Evaluation of LARS-WG for generating long term data for assessment of climate change impact in Bihar

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ABSTRACT

Long term weather data is requisite to drive physically based hydrological and crop growth models to assess climate change impacts. However, lack of sufficient historical weather data many a times restrict use of these models. Realization of above facts has resulted in development of a range of weather generators such as WGEN, CLIGEN, ClimGen and LARS-WG. Any generator must be tested to ensure that the data that it produces is satisfactory for the purposes for which it is to be used. The aim of this paper is to test a commonly used weather generator, LARSWG (version 4.0) at three sites at Bihar. Statistical test were conducted, including *t*-test and *F*-test, to compare the differences between generated weather data versus 30 years observed weather data. In recent years the weather generators have also been employed to construct climate change scenarios for impact assessment. The results showed that the generated weather series was similar to the observed data for its distribution of monthly precipitation and its variances, monthly means and variance of minimum and maximum air temperatures.

Key words: Weather generators, weather data, climate change.

Weather is a key determinant in agricultural production, particularly in rainfed cropping systems commonly found in tropical and arid regions. Application of simulation models for agricultural systems requires observed long-term daily weather data. These requirements often include observed daily maximum and minimum air temperature and total precipitation (Kuchar, 2004). There is therefore a serious limit on the application of agricultural, hydrological and ecosystem simulation models if weather data are not directly available (Hoogenboom, 2000). Weather generators are now widely used by researchers, from many different backgrounds in conjunction with their impact models and are becoming a standard component of decision support systems in agriculture, environmental management and hydrology. Generators may not be used as supplied i.e. testing and validation for locations other than those for which they were developed and validated is necessary. The objective of this study is to test the weather Generator, LARSWG (version 4.0) in Bihar. Validation of this model at different sites will offer the opportunity to evaluate long-term effects of weather on crop yields, hydrological and ecosystem systems, which are impossible to evaluate with a limited observed record of historical data.

MATERIAL AND METHODS

LARS-WG (Long Ashton Research Station Weather Generator) (Semenov & Barrow, 2002) is a 'serial' type weather generator and uses semi-empirical distributions for the generation of lengths of wet and dry day series, daily precipitation and daily solar radiation and temperature. The simulation of precipitation occurrence is modeled as alternate wet and dry series, where a wet day is defined as a day with precipitation >0.0mm. Daily minimum and maximum temperatures are considered as stochastic processes with daily means and daily standard deviations conditioned on the wet or dry status of the day. The seasonal cycles of means and standard deviations are modeled by finite Fourier series of order 3 and the residuals are approximated by a normal distribution. In this paper an attempt has been made to test the applicability of a stochastic weather generator LARS-WG for generation of daily rainfall and temperature data for 30 years (1961-90) for different sites located in Bihar. The LARS-WG is tested for three sites (Pusa, Patna, and Madhepura) located in Bihar situated in the eastern part of India. Bihar has a sub-humid tropical climate with an average annual rainfall of 1235 mm, most of which is concentrated in the Indian southwest monsoon season of June to October. For each of the 3 sites, 30 years of daily data were generated using LARSWG. Observed daily data were first used to calculate site-specific parameters. These parameters were then used by LARS-WG to generate synthetic data series. The performance of the generator was tested using number of statistical tests such as t-test for monthly means, F-test for standard deviations, and the χ^2 test for goodness-of-fit to compare the probability distributions for the lengths of wet and dry series for each season and for the distribution of precipitation for each month. The percent difference (E) between observed (Obs) and simulated (Gen) mean monthly data was also calculated:

$$E\,(\%) = Gen\text{-}Obs/Obs*100$$

Table 1: Comparison of the observed and generated precipitation (mm), maximum and minimum temperature (°C) at Pusa

Pusa	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Precipitation						
Obs. Mean	13.7	12.4	7.6	17.4	64.3	136.2	347.2	307.7	251.1	79.5	7.5	3.1
Gen mean	14.3	9.0	4.2	15.6	47.0	130.3	344.4	283.1	280.2	98.6	20.3	17.6
Obs. Var.	20.99	12.97	11.79	21.67	49.76	85.09	171.2	200.43	141.25	106.33	14.91	5.47
Gen Var.	18.23	14.38	7.89	21.14	38.12	112.02	168.6	122.18	156.72	115.41	22.41	12.26
% difference of mean	4.4	-27.4	-44.7	-10.3	-26.9	-4.3	-0.8	-8.0	11.6	24.0	170.7	467.7
p-value for t-test	0.906	0.34	0.194	0.746	0.136	0.819	0.949	0.568	0.453	0.508	0.012	0.000
p-value for F-test	0.452	0.582	0.034	0.895	0.157	0.145	0.935	0.01	0.579	0.662	0.032	0.000
						Maximum Temperature						
Obs. Mean	22.9	25.8	31.6	36.1	36.6	35.4	32.6	32.5	32.5	31.9	28.9	24.6
Gen mean	23.1	26.1	31.5	35.9	36.8	34.9	33.3	32.1	32.4	31.7	28.9	24.3
Obs. Var.	1.08	1.41	1.27	1.7	1.79	1.69	0.99	0.77	0.76	1.24	0.96	0.96
Gen Var.	0.81	1.16	0.99	1.07	1.71	1.41	0.91	0.71	0.84	0.83	0.64	0.83
% difference of mean	0.9	1.2	-0.3	-0.6	0.5	-1.4	2.1	-1.2	-0.3	-0.6	0.0	-1.2
p-value for t-test	0.42	0.372	0.735	0.588	0.66	0.218	0.006	0.041	0.631	0.466	1.0	0.201
p-value for F-test	0.127	0.299	0.186	0.015	0.807	0.335	0.653	0.665	0.593	0.034	0.033	0.438
						Minimum Temperature						
Obs. Mean	7.6	9.8	14.5	20	23.2	24.8	24.8	24.9	24.7	21.1	14.1	9
Gen mean	7.5	9.8	14.5	19.5	23.2	24.6	24.8	24.5	24.3	21	14.3	9.3
Obs. Var.	1.24	1.63	1.49	1.61	1.96	1.54	1.82	1.6	1.59	2.05	1.89	1.47
Gen Var.	1.2	1.28	1.38	1.36	1.57	1.4	1.22	1.36	1.07	1.68	1.21	1.26
% difference of mean	-1.3	0.0	0.0	-2.5	0.0	-0.8	0.0	-1.6	-1.6	-0.5	1.4	3.3
p-value for t-test	0.752	1	1	0.199	1	0.601	1	0.301	0.258	0.837	0.627	0.4
p-value for F-test	0.861	0.199	0.682	0.369	0.238	0.611	0.035	0.387	0.037	0.289	0.019	0.411

A probability of 0.05 or lower indicates a departure from the observation that is significant at 5% level.

RESULTS AND DISCUSSION

Precipitation and temperature were tested in two ways by comparing: (1) the monthly means using the *t*-test and (2) the monthly variance using the *F*-test. Probability levels (p-value) calculated by the **t**-test and **F**-test for the monthly means and variance, and percent difference (negative values show model underestimation) are shown. LARSWG performed well in simulating the range of monthly mean precipitation and temperature values at the test sites.

Pusa: Table 1. summarizes the outcome of the series of statistical comparisons for Pnsa. The results show that LARSWG generated the monthly means for both Tmin and Tmax with an over and under-estimation range of -0.3 to 2.1% for maximum temperature and -0.3 to 3.3% for minimum temperature. Mean monthly rainfall is overestimated during September to January months whereas; it is underestimated for rest of the months. The *t*-test (5% level of significance) indicated there is no significant difference between generated values and observed data apart for monthly means of precipitation at Pusa except during November-December.

Patna: At Patna, percent difference of generated and observed values for mean monthly rainfall ranges from -4.5 (October) to 58.7% (December). For three months (Feb, June and October) rainfall is underestimated and overestimated for other months. For April month, where the least difference of generated and observed rainfall is noticed (1.7 mm) highest probability (p for t-test values is attained. As temperature is concerned, September and July months showed no difference of observed and generated maximum temperature and minimum temperature respectively with (p for t-test = 1.0) as presented in Table 2. Probability value more than 0.90 shows a good agreement between observed and generated values. Although rainfall is overestimated for the most of the months, yet no significant difference at 5% level of significant is found between observed and generated mean. For maximum temperature also no significance difference is there between observed and generated means but minimum temperature generated is significantly different for April month at Patna.

Madhepura: In Madhepura rainfall is underestimated in seven months out of 12 months but highest value of difference (-4.19) is observed for December month with zero value of p for t-test and F-test (Table 3). For March, April and December months significant differences are recorded between observed and generated rainfall at 5% level of significance. Maximum temperature and minimum temperature

Table 2 : Comparison of the observed and generated precipitation (mm) and maximum and minimum temperature (°C) at Patna.

Pusa	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation												
Obs. Mean	11.5	14.7	10.2	11.7	43.2	120.6	367.4	255.6	207	95.4	8	4.6
Gen mean	14.2	8.8	9.6	11.9	50	102.6	377.6	261.6	210.9	91.1	9.8	7.3
Obs. Var.	10.93	18.06	14.29	15.4	37.33	79.36	171.71	122.15	126.57	100.2	16.94	6.09
Gen Var.	14.96	15.4	11.81	18.53	43.67	77.73	128.33	107.7	110.45	68.77	16.55	8.87
% difference of mean	23.5	-40.1	-5.9	1.7	15.7	-14.9	2.8	2.3	1.9	-4.5	22.5	58.7
p-value for t-test	0.428	0.179	0.86	0.964	0.519	0.378	0.795	0.841	0.899	0.847	0.679	0.175
p-value for F-test	0.096	0.396	0.31	0.325	0.403	0.912	0.123	0.502	0.468	0.047	0.901	0.047
Maximum temperature												
Obs. Mean	22.7	25.7	31.7	36.6	37.2	35.9	32.6	32.2	32	31.1	28.5	24.2
Gen mean	23	25.9	31.3	36.2	37.5	35.6	32.8	32.1	32	31.3	28.2	24.4
Obs. Var.	1.01	1.41	1.32	1.68	2.08	2.07	1.18	0.62	0.83	0.92	0.81	0.95
Gen Var.	0.75	0.93	1.19	1.09	1.44	1.36	0.87	0.6	0.77	0.7	0.57	0.99
% difference of mean	1.3	0.8	-1.3	-1.1	0.8	-0.8	0.6	-0.3	0.0	0.6	-1.1	0.8
p-value for t-test	0.197	0.519	0.223	0.278	0.519	0.51	0.458	0.528	1.0	0.347	0.103	0.428
p-value for F-test	0.115	0.028	0.58	0.023	0.052	0.027	0.106	0.861	0.689	0.147	0.063	0.826
Minimum temperature												
Obs. Mean	8.5	10.7	15.4	21.5	24.6	26.2	25.9	25.9	25.2	21.6	14.7	9.5
Gen mean	8.6	10.6	15.2	20.9	24.7	25.9	25.9	26	25.1	21.4	14.8	10.1
Obs. Var.	1.25	1.21	0.89	0.91	0.77	0.74	0.71	0.74	0.64	1	1.55	1.54
Gen Var.	0.84	0.9	0.9	0.85	0.52	0.57	0.4	0.35	0.54	0.69	0.76	0.92
% difference of mean	1.2	-0.9	-1.3	-2.8	0.4	-1.1	0.0	0.4	-0.4	-0.9	0.7	6.3
p-value for t-test	0.717	0.718	0.39	0.011	0.558	0.084	1.0	0.506	0.516	0.371	0.752	0.072
p-value for F-test	0.036	0.117	0.952	0.716	0.038	0.166	0.003	0.0	0.366	0.05	0	0.007

Table 3 : Comparison of the observed and generated precipitation (mm) maximum and minimum temperature (°C) at Madhepura.

Pusa	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation												
Obs. Mean	8.8	5.5	24.5	40.7	88.1	195.9	299.5	213.9	180	58.9	15.7	2.5
Gen mean	15.8	2.2	12.5	22.2	63.5	203.1	321.4	205.9	205.4	79.8	18.5	11.5
Obs. Var.	15.68	10.32	27.06	40.03	75.82	116.21	177.47	105.73	172.48	73.77	41.86	4.89
Gen Var.	15.9	7.02	14.52	30.11	55.69	93.13	145.64	90.1	105.61	81.76	30.53	10.71
% difference of mean	-1.72	1.45	2.14	2.02	1.43	-0.26	-0.52	0.32	-0.69	-1.04	-0.3	-4.19
p-value for t-test	0.091	0.153	0.037	0.048	0.157	0.792	0.603	0.754	0.494	0.303	0.768	0
p-value for F-test	0.941	0.042	0.001	0.131	0.102	0.239	0.293	0.394	0.01	0.583	0.095	0
Maximum temperature												
Obs. Mean	8.2	10.1	14.3	19.5	22.3	24.5	24.8	25	24.7	21.1	14.3	9.3
Gen mean	8.2	10.2	14.1	19.2	22.5	24.4	24.5	25.1	24.7	21	14.5	9.6
Obs. Var.	0.99	1.19	1.44	1.95	1.86	1.49	1.43	1.28	1.39	1.64	1.34	1.37
Gen Var.	0.98	0.96	1.32	0.9	1.02	0.84	0.8	0.65	0.84	0.96	0.98	0.83
% difference of mean	0	-0.36	0.56	0.77	-0.52	0.32	1	-0.38	0	0.29	-0.66	-1.03
p-value for t-test	1	0.721	0.577	0.447	0.608	0.75	0.32	0.704	1	0.774	0.512	0.309
p-value for F-test	0.957	0.253	0.642	0	0.002	0.003	0.003	0	0.008	0.005	0.097	0.009
Minimum temperature												
Obs. Mean	22.9	25.7	30.9	34.5	34.3	33.6	31.6	31.7	31.7	30.7	28.1	24.7
Gen mean	23.3	25.8	30.3	34.5	34.5	33.4	32	31.6	31.6	30.9	28.1	24.7
Obs. Var.	0.82	0.87	1.37	1.93	1.62	1.24	0.91	0.67	0.84	0.74	0.57	0.55
Gen Var.	0.68	0.56	1.07	1.11	0.98	0.81	0.6	0.75	0.77	0.59	0.59	0.56
% difference of mean	-2.06	-0.53	1.89	0	-0.58	0.74	-2.01	0.54	0.48	-1.16	0	0
p-value for t-test	0.044	0.599	0.064	1	0.565	0.463	0.049	0.588	0.633	0.252	1	1
p-value for F-test	0.319	0.021	0.189	0.004	0.009	0.025	0.028	0.547	0.642	0.228	0.854	0.923

are generated with no difference from observed for January and September in case maximum temperature and during April, November-December for minimum temperature.

Mean monthly temperature (minimum and maximum) is better simulated as compared to monthly variance as shown by significant figures of difference between observed and generated values for Pusa, Patna and Madhepura. More number of significant figures denote lesser similarity between observed and generated values.

Chi-Square test for monthly rainfall distribution which tells how rainfall is distributed between months showed that during September and December months the probability of χ^2 tests is high. For Pusa and Madhepura, 7 and 8 months respectively out of 12 showed a close agreement between observed and generated values with high probability. Temperature is better simulated than rainfall may be due to discontinuous data of daily rainfall. Based on the results from this study, it can be concluded that LARSWG performs satisfactorily in the simulation of weather parameters in Bihar.

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