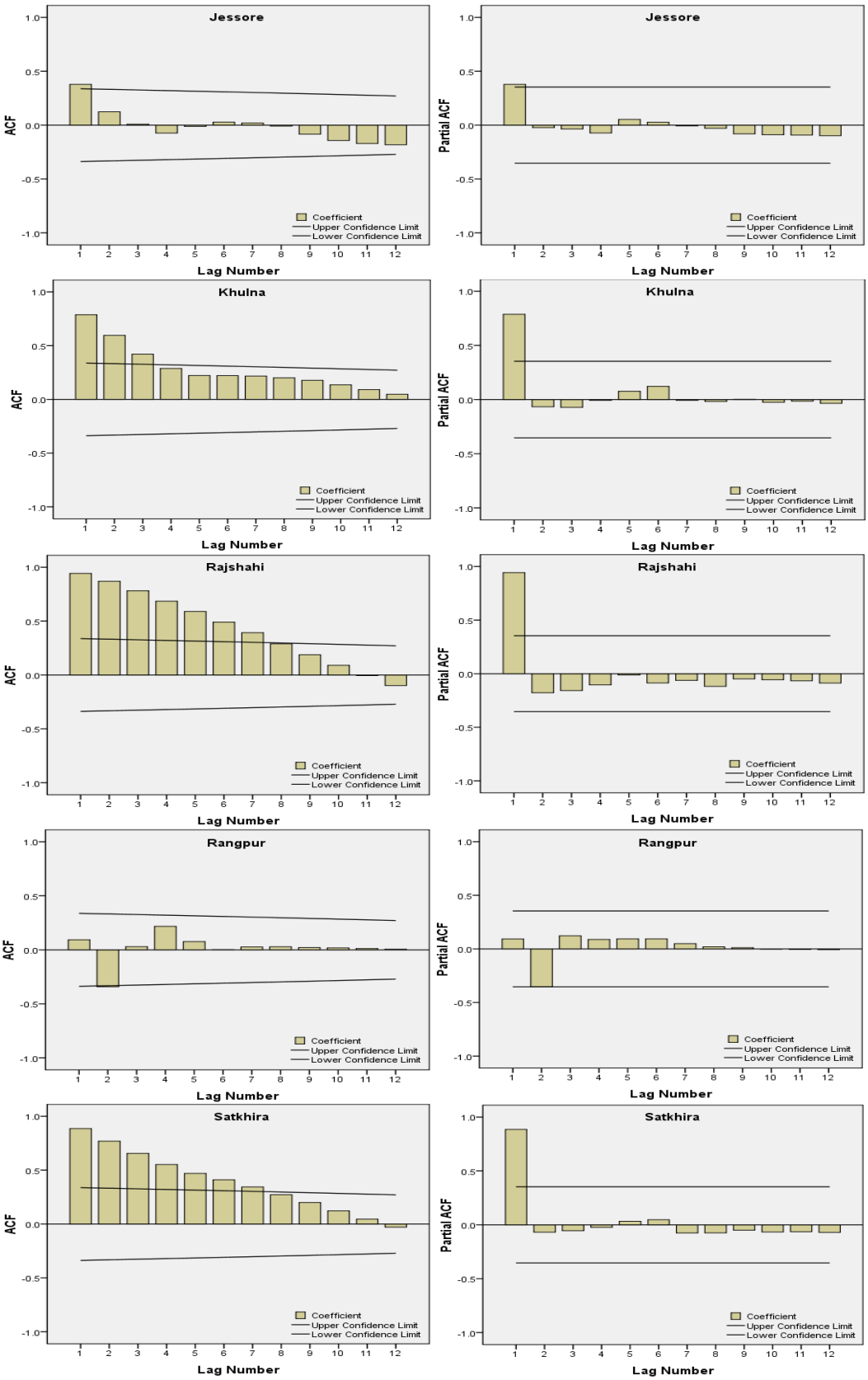

Figure S3. (b) Continued

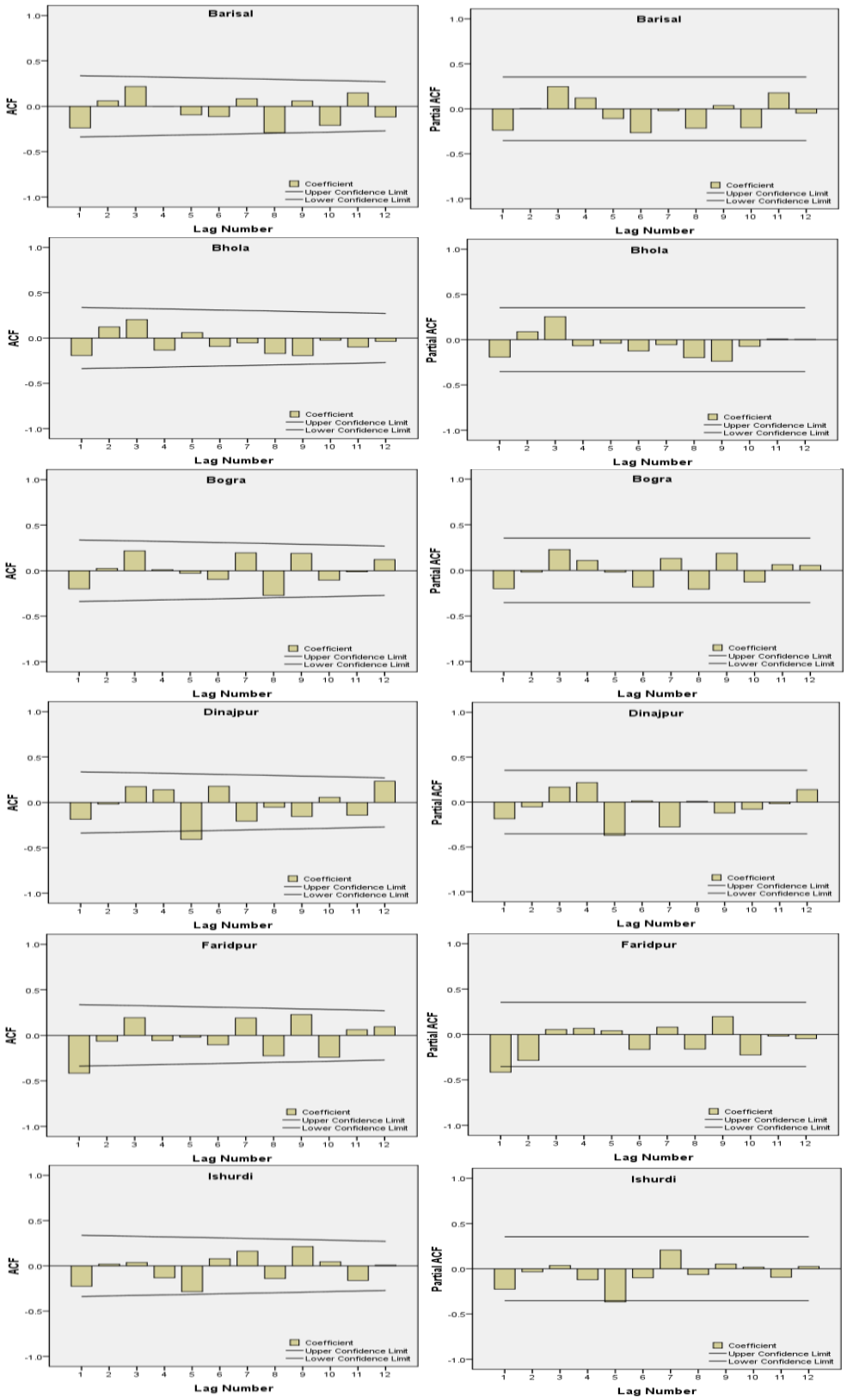

Figure S4. (a) Plot of auto-correlation function (ACF) and partial auto-correlation function (PACF) of actual annual surplus data. It is observed that there is no spike that cross the solid lines (represent the 95% confidence intervals) except a few cases. Therefore, classical ARIMA model is not suitable for modeling the annual surplus.

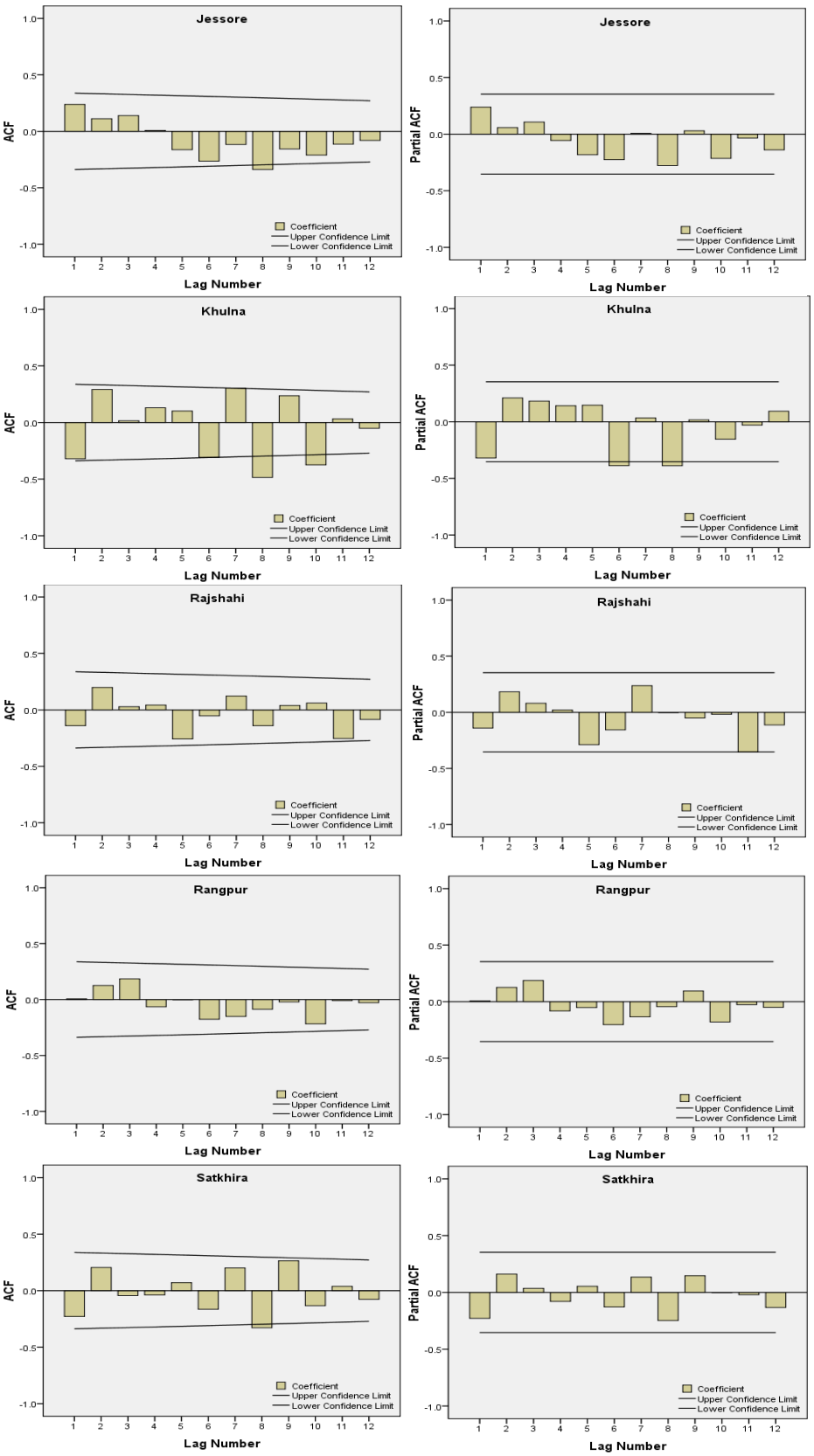

Figure S4. (a) (Continued)

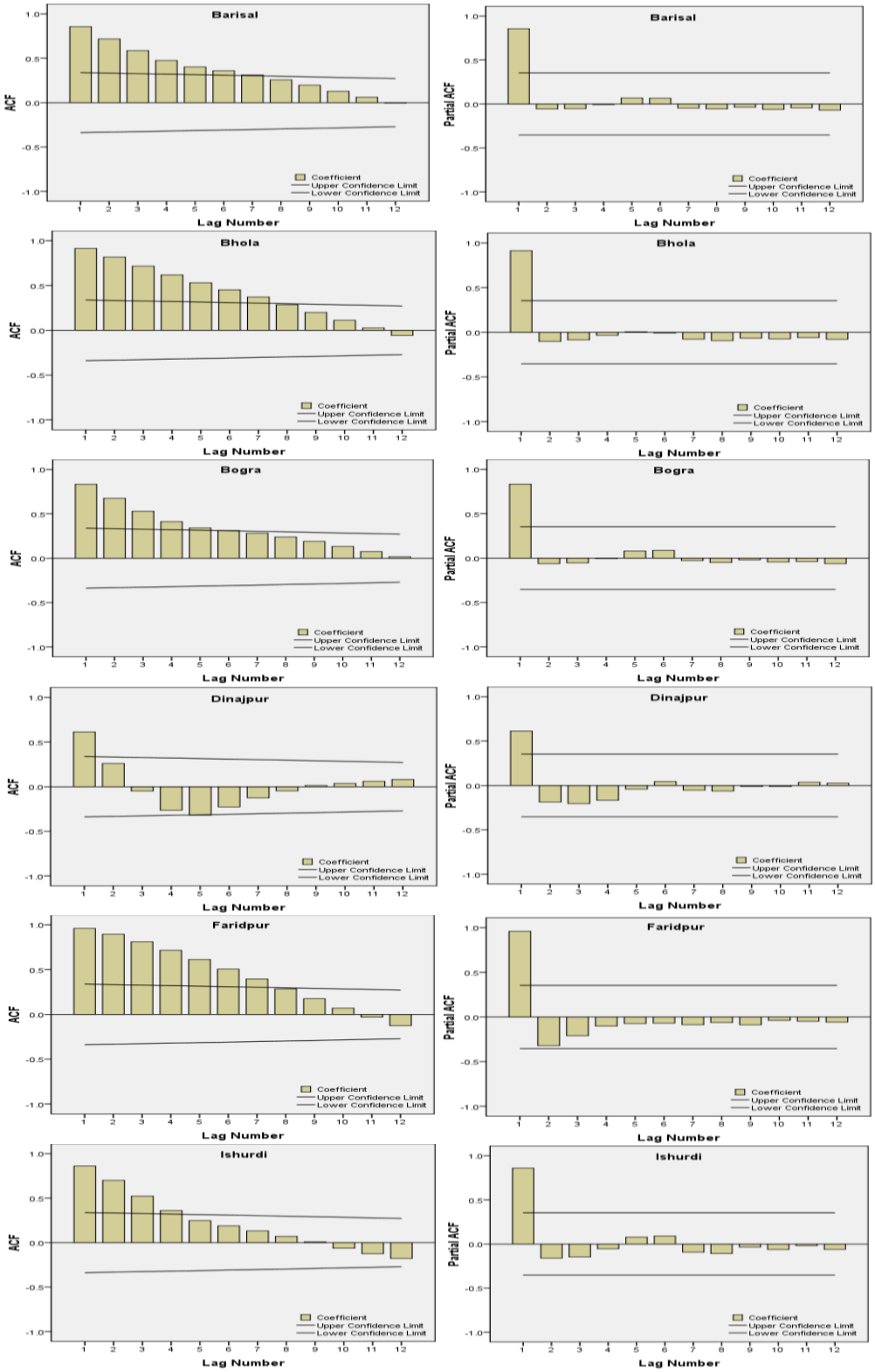

Figure S4. (**b)** Plot of auto-correlation function (ACF) and partial auto-correlation function (PACF) of DWT denoised annual surplus time series data. It is observed that there are spike at different lags that cross the solid lines (represent the 95% confidence intervals). Therefore, ARIMA model is suitable for modeling the denoised annual surplus time series data. It is also seen that lag-1 auto-correlation is higher than the figure in S3 (a) that also satisfy the condition of denoising.

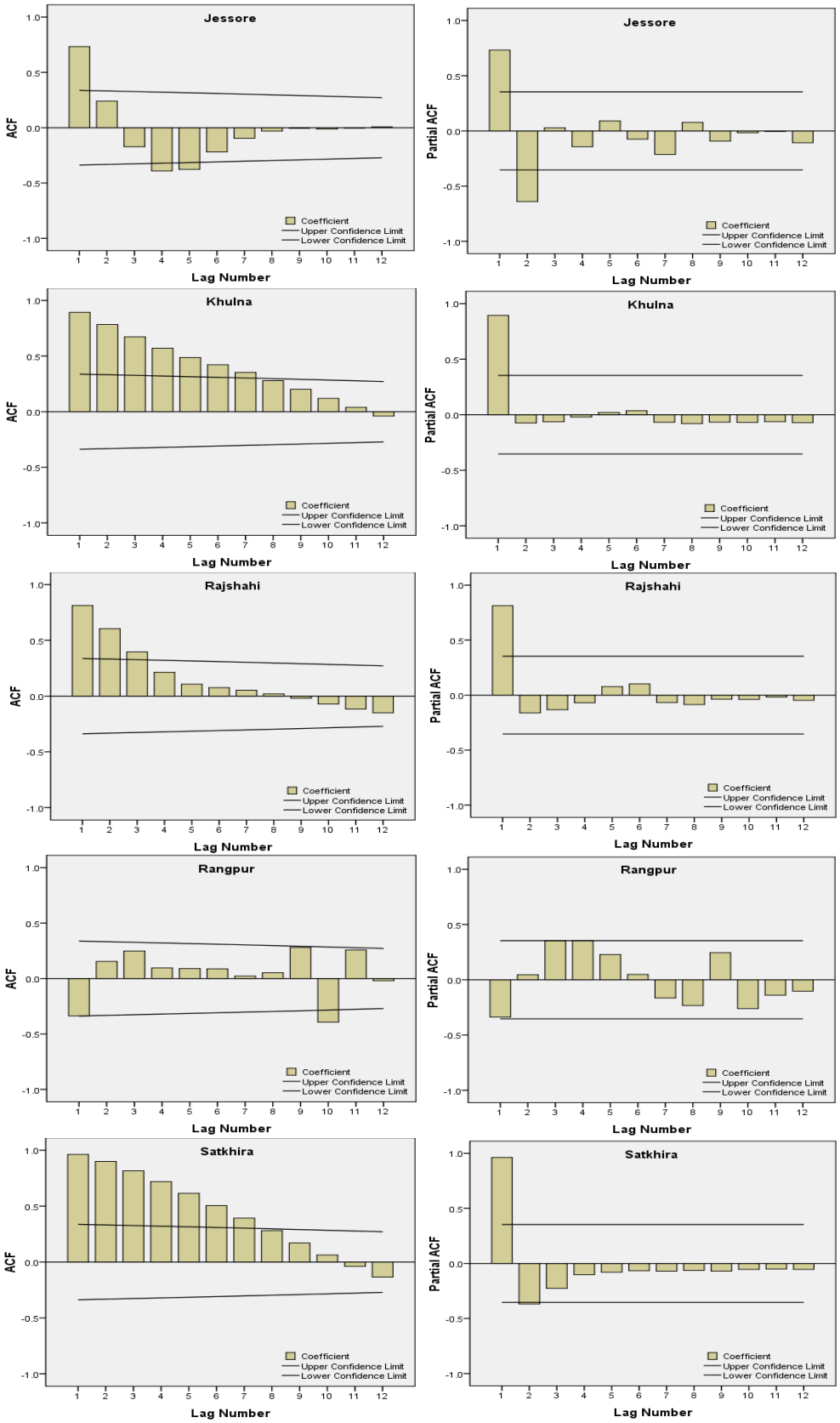

Figure S4. (**b**) (Continued)

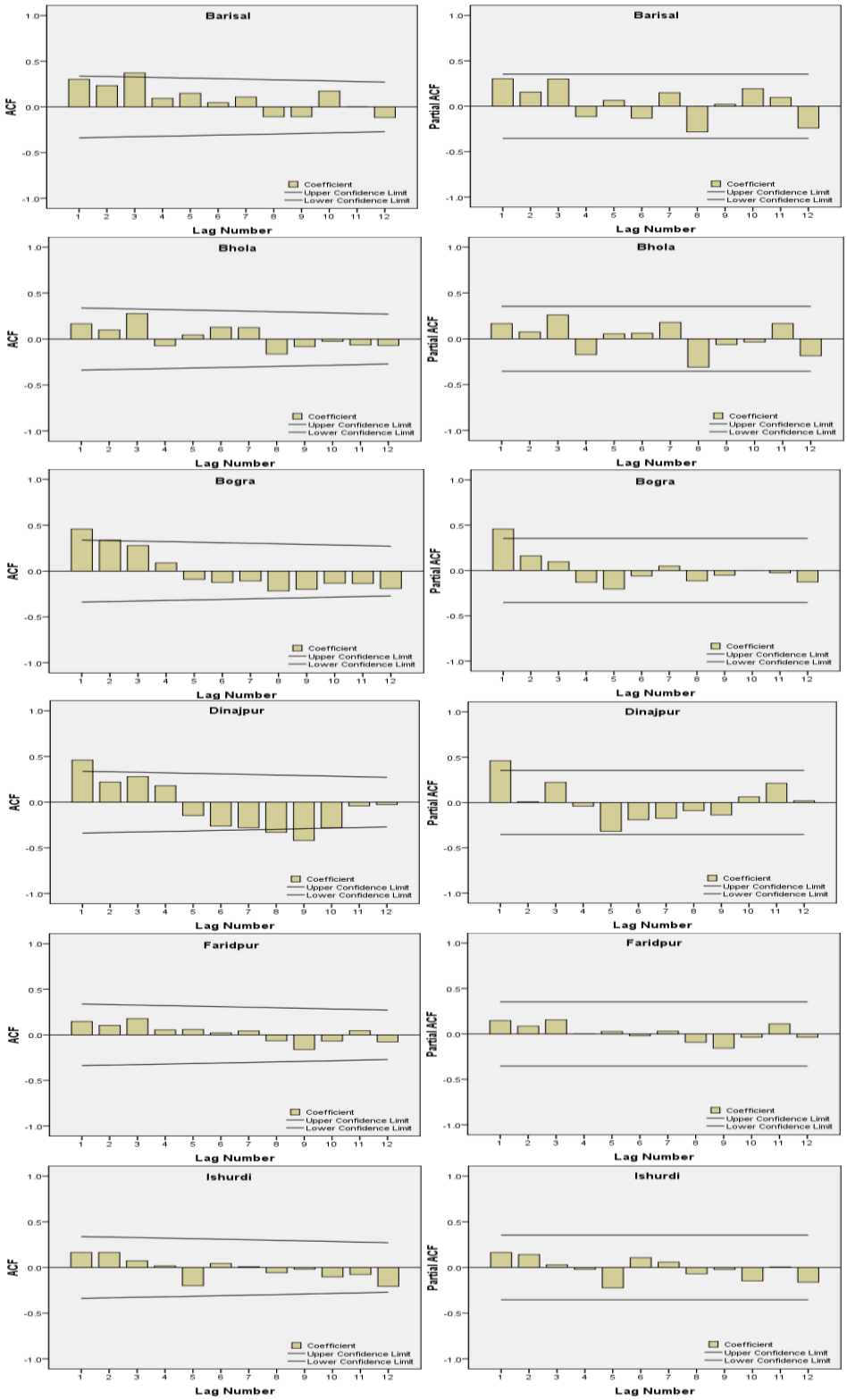

Figure S5. (a) Plot of auto-correlation function (ACF) and partial auto-correlation function (PACF) of actual deficit time series data. It is observed that there is no spike that cross the solid lines (represent the 95% confidence intervals) except some cases. Therefore, classical ARIMA model is not suitable for modeling the annual deficit.

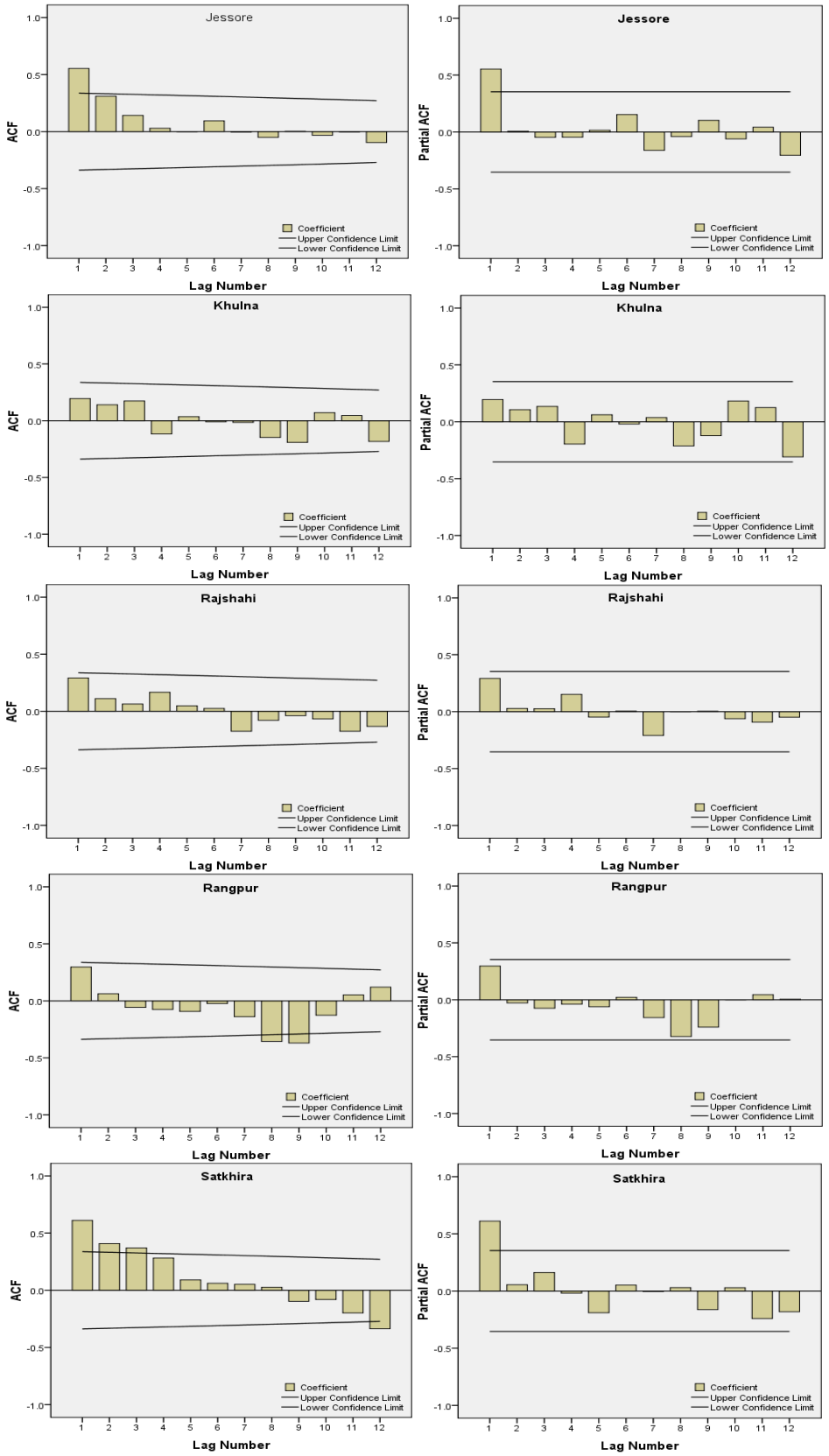

Figure S5. (a) (Continued)

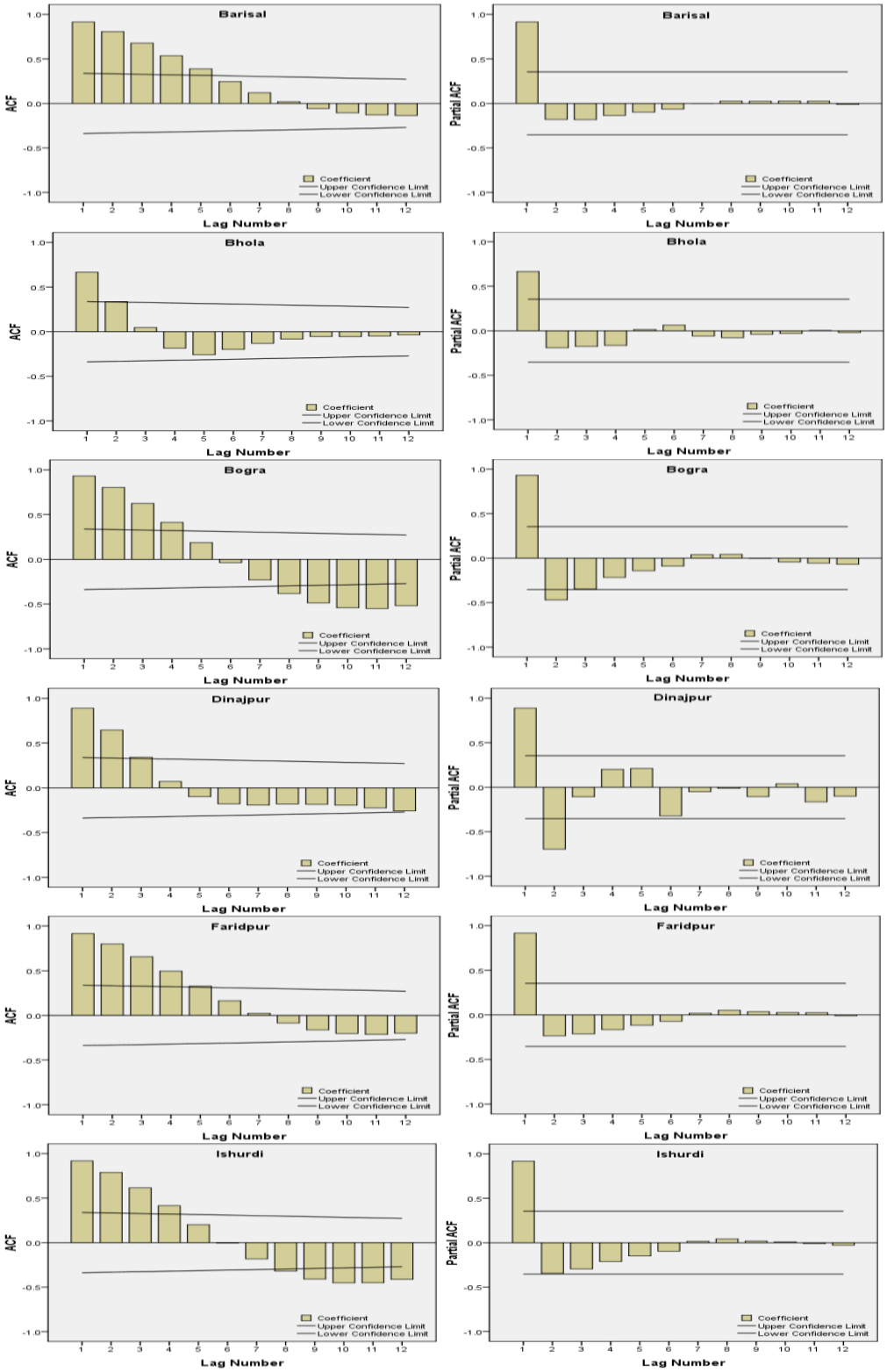

Figure S5. (**b)** Plot of auto-correlation function (ACF) and partial auto-correlation function (PACF) of DWT denoised annual deficit time series data. It is observed that there are spike at different lags that cross the solid lines (represent the 95% confidence intervals). Therefore, ARIMA model is suitable for modeling the denoised annual deficit time series data. It is also seen that lag-1 auto-correlation is higher than the figure in S3 (a) that also satisfy the condition of denoising.

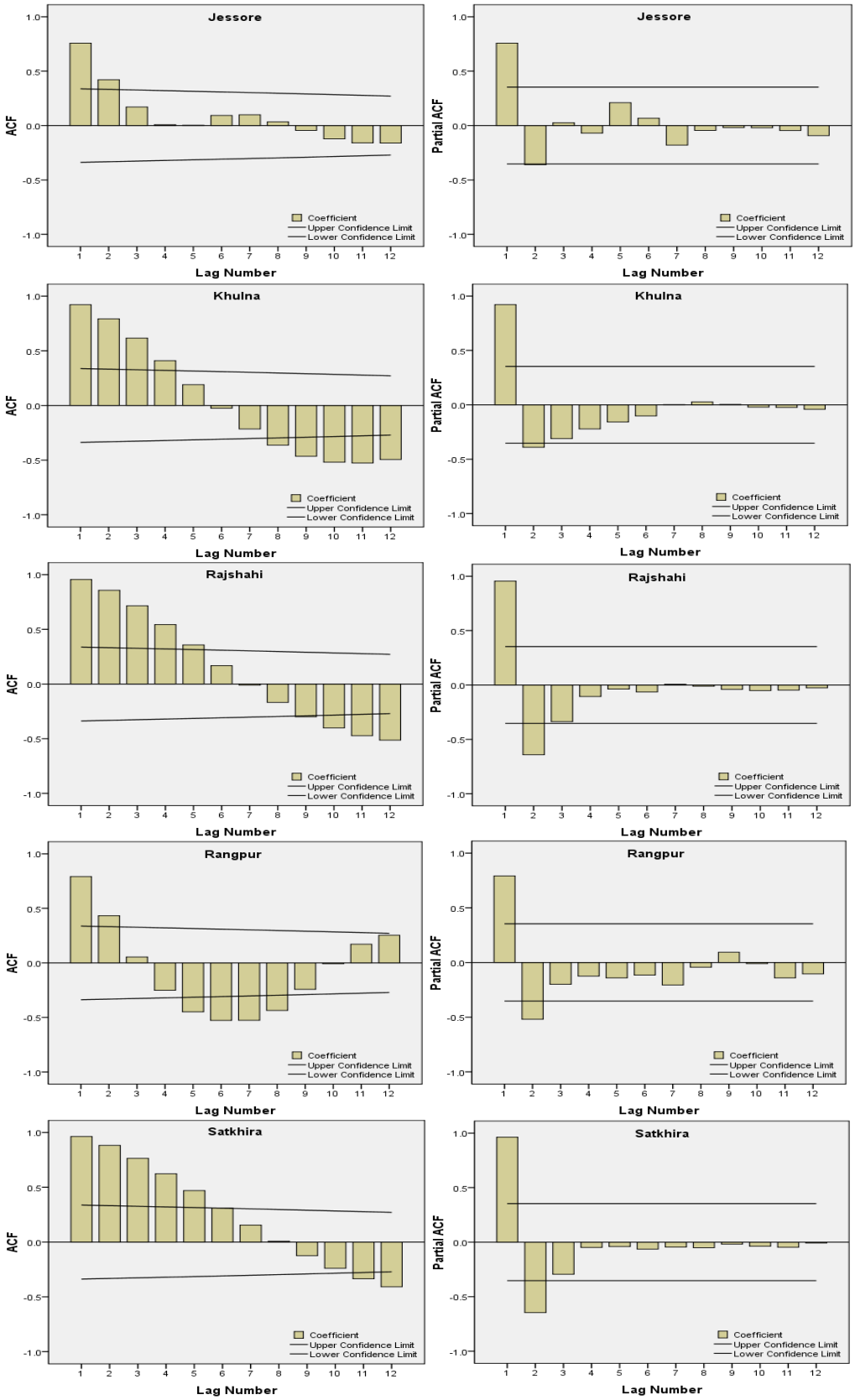

Figure S5. (**b**) (Continued)

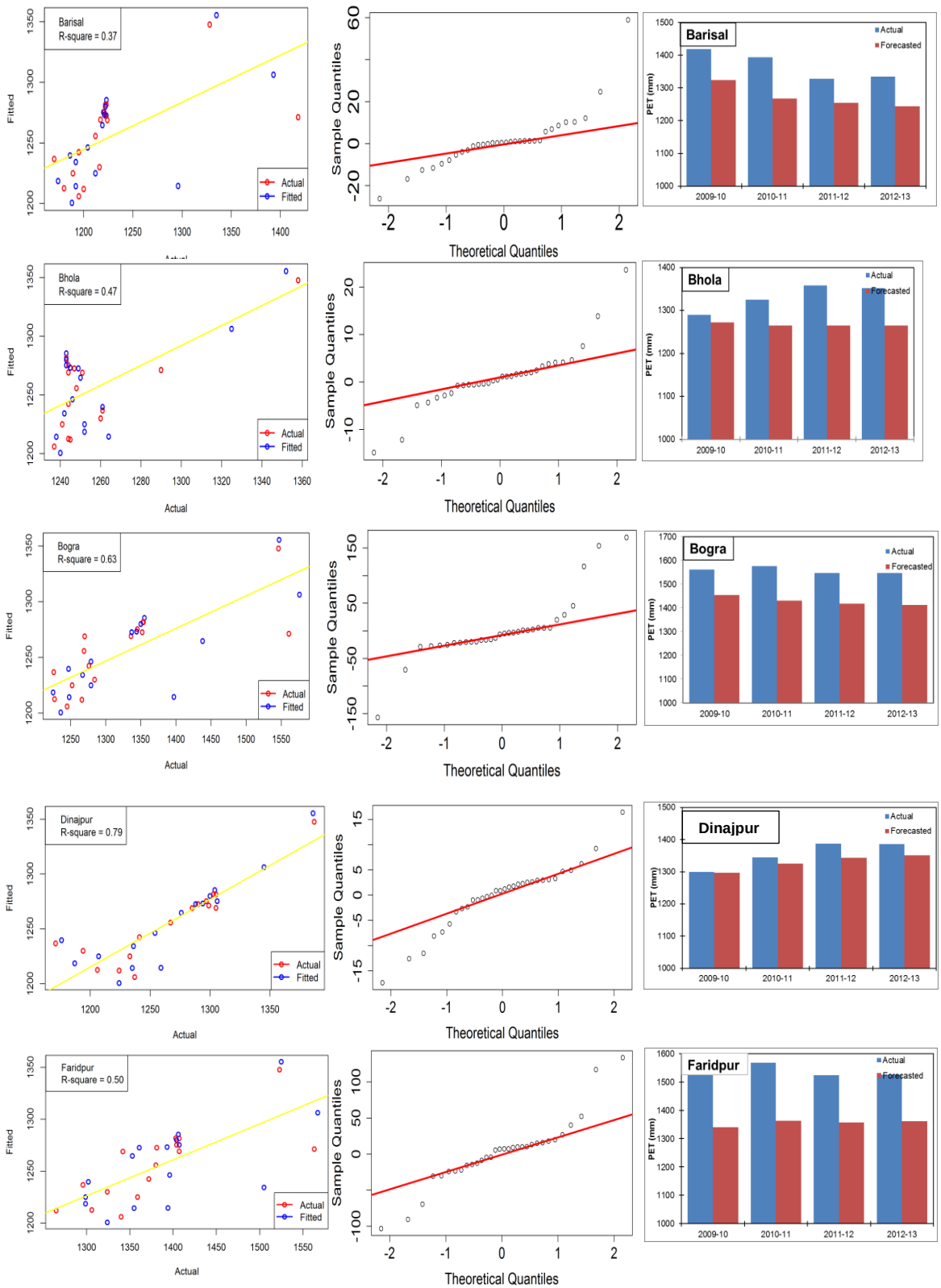

Figure S6. Plot of best wavelet ARIMA model of PET first panel represents actual versus fitted values for the period of 1981-82 to 2012-2013, second panel is normal Q-Q plot of residuals of the model, and third panel shows actual, fitted and forecasted values for the period of 2009-2010 to 2012-13

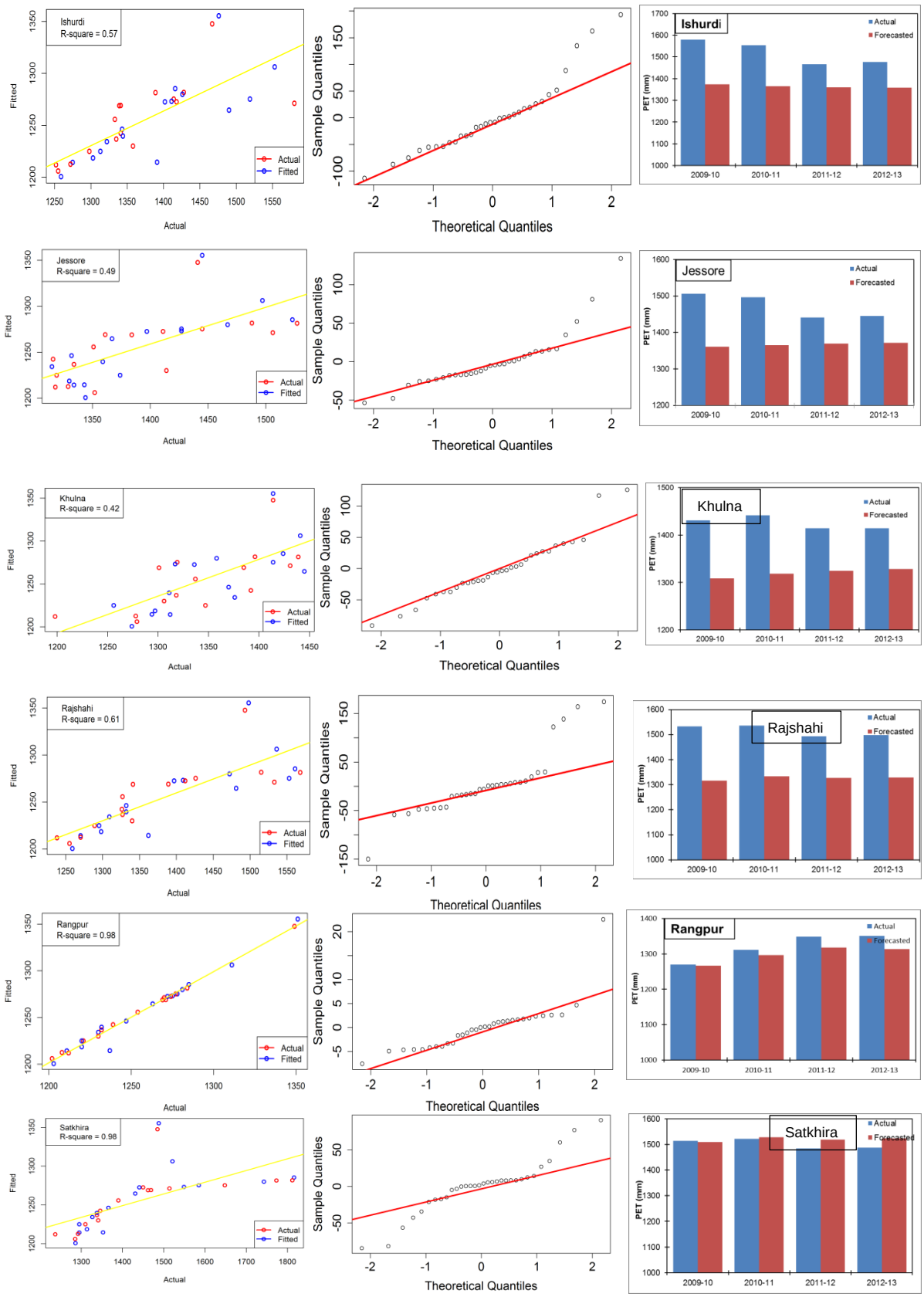

Figure S6. (Continued)

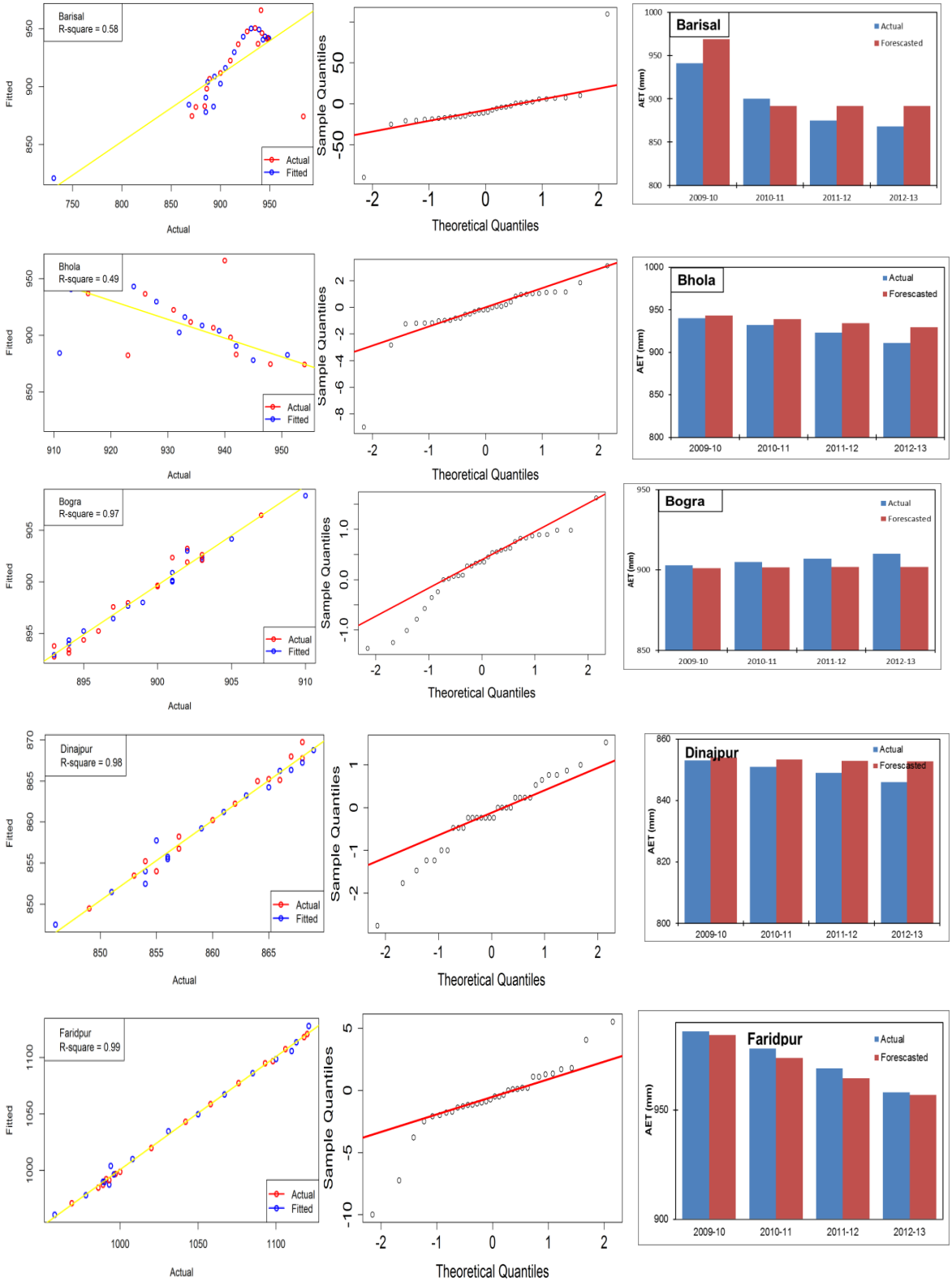

Figure S7. Plot of best wavelet ARIMA model of AET first panel represents actual versus fitted values for the period of 1981-82 to 2012-2013, second panel is normal Q-Q plot of residual of the model, and third panel shows actual, fitted and forecasted values for the period of 2009-2010 to 2012-13.

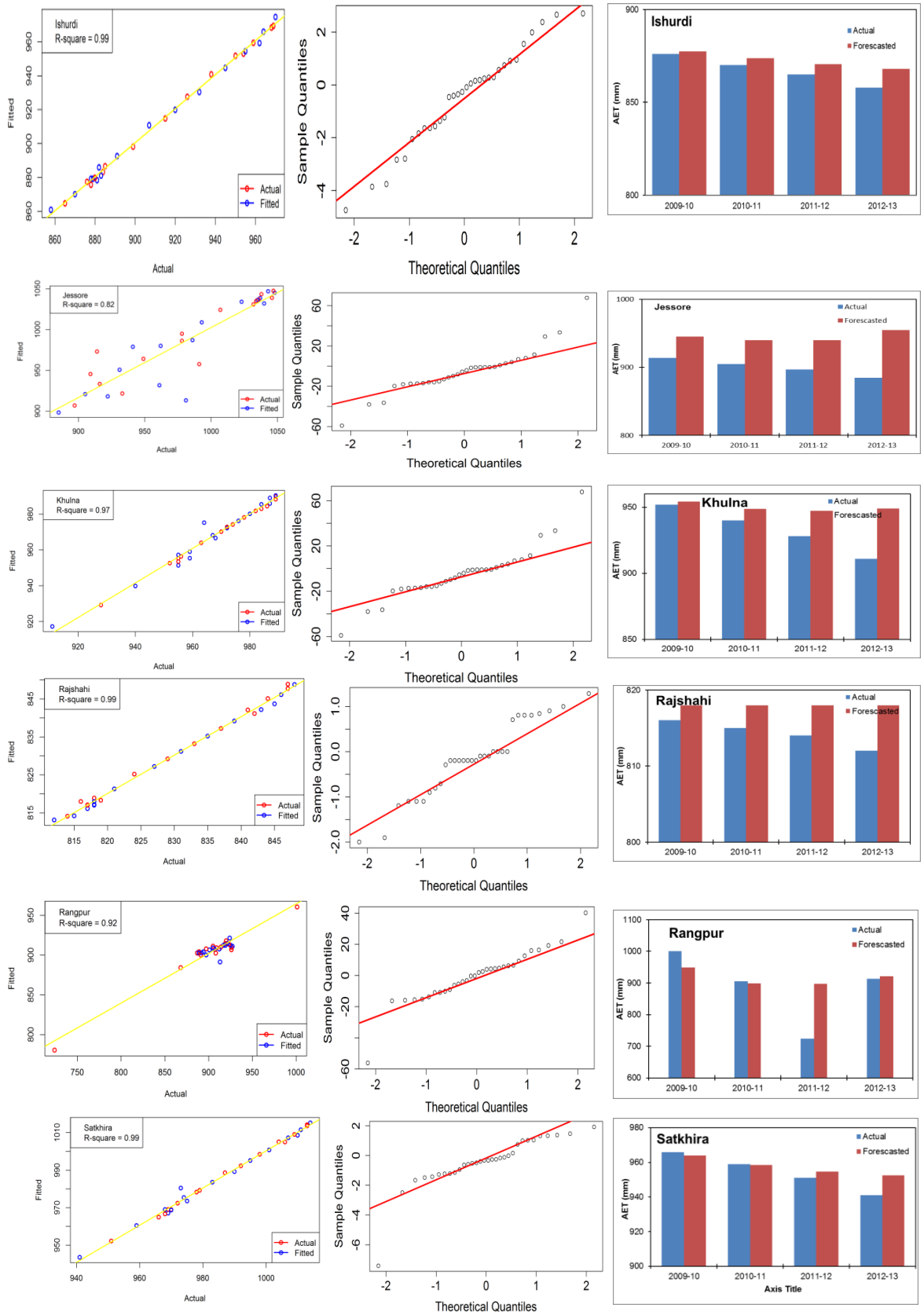

Figure S7. (Continued)

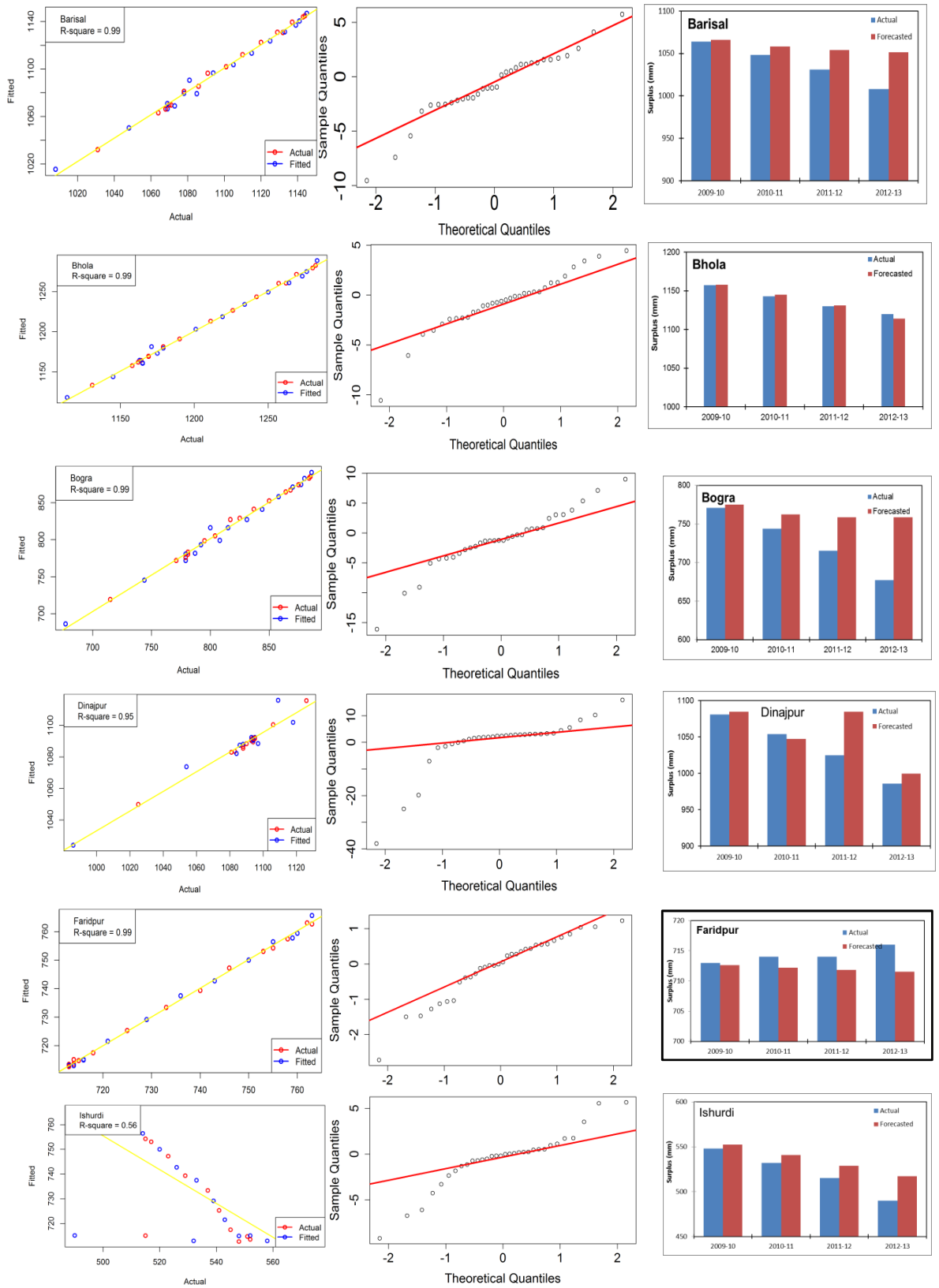

Figure S8. Plot of best wavelet ARIMA model of annual surplus first panel represents actual versus fitted values for the period of 1981-82 to 2012-2013, second panel is normal Q-Q plot of residual of the model, and third panel shows actual, fitted and forecasted values for the period of 2009-2010 to 2012-13.

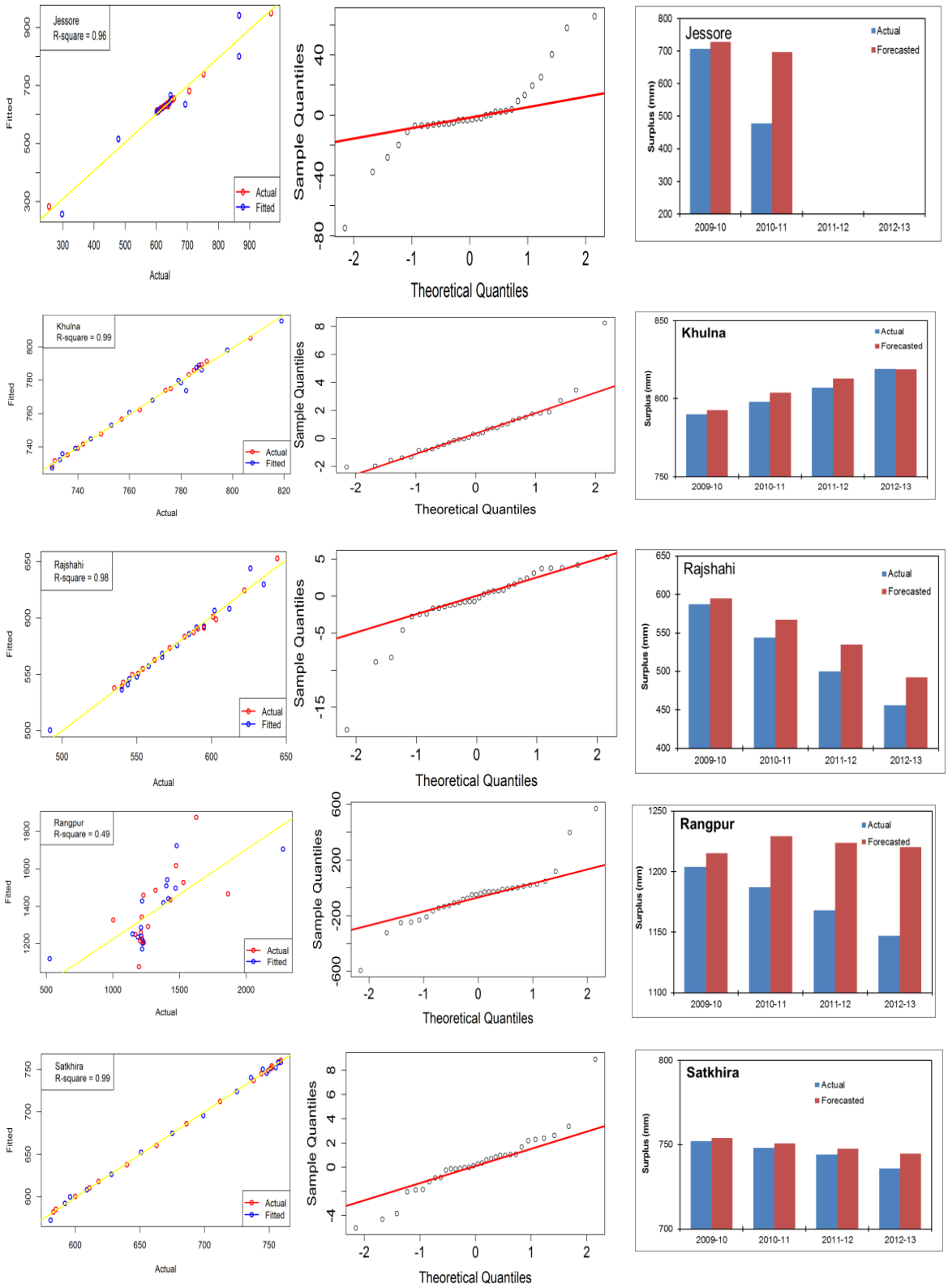

Figure S8. (Continued)

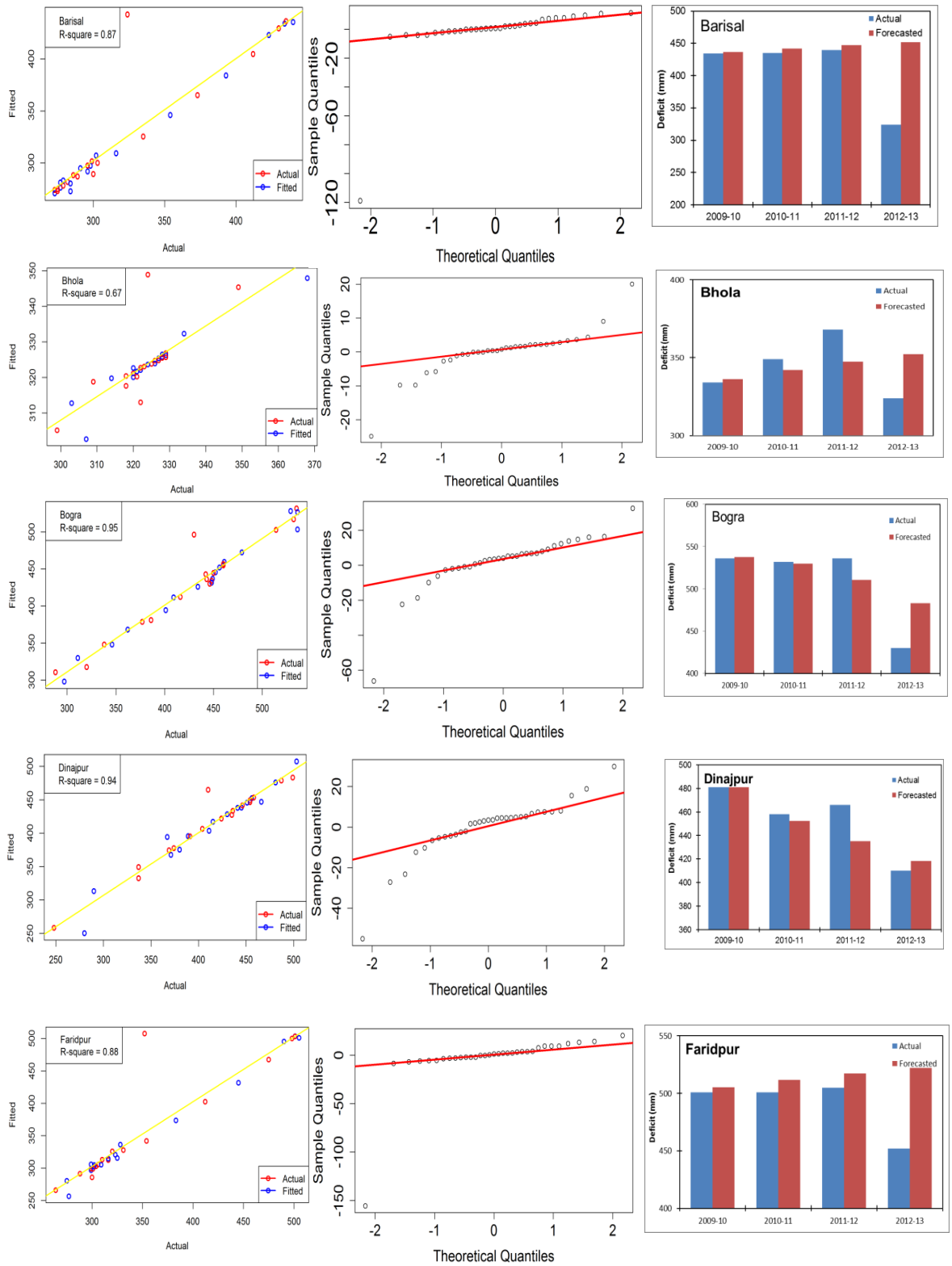

Figure S9. Plot of best wavelet ARIMA model of annual deficit first panel represents actual versus fitted values for the period of 1981-82 to 2012-2013, second panel is normal Q-Q plot of residual of the model, and third panel shows actual, fitted and forecasted values for the period of 2009-2010 to 2012-13.

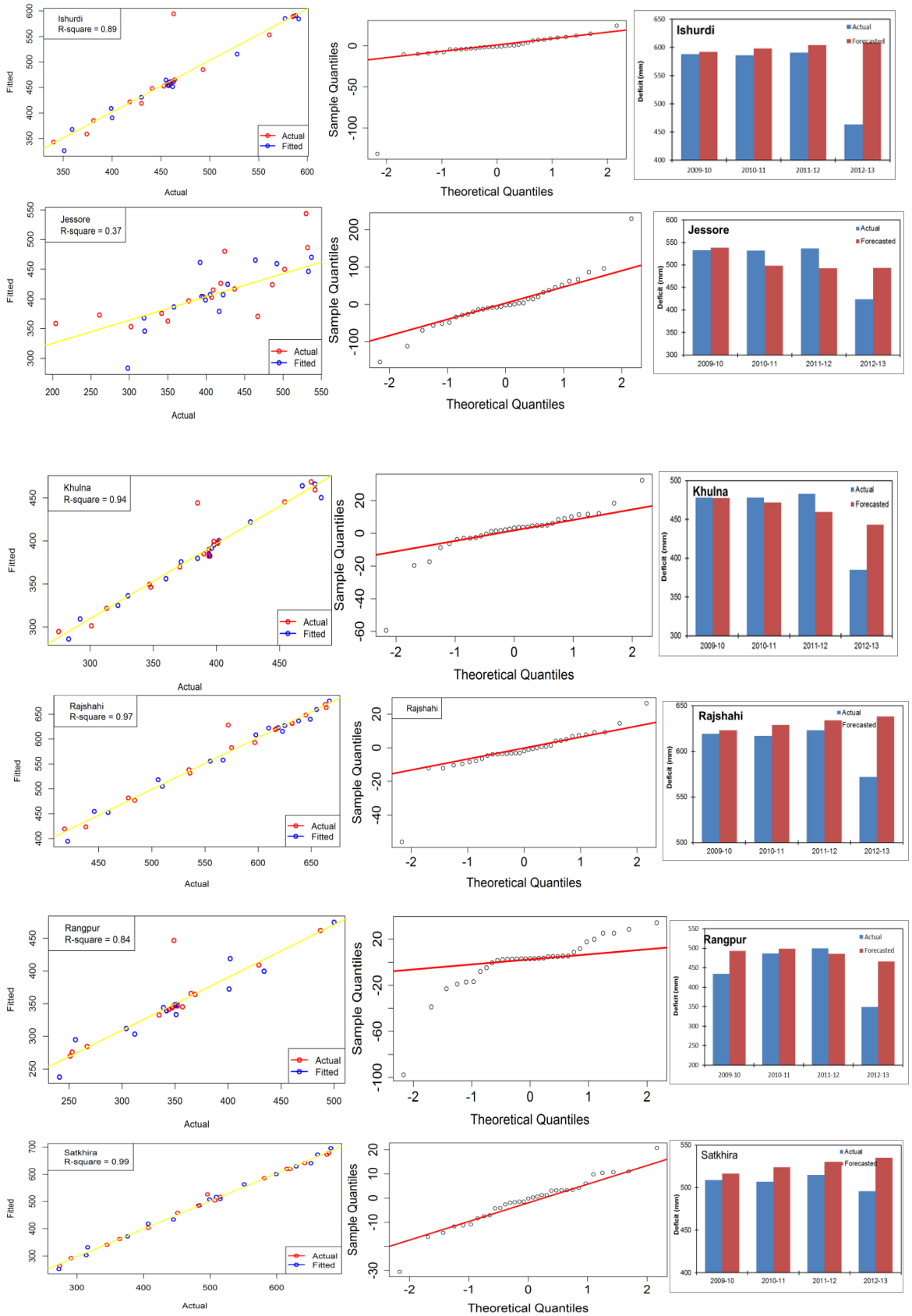

Figure S9. (Continued)

Table S1: ***Z*** statistic of MK or MMK of original time series, approximation and different models of P_{ET} of DWT (the dominant components are bold and asterisk for significant at 5% level)

Stations	Barisal			Bhola			Bogra			Dinajpur		
	Z	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE
Original	0.72			2.37*			-0.2			-0.98		
A	-1.80	0.24	11.56	-1.8	-0.15	17.15	-1.8	0.83	4.66	-1.8	0.83	3.47
D1	0.91	0.5	0.5	2.02*	0.25	0.68	1.16	-0.42	5.1	-	-0.31	7.7
D2	-0.03	0.17	1.51	0.61	0.21	0.94	0.16	0.60	3.7	0.43	0.63	8.82
D3	0.45	0.17	1.51	0.46	0.21	0.94	1.08	0.60	3.7	0.90	0.63	8.82
D4	**0.76**	0.37	3.93	1.2	0.8	7.28	1.14	0.13	3.76	2.10*	-0.03	13.35
D1+A	-0.89	0.35	0.71	1.58	0.11	0.72	-2.35*	0.90	0.54	-1.7	0.95	0.44
D2+A	-1.51	0.14	2.75	0.48	0.13	1.05	-1.54	0.89	0.62	-2.05*	0.93	1.25
D3+A	-0.66	0.50	1.90	0.31	0.14	1.23	-1.91	0.89	5.72	-1.56	0.95	3.03
D4+A	0.06	0.53	9.99	0.9	0.77	8.71	-0.34	0.58	7.32	-1.79	0.85	2.41
D1+D2+A	-0.89	0.35	0.82	0.73	0.39	0.68	-1.12	0.88	0.77	-1.76	0.97	0.18
D1+D3+A	-0.81	0.58	0.88	0.79	0.31	0.69	-1.33	0.87	0.89	-1.51	0.98	0.38
D1+D4+A	0.91	0.63	1.16	**2.29***	0.83	0.35	0.24	0.87	0.53	**-1.15**	0.97	0.2
D2+D3+A	-0.46	0.43	1.24	1.01	0.08	2.42	-1.33	0.89	1.1	-1.37	0.96	1.35
D2+D4+A	0.54	0.5	2.84	2.36*	0.77	0.68	0.10	0.88	0.6	-1.27	0.94	0.85
D3+D4+A	0.56	0.85	2.04	1.83	0.90	0.74	**-0.30**	0.87	1.37	-1.54	0.96	2.1
	Faridpur			Ishurdi			Jessore			Khulna		
	Z	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE
Original	-0.51			-0.22			0.2			-1.35		
A	-1.8	0.75	7.11	-1.8	0.92	4.49	-1.8	0.79	4.46	-1.8	0.49	6.59
D1	2.24*	-0.22	3.09	3.25*	0.26	4.19	0.45	-0.14	6.00	0.12	-0.28	3.34
D2	-	0.47	2.3	**-0.16**	0.62	4.44	**0.28**	0.61	4.51	-0.11	0.3	4.49
D3	0.40	0.47	2.3	0.5	0.62	4.44	0.87	0.61	4.51	-0.01	0.3	4.49
D4	1.15	-0.33	4.62	1.24	0.03	6.26	0.71	0.63	3.88	0.44	0.21	11.19
D1+A	-1.57	0.92	0.36	-1.38	0.85	0.75	-2.77	0.56	1.95	-1.90	0.7	0.86
D2+A	-1.28	0.85	0.94	-1.74	0.88	1.11	-1.44	0.72	1.32	-2.35*	0.65	2.36
D3+A	-0.95	0.93	0.87	-1.48	0.88	3.71	-1.32	0.19	2.98	**-1.41**	**0.93**	1.08
D4+A	-0.96	0.51	10.5	-0.71	0.87	5.33	0.01	0.84	4.51	-1.52	0.54	5.44
D1+D2+A	-1.31	0.89	0.33	-1.45	0.88	0.41	-1.14	0.64	1.51	-1.77	0.72	0.76
D1+D3+A	-0.81	0.95	0.19	-1.06	0.79	0.97	-0.80	0.13	3.14	-1.24	0.98	0.11
D1+D4+A	-0.47	0.78	0.65	-0.12	0.95	0.2	0.29	0.92	1.33	-1.86	0.72	0.8
D2+D3+A	-0.94	0.95	0.86	-1.3	0.83	1.91	-0.88	0.48	2.35	-1.16	0.92	0.55
D2+D4+A	-0.91	0.79	1.19	-0.62	0.97	0.82	0.42	0.93	0.55	-1.8	0.72	1.65
D3+D4+A	**-0.49**	0.91	0.95	-0.6	0.93	3.73	-0.32	0.88	3.14	-1.39	0.86	0.65
	Rajshahi			Rangpur			Satkhira					
	Z	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE			
Original	-1.52			-0.79			-2.07					
A	-1.8	0.97	0.52	-1.8	0.68	6.86	-1.8	0.99	0.48			
D1	-	-0.1	12.77	-	0.28	3.74	NA	-0.08	12.88			
D2	1.18	0.27	15.54	-	0.44	4.95	0.32	0.8	12.19			
D3	-0.01	0.27	15.54	0.71	0.44	4.95	-2.25	0.8	12.19			
D4	1.38	-0.2	11.47	2.25*	0.02	8.1	-0.98	0.24	6.7			
D1+A	-1.85	0.96	0.38	-2.22*	0.89	0.47	-1.88	0.99	0.15			
D2+A	-2.01	0.96	0.65	-1.88	0.88	1.03	-1.67	0.99	0.24			
D3+A	-1.86	0.98	0.47	-1.3	0.94	1.82	-1.97	0.98	0.98			
D4+A	-1.18	0.96	0.45	-1.37	0.81	1.8	-1.81	0.98	1.03			
D1+D2+A	-1.98*	0.97	0.51	-1.99*	0.88	0.53	-1.63	0.99	0.4			
D1+D3+A	-1.69	0.97	0.16	-1.67	0.97	0.23	-1.82	0.99	0.14			
D1+D4+A	-1.06	0.97	0.26	-1.28	0.92	0.34	-1.77	0.99	0.19			
D2+D3+A	-1.94	0.96	0.37	-1.11	0.99	0.26	-1.65	0.99	0.27			
D2+D4+A	-1.38	0.97	0.34	-1	0.89	0.74	-2.17*	**1**	0.05			
D3+D4+A	**-1.39**	0.97	1.02	**-0.81**	0.97	0.5	-1.79	0.98	1.2			

Table S2: *Z* statistic of MK or MMK of original time series, approximation and different models of A_{ET} of DWT (the dominant components are bold and asterisk for significant at 5% level)

Stations	Barisal			Bhola			Bogra			Dinajpur		
	Z	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE
Original	-1.35			-0.21			0.31			-0.68		
A	-1.8	0.23	12.94	1.8	0.22	9.59	1.8	-0.03	16.07	-1.8	0.42	14.63
D1	0.57	0.01	1.32	-0.1	0.48	1.74	-0.05	0.55	0.1	0.04	0.28	0.34
D2	-0.34	-0.15	1.38	0.7	0.4	0.83	0.54	0.18	1.59	-0.24	0.49	0.3
D3	1.82	-0.15	1.38	0.16	0.4	0.83	0.8	0.18	1.59	0.53	0.49	0.3
D4	-1.2	0.87	4.34	-1.38	0.82	3.15	1.38	0.47	6.77	-2.26	0.33	2.95
D1+A	**-1.33**	0.56	0.81	0.69	0.2	1.07	0.02	0.48	0.14	0.04	0.3	0.34
D2+A	-1.93	0.57	1.89	3.99	0.03	1.02	0.67	0.18	1.65	**-0.66**	0.55	0.33
D3+A	-1.41	0.71	3.54	2.18	0.08	3.03	1.14	0.38	0.63	0.37	0.66	0.65
D4+A	-1.86	0.86	4.5	-0.81	0.91	1.83	1.65	0.46	6.74	-2.64	0.37	3.55
D1+D2+A	-1.09	0.65	0.98	0.76	0.5	0.78	-0.72	0.58	0.11	-0.24	0.54	0.25
D1+D3+A	-0.21	0.63	0.78	0.66	0.57	0.61	0.19	0.7	0.08	0.28	0.71	0.24
D1+D4+A	-1.86	0.92	0.38	-0.37	0.9	0.18	**0.24**	0.6	0.09	-0.86	0.54	0.41
D2+D3+A	-0.87	0.71	1.62	1.46	0.44	1.13	1.32	0.42	1.28	-0.06	0.65	0.52
D2+D4+A	-2.5	0.92	0.52	**-0.35**	0.89	0.62	1.86	0.41	1.4	-0.97	0.39	1.06
D3+D4+A	-1.64	0.92	1.33	-0.74	0.9	2.13	1.55	0.64	0.57	-1	0.78	0.83
	Faridpur			Ishurdi			Jessore			Khulna		
	Z	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE
Original	-1.91			-2.9*			-0.36			-1.82		
A	-1.8	0.73	7.32	-1.8	0.43	5.94	-1.8	0.62	8.07	1.8	0.2	14.81
D1	0.41	0.23	2.62	-0.24	0.39	4.94	0.05	-0.02	2.02	-0.18	0.43	0.47
D2	-0.4	-0.36	1.75	-0.72	0.04	2.55	0.89	0.41	3.31	-2.22*	0.26	1.51
D3	0.93	-0.36	1.75	-0.08	0.04	2.55	0.57	0.41	3.31	-1.1	0.26	1.51
D4	-1.65	0.55	2.04	-2.23*	0.36	2.36	0.49	0.24	7.2	-1.3	0.78	6.23
D1+A	-0.99	0.71	0.47	-3.17*	0.51	1.81	-1.99	0.8	0.51	-0.08	0.44	0.46
D2+A	-1.61	0.81	1.11	-2.17*	0.70	0.52	-1.35	0.76	0.88	-1.3	0.16	1.35
D3+A	**-1.73**	0.76	7.52	-1.54	0.70	1.17	-1.25	0.7	1.85	0.02	-0.34	2.09
D4+A	-7.98*	0.87	7.44	-4.05*	0.60	2.5	**-0.40**	0.55	10.05	-1.12	0.81	6.76
D1+D2+A	-1.05	0.82	0.24	-1.86	0.76	0.57	-1.90	0.76	0.32	-0.7	0.31	0.57
D1+D3+A	-0.6	0.69	0.53	-1.35	0.65	0.72	-1.28	0.78	0.24	-0.37	0.27	0.57
D1+D4+A	-2.35*	0.91	0.18	-2.71*	0.55	0.94	-0.96	0.84	0.74	-1.41	0.95	0.25
D2+D3+A	-1.43	0.71	1.68	-1.49	0.74	0.27	-0.89	0.72	0.68	-1.19	0.06	1.87
D2+D4+A	-5.18*	0.93	1.49	**-3.09***	0.85	0.73	-0.13	0.83	0.65	**-1.68**	0.88	0.81
D3+D4+A	-4.1*	0.86	3.9	-4.41*	0.71	1.83	-0.58	0.85	1.92	-1.28	0.86	7.69
	Rajshahi			Rangpur			Satkhira					
	Z	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE			
Original	-0.73			-0.68			-1.49					
A	-1.80	0.36	11.28	-1.8	0.75	11.85	-1.80	0.38	11.67			
D1	-0.44	0.56	0.3	0.89	-0.11	1.65	0.18	0.25	0.65			
D2	**-0.54**	0.25	0.23	-0.45	-0.24	1.58	0.21	-0.35	0.91			
D3	0.78	0.25	0.23	-0.42	-0.24	1.58	-1.08	-0.35	0.91			
D4	-1.45	00	2.30	**-0.59**	-0.03	14.6	-1.13	0.77	2.16			
D1+A	-0.96	0.56	0.20	-2.10*	0.83	0.55	-0.66	0.52	0.33			
D2+A	-2.92*	0.61	1.22	-3.00*	0.81	1.52	**-1.22**	0.30	1.45			
D3+A	-1.73	0.65	2.03	-2.28*	0.89	1.00	-1.92	0.52	2.20			
D4+A	-2.24*	0.44	12.79	-2.38*	0.79	11.09	-3.78*	0.74	5.83			
D1+D2+A	-1.05	0.75	0.10	-0.31	0.83	0.41	-0.87	0.67	0.20			
D1+D3+A	-0.37	0.86	0.11	-0.79	0.94	0.15	-0.73	0.75	0.28			
D1+D4+A	-1.41	0.62	0.28	-3.40*	0.79	0.62	-1.77	0.86	0.16			
D2+D3+A	-			-1.25	0.96	0.43	-					
D2+D4+A	-2.91*	0.63	1.14	-3.20*	0.80	1.59	-9.74*	0.78	1.13			
D3+D4+A	-1.73	0.63	3.21	-2.59*	0.89	1.04	-3.95*	0.88	3.08			

Table S3: *Z* statistic of MK or MMK of original time series, approximation and different models of surplus of DWT (the dominant components are bold and asterisk for significant at 5% level)

Stations	Barisal			Bhola			Bogra			Dinajpur		
	Z	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE
Original	-1.3			-1.23			-1.43			-1.15		
A	1.80	-0.40	16.29	-1.80	0.32	10.42	-1.80	0.48	15.91	1.80	-0.20	15.03
D1	0.02	0.36	0.30	-0.41	0.37	0.47	-0.21	0.48	0.48	-0.28	0.50	0.26
D2	-0.28	0.41	0.37	-0.47	0.23	0.69	0.66	0.41	0.50	-0.11	0.11	0.36
D3	-0.64	0.41	0.37	-0.09	0.23	0.69	-0.06	0.41	0.50	0.11	0.11	0.36
D4	-2.31*	0.32	2.30	-1.35	0.76	1.08	-0.54	0.53	10.17	-2.32*	0.59	2.25
D1+A	0.02	0.36	0.30	-0.37	0.37	0.47	-0.34	0.58	0.49	-0.17	0.32	0.28
D2+A	-0.11	0.35	0.31	-0.47	0.23	0.69	0.41	0.57	0.34	0.37	0.05	0.52
D3+A	-0.70	0.35	2.23	-0.11	0.46	2.32	-0.34	0.52	1.27	0.63	0.38	1.92
D4+A	-2.20*	0.31	2.19	**-1.33**	0.76	1.11	-0.64	0.56	9.35	-1.39	0.54	1.60
D1+D2+A	-1.85	0.79	0.11	-1.75	0.56	0.22	0.14	0.47	0.42	-		
D1+D3+A	-0.54	0.76	0.17	-1.43	0.41	0.48	-			0.02	0.56	0.29
D1+D4+A	-			-4.68*	0.64	0.22	-			-1.70	0.71	0.19
D2+D3+A	-0.89	0.54	0.82	-0.69	0.38	1.12	-0.55	0.66	0.65	0.67	0.47	1.80
D2+D4+A	**-0.93**	0.32	0.57	-0.95	0.76	0.22	**-1.49**	0.75	0.65	**-1.24**	0.69	0.28
D3+D4+A	-1.83	0.52	1.93	-1.56	0.84	0.96	-2.26*	0.91	1.16	-0.96	0.85	1.50
	Faridpur			Ishurdi			Jessore			Khulna		
	Z	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE
Original	-0.62			-0.15			-0.28			0.21		
A	-1.80	0.43	13.05	1.80	0.23	14.41	1.80	-0.14	15.79	1.80	-0.46	19.60
D1	-0.21	0.12	0.14	-0.37	0.24	0.21	-0.31	0.02	0.51	-0.08	0.06	0.65
D2	-0.60	0.31	0.16	-1.01	0.49	0.86	0.41	0.13	0.75	0.66	0.47	0.86
D3	-4.53*	0.31	0.16	0.64	0.49	0.86	-1.20	0.13	0.75	-0.90	0.47	0.86
D4	-0.54	0.67	2.80	-1.46	0.30	3.29	**-0.31**	0.53	3.62	0.96	0.75	2.66
D1+A	-0.81	0.10	0.13	0.61	0.59	0.11	0.50	0.01	0.98	-0.17	0.04	0.65
D2+A	-0.89	0.24	0.22	0.02	0.50	0.71	1.30	0.14	2.49	1.31	0.26	1.72
D3+A	-1.22	0.58	0.91	1.64	0.46	1.56	-0.47	0.65	1.58	-0.41	0.58	2.35
D4+A	-0.79	0.69	3.49	0.84	0.35	3.99	0.73	0.48	3.70	0.95	0.71	2.42
D1+D2+A	-			-0.37	0.75	0.08	0.15	0.12	0.59	0.05	0.00	0.85
D1+D3+A	-1.47	0.52	0.08	0.25	0.75	0.07	-0.21	0.71	0.47	-0.78	0.27	0.70
D1+D4+A	-			-			1.58	0.54	0.46	0.76	0.89	0.12
D2+D3+A	-1.63	0.49	0.25	1.32	0.56	0.61	-0.01	0.73	1.51	**0.30**	0.62	1.22
D2+D4+A	**-0.79**	0.67	0.41	**-0.19**	0.67	0.33	0.86	0.55	1.03	1.39	0.80	0.85
D3+D4+A	-1.08	0.75	2.29	1.79	0.54	0.99	-0.47	0.86	1.06	0.52	0.92	1.01
	Rajshahi			Rangpur			Satkhira					
	Z	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE			
Original	-1.10			-1.09			0.66					
A	1.80	0.04	18.35	-1.80	0.57	14.39	1.80	0.51	11.40			
D1	-0.57	0.48	0.16	-0.02	0.00	0.58	-0.28	0.32	0.69			
D2	-2.24*	0.60	0.82	0.89	0.49	0.56	0.81	-0.14	0.85			
D3	0.36	0.60	0.82	-1.53	0.49	0.56	-0.81	-0.14	0.85			
D4	-2.01*	0.58	1.75	-2.10*	0.53	2.78	1.36	0.74	7.61			
D1+A	0.02	0.38	0.47	**-1.12**	0.45	0.96	3.03*	0.84	0.15			
D2+A	0.50	0.32	1.07	-0.55	0.58	1.19	1.91	0.69	3.48			
D3+A	2.87*	0.11	11.42	-2.55*	0.74	3.43	2.29*	0.70	6.15			
D4+A	-0.33	0.57	2.12	-3.50*	0.68	5.54	2.28*	0.67	6.91			
D1+D2+A	0.04	0.45	0.50	0.02	0.39	0.36	**0.70**	0.91	0.10			
D1+D3+A	0.43	0.49	0.60	**-1.12**	0.70	0.28	1.09	0.93	0.10			
D1+D4+A	**-0.73**	0.59	0.35	-3.03*	0.77	0.86	1.50	0.86	0.15			
D2+D3+A	0.41	0.35	1.02	-0.95	0.73	0.86	1.83	0.85	3.82			
D2+D4+A	-0.50	0.68	0.74	-1.64	0.75	1.24	2.42*	0.80	2.28			
D3+D4+A	-0.22	0.57	3.71	-2.94*	0.80	3.48	1.85	0.80	5.20			

Table S4: *Z* statistic of MK or MMK of original time series, approximation and different models of annual water deficit of DWT (the dominant components are bold and asterisk for significant at 5% level)

Stations	Barisal			Bhola			Bogra			Dinajpur		
	Z	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE
Original	2.40*			1.18			0.44			-0.49		
A	1.80	0.18	15.33	-1.80	0.15	10.99	-1.80	0.67	9.25	-1.80	0.52	8.10
D1	-0.29	-0.50	1.98	0.07	-0.05	1.94	1.03	0.19	1.59	-0.03	0.47	1.54
D2	1.56	0.16	1.81	-1.04	0.38	0.95	0.73	0.32	2.05	0.89	-0.08	3.88
D3	1.22	0.16	1.81	0.52	0.38	0.95	0.94	0.32	2.05	0.77	-0.08	3.88
D4	1.30	0.91	4.93	1.38	0.86	3.20	1.25	0.30	2.31	2.17*	0.10	6.94
D1+A	3.48*	0.14	2.02	-0.65	-0.14	1.36	-1.41	0.79	0.67	-1.77	0.65	1.00
D2+A	-			-2.55*	-0.11	1.67	-1.49	0.80	1.89	-1.73	0.63	2.21
D3+A	1.77	0.44	3.57	-1.22	-0.35	3.40	-1.36	0.81	6.50	-1.27	0.75	1.93
D4+A	1.78	0.91	3.78	0.98	0.91	3.31	-0.30	0.68	8.15	-0.24	0.56	2.48
D1+D2+A	1.25	0.67	1.58	-0.37	0.41	0.90	-1.31	0.80	0.70	-1.44	0.73	0.60
D1+D3+A	0.92	0.38	1.46	-0.26	-0.08	1.20	-0.79	0.81	0.39	-1.18	0.93	0.48
D1+D4+A	2.16*	0.91	0.81	0.83	0.93	0.15	**0.63**	0.87	0.28	-0.79	0.72	0.69
D2+D3+A	1.20	0.41	3.15	-0.70	0.21	1.35	-1.05	0.81	1.59	-1.41	0.91	0.78
D2+D4+A	**2.25***	0.90	0.75	0.55	0.95	1.61	0.11	0.88	1.05	**-0.32**	0.69	1.28
D3+D4+A	1.86	0.88	2.19	**1.14**	0.89	2.39	-0.30	0.91	3.41	-0.20	0.72	1.02
	Faridpur			Ishurdi			Jessore			Khulna		
	Z	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE
Original	2.14*			1.28			1.77			1.17		
A	1.80	0.36	10.81	-1.80	0.81	16.32	-1.80	0.15	17.72	-1.80	0.58	10.86
D1	-			-			1.54	0.45	0.47	-		
D2	1.11	0.01	0.86	0.62	0.82	0.32	0.55	0.55	0.45	**1.30**	0.67	1.27
D3	0.27	0.01	0.86	0.86	0.82	0.32	0.83	0.55	0.45	0.17	0.67	1.27
D4	1.44	0.64	1.37	**1.12**	-0.03	4.10	0.80	0.70	11.39	1.00	0.41	7.16
D1+A	0.02	0.12	0.62	-2.66*	0.84	2.18	-1.32	0.13	1.87	-1.88	0.46	0.66
D2+A	1.87	0.15	0.66	-0.42	0.86	0.83	-0.19	0.28	1.34	-1.08	0.63	0.99
D3+A	1.07	0.37	1.13	-0.55	0.73	3.05	-0.09	-0.54	4.09	-1.43	0.17	5.66
D4+A	1.94	0.69	1.14	0.04	0.41	13.27	0.30	0.67	15.60	-0.10	0.71	11.79
D1+D2+A	0.63	0.32	0.40	-0.18	0.91	0.40	0.60	0.49	0.79	-0.37	0.63	0.54
D1+D3+A	1.97*	0.46	0.61	-0.08	0.61	1.12	-0.08	-0.18	1.78	-0.63	0.44	0.68
D1+D4+A	1.80	0.76	0.50	0.60	0.72	3.14	1.00	0.75	3.77	0.24	0.77	1.22
D2+D3+A	1.53	0.21	1.16	0.25	0.86	0.26	0.43	0.05	1.33	-0.41	0.65	1.04
D2+D4+A	**2.11***	0.66	0.97	0.80	0.91	0.40	**1.58**	0.84	0.40	0.24	0.85	1.01
D3+D4+A	2.70*	0.77	1.74	0.85	0.69	2.79	1.39	0.63	4.35	0.22	0.66	3.44
	Rajshahi			Rangpur			Satkhira					
	Z	*Co*	MSE	*Z*	*Co*	MSE	*Z*	*Co*	MSE			
Original	-0.63			0.26			-1.52					
A	-1.80	0.93	5.40	-1.80	-0.34	13.52	-1.80	0.99	1.64			
D1	-			-			-0.93	0.30	6.18			
D2	0.70	0.27	4.35	0.83	0.40	2.05	0.70	0.73	10.11			
D3	**-0.34**	0.27	4.35	0.60	0.40	2.05	-1.98	0.73	10.11			
D4	1.37	-0.14	6.94	2.29*	0.17	3.97	0.33	0.07	4.85			
D1+A	-1.86	0.88	0.50	-3.56*	-0.30	1.30	-1.95	0.96	0.60			
D2+A	-2.07*	0.89	1.43	-0.49	0.10	1.03	-1.84	0.96	0.75			
D3+A	-2.02*	0.93	6.99	0.05	0.72	0.41	-2.11*	0.98	2.09			
D4+A	-1.09	0.92	5.65	**0.14**	-0.09	3.47	-1.25	0.95	1.78			
D1+D2+A	-1.61	0.88	0.36	-1.09	0.12	0.81	-1.80	0.94	0.80			
D1+D3+A	-1.83	0.91	0.35	-0.05	0.76	0.26	-1.93	0.96	0.40			
D1+D4+A	-1.18	0.95	0.42	-1.57	-0.18	1.48	-1.29	0.98	0.51			
D2+D3+A	-1.68	0.89	1.07	0.12	0.90	0.15	-1.88	0.98	0.31			
D2+D4+A	-1.11	0.94	0.80	0.59	0.24	1.16	**-1.57**	0.99	0.16			
D3+D4+A	**-1.05**	0.94	5.09	0.46	0.76	0.48	-1.28	0.95	1.82			

Table S5: Parameter estimation of denoised ARIMA model for WBC

P_{ET}						
Stations	**Coefficient**					
	AR1	AR2	AR3	MA1	MA2	MA3
Barisal	-0.3	-0.6		1.9	1.0	
Bhola				1.4	0.4	
Bogra	0.8			1.4	0.4	
Dinajpur	1.7	-0.8		1.0		
Faridpur	1.7	-0.8		-1.0		
Ishurdi	0.6					
Jessore	0.6			0.6		
Khulna	0.7					
Rajshahi	0.0					
Rangpur	1.4	-0.7		0.7	0.8	0.9
Satkhira				1.5	0.0	-0.5
	A_{ET}					
Barisal				-1.6	0.9	
Bhola				0.2		
Bogra				0.3	0.8	0.6
Dinajpur	0.8					
Faridpur	1.3	-0.4				
Ishurdi	0.9			0.5		
Jessore				-0.1		
Khulna	1.2	-0.3				
Rajshahi	0.9					
Rangpur	0.1	-0.9	0.7	-0.6	0.7	1.0
Satkhira	0.9			0.5		
	Surplus					
Barisal	0.8			1.0		
Bhola	1.4	-0.5				
Bogra						
Dinajpur				1.6	1.0	
Faridpur	0.8			-0.1	1.0	
Ishurdi	-0.3			1.0		
Jessore	1.4	-0.9		0.6	0.6	1.0
Khulna	1.3	-0.4				
Rajshahi	0.0			1.0		
Rangpur	-1.1	-0.9	-0.4	-0.8		
Satkhira	1.5	-0.6				
	Deficit					
Barisal	0.6					
Bhola	1.3	-0.9		-0.7	0.9	0.1
Bogra	1.9	-1.0		-1.0	0.0	
Dinajpur	1.1	-0.5		0.6	0.7	0.9
Faridpur	0.7					
Ishurdi	0.7					
Jessore	0.4			0.4		
Khulna	1.9	-1.0		-1.0		
Rajshahi	0.8					
Rangpur	1.4	-0.9		0.3		
Satkhira		0.8		1.0		

Calculation of Water Balance Components

Penman-Monteith Equation

The mathematical expression of the standard Penman-Monteith Equation (Allen et al., 1998) can be given as:

$$PET = \frac{0.408\Delta(R_{n-}G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, PET is the reference potential evapotranspiration (mm/day), R_n is the net radiation at the crop surface (MJ m-2day-1), G is the soil heat flux (MJ m-2day-1), γ is the psychrometric constant (kPa°C-1), T is the daily mean temperature (°C), $u_2$is the average daily wind speed at 2 m (m/s), $e_s$is the saturation vapor pressure (kPa), e_a is the actual vapor pressure (kPa) and Δ is the is the slope of the saturation vapor pressure temperature curve (kPa °C-1).

Soil -Water Balance

In the present study, the soil-water balance concept proposed by Thornthwaite and Mather (1955) has been used to calculate the water balance components (WBCs) like Actual Evapotranspiration (A_{ET}), water deficit and surplus. The monthly climatic data have been rearranged following hydrologic year. The hydrologic year in Bangladesh commences in April and ends in March. The field capacity of the soil (C_{AP}) has been estimated using Thornthwaite and Mather (1957) suggested values for water holding capacity of the soil and rooting depth of the plants (Table S6). Soil texture map of Bangladesh prepared by the Soil Resource Development Institute of Bangladesh (SRDI, 1998) and the description of the soils of Bangladesh presented by Huq and Shoaib (2013) have been used for the calculation of WBCs. The first step of the calculation for WBCs like AET, surplus and deficit is the subtraction of 5% rainfall from the monthly rainfall data as this amount of water has been lost due to direct runoff (Wolock and McCabe, 1999; Karim et al., 2012; Kanoua and Merkel, 2015). The remaining amount of rainfall has been included in the calculation.

Soil moisture storage (S_B) and Changes in Soil Moisture Storage ΔS_B

The total amount of water which is held in the soil within the plant's root zone is termed as soil moisture storage(S_B). The field capacity of the soil (C_{AP}) represents the maximum amount of water stored in the soil zone i.e. $S_B = C_{AP}$. Soil moisture storage (S_B) can be calculated by multiplying the depth of the root zone by the water content at the field capacity. The change in soil moisture storage (ΔS_B) is the amount of water which is added or removed from what is stored (Bakundukize et al., 2011) and the amount of change varies between 0 and the field capacity of the soil (Ritter, 2006). During the dry months ($P_{ET} > (P - R_0)$), a certain amount of water withdrawal from the soil moisture storage takes place to meet the evapotranspiration demand. However, water is added to the storage during the wet months ($P_{ET} < (P - R_0)$) until water is reached to the maximum storage capacity (Bakkundukize et al., 2011).

Actual Evapotranspiration (A_{ET})

In wet months, A_{ET} is equal to the P_{ET} as there is enough rain, i.e. $(P - R_0) > P_{ET}$. Here, P is the rainfall and R_0 is the direct runoff. In dry months, P_{ET} is higher than $(P - R_0)$, i.e. $(P - R_0) < P_{ET}$ and P is not able to meet the evapotranspiration demand. Hence, water is progressively taken from the soil moisture storage (S_B) till it is fully depleted to fulfill the evapotranspiration demand. Therefore, A_{ET} can still equal to P_{ET} when there is

enough water within the soil, even if there is not enough rainfall. In those months, A_{ET} equals the $(P - R_0)$ plus the amount of water drawn from the soil moisture storage i.e., $(P - R_0) + \Delta S_B$.

Surplus

In wet months $(P - R_0) > P_{ET}$, the moisture storage in soil reaches the water holding capacity and any excess rainfall is counted as surplus i.e., $\text{Surplus} = (\text{P} - R_0) - P_{ET}$.

Deficit

In dry month , the difference between the P_{ET} and A_{ET} for a particular month is termed as the deficit for that month i.e., $\text{Deficit} = P_{ET} - A_{ET}$.

Table S6: Water capacity suggested values for different combinations of soil texture and vegetation (Thornthwaite and Mather, 1957)

Vegetation	Soil texture	Water holding Capacity (%)	Rooting depth (m)	Water capacity of the root-zone (C_{AP}) (mm)
Shallow rooted crops	Fine sand	10	0.50	50
	Fine sandy loam	15	0.50	75
	Silty loam	20	0.62	125
	Clay loam	25	0.40	100
	Clay	30	0.25	75
Moderately rooted crops	Fine sand	10	0.75	75
	Fine sandy loam	15	1.00	150
	Silty loam	20	1.00	200
	Clay loam	25	0.80	200
	Clay	30	0.50	150
Deep rooted crops	Fine sand	10	1.00	100
	Fine sandy loam	15	1.00	150
	Silty loam	20	1.25	250
	Clay loam	25	1.00	250
	Clay	30	0.67	200
Orchards	Fine sand	10	1.50	150
	Fine sandy loam	15	1.67	250
	Silty loam	20	1.50	300
	Clay loam	25	1.00	250
	Clay	30	0.67	200
Mature Forest	Fine sand	10	2.50	250
	Fine sandy loam	15	2.00	300
	Silty loam	20	2.00	400
	Clay loam	25	1.60	400
	Clay	30	1.17	350

<u>Programming and Mapping</u>

In the present study, the open sources programming platform "R" (R 3.4.0) (R Core Development Team, 2016) has been used for relevant analysis. In the present study, mapping has been done in ArcGIS version 10.2. The spatial distribution maps have been prepared using geostatistical analyst tool integrated into ArcMap following the inverse distance weighting (IDW) technique and details about the method can be found in Burrough and McDonnell (1998).

R Codes for MK, MMK test and Sen's Slope

```
MMKTest <- function(x, ci) {
    x = x
    z = NULL
    z0 = NULL
    pval = NULL
    pval0 = NULL
    S = 0
    Tau = NULL
    essf = NULL
    ci = ci
    if (is.vector(x) == FALSE) {
        stop("Input data must be a vector")
    }
    if (any(is.finite(x) == FALSE)) {
        x[-c(which(is.finite(x) == FALSE))] -> x
        warning("The input vector contains non-finite numbers. An attempt was made to remove them")
    }
    n <- length(x)
    for (i in 1:(n-1)) {
        for (j in (i+1):n) {
            S = S + sign(x[j]-x[i])
        }
    }
    acf(rank(lm(x ~ I(1:n))$resid), lag.max=(n-1), plot=FALSE)$acf[-1] -> ro
    qnorm((1+ci)/2)/sqrt(n) -> sig
    rep(NA,length(ro)) -> rof
    for (i in 1:(length(ro))) {
        if(ro[i] > sig || ro[i] < -sig) {
            rof[i] <- ro[i]
        } else {
            rof[i] = 0
```

```
    }
}
2 / (n*(n-1)*(n-2)) -> cte
ess=0
for (i in 1:(n-1)) {
    ess = ess + (n-i)*(n-i-1)*(n-i-2)*rof[i]
}
essf = 1 + ess*cte
var.S = n*(n-1)*(2*n+5)*(1/18)
if(length(unique(x)) < n) {
    unique(x) -> aux
    for (i in 1:length(aux)) {
        length(which(x == aux[i])) -> tie
        if (tie > 1) {
            var.S = var.S - tie*(tie-1)*(2*tie+5)*(1/18)
        }
    }
}
VS = var.S * essf
if (S == 0) {
    z = 0
    z0 = 0
}
if (S > 0) {
    z = (S-1)/sqrt(VS)
    z0 = (S-1)/sqrt(var.S)
} else {
    z = (S+1)/sqrt(VS)
    z0 = (S+1)/sqrt(var.S)
}
pval = 2*pnorm(-abs(z))
pval0 = 2*pnorm(-abs(z0))
```

```
    Tau = S/(.5*n*(n-1))

    rep(NA, times=(n^2-n)/2) -> V

    k = 0

    for (i in 2:n) {

        for (j in 1:(n-1)) {

            k = k+1

            V[k] = (x[i]-x[j])/(i-j)


        }

    }

    median(na.omit(V)) -> slp

        return(list("Mann-Kendall.Z" = z0, "Mann-Kendall_p.value" = pval0, "Modified_Mann-Kendall.Z" =
z,

    "Modified_Mann-Kendall_p.value" = pval, "Tau.value" = Tau, "Sen's Slope" = slp))

}
```

References

Allen, R. G., Pereira, L. S., Raes, D. and Smith, M.: Crop evapotranspiration: guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper, No. 56, Rome, Italy, p.328, 1998.

Bakundukize, C., Camp, M. V. and Walraevens, K. Estimation of groundwater recharge in Bugesera region (Burundi) using soil moisture budget approach, Geologica Belgica, 14/1–2, 85–102, 2011.

Burrough, P. A. and McDonnell, R. A. Principles of geographical information systems. Oxford University Press, Oxford, 1998.

Huq, S. M. I. and Shoaib, J. U. The Soils of Bangladesh, 1–172, ISBN 978-94-007-1128-0, doi:10.1007/978-94-007-1128-0, 2013.

Kanoua, W. and Merkel, B. J. Groundwater recharge in Titas Upazila in Bangladesh. Arabian Journal of Geoscience, 8, 1361, 2015.

Karim, M. R., Ishikawa, M. and Ikeda, M. Modeling of seasonal water balance for crop production in Bangladesh with implications for future projection. Italian Journal of Agronomy 7(2). doi:10.4081/ija.2012.e21. 2012.

SRDI (Soil Resources Development Institute). Soil map of Bangladesh, Soil Resources Development Institute, 1998.

Team, R. C. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, 2016.

Thornthwaite, C. W. and Mather, J. R. Instructions and tables for computing potential evapotranspiration and the water balance. Publications in Climatology, Laboratory of Climatology, Drexel Institute of Technology, Centerton, New Jersey, USA, 10(3), 183–311, 1957.

Thornthwaite, C. W. and Mather, J. R. The Water Balance, Publications in Climatology, VIII(1): 1-104, Drexel Institute of Climatology, Centerton, New Jersey, 1955.

Wolock, D. M. and McCabe, G. J. Effects of potential climatic change on annual runoff in the conterminous United States, Journal of the American Water Resources Association, 35, 1341–1350, 1999.