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Trend and Variability Analysis and Forecasting of Sunshine-Hour in Bangladesh

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Abstract

An attempt has been taken to investigate the trend and variability pattern for annual and seasonal (Three crop seasons) average sunshine-hours (ASSH) for six divisional stations of Bangladesh: Dhaka, Khulna, Rajshahi, Barisal, Sylhet and Chittagong. The monthly ASSH (2008-2011) are forecasted applying the univariate Box-Jenkin's ARIMA (autoregressive integrated moving average) modelling technique on the basis of the minimum root mean square forecasting error. Several diagnostic techniques are used for detection of outlier and residual's stationarity and normality. The significant negative rates are observed for linear trend (LT) of Annual and Seasonal Average ASSH in all the six stations with only one minor positive rate for Prekharif season in Khulna. The findings support that the climate of Bangladesh is changing in terms of sunshine-hour which may have tremendous effects in the agricultural production.

Key words: Bangladesh, Forecasting, Sunshine-Hour

1. Introduction

Sunshine-hour is one of the vital climatic phenomena for agriculture. Adequate sunshine and proper sunshine-hour are essential for required plant growth and development. Poor crop growth may occur due to lack of bright sunshine. Intense light protects the plants against injury. Daylight duration is important for raising crops in any latitude and it influences the flowering of plants. Sunlight plays a crucial role on stomata opening and photosynthetic capacity too. Inadequate light may cause different diseases, structural changes and alteration of color. Light saturation is a condition of a leaf or plant receiving that amount of light or more to produce the maximum photosynthate under prevailing conditions of CO_2 and light supply (Lenka, 1998). Weather prediction is a complex process and a challenging task for reseasrhers. The prediction of atmospheric parameters is essential for various applications. Some of them include climate monitoring, drought detection, severe weather prediction, agriculture and production, planning in energy and industry, communication, pollution dispersal etc. Accurate prediction of weather parameters is a difficult task due to the dynamic nature of atmosphere. So, it is significant to study the temporal sunshine-hour and its forecasting for proper planning of expected production. In this paper, the within-year and between-year variability analyses are conducted for Annual and Seasonal ASSH and the univariate Box-Jenkin's ARIMA (autoregressive integrated moving average) models are developed for monthly ASSH. Box-Jenkins model is used as the alternative model for forecasting climatic data. ARIMA models provide maximum likelihood estimators that are unbiased when the data are seasonal and autocorrelated, and when a variable is lagged on itself. In within-year variability analysis, the maximum, mean and minimum ASSH and the coefficient of variation (CV) are used in detecting the pattern of sunshine-hour variability in annual and seasonal aspects for a year. But in between-year variability analysis, the trend lines are estimated to investigate the year-to-year variation of different years/seasons for various stations.

Keeping the above views in mind the present work was undertaken for Trend and Variability Analysis and Forecasting of Sunshine-Hour in Bangladesh

2. Sources of Data and Methodology

The sources of data and the methodology used are presented below under different captions.

2.1. *Methodology*

The within and between-year variability for annual and seasonal ASSH are calculated. The linear trend for annual and seasonal ASSH are fitted with the least square method taking the following equation-

$$Y = a + bX$$

Whe re, Y = ASSH

X = time

a and b = parameters

Stationarity of residuals for ASSH trend is tested using the ACF and the PACF display and the normality is checked by normal probability plot. Classical 't' value is used for the identification of significant ASSH trend when residuals follow normality and stationarity pattern.

The Univariate Box-Jenkin's ARIMA model is fitted to forecast the monthly ASSH data for January 2008 to December 2011. After confirming that the series is stationary, an effort is made for an ARIMA model to express each observation as a linear function of the previous value of the series (autoregressive parameter) and of the past error effect (moving average parameter). The available data are divided into training, validation and test sets. The training set is used to build the model, the validation set is used for parameter optimization and the test set is used to evaluate the model. The adequacy of the above model is checked by comparing the observed data with the forecasted results. In this study, the data for the last two years are used to compare with the fitted model forecasts for the years and the models are selected for the minimum root mean square forecasting error of the data set of those two years. The diagnostic techniques: histogram of residuals, normal probability plot of residuals, ACF and PACF display of residuals, TS plots for residual versus fitted values and TS plots for residual versus order of the data are used for checking residuals of ARIMA models. The Box-Cox transformation is used for variance stabilization and the transformation of the data to get stationary series from nonstationary series (Pankraiz, 1991). The software package "Minitab 13" is used to fit the ARIMA univariate models. A detailed description of the nonseasonal and seasonal ARIMA models and the standardized notation used in this paper is set in the Appendix 1.

2.2. *Sources of Data*

Data are taken from Bangladesh Meteorological Department, Dhaka. The monthly average sunshine-hour are taken for Dhaka, Khulna, Rajshahi, Barisal, Sylhet and Chittagong divisions for 1961-2007, 1948-2007, 1979-2006, 1967-2007, 1961-2007, 1961-2007, respectively. The missing data are filled in by the median of the corresponding years. The seasonal data for the three crop seasons: Kharif, Prekharif and Rabi are made by averaging the monthly data taking from June-October, March-May and November-February, respectively

2.2.1. Box- Jenkins Modelling Strategy and ARIMA Model

Box-Jenkins (1976) formalized the ARIMA modelling framework in three steps: (I) Identification, (II) Estimation and (III) Verification. In the 1st stage, it is tried to identify that how many terms to be included is based on the autocorrelation function (ACF) and partial autocorrelation function (PACF) of the differenced and/or transformed time series (Box Jenkins, 1976). In the 2nd stage, the coefficients of the model are estimated using the maximum likelihood method. The verification of the model is achieved through diagnostic checks of the residuals (histogram or normal probability (NP) plot of residuals, standardized residuals and ACF and PACF of the residuals). The credibility of the ARIMA models is often tested through comparison of prediction with observation not used in the fitted model. A suitable ARIMA model gives the least mean squared error forecasts among all the linear univariate models with fixed coefficients. It can produce point forecasts for each time period and interval forecasts constructing a confidence interval around each point forecast. To have the 95% interval for each forecast the formulae $f \pm 2s$ is used, where f denotes a forecast and s is its standard error. The forecasts for a stationary model converge to the mean of the series and the speed of converging movement depends on the nature of the model. For nonstationary model the forecasts do not converge to the mean.

3. Results and Discussions

The findings of the analyses of ASSH are presented below under different headings.

3.1. *Decadal Variability for ASSH*

The decadal averages for annual and seasonal ASSH of the six divisional stations are presented in the Table 1. The data on ASSH of Dhaka is available for 1961-2007. The decadal average annual ASSH of Dhaka decreased from 7.6 during 1961-70 to 5.9 in 2001-07. Similar trend is observed during Kharif, Prekharif and Rabi seasons too.

The information on ASSH of Khulna is available for 1984-2007. The decadal average annual ASSH diminished from 6.8 during 1984-90 to 6.6 in 2001-07. Similar trend is observed during Kharif and Rabi seasons. Prekharif ASSH of Khulna reduced from 8.2 during 1984-90 to 8.0 in 1991-00 and increased from 8.0 during 1991-00 to 8.3 in 2001-07.

The record on ASSH of Rajshahi is available for 1971-2006. The decadal average annual ASSH dropped from 7.1 during 1979-90 to 6.8 in 1991-00. It is found to be higher (6.9) in the last decade (2001-06) compared to 1991-00. Similar pattern is experienced in Rabi ASSH. During Kharif and Prekharif seasons, the decadal average ASSH abridged from 1979-90 to 2001-06.

The fact on ASSH of Barisal is available for 1967-2007. The decadal average annual ASSH inflated from 6.7 during 1967-70 to 7.3 in 1971-80 and went down from 7.3 during 1971-80 to 6.1 in 1991-00 and again expanded from 6.1 during 1991-00 to 6.2 in 2001-07. Similar pattern is observed in Rabi and Prekharif ASSH. Kharif ASSH went up from 4.7 during 1967-70 to 5.3 in 1971-80 and then again dwindled from 5.3 during 1971-80 to 4.4 in 2001-07.

The statistics on ASSH of Sylhet is available for 1961-2007. The decadal average annual ASSH augmented from 6.9 during 1961-70 to 7.0 in 1971-80 and declined from 7.0 during 1971-80 to 5.95 in 2001-07. Similar pattern is observed in Rabi season. Kharif ASSH enhanced from 4.9 during 1961-70 to 5.2 in 1971-80 and fell from 5.2 during 1971-80 to 4.4 in 1991-00 and again developed from 4.4 during 1991-00 to 4.6 in 2001-07. Prekharif ASSH shows similar pattern as Kharif ASSH.

The documentation on ASSH of Chittagong is available for 1961-2007. The decadal average annual ASSH boosted from 7.5 during 1961-70 to 7.6 during 1971-80 and decreased from 7.6 during 1971-80 to 6.5 during 2001-07. Similar pattern is observed for all the three seasons.

3.2. *Within-Year Variability for ASSH*

The within-year variabilities for annual and seasonal ASSH of the six divisional stations of Bangladesh are analyzed and the results are presented in the Table 2. The annual average ASSH ranges from 6.46 during Sylhet to 7.18 in Chittagong while the CV ranges from 5.08 during Khulna to 9.98 in Dhaka. The seasonal average ASSH is highest in Prekharif season and the lowest in Kharif season in Dhaka, Khulna and Rajshahi but it is highest in Rabi season and lowest in Kharif season in Barisal, Sylhet and Chittagong. The yearly maximum annual ASSH varies from 7.19 in Khulna to 8.47 in Barisal. The yearly minimum ASSH is highest in Rajshahi (6.26) and the lowest in Dhaka (5.51). CVs of Kharif and Prekharif ASSH are highest in Sylhet but these are lowest in Khulna. The CV of Rabi ASSH is highest in Dhaka and lowest in Rajshahi.

3.3. *Between-Year Variability*

3.3.1. Annual and Seasonal ASSH

The rates obtained from the LT for annual, Kharif, Prekharif and Rabi seasons are shown in the Table 3. The Stationarity and normality of the residuals are examined and pointed out against each trend value. The respective ‘t’ values are also presented. The growth rates for annual and seasonal average ASSH are found negative in all the six stations except a few. The highest negative rate of annual ASSH is allowed for Dhaka (– 0.0443) and the residuals show nonstationarity while the lowest rate is experienced for Khulna (– 0.0157) and the residuals show nonnormality. The significant negative rate is found for Rajshahi (– 0.0185*), Barisal (– 0.0337*), Sylhet (– 0.0311*) and Chittagong (- 0.0267*).

During Kharif season, the significant negative growth rates are accredited for Dhaka (– 0.0354*) Barisal (– 0.0266*), Sylhet (– 0.0311*) and Chittagong (- 0.0267*). The fairly high negative rates are observed for both Khulna (– 0.0101) and Rajshahi (– 0.0179).

During Prekharif season, the significant negative growth rates are attributed for Dhaka (– 0.0361*), Rajshahi (– 0.0255*), Barisal (– 0.0343*), Sylhet (– 0.0355*) and Chittagong (– 0.0311*). The insignificant positive rate is observed only for Khulna (+ 0.0022).

During Rabi season, the significant negative growth rates are recognized for Dhaka (– 0.0615*), Khulna (– 0.0362*), Barisal (– 0.0421*), Sylhet (– 0.0442*) and Chittagong (– 0.0383*). The fairly high negative rate is only observed for Rajshahi (–0.0141).

Table 1. Decadal averages for annual and seasonal average sunshine-hour

Decade	Dhaka					Khulna					Rajshahi					Barisal					Sylhet					Chittagong			
	A	K	Pk	R	Y	A	K	Pk	R	Y	A	K	Pk	R	Year	A	K	Pk	R	Year	A	K	Pk	R	Y	A	K	Pk	R
1961-70	7.6	5.8	8.7	8.9	-	-	-	-	-	-	-	-	-	-	1967-70	6.7	4.7	7.8	8.4	1961-70	6.9	4.9	7.6	8.9	1961-70	7.5	5.5	8.6	9.1
1971-80	7.5	5.8	8.5	8.7	-	-	-	-	-	-	-	-	-	-	1971-80	7.3	5.3	8.5	8.9	1971-80	7.0	5.2	7.5	9.0	1971-80	7.6	5.7	8.7	9.1
1981-90	7.0	5.6	7.8	8.0	1984-90	6.8	5.0	8.2	8.1	1979-90	7.1	5.7	8.3	8.0	1981-90	6.8	5.0	8.1	8.0	1981-90	6.3	4.7	6.7	8.1	1981-90	7.0	5.4	7.9	8.4
1991-00	6.4	5.1	7.5	7.2	1991-00	6.7	4.9	8.0	7.8	1991-00	6.8	5.5	8.0	7.6	1991-00	6.1	4.4	7.2	7.4	1991-00	5.96	4.4	6.3	7.7	1991-00	6.8	5.2	7.7	8.1
2001-07	5.9	4.3	7.5	6.6	2001-07	6.6	4.8	8.3	7.5	2001-06	6.9	5.5	7.9	7.8	2001-07	6.2	4.4	7.5	7.6	2001-07	5.95	4.6	6.6	7.3	2001-07	6.5	5.1	7.7	7.5

A= annual, K = Kharif, PK= Prekharif R = Rabi

Table 2. Within-year variability for annual and seasonal average sunshine-hour

Period	Dhaka				Khulna				Rajshahi				Barisal				Sylhet				Chittagong			
	Max	Ave	Min	CV	Max	Ave	Min	CV	Max	Ave	Min	CV	Max	Ave	Min	CV	Max	Ave	Min	CV	Max	Ave	Min	CV
Annual	8.17	6.91	5.51	9.98	7.19	6.67	5.99	5.08	7.78	6.93	6.26	5.32	8.47	6.63	5.59	9.24	7.67	6.46	5.34	8.96	8.23	7.18	6.09	7.06
Kharif	6.76	5.40	4.04	12.12	5.40	4.90	4.34	6.17	6.68	5.54	4.50	9.87	6.50	4.79	3.42	12.22	5.94	4.76	3.56	12.31	6.60	5.43	4.56	8.56
Prekharif	9.50	8.03	7.03	8.59	9.03	8.17	7.40	6.19	9.77	8.09	7.30	6.20	9.87	7.85	5.40	11.46	8.40	6.93	5.17	11.61	9.93	8.19	5.73	9.37
Rabi	9.70	7.97	5.65	12.46	8.90	7.77	5.68	8.45	8.58	7.78	7.15	5.12	9.88	8.03	6.53	9.61	9.83	8.22	6.45	9.78	9.98	8.60	6.70	9.34

Max = Maximum Ave = Average Min = Minimum CV= Coefficient of Variation

Table 3. Rates of LT for annual and seasonal ASSH and residual's stationarity and normality

Station	Annual	Kharif	Prekharif	Rabi
Dhaka	– 0.0443 (t=-12.40, Ap.N, NS)	– 0.0354*(t=-7.41, Ap.N, S)	– 0.0361* (t=-6.91, N, Ap.S)	– 0.0615*(t=-10.79, N, S)
Khulna	– 0.0157 (t=-1.62, NN, S)	– 0.0101 (t=-1.14, N, S)	+ 0.0022 (t=0.14, Ap.N, S)	– 0.0362* (t=-1.99, Ap.N, S)
Rajshahi	– 0.0185* (t=-2.18, Ap.N, S)	– 0.0179 (t=-1.35, N, S)	– 0.0255* (t=-2.20, Ap.N, S)	– 0.0141 (t=-1.46, Ap.N, S)
Barisal	– 0.0337*(t=-5.46, N, S)	– 0.0266* (t=-4.04, N,S)	– 0.0343* (t=-3.21, N,S)	– 0.0421* (t=-5.39, Ap.N, Ap.S)
Sylhet	– 0.0311* (t=-7.32, N,S)	– 0.0180* (t=-3.13, N, S)	– 0.0355* (t=-5.08, N, S)	– 0.0442* (t=-7.69, Ap.N, S)
Chittagong	- 0.0267* (t=-5.64, Ap.N, S)	– 0.0145* (t=-2.73, N, S)	– 0.0311* (t=-3.78, Ap.N, S)	– 0.0383* (t=-4.79, Ap.N, S)

*Significant at the 5% level, S-stationary, NS-not stationary, NN-not normal, Ap.N-approximately normal, Ap. S- approximately stationary

3.4. Model Fitting and Forecasting

The estimated ARIMA models for nonseasonal and seasonal autoregression and moving average coefficients are presented in the Table 5. The ACF displays for residual autocorrelations for the estimated models are fairly small relative to their standard errors for all variables. The histograms of the residuals are symmetrical suggesting that the shocks may be normally or approximately normally distributed. The normal probability plots of the residuals do not deviate badly from the straight lines (fairly close to a straight line), again suggesting that the shocks are normal. Some plots are observed Fig. 1. The point and the interval forecasted values of ASSH are presented in the Table 6.

Table 4. Rates of LT for CV of Annual and Seasonal ASSH and Residual's Stationarity and Normality

Station	Annual(%/yr)	Kharif(%/yr)	Prekharif(%/yr)	Rabi(%/yr)
Dhaka	+ 0.119*(t=2.93,N, S)	+ 0.157 (t=1.88,N, S)	+ 0.161*(t=2.72,N, S)	+ 0.143*(t=2.74,Ap.N, S)
Khulna	– 0.035 (t=–0.36,Ap.N, S)	– 0.679*(t=–2.83,N, S)	–0.321*(t=–2.15,Ap.N, S)	+ 0.552 (t=3.96,NN, S)
Rajshahi	– 0.037 (t=–0.34,N, S)	– 0.355 (t=–1.62,N, S)	+ 0.027 (t=0.19,Ap.N, S)	+ 0.197*(t=2.13,N, S)
Barisal	+ 0.086 (t=1.58,N, S)	+ 0.037 (t=0.30,N, S)	+ 0.158 (t=1.54,NN, S)	+ 0.153 (t=2.33,NN, NS)
Sylhet	– 0.0008 (t=–0.02,N, S)	– 0.018 (t=–0.17,Ap.N, S)	+ 0.080 (t=0.73,NN, S)	+ 0.153*(t=3.82,Ap.N, S)
Chittagong	– 0.015 (t=–0.30,Ap.N, S)	+ 0.013 (t=0.12,Ap.N, S)	+ 0.204*(t=2.50,N, S)	+ 0.055 (t=0.63,NN,S)

*Significant at the 5% level, S-stationary, NS-not stationary, NN-not normal, Ap.N-approximately normal, Ap. S- approximately stationary

Table 5. Results of estimated ARIMA models for monthly ASSH

Variable	Model	Equation of Model	MRMSFE	SS	DF	MS
Dhaka	ARIMA $(2,0,0)(1,1,1)_{12}$	$(1 - 0.1172\ B)\ (1 - 0.0866\ B^2)(\ 1 - 0.0618B^{12})\ \nabla_{12}\ \ y_t\ =\ 0.00736 + (1 - 0.8797\ B^{12})\ \varepsilon_t$ se of coeff. (0.0738) (0.0737) (0.0959) (0.01032)(0.0623)	1.086	124.90	187	0.668
Khulna	ARIMA $(1,1,1)(1,1,1)_{12}$	$(1 - 0.1187\ B)\ (1 - 0.0661B^{12})\ \nabla_{12}\ \ y_t\ =\ -0.000114 + (1 - 0.97\ B)(1 - 0.9497\ B^{12})\ \varepsilon_t$ se of coeff. (0.0397) (0.043) (0.00009) (0) (0.0185)	1.059	520.52	630	0.826
Rajshahi	ARIMA $(1,0,0)(1,1,1)_{12}$	$(1 - 0.2139B)(\ 1 + 0.0714B^{12})\ \nabla_{12}\ \ y_t\ =\ -0.01618 + (1 - 0.9322\ B^{12})\varepsilon_t$ se of coeff. (0.056) (0.0611) (0.004915) (0.0342)	0.726	212.30	308	0.689
Barisal	ARIMA $(1,0,1)(0,1,1)_{12}$	$(1 - 0.7277\ B)\ \nabla_{12}\ \ y_t\ =\ -0.00\ 895 + (1 - 0.4713\ B)\ (1 - 0.9617\ B^{12})\ \varepsilon_t$ se of coeff. (0.0817) (0.1046) (0.001426) (0.0199)	0.756	387.10	476	0.813
Sylhet	ARIMA $(1,0,1)(1,1,1)_{12}$	$(1 - 0.8372\ B)\ (1 + 0.0413\ B^{12})\ \nabla_{12}\ \ y_t\ =\ -0.00506 + (1 - 0.7212\ B^{12})(1 - 0.9422)\ \varepsilon_t$ se of coeff. (0.0837) (0.0468) (0.000905)(0.1052)(0.0201)	1.092	507.11	547	0.927
Chittagong	ARIMA $(1,0,0)(0,1,1)_{12}$	$(1 - 0.2226\ B)\ \nabla_{12}\ \ y_t\ =\ -0.02081 + (1 - 0.9505\ B^{12})\ \varepsilon_t$ se of coeff. (0.0435) (0.003429) (0.0197)	1.266	511.14	501	1.020

MRMSFE = minimum root mean square forecasting error, SS = Sum square error,
DF = Degrees of freedom, MS = mean square error

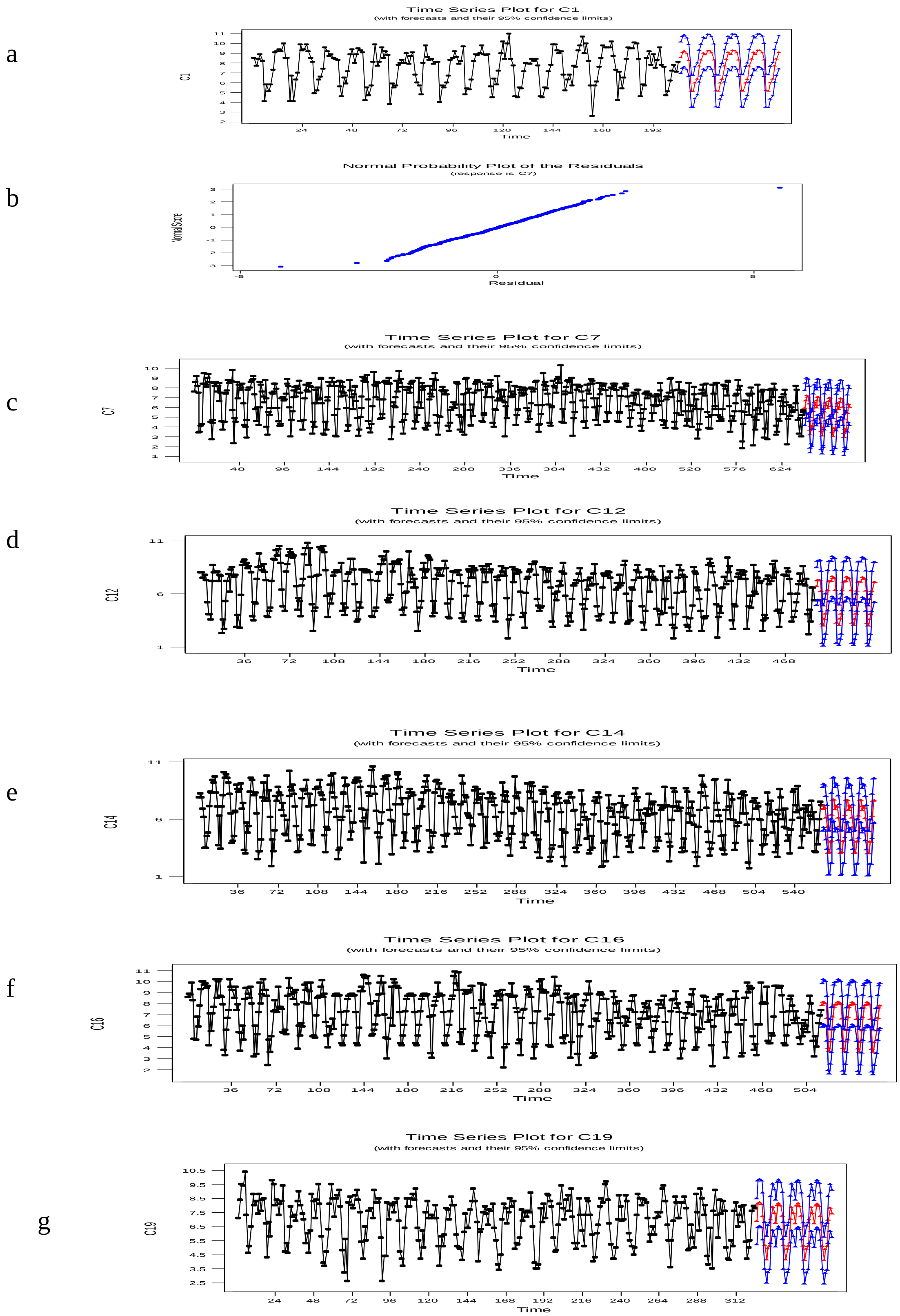

Fig. 1. (a) Forecasted ASSH for Dhaka (Red line- Indication of point estimate and blue line- Indication of 95% confidence interval) (b) NP plot for residuals of Khulna (c) Forecasted ASSH for Khulna (d) Forecasted ASSH for Barisal (e) Forecasted ASSH for Sylhet (f) Forecasted ASSH for Chittagong (g) Forecasted ASSH for Rajshahi

Table 6. Point and interval forecasts of monthly average sunshine-hour in six divisional stations

Period	Dhaka for 2008			Khulna for 2008			Barisal for 2008			Sylhet for 2008			Chittag. for 2008			Rajshahi for 2007		
	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)
Jan	8.6	7.0	10.2	5.9	4.1	7.7	6.7	4.9	8.5	6.9	5.0	8.8	7.8	5.9	9.8	6.9	5.2	8.5
Feb	9.1	7.5	10.7	6.7	4.9	8.5	7.3	5.4	9.1	7.2	5.3	9.1	8.1	6.1	10.2	8.1	6.4	9.8
Mar	9.2	7.6	10.9	7.2	5.4	9.0	7.2	5.4	9.1	7.0	5.1	8.9	8.1	6.0	10.1	8.2	6.5	9.9
Apr	9.0	7.3	10.6	7.1	5.3	8.9	7.3	5.4	9.2	6.1	4.2	8.0	8.0	6.0	10.0	8.1	6.4	9.8
May	8.3	6.6	9.9	6.4	4.6	8.2	6.2	4.4	8.1	5.3	3.4	7.2	6.7	4.6	8.7	7.2	5.6	8.9
Jun	5.1	3.5	6.8	3.7	1.9	5.5	3.2	1.3	5.1	3.0	1.1	5.0	4.0	1.9	6.0	5.1	3.5	6.8
Jul	5.1	3.5	6.7	3.2	1.4	5.0	3.0	1.1	4.9	3.1	1.2	5.0	3.7	1.6	5.7	4.1	2.5	5.8
Aug	6.0	4.4	7.6	4.1	2.3	5.9	3.6	1.7	5.5	4.0	2.1	6.0	4.5	2.5	6.6	4.9	3.3	6.6
Sep	6.4	4.8	8.0	3.8	2.0	5.6	4.1	2.2	6.0	4.1	2.2	6.0	5.6	3.6	7.6	5.1	3.4	6.8
Oct	7.7	6.1	9.3	5.6	3.8	7.4	6.3	4.4	8.2	6.4	4.4	8.3	6.8	4.8	8.8	7.0	5.3	8.7
Nov	8.3	6.7	9.9	6.5	4.7	8.3	7.2	5.3	9.0	7.7	5.8	9.6	7.7	5.7	9.7	7.9	6.2	9.6
Dec	9.0	7.4	10.6	6.2	4.4	8.0	7.2	5.3	9.1	7.7	5.8	9.7	7.9	5.9	9.9	7.4	5.8	9.1

PE-point estimate IE (L)-interval estimate (lower limit) IE (U)- interval estimate (upper limit)

Table 6. continued

Period	Dhaka for 2009			Khulna for 2009			Barisal for 2009			Sylhet for 2009			Chittag. for 2009			Rajshahi for2008		
	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)
January	8.9	7.2	10.5	6.0	4.1	7.8	7.2	5.3	9.1	6.8	4.9	8.8	7.9	5.9	10.0	6.7	5.1	8.4
February	9.3	7.6	10.9	6.7	4.9	8.5	7.6	5.7	9.5	7.2	5.3	9.1	8.1	6.1	10.2	8.0	6.3	9.7
March	9.3	7.6	10.9	7.1	5.2	8.9	7.5	5.6	9.4	7.0	5.1	9.0	8.0	6.0	10.1	8.1	6.5	9.8
April	9.0	7.4	10.7	7.0	5.2	8.9	7.5	5.6	9.4	6.1	4.2	8.1	8.0	5.9	10.0	8.0	6.3	9.6
May	8.3	6.7	10.0	6.2	4.4	8.0	6.4	4.5	8.2	5.4	3.4	7.3	6.6	4.6	8.7	7.3	5.6	8.9
June	5.2	3.5	6.8	3.5	1.7	5.4	3.3	1.4	5.2	3.0	1.1	5.0	3.9	1.9	6.0	5.1	3.5	6.8
July	5.1	3.5	6.8	3.1	1.3	4.9	3.1	1.2	5.0	3.1	1.2	5.0	3.6	1.6	5.7	4.1	2.5	5.8
August	6.0	4.3	7.6	3.9	2.1	5.8	3.7	1.8	5.5	4.1	2.1	6.0	4.5	2.5	6.6	4.9	3.2	6.6
September	6.3	4.7	8.0	3.8	1.9	5.6	4.1	2.3	6.0	4.1	2.1	6.0	5.6	3.6	7.6	5.1	3.5	6.8
October	7.7	6.1	9.4	5.5	3.7	7.4	6.3	4.4	8.2	6.3	4.4	8.3	6.8	4.7	8.8	7.0	5.4	8.7
November	8.4	6.7	10.0	6.5	4.6	8.3	7.1	5.3	9.0	7.7	5.7	9.6	7.7	5.6	9.7	7.9	6.2	9.5
December	9.1	7.4	10.7	6.2	4.3	8.0	7.2	5.3	9.0	7.7	5.8	9.6	7.9	5.8	9.9	7.5	5.8	9.1

Table 6. continued

Period	Dhaka for 2010			Khulna for 2010			Barisal for 2010			Sylhet for 2010			Chittagg. for 2010			Rajshahi'2009		
	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)
January	8.9	7.2	10.5	5.9	4.0	7.8	7.2	5.3	9.1	6.8	4.9	8.7	7.9	5.9	9.9	6.7	5.1	8.4
February	9.3	7.6	10.9	6.6	4.8	8.5	7.6	5.7	9.5	7.2	5.2	9.1	8.1	6.1	10.2	8.0	6.3	9.7
March	9.3	7.6	10.9	7.0	5.1	8.8	7.5	5.6	9.3	7.0	5.1	9.0	8.0	6.0	10.0	8.1	6.5	9.8
April	9.1	7.4	10.7	7.0	5.1	8.8	7.4	5.5	9.3	6.1	4.2	8.0	7.9	5.9	10.0	8.0	6.3	9.6
May	8.3	6.7	10.0	6.1	4.3	8.0	6.3	4.4	8.2	5.3	3.4	7.3	6.6	4.6	8.6	7.2	5.6	8.9
June	5.2	3.5	6.8	3.4	1.6	5.3	3.3	1.4	5.2	3.0	1.1	5.0	3.9	1.9	5.9	5.1	3.5	6.8
July	5.1	3.5	6.8	3.0	1.2	4.9	3.0	1.1	4.9	3.1	1.1	5.0	3.6	1.6	5.7	4.1	2.4	5.8
August	6.0	4.3	7.7	3.9	2.0	5.7	3.6	1.7	5.5	4.0	2.1	6.0	4.5	2.5	6.5	4.9	3.2	6.6
September	6.4	4.7	8.0	3.7	1.8	5.5	4.1	2.2	6.0	4.0	2.1	6.0	5.6	3.5	7.6	5.1	3.4	6.8
October	7.7	6.1	9.4	5.5	3.6	7.3	6.3	4.4	8.2	6.3	4.4	8.2	6.7	4.7	8.8	7.0	5.3	8.7
November	8.4	6.7	10.1	6.4	4.5	8.3	7.1	5.2	9.0	7.6	5.7	9.6	7.6	5.6	9.7	7.9	6.2	9.5
December	9.1	7.4	10.8	6.1	4.2	8.0	7.1	5.2	9.0	7.7	5.7	9.6	7.8	5.8	9.9	7.4	5.8	9.1

Table 6. continued

Period	Dhaka for 2011			Khulna for 2011			Barisal for 2011			Sylhet for 2011			Chittagong for 2011			Rajshahi'2010		
	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)	PE	IE (L)	IE (U)
Jan	8.9	7.2	10.6	5.8	3.9	7.7	7.1	5.2	9.0	6.8	4.8	8.7	7.9	5.8	9.9	6.7	5.0	8.4
Feb	9.3	7.6	11.0	6.5	4.7	8.4	7.6	5.7	9.5	7.1	5.2	9.1	8.1	6.1	10.1	8.0	6.3	9.7
Mar	9.3	7.6	11.0	6.9	5.0	8.8	7.4	5.5	9.3	7.0	5.1	8.9	8.0	5.9	10.0	8.1	6.4	9.8
Apr	9.1	7.4	10.7	6.9	5.0	8.8	7.4	5.5	9.3	6.1	4.1	8.0	7.9	5.9	9.9	7.9	6.3	9.6
May	8.3	6.7	10.0	6.0	4.1	7.9	6.3	4.4	8.2	5.3	3.4	7.2	6.6	4.5	8.6	7.2	5.5	8.9
Jun	5.2	3.5	6.9	3.4	1.5	5.2	3.2	1.3	5.1	3.0	1.1	4.9	3.9	1.8	5.9	5.1	3.4	6.8
Jul	5.1	3.5	6.8	2.9	1.1	4.8	3.0	1.1	4.9	3.0	1.1	5.0	3.6	1.6	5.6	4.1	2.4	5.8
Aug	6.0	4.3	7.7	3.8	1.9	5.7	3.6	1.7	5.5	4.0	2.1	5.9	4.5	2.4	6.5	4.9	3.2	6.5
Sep	6.4	4.7	8.0	3.6	1.7	5.5	4.1	2.2	6.0	4.0	2.1	6.0	5.5	3.5	7.6	5.1	3.4	6.8
Oct	7.7	6.1	9.4	5.4	3.5	7.3	6.2	4.3	8.1	6.3	4.3	8.2	6.7	4.7	8.7	7.0	5.3	8.6
Nov	8.4	6.7	10.1	6.3	4.4	8.2	7.1	5.2	9.0	7.6	5.7	9.5	7.6	5.6	9.6	7.8	6.2	9.5
Dec	9.1	7.4	10.8	6.0	4.1	7.9	7.1	5.2	9.0	7.6	5.7	9.6	7.8	5.8	9.8	7.4	5.7	9.1

4. Conclusions

The foregoing analyses indicate that the annual and seasonal average ASSH follow significant negative trend in all the six stations with a few exceptions. The highest rate of annual ASSH is found in Dhaka (– 0.0443) where the residuals show nonstationarity but the lowest rate is experienced in Khulna (– 0.0157) where the residuals show nonnormality. The significant negative rate of annual ASSHs are found in Rajshahi (– 0.0185*), Barisal (– 0.0337*), Sylhet (– 0.0311*) and Chittagong (- 0.0267*). The Prekharif season in Khulna follow very slight positive trend. It is found insignificant but fairly high negative rates in Kharif ASSH of Khulna and Rajshahi, and in Rabi ASSH of Rajshahi. CV of annual ASSH follow significant positive trend in Dhaka and Barisal but it demonstrates very slight negative trend coefficients in rest of the four stations. The aforesaid forecasted values for monthly ASSH during 2008-2011are obtained from the best fitted ARIMA (autoregressive integrated moving average) models and these models are selected on the basis of minimum root mean square forecasting error for last two years of 24 observations amongst the set of models for a particular station. The selected models for Dhaka, Khulna, Rajshahi, Barisal, Sylhet and Chittagong are ARIMA(200)(111) $_{12}$, ARIMA(111)(111)$_{12}$, ARIMA(100)(111)$_{12}$, ARIMA(101)(011)$_{12}$, ARIMA(101)(111)$_{12}$ and ARIMA(100) (011)$_{12}$, respectively.

So, it can be concluded that the availability of sunshine-hour is decreasing which will definitely have some odd impacts on plant growth, yield and quality of its produce. Naturally it is the high time to explore new varieties of crops needing less sunshine-hour but will give the expected high yield and quality.

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Appendix 1: Standardized ARIMA Notations

The ARIMA models have a general form of p, d, q where p is the order of the standard autoregressive term AR, q is the order of the standard moving average term MA, and d is the order of differencing AR describes how a variable y_t such as sunshine-hour depends on some previous values y_{t-1}, y_{t-2} etc. while MA describes how this variable y_t depends on a weighted moving average of the available data y_{t-1} to $y_{t-n.}$ For example, for a one step ahead forecast (suppose: for t being September) with an AR-1, all weight is given to the sunshine-hour in the previous month (September), while with an AR-2 the weight is given to the sunshine-hour of the two immediately previous months (September and August). By contrast, with a MA-1, MA-2, a certain weight is given to the sunshine-hour of the immediately previous month (September), a smaller weight is given to the sunshine-hour observed two months ago (August) and so forth, i.e., the weights decline exponentially.

The combined multiplicative seasonal ARIMA (p, d, q) × 12 (P, D, Q) model gives the following:

$$\phi_p(B)\Phi_p(B^s)\nabla_s^D\nabla^d z_t = C + \theta_q(B)\Theta_Q(B^s)\varepsilon_t$$

The standard expression of ARIMA model where B denotes the backward shift operator where

$$-\phi_p(B) = 1 - \phi_1 B - \phi_2 B^2 - ... - \phi_p B^p$$

The standard autoregressive operator of order p

$$-\Phi_p(B^s) = 1 - \Phi_1 B - \Phi_2 B^2 - ... - \Phi_p B^{ps}$$

The seasonal autoregressive operator of order p

- ∇_s^D is the seasonal differencing operator of order D
- ∇^d is the differencing operator of order d
- y_t is the value of the variable of interest at time t
- $C = \mu\phi_p(B)\Phi_p(B^s)$ is a constant term, where μ is the true mean of the stationary time series being modeled. It was estimated from sample data using the approximate likelihood estimator approach.

$$-\theta_q(B) = 1 - \theta_1 B - \theta_2 B^2 - ... - \theta_q B^q$$

The standard moving average operator of order q

$$-\Theta_Q(B^s) = 1 - \Theta_1 B^1 - \Theta_2 B^2 - ... - \Theta_Q B^{QS}$$

The seasonal moving average operator of order Q

- $\phi_1, \phi_2, ..., \phi_p$; $\Phi_1, \Phi_2, ..., \Phi_p$; $\theta_1, \theta_2, ..., \theta_q$; $\Theta_1\ \Theta_2, ..., \Theta_Q$ are unknown coefficients that are estimated from sample data using the approximate likelihood estimator approach.
- ε_t is the error term at time at time t
- S is the annual period, i,e. 12 months

Thus, the multiplicative seasonal modeling approach with the general form of ARIMA (p, d, q) × S (P, D, Q) has been used in this paper. In this form, p is the order of the seasonal autoregressive term (ARS), Q is the order of the seasonal moving average term, D is the order of the seasonal differencing and s is the annual cycle (e.g, s = 12 using the monthly data). ARS describes how the variable y depends on y_{t-12} (ARS-1), y_{t-24} (ARS-2), etc., while MAS describes how y depends on a weighted moving average of the available data y_{t-12} to y_{t-12n}. For example, for a one step ahead forecast (suppose: for t being September and with an ARS-1, all weight is given to the sunshine-hour in the previous September while with an ARS-2, the weight is given to the September sunshine-hours 1 and 2 years ago. By contrast, with a MAS-1, MAS-2, the model gives a certain weight to September sunshine-hours 1 year ago, to the September sunshine-hours 2 years ago, and so on. These weights decline exponentially.