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Assessment of Solar Energy with Respect to Bihar: A Case Study

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ABSTRACT

A well-known statistical simulation method known as ARIMA was employed in this article to forecast the total daily solar energy output till the year 2040. The ARIMA model's attractiveness resides in its simplicity, solar energy, which is created by sunshine, is a non-depleting renewable energy source that is unpolluting. The amount of solar energy that enters the earth every hour is sufficient to supply all of the energy needed for a year. In the modern period, we required electricity constantly. This solar energy is produced for use in commercial, industrial, and residential settings. It is simple to collect energy from direct sunshine. As a result, it is incredibly effective and does not pollute the environment. In this paper, we evaluated solar energy from sunlight and forecasted the sun radiation till 2040 through ARIMA Model.The model is created using sophisticated statistical approach. Error analysis is performed to demonstrate the effectiveness of the proposed method. The developed model's accuracy can be improved in future research.

Key words: *Arima, Forecast, Sunshine, Statistical approach.*

Introduction

Regarding many domains, the term "energy" has several diverse meaning. We all rely heavily on energy to do our everyday tasks because it is the capacity to conduct work (Schlor, Hogler, *et al.*, 2012). Energy cannot be generated or destroyed but can only be changed from one form to another, according to the rule of conservation of energy. Energy never runs out; it merely shifts from one form to another (Rashidi *et al*., 2012). Energy is inextricably related to the century's economic progress and growth. The usage of energy has become a key component of current development programs that have prioritized rapid economic expansion (Khan *et al.*, 2019). Most of the energy utilized for labour in many nations comes from non-renewable sources, such as gasoline, nuclear power, coal, and natural gas (Shrish Bajpai *et al.*, 2016). Renewable resources have a nearly endless lifespan but have a finite amount of energy per unit. Biomass, Hydropower, Geothermal, Wind, and Solar are the five main categories of renewable energy sources. The majority of energy utilized for work in many nations comes from non-renewable energy sources, such as gasoline, nuclear energy, coal, natural gas, etc. (Shrish Bajpai *et al.*, 2016). The average daily energy usage of a person in India is still only 18 kWh, according to data from 2020 on energy consumption (BP) and population (PRB). But with 77 kWh, China is already consuming more energy than the rest of the globe and will in a few decades use roughly the same amount as industrialized nations do. In 2020, the world's population of around 7.7 billion people

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consumed 71,4 GJ of primary energy per person. It indicates a 58 kWh daily primary energy usage average per person across the globe. The past 10 years are now more significant for the per-watt cost of solar energy devices due to the diminishing availability of renewable energy sources. It will undoubtedly become economically viable in better technology in terms of both price and applications in the upcoming years. The earth receives sunlight on a daily basis (around 1366W). This energy source can be used endlessly and is totally free. The primary advantage of solar energy over other conventional power sources is that it can be produced using the tiniest photovoltaic (PV) solar cells, which allow sunlight to be directly transformed into solar energy. Many research projects have been conducted to combine the Sun's energy conversion process by creating solar cells, panels, and modules with high conversion rates. The greatest benefit of solar energy is that it is inexpensive, accessible to the general public, and abundant when compared to the cost of various fossil fuels and oils throughout the previous 10 years. Moreover, compared to traditional energy production technology, solar energy requires a lot less human costs. Any nation or state needs energy in order to prosper economically. The situation is the same in the state of Bihar in eastern India. The state has experienced encouraging growth in recent years and is poised to make major economic progress in the next years. At this point, Bihar needs to fullfill the power requirement with a strong political resolve in order to advance its progress. However, due to its position, climate, and geographical features, Bihar possesses a number of natural and strategic advantages. In the upcoming years, the state's strong solar energy potential may serve as its primary energy source. Since Bihar is predominantly an agriculturally based state, it has a significant potential for creating agricultural waste that might serve as an excellent starting point for the production of energy. Additionally, the state's northern regions have excellent potential for small-scale wind and hydropower. There are 45,098 villages in the 94,163 square kilometre state of Bihar, which has a population of 82.9 million. 12.6 million Households, or almost 89 percent of the population, live in rural areas. The State has a population density of 881 people per square kilometer, which is higher than the national average of 312. Bihar has several resources particularly fertile soils, favourable climate, and enough ground water for the cultivation of a wide range of crops. Bihar has experienced more growth in the past ten years as a result of these innate natural qualities and a strong political resolve. The post-bifurcation electricity availability situation in Bihar in 2000 became extremely precarious because major power facilities were located in the newly formed State of Jharkhand. Under the current context of constrained demand, the peak capacity of Bihar's power system is approximately 1,500 MW, while the available capacity is approximately 950 MW. All consumer categories experience widespread power restriction as a result of the scenario. Currently, just 6% of homes and 50% of the communities in the country have access to electricity state. Demand for electricity is currently 95 units per person per year in Bihar (compared to 717 units nationally). In India, the annual growth rate of electricity is thought to be around 8%. Bihar's estimated percentage is 14%. The projections are based on optimistic program acceleration for domestic household electrification, which results in a domestic consumption growth rate of 27% compounded annually. The energy requirement has been calculated to be 2.5 times greater than what it was in 2004-2005 for normal hours and peak load growth.Various periods of the year, scientists measure the amount of sunshine that strikes particular regions. The amount of sunshine that strikes areas with comparable climates and latitudes is then estimated. Total radiation on a horizontal surface or total radiation on a surface that tracks the sun are the two common ways that solar energy is measured. Kilowatt-hours per square meter (kWh/m^2) are frequently used to express radiation statistics for solar electric (photovoltaic) systems. Watts per square meter (W/m^2) can also be used to indicate direct estimations of solar energy. British thermal units per square foot (Btu/ft2) are the standard unit of measurement for radiation data for solar water heating and space heating systems. Efficiently and rapidly deliver your material based on the global distribution map annual solar radiation the average annually amount of PV energy that can be generated is 640-2400 kwh/m^2 depending on areas. The model is created using sophisticated statistical approache Time series approaches are highly studied in forecasting and are constantly being improved. ARIMA, which stands for Autoregressive Integrated Moving Average, is one of the most well-studied models in this field. The reasons for the popularity are the ease of installation and the usage of the well-known Box-Jenkins methodology. This ease of use is due to the linear correlation assumption between past and present time series values.

Bihar

There are 45, 098 villages in the 94,163 square kilometer state of Bihar, which has a population of 82.9 million. 12.6 million households, or almost 89 percent of the population, live in rural areas. Compared to the national average of 312 people per square kilometer, the State has a population density of 881 people. For the production of a wide range of crops, Bihar is blessed with a very fertile soil, favourable weather conditions, and ample groundwater. Due to these innate natural advantages and a strong political resolve, Bihar has experienced faster growth than the rest of the country during the past ten years. During the period 2000-2010, the state's decadal growth rate was roughly 28.23%, compared to the national average of 21.54. However, about 95% of rural homes still rely on kerosene as a source of lighting, which is a large proportion when compared to that in metropolitan regions (40%) according to the 2001 census. In Bihar, which ranks second on the list of states with the least electrification after Jharkhand, transmission cables have still not reached 50% of the inhabited villages, according to the Rural Electrification Corporation Ltd. Report 2004.

Materials and Methods

- Autoregressive integrated moving average (ARIMA) models predict future values based on past values.

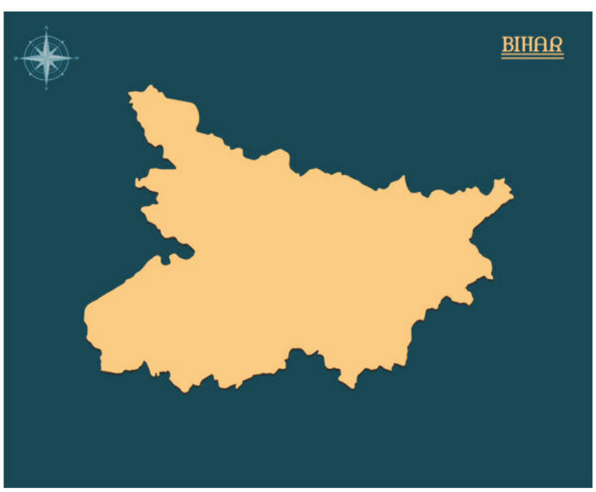


Fig: Bihar Map Source internate

- ARIMA makes use of lagged moving averages to smooth time series data.
- Autoregressive models implicitly assume that the future will resemble the past

FLOWCHART OF ARIMA MODEL

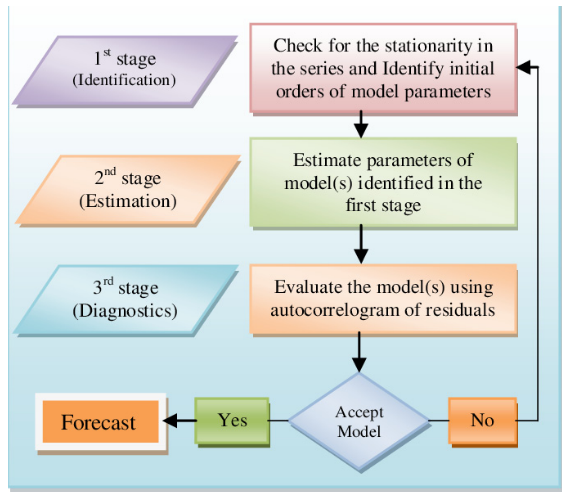


Fig. Flowchart of Arima Model

Annual solar radiation forecasting using B-J methodology

ADF in level form
ADF in first difference
Null Hypothesis: ANNSR has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.683357	0.0031
Test critical values:	1% level	-4.226815	
	5% level	-3.536601	
	10% level	-3.200320	

*MacKinnon (1996) one-sided p-values.

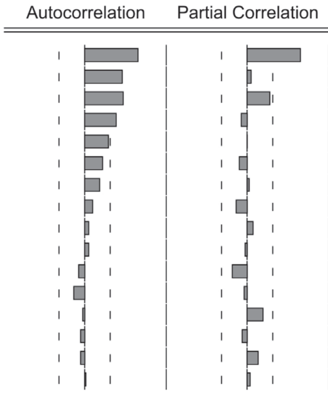
Here p-value is significant at 5 per cent.

This data set is stationary in level form. So here ARMA model is utilised for forecasting.

Correlorgam in level for identification of best ARMA (p, q) model.

The Correlorgam suggest four ARMA model: ARMA (1, 1), (1, 2), (1, 3) and (1, 4). After estimating all this models we forecast the model with satisfying all the necessary criterion. We select one best model on the basis of higher R-square, lower Akaike

Date: 09/03/23 Time: 20:47
Sample: 1984 2021
Included observations: 38



Lag	AC	PAC	Q-Stat	Prob
1	0.674	0.674	18.638	0.000
2	0.479	0.047	28.331	0.000
3	0.498	0.291	39.100	0.000
4	0.409	-0.066	46.586	0.000
5	0.307	0.003	50.927	0.000
6	0.223	-0.099	53.298	0.000
7	0.185	0.030	54.980	0.000
8	0.092	-0.136	55.408	0.000
9	0.057	0.066	55.576	0.000
10	0.052	-0.021	55.724	0.000
11	-0.082	-0.183	56.102	0.000
12	-0.143	-0.034	57.290	0.000
13	-0.029	0.199	57.342	0.000
14	-0.045	-0.058	57.467	0.000
15	-0.052	0.133	57.644	0.000
16	0.014	0.034	57.658	0.000

info criterion and lower Schwarz criterion.

Result of ARMA (1, 1) estimates:

Dependent Variable: ANNSR
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 09/03/23 Time: 20:52
Sample: 1984 2021
Included observations: 38
Convergence achieved after 11 iterations
Coefficient covariance computed using outer product of gradients

ARMA (1, 2) estimates:

Dependent Variable: ANNSR
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 09/03/23 Time: 20:54
Sample: 1984 2021
Included observations: 38
Convergence achieved after 21 iterations
Coefficient covariance computed using outer product of gradients

ARMA (1, 3) estimates:

Dependent Variable: ANNSR
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 09/03/23 Time: 20:56
Sample: 1984 2021
Included observations: 38
Convergence achieved after 18 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.791128	0.243966	19.63850	0.0000
AR(1)	0.952984	0.075128	12.68482	0.0000
MA(1)	-0.501876	0.193038	-2.599882	0.0137
SIGMASQ	0.018697	0.004317	4.331515	0.0001
R-squared	0.556517	Mean dependent var	4.820263	
Adjusted R-squared	0.517386	S.D. dependent var	0.208086	
S.E. of regression	0.144558	Akaike info criterion	-0.894732	
Sum squared resid	0.710503	Schwarz criterion	-0.722355	
Log likelihood	20.99991	Hannan-Quinn criter.	-0.833402	
F-statistic	14.22195	Durbin-Watson stat	1.732040	
Prob(F-statistic)	0.000004			

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.798315	0.139276	34.45190	0.0000
AR(1)	0.857082	0.108750	7.881184	0.0000
MA(2)	-0.284913	0.172559	-1.651100	0.1079
SIGMASQ	0.019445	0.004237	4.589569	0.0001
R-squared	0.538786	Mean dependent var	4.820263	
Adjusted R-squared	0.498091	S.D. dependent var	0.208086	
S.E. of regression	0.147420	Akaike info criterion	-0.864759	
Sum squared resid	0.738910	Schwarz criterion	-0.692381	
Log likelihood	20.43042	Hannan-Quinn criter.	-0.803428	
F-statistic	13.23950	Durbin-Watson stat	2.320739	
Prob(F-statistic)	0.000007			

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.798707	0.120341	39.87581	0.0000
AR(1)	0.631016	0.126498	4.988343	0.0000
MA(3)	0.658308	0.257521	2.556329	0.0152
SIGMASQ	0.016185	0.003362	4.813409	0.0000
R-squared	0.616113	Mean dependent var	4.820263	
Adjusted R-squared	0.582241	S.D. dependent var	0.208086	
S.E. of regression	0.134495	Akaike info criterion	-1.009013	
Sum squared resid	0.615024	Schwarz criterion	-0.836635	
Log likelihood	23.17124	Hannan-Quinn criter.	-0.947682	
F-statistic	18.18927	Durbin-Watson stat	1.887188	
Prob(F-statistic)	0.000000			

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.798493	0.101593	47.23242	0.0000
AR(1)	0.694575	0.114548	6.063636	0.0000
MA(4)	0.167035	0.182969	0.912918	0.3677
SIGMASQ	0.020166	0.005122	3.937203	0.0004
R-squared	0.521680	Mean dependent var	4.820263	
Adjusted R-squared	0.479475	S.D. dependent var	0.208086	
S.E. of regression	0.150129	Akaike info criterion	-0.833026	
Sum squared resid	0.766316	Schwarz criterion	-0.660648	
Log likelihood	19.82749	Hannan-Quinn criter.	-0.771695	
F-statistic	12.36069	Durbin-Watson stat	2.083802	
Prob(F-statistic)	0.000013			

Coefficient covariance computed using outer product of gradients

ARMA (1, 4) estimates:

Dependent Variable: ANNSR
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 09/03/23 Time: 20:58
Sample: 1984 2021
Included observations: 38
Convergence achieved after 16 iterations
Coefficient covariance computed using outer product of gradients

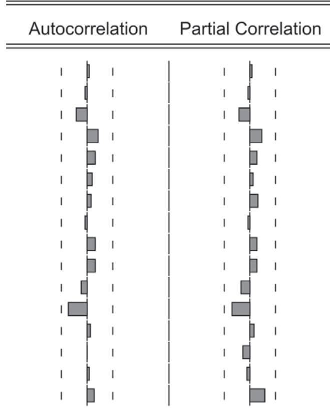
After comparing all these ARMA estimates.

We have ARMA (1, 3) estimates is best estimates. It's all coefficients are statistically significant and higher R-square value. No we forecast on the bases of this model with satisfying all criterion.

Stationarity of residual of ARMA (1, 3) estimates:

Residual are stationary. As all the p-value in the correlogram are insignificant, so we accept the null hypotheses and conclude that the residuals are white noise.

Date: 09/03/23 Time: 21:04
Sample: 1984 2021
Included observations: 38
Q-statistic probabilities adjusted for 2 ARMA terms



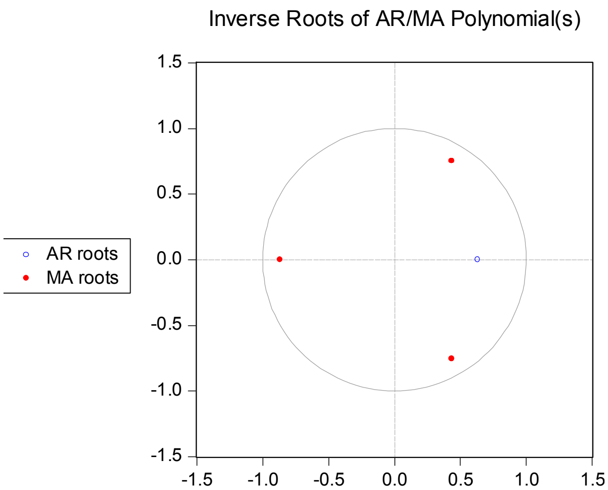
	AC	PAC	Q-Stat	Prob
1	0.032	0.032	0.0418	
2	-0.017	-0.018	0.0533	
3	-0.138	-0.137	0.8837	0.347
4	0.144	0.156	1.8144	0.404
5	0.098	0.086	2.2595	0.520
6	0.058	0.037	2.4221	0.659
7	0.050	0.094	2.5444	0.770
8	-0.021	-0.023	2.5665	0.861
9	0.093	0.087	3.0203	0.883
10	0.090	0.088	3.4638	0.902
11	-0.068	-0.116	3.7234	0.929
12	-0.235	-0.228	6.9456	0.731
13	0.033	0.044	7.0116	0.798
14	-0.002	-0.087	7.0120	0.857
15	0.028	-0.035	7.0653	0.899
16	0.087	0.188	7.5908	0.910

AR and MA roots are also within the range. Now we can go for forecasting

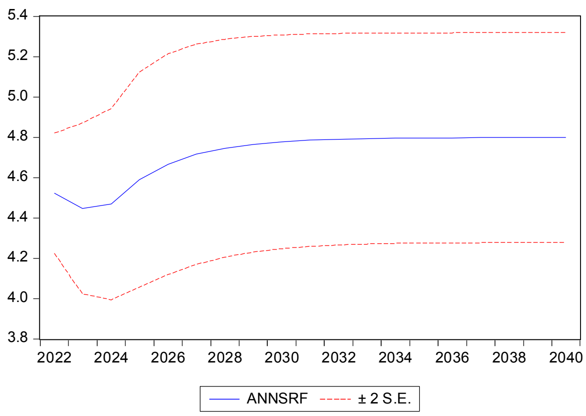
forecasted graph for ANNSR

Forecasted dataset are available in excel sheet

The graph above displays the shortwave downward irradiance (Kw-hr/m^2/day) year over year.



The graph clearly demonstrates that the line of the



graph has no significant deviation. The information regarding solar radiation till 2022 came from the NASA website and from 2022 till 2040 we have forecasted the sun radiation through ARIMA Model.

Conclusion

After comparing all these ARMA estimates. We have ARMA (1, 3) estimates is best estimates. Its all coefficients are statistically significant and higher R-square value. The potential for renewable energy technology in rural Bihar is enormous. Numerous devices used in the agriculture sector are powered by non-renewable energy sources. In the same way that we can power engines to pump water for irrigation in fields using solar energy.. There are numerous pricey government programs for domestic purposes that people should take advantage of and employ to meet their everyday necessities by the renewable energy sources, of energy. In Bihar, all bachelor's degrees should include a course on renewable energy technology and should include a lesson on renewable energy as a subject. Promoting and raising student understanding of the use of renewable resources should be required in all institutions (Shrish Bajpai *et al*., 2016) for raising awareness among Bihar's rural population.

Conflict of interest

None

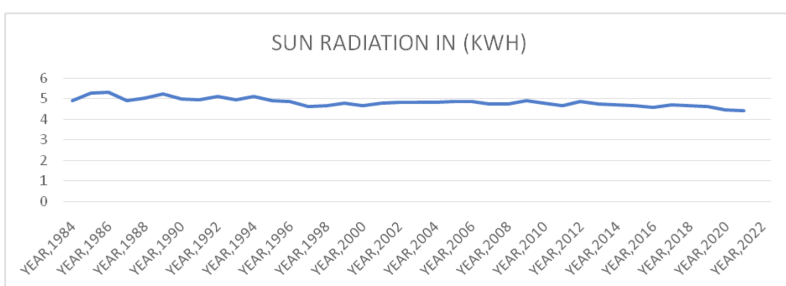


Fig. Sun Radiation Downloaded from NASA

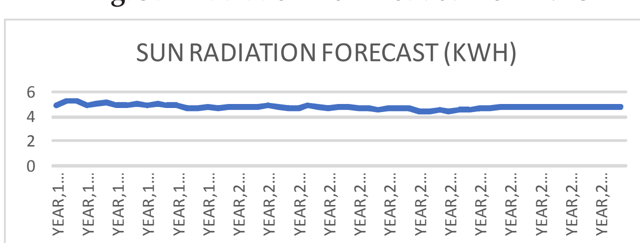


Fig. Forecasted Sun Radiation

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