Chapter 4 : Resources estimation and mapping – solar

This chapter presents development of artificial neural network (ANN) model to predict the solar energy potential within AP and TS. Generalized Feed-forward with Back-Propagation Neural Networks (FBPNN) were considered using MATLAB. Three layered neural network with different architectures is designed and evaluated. Geographical parameters, such as latitude, longitude, and altitude and meteorological parameters, such as temperature, sunshine duration, relative humidity and precipitation were used as input data, whereas the mean solar radiation was used as the output of the network. The first section presents details of data collection and its analysis. Then the development and optimization of ANN for prediction of solar radiation is discussed. This is followed by the mapping of solar radiation over AP and TS using GIS approach. These maps are used to identify the regions with higher solar potential. Finally, available ideal land area within the region of higher solar potential to install PV panels is estimated using remote sensing map.

4.1 Data collection

To develop ANN model, 28 locations within AP and TS with an interval of one degree in latitude and one degree in longitude were considered. Meteorological data was obtained from NASA geo-satellite database for all specified locations pertaining to the period of 22 years (1983 - 2005), as shown in Appendix-IV. Five meteorological parameters: temperature, sunshine duration, relative humidity, precipitation, and solar radiation were considered for developing the model. These five parameters were obtained at 28 locations over 22 years for 12 months, as monthly mean values. Therefore, each station has 1,320 data value and 36,960 in total for 28 locations. Three sets of data were made, consisting data of 20, 4 and 4 locations. The first data set with 20 locations was used to train the model, second data set with 4 locations was used to validate the model and third data set with 4 locations was used to check the accuracy of the model. Every location has meteorological data for 12 months. Each input data set for the model has a combination of three geographical coordinates (latitude, longitude, and altitude), month, and four meteorological data (mean temperature, mean sunshine duration, mean relative humidity, and mean precipitation). In total, there were eight data in each input data set which correspond to one output as solar radiation. Therefore, the model was trained and validated with 288 data set and tested with 48 data set. Each data set consists of eight input and one output, making a total of nine data values.

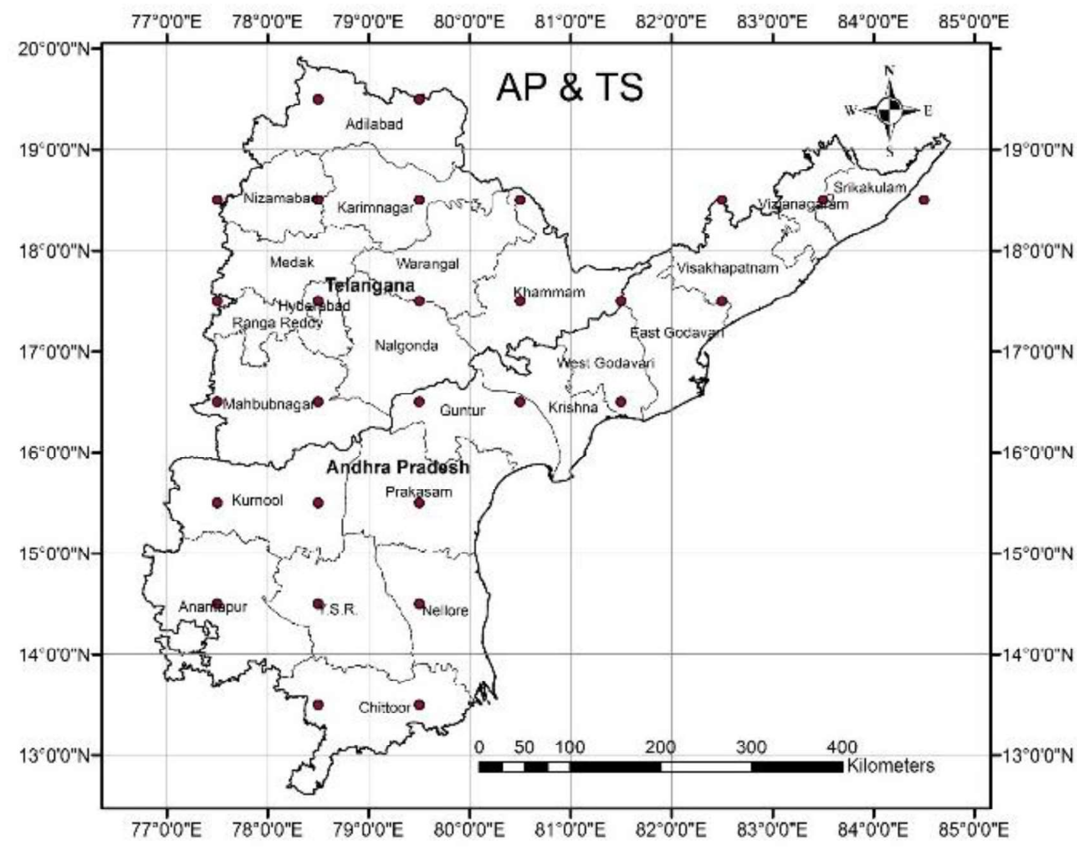


Figure 4.1. Locations of the stations on AP and TS map used to develop ANN model.

In order to evaluate the prediction ability of the model at new locations, data for test location was separated from training and validation data taken to develop the model. The geographical map of AP and TS with location of stations for which the data was obtained as shown in Figure 4.1. The geographical parameters of these stations are given in Table 4.1. The mean sunshine durations for all stations are shown in Figure 4.2 and the mean solar radiation data for all stations is presented in Table 4.2.

Table 4.1. Geographical parameters of data stations.

St.No.	Latitude (Degree)	Longitude (Degree)	Altitude (Meter)	St.No.	Latitude (Degree)	Longitude (Degree)	Altitude (Meter)
1	19.5	78.5	345	15	17.5	82.5	245
2	19.5	79.5	293	16	16.5	77.5	433
3	18.5	77.5	461	17	16.5	78.5	366
4	18.5	78.5	390	18	16.5	79.5	219
5	18.5	79.5	298	19	16.5	80.5	107
6	18.5	80.5	287	20	16.5	81.5	67
7	18.5	82.5	461	21	15.5	77.5	418
8	18.5	83.5	264	22	15.5	78.5	327
9	18.5	84.5	113	23	15.5	79.5	173
10	17.5	77.5	479	24	14.5	77.5	514
11	17.5	78.5	406	25	14.5	78.5	374
12	17.5	79.5	277	26	14.5	79.5	183
13	17.5	80.5	197	27	13.5	78.5	466
14	17.5	81.5	199	28	13.5	79.5	224

1-Adilabad, 2-Hudkili, 3-Nanded, 4-Nizamabad, 5-Peddapalle, 6-Khammam, 7-Vishakhapatnam, 8-Koratam, Andhra Pradesh, 9-Devunalthada, 10-Bidar, 11- Secunderabad, 12-Warangal, 13-Karivarigudem, 14-Kondepudi, 15-Kakinada, 16-Makthal, 17-Nagarkurnool, 18-Narasaraopet, 19-Guntur,20-Anakoderu, 21-Dudekonda, 22-Nandyal, 23-Ongole, 24-Palacherla, 25-Animela, 26-Billupadu, 27-Madanapalle Rural, 28-Chittoor.

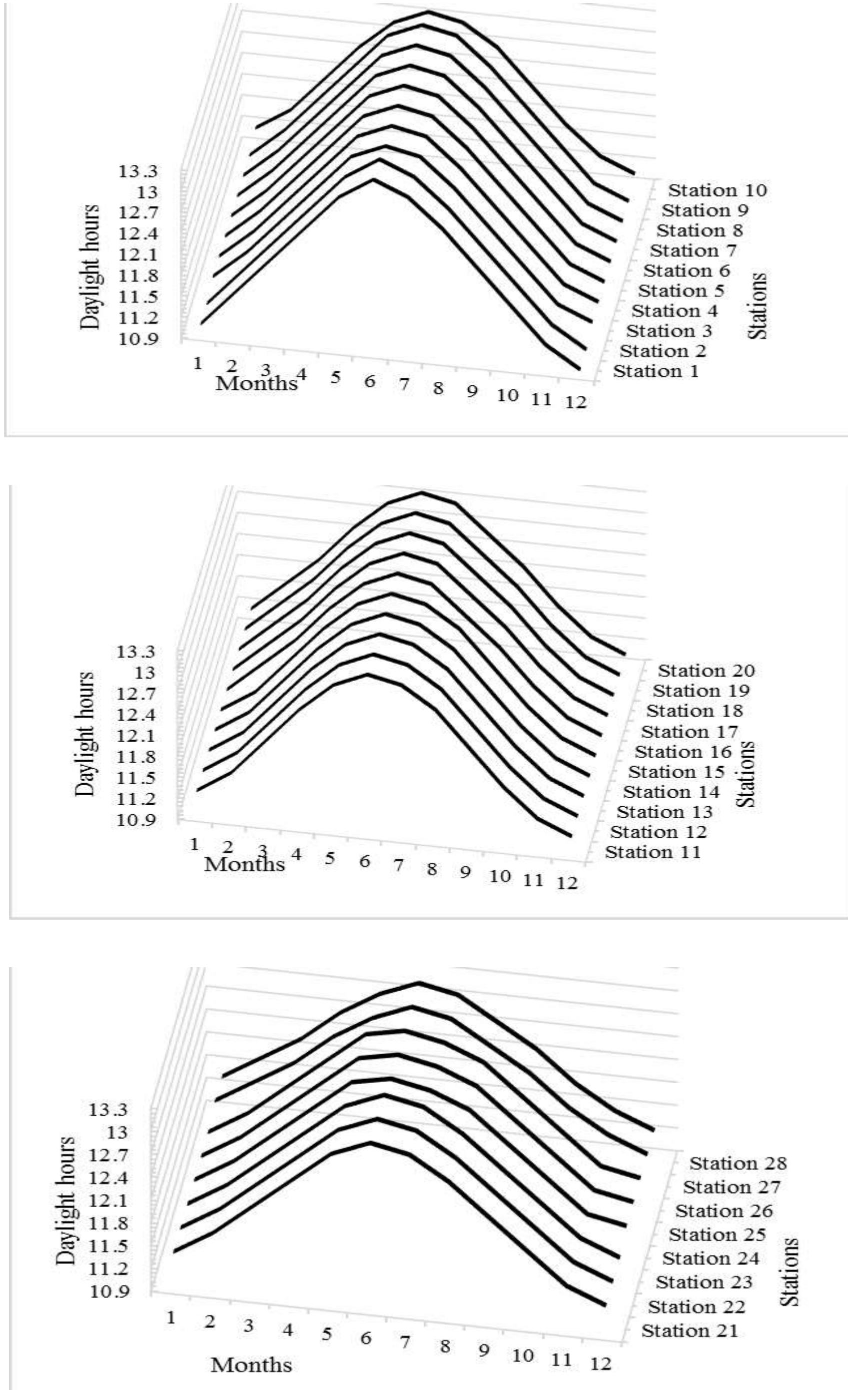


Figure 4.2. (a) Sunshine durations for stations number 1 to 10, (b) Sunshine durations for stations number 11 to 20, and (c) Sunshine durations for stations number 21 to 28.

Table 4.2. Monthly mean solar radiation (kWh/m^2) at 28 data stations.

St. No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	4.88	5.73	6.34	6.68	6.59	4.83	4.04	3.84	4.67	5.07	4.93	4.71
2	4.80	5.65	6.23	6.64	6.51	4.76	3.91	3.77	4.59	5.01	4.91	4.66
3	5.05	5.88	6.40	6.65	6.58	5.01	4.23	4.16	4.79	5.09	5.01	4.78
4	4.98	5.78	6.39	6.66	6.48	4.83	4.19	4.05	4.67	5.00	4.91	4.72
5	4.87	5.67	6.37	6.65	6.38	4.80	4.09	3.97	4.59	4.96	4.90	4.72
6	4.86	5.63	6.29	6.68	6.40	4.58	3.81	3.64	4.44	4.84	4.93	4.75
7	4.97	5.78	6.23	6.61	6.21	4.26	3.40	3.31	4.08	4.68	4.74	4.70
8	4.81	5.53	6.03	6.30	6.03	4.25	3.64	3.60	4.12	4.53	4.51	4.53
9	4.75	5.50	6.22	6.54	6.19	4.55	4.07	4.05	4.36	4.58	4.43	4.45
10	5.15	5.96	6.47	6.55	6.44	4.91	4.26	4.24	4.67	4.97	5.00	4.84
11	5.05	5.82	6.36	6.51	6.28	4.84	4.26	4.18	4.51	4.79	4.84	4.74
12	4.88	5.70	6.38	6.50	6.18	4.87	4.26	4.17	4.55	4.74	4.75	4.63
13	4.80	5.58	6.28	6.61	6.21	4.68	4.05	3.94	4.49	4.63	4.79	4.63
14	4.81	5.58	6.21	6.52	6.11	4.51	3.81	3.77	4.29	4.49	4.72	4.61
15	4.83	5.62	6.14	6.50	6.06	4.41	3.80	3.83	4.16	4.44	4.55	4.56
16	5.18	5.93	6.41	6.51	6.23	5.07	4.38	4.42	4.78	4.86	4.91	4.82
17	5.05	5.79	6.34	6.48	6.13	4.97	4.42	4.36	4.59	4.72	4.74	4.70
18	4.87	5.58	6.28	6.47	6.08	4.91	4.30	4.30	4.55	4.49	4.57	4.53
19	4.70	5.54	6.28	6.53	6.05	4.81	4.17	4.26	4.53	4.34	4.53	4.47
20	4.74	5.49	6.19	6.39	5.99	4.67	4.09	4.22	4.37	4.28	4.51	4.47
21	5.23	6.02	6.55	6.60	6.28	5.14	4.59	4.61	4.92	4.76	4.82	4.84
22	5.09	5.85	6.35	6.55	6.15	4.96	4.34	4.41	4.63	4.51	4.59	4.67
23	4.82	5.69	6.28	6.44	6.02	4.88	4.25	4.34	4.59	4.26	4.29	4.34
24	5.26	6.11	6.54	6.55	6.20	5.14	4.67	4.71	5.00	4.67	4.59	4.75
25	5.20	6.07	6.49	6.63	6.21	5.14	4.57	4.65	4.91	4.51	4.46	4.59
26	4.87	5.84	6.40	6.58	6.05	5.03	4.44	4.59	4.84	4.26	4.08	4.15
27	5.22	6.03	6.43	6.45	6.09	5.18	4.65	4.75	4.96	4.48	4.33	4.55
28	4.93	5.85	6.42	6.45	5.94	5.09	4.59	4.73	4.88	4.30	4.05	4.23

Presented solar radiation is based on the data obtained from NASA geo-satellite database, as shown in Appendix-IV.

4.2 Methodology adopted

The ANN approach is used to develop a model to predict solar radiation. The proposed model is optimized for accurate prediction of solar radiation. Optimal model is then used to predict the solar radiation. Predicted solar radiation is further analyzed and mapped using GIS approach.

4.2.1 ANN approaches

Similar approach as discussed in Chapter 3, is used to develop ANN model to predict solar radiation, wherein, FBPNN is used to predict solar radiations, considering geographical parameters and mean monthly meteorological data as inputs. To develop the ANN model different architecture of multi-layer network is used.

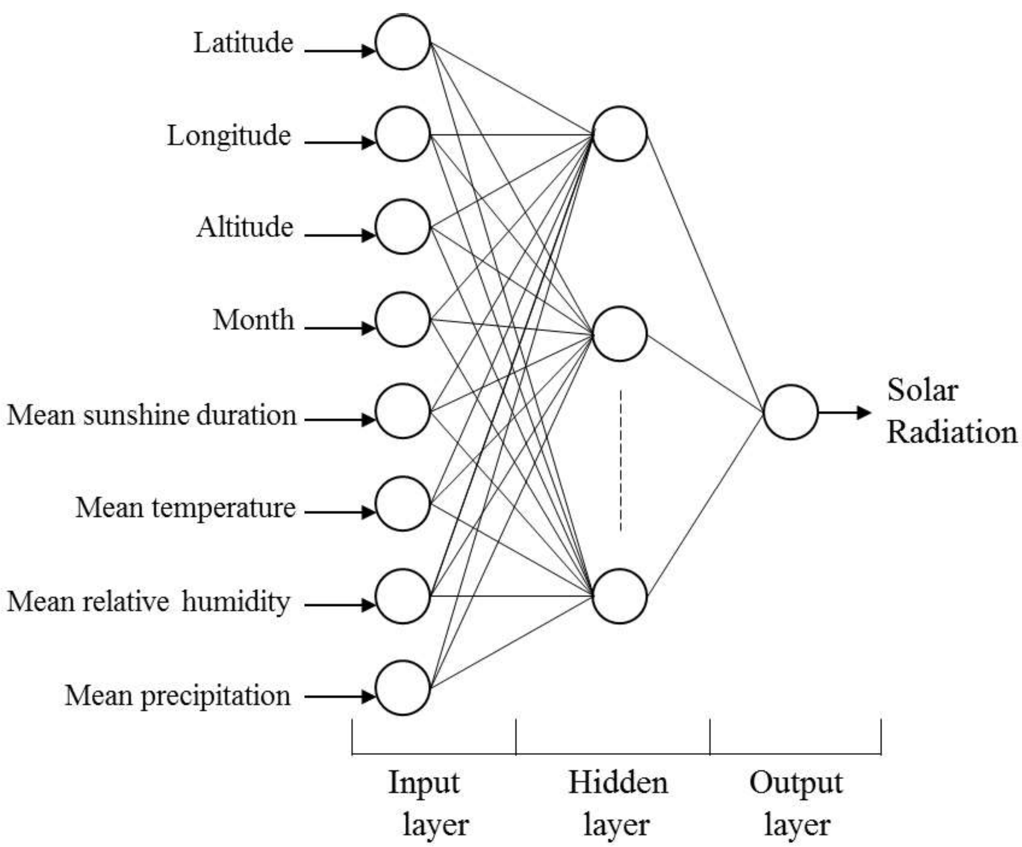


Figure 4.3. Architecture of ANN model in the present study for prediction of solar radiation.

Design of ANN model

The model network is composed of 3 layers which are input, hidden and output layer. As shown in Figure 4.3, there are eight input parameters in the model and one output parameter. Each neuron in the input layer takes one input parameter. One neuron in the output layer gives an estimated value of solar radiation based on the relation established in the hidden layer among input parameters. The number of neurons is varied in the hidden layer to optimized the model for better accuracy. The number of neurons in the hidden layer varies from 1 to 10 for each ANN model.

Training and testing of the model

The ANN model of 15 different architectures with a different number of neurons in the hidden layer (1 to 15) was trained and validated with the training and validation data set. After training and validation, the model was used to predict solar radiation for test location with input data set and compared with the measured value. The test location data is treated as new pertaining to an unknown location. Accuracy of the model was evaluated considering Mean Absolute Percentage Error (MAPE) and Mean Squared Error (MSE), using the following equations:

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{S_{mi}-S_{pi}}{S_{mi}}\right| \quad (4.1)$$

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(S_{mi} - S_{pi}\right)^2 \quad (4.2)$$

where,

S_{mi} = measured wind speed.

S_{pi} = predicted wind speed.

n = number of testing examples.

4.2.2 GIS approach

As discussed in Chapter 3, GIS approach is used to plot the solar maps. Predicted solar radiation from the developed model was then used to create map using ArcGIS 10.0. In this study 3D surface plot is generated using scattered Z-value with latitude and longitude is taken as X-Y coordinate, and solar radiation as Z-value. The solar radiation values at all available locations with their geographical coordinates are imported in ArcGIS and converted into a shape-file. Shape-file was then analyzed using Kriging method to create surface plot. The surface plot is then analyzed using spatial analyst to form a contour plot of solar radiation.

4.3 Estimation of solar radiation

The MAPE values and MSE values evaluate the accuracy of a given forecasting method and present accuracy as a percentage and neglect the signs of errors. MAPE and MSE values were calculated in all different architectures of the model. The model has been evaluated for a number of neurons in the hidden layer (1 to 15). It was observed that MAPE and MSE first decrease with an increase in the number of neurons in the hidden layer and then increases after a certain number. Optimum number of neurons was found for minimum MAPE as well as MSE and then considered for further calculations. The MAPE and MSE were calculated for each month of each location. The average MAPE and MSE over 12 months for four test location is studied and presented. Figure 4.4 shows the variation of yearly mean MAPE for all test locations with numbers of neurons in the hidden layer and it is found that nine neurons in one hidden layer give better results with minimum MAPE as 2.19. The variation of yearly mean MSE for all test locations with a varying number of neurons in the hidden layer is presented in Figure 4.5 and minimum MSE is found with nine neurons in the hidden layer as 0.017. Based on MAPE and MSE calculations, it can be concluded that ANN model with nine neurons in hidden layer predicts solar radiation more accurately with error less than 2.5% and can be considered an optimum model for prediction of solar radiation (Celik and Kolhe, 2013).

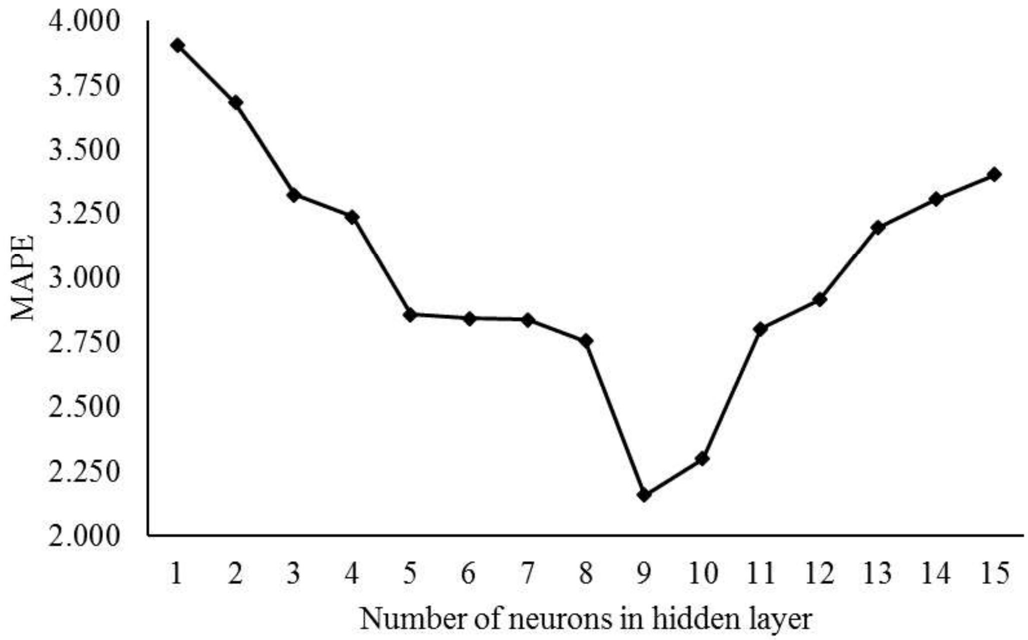


Figure 4.4. Average MAPE of ANN model with different number of neurons in hidden layer.

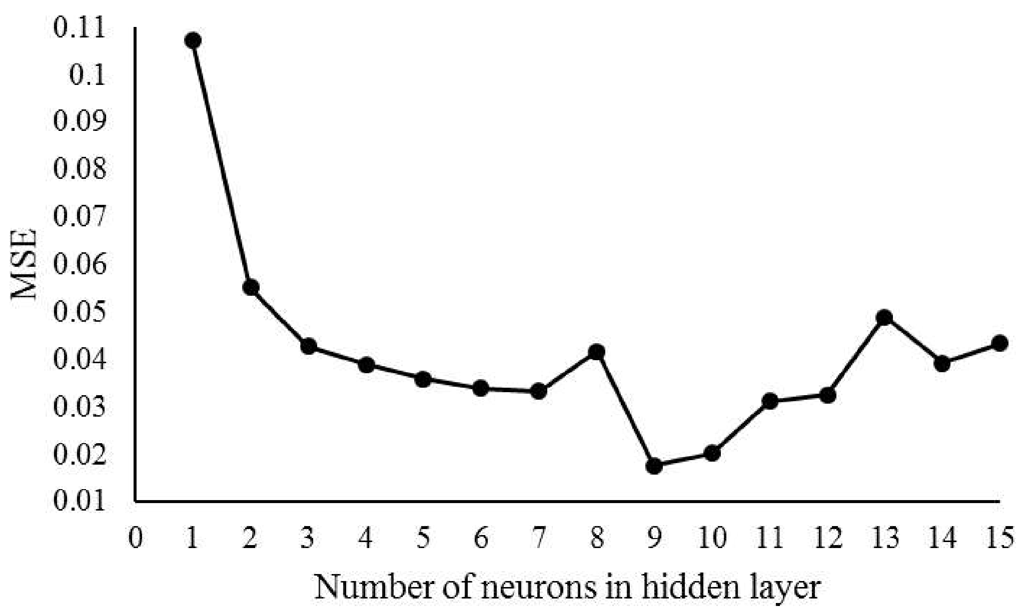


Figure 4.5. Average MSE of ANN model with different number of neurons in hidden layer.

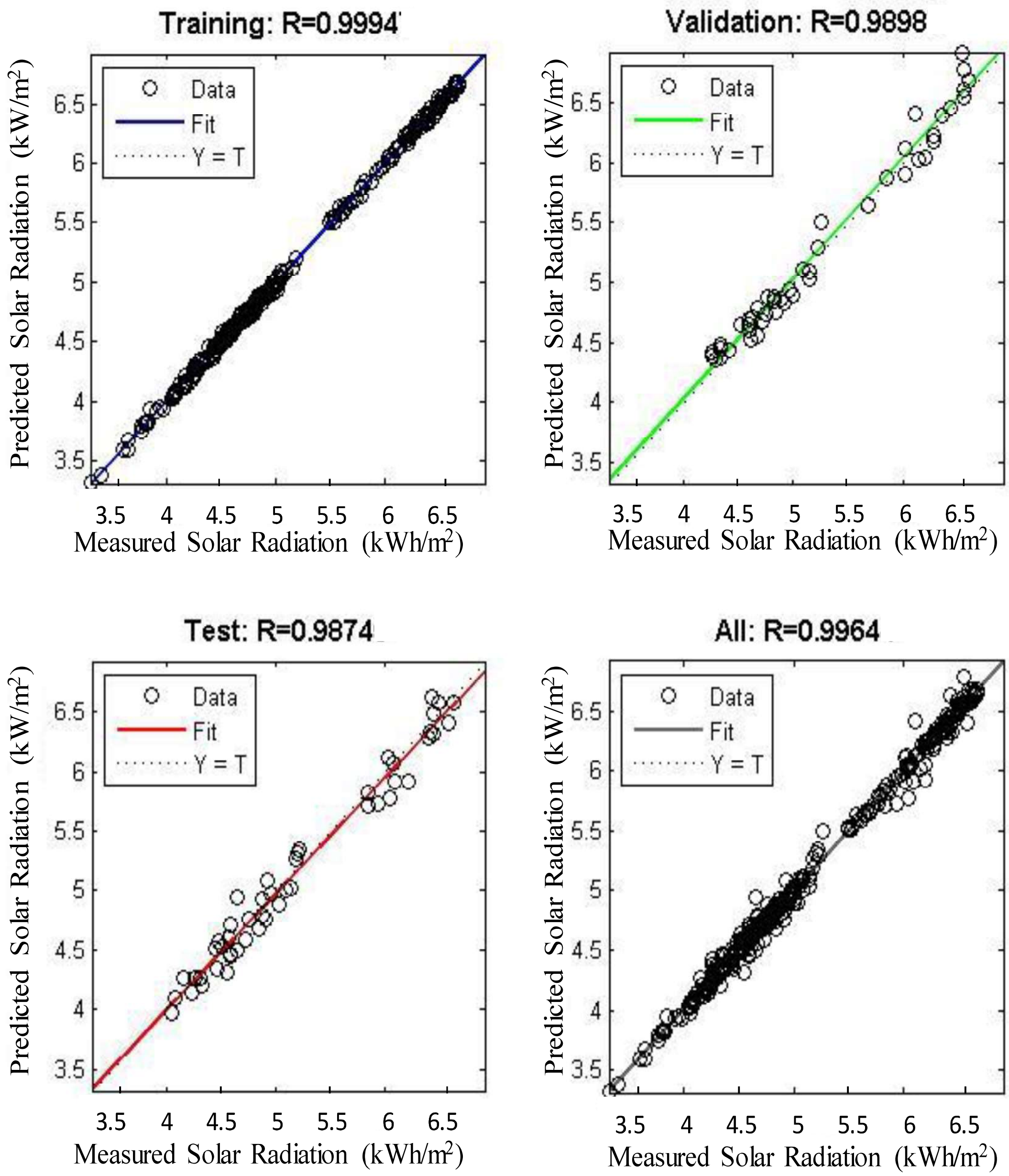


Figure 4.6. Performance of ANN model with optimal configuration (R-value for training, validation, testing, and whole datasets).

Optimum model is also simulated with varying number of iterations. Minimum MAPE has come with 25 iterations for the training of network. It can be observed from Figure 4.4 and 4.5 that prediction of solar radiation from the optimum model is close and similar in their trend to the measured data. R-values have been calculated to check the overall efficiency of optimum model. It can be observed in Figure 4.6, that the optimum model gives R-values 0.999 for training, 0.989 for validation, 0.987 for testing and 0.996 for all data. Yearly average MAPE and MSE for four test location given in Table 4.3 shows accuracy of the predicted value significantly high. The average error is less than 2.5% and average difference between predicted and measured value of solar radiation is less than 0.16 KWh/m^2. For better understating of error in the optimum model, monthly MAPE and MSE are presented in Table 4.4. The MAPE and MSE for training data sets are 0.461 and 0.00079 and for validation data sets 1.73 and 0.0139, respectively, which shows that the developed model is capable to predict solar radiation with acceptable accuracy within AP and TS. With all these investigations, it can be concluded that the model estimation is acceptable with a permissible error.

Table 4.3. Yearly average MAPE and MSE at test locations.

Test location	**Station number**	**MAPE**	**MSE**
1	25	2.01	0.012
2	26	2.47	0.024
3	27	2.03	0.014
4	28	2.23	0.019

Table 4.4. MAPE and MSE of predicted solar radiation at four test locations.

Month	MSE				MAPE			
	T1	T2	T3	T4	T1	T2	T3	T4
1	0.0144	0.0037	0.0148	0.0236	2.31	1.25	2.33	3.11
2	0.0000	0.0146	0.0087	0.0008	0.01	2.07	1.54	0.49
3	0.0089	0.0140	0.0382	0.0076	1.46	1.85	3.04	1.36
4	0.0022	0.0319	0.0011	0.0170	0.71	2.71	0.50	2.02
5	0.0845	0.0779	0.0295	0.0466	4.68	4.61	2.82	3.63
6	0.0121	0.0192	0.0084	0.0066	2.14	2.75	1.77	1.60
7	0.0016	0.0058	0.0895	0.0174	0.87	1.72	6.43	2.87
8	0.0223	0.0146	0.0000	0.0200	3.21	2.63	0.08	2.99
9	0.0208	0.0244	0.0002	0.0065	2.93	3.23	0.31	1.65
10	0.0008	0.0001	0.0081	0.0009	0.62	0.27	2.01	0.68
11	0.0120	0.0003	0.0162	0.0051	2.46	0.40	2.94	1.76
12	0.0170	0.0138	0.0566	0.0066	2.84	2.83	5.23	1.92

The monthly predicted solar radiation was compared with the measured values and plotted for four test locations. Figure 4.7 and 4.8 compares the variation in predicted and measured solar radiation at four test locations (station number 25 to 28). The result indicates better fitting of value, and prediction for each month is very near to actual value for all test locations. As it can be seen in the Figure 4.7 and 4.8, the predicted values of solar radiation follow the trend and are reasonably close to the measured values of wind speed. The MAPE for predicted monthly mean solar radiation is less than 5 and average MAPE is less than 2.5. Which means that the prediction of solar radiation in individual month could have an error maximum of 5% and when it comes to monthly prediction for a year the overall error may come down. The MSE for the predicted solar radiation at test locations is varies from zero to 0.09, which means that the maximum difference between measured and predicted solar radiation would be.3 KWh/m^2. This indicates that the model is reliable and can be used to estimate solar radiation at any location within AP and TS, where solar radiation data is not available. Solar radiation can be predicted in the form of monthly mean value for each month individually at any locations. The optimum model was then used to predict the solar radiation for 15 different major cities in AP and TS.

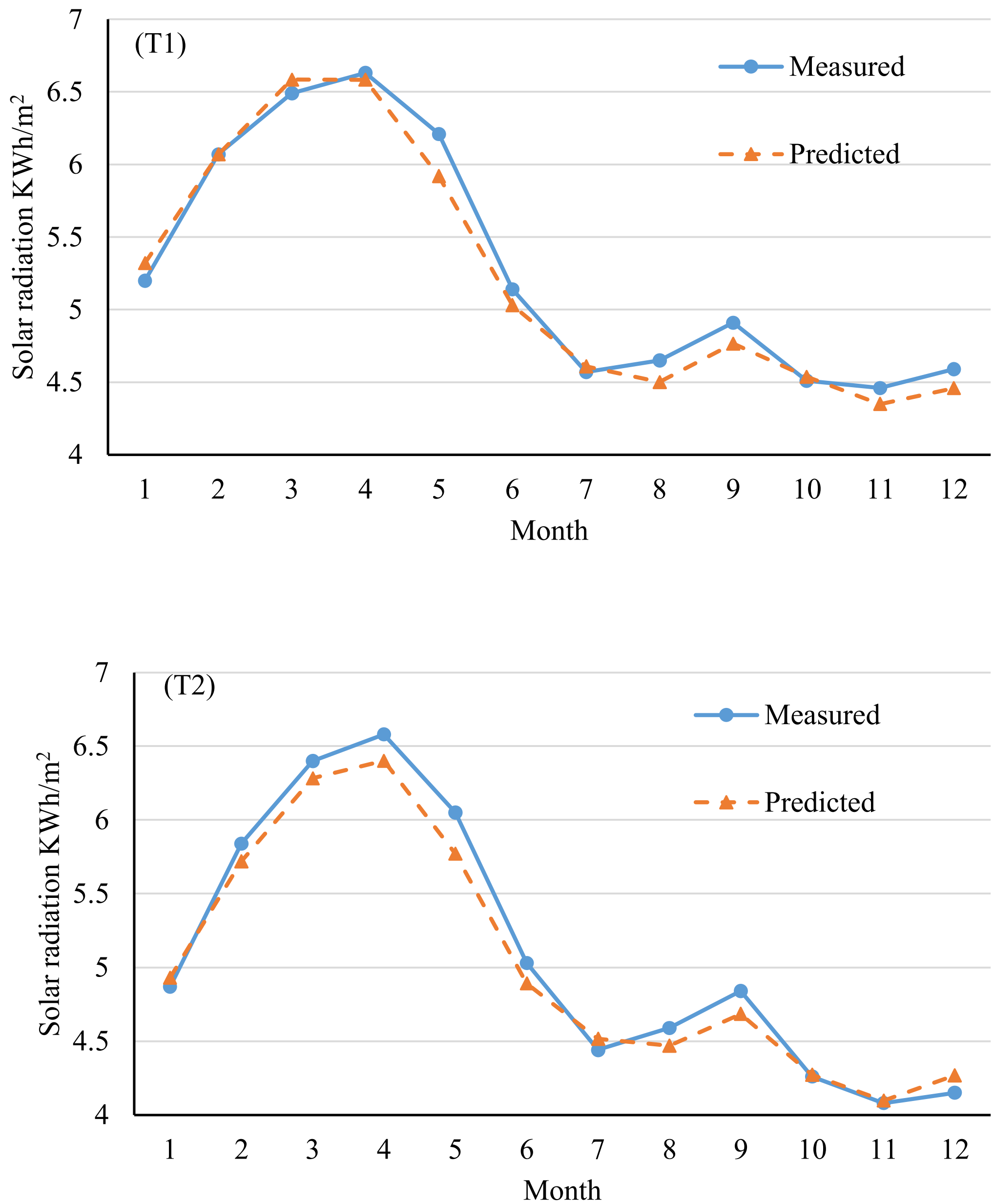
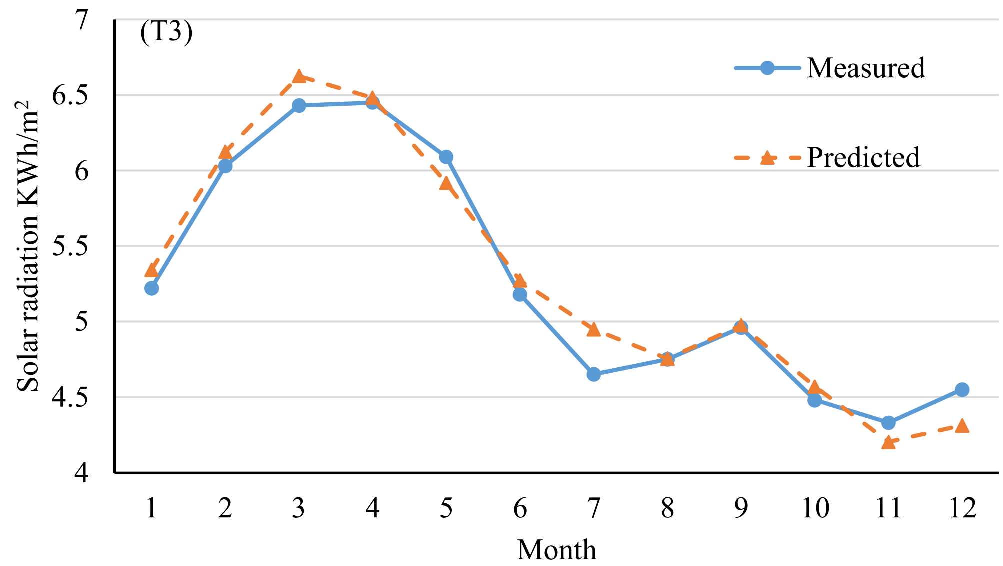


Figure 4.7. Testing of model efficiency by comparing predicted values with measured values at two test locations, (T1) station No. 25 and (T2) station No. 26.



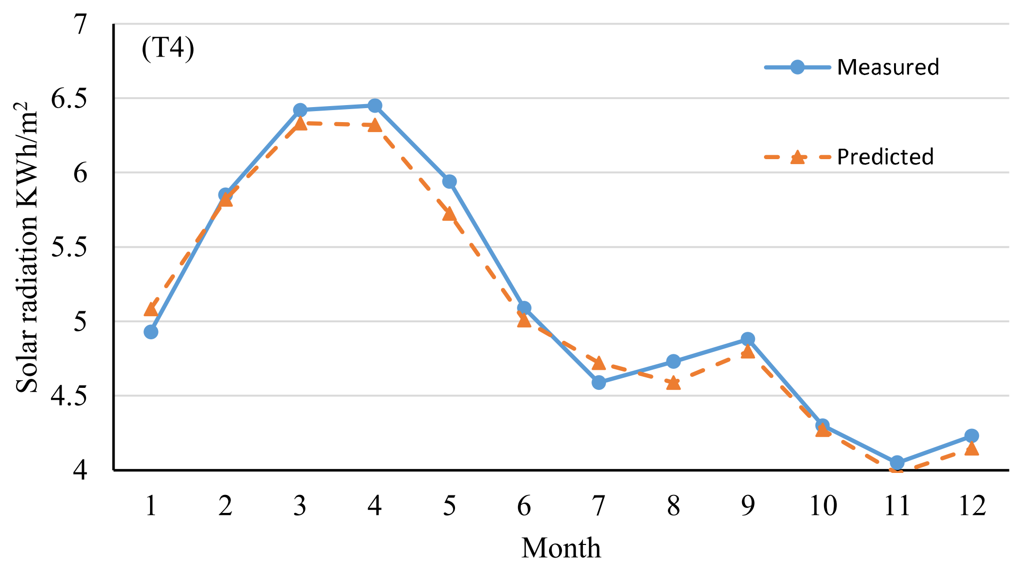


Figure 4.8. Testing of model efficiency by comparing predicted values with measured values at two test locations, (T3) station No. 27 and (T4) station No. 28.

Similar approach has been adopted to develop a new ANN model for predicting solar radiation, where the measured data is not available. This ANN model requires historical data (minimum 10 years) to get trained. This approach is tested at a sample location (Ranga Reddy district in

TS), where monthly mean measured solar radiation was available for 20 years (1995 – 2015). It is observed from training and optimization of the ANN model that seven neurons in hidden layers gives better accuracy. The model is validated by comparing predicted solar radiation with measured solar radiation for 2009 and 2013. Table 4.5 presents variation in the MAPE for predicted solar radiation in each month for the years 2009 and 2013. The average MAPE value for the year 2009 and 2013 are 1.95 and 3.72, respectively. Since the MAPE value is below 6.0, the model can be used to predict the solar radiations in successive years. Table 4.6 shows the projected solar radiation for the years 2016 and 2017. The projected monthly mean solar radiation through this approach can be used for checking the feasibility of setting-up solar fields at any location, where the measured data is not available.

Table 4.5. The MAPE value of the ANN model for the validation years.

Month	**MAPE**	
	2009	**2013**
January	3.73	3.66
February	0.32	4.50
March	3.05	5.01
April	1.22	1.32
May	1.56	4.65
June	1.14	4.04
July	5.93	4.19
August	1.00	5.72
September	2.36	3.34
October	1.30	4.24
November	1.56	0.65
December	0.24	3.29

Table 4.6. Projected solar radiation for the years 2016 and 2017.

Month	Projected solar radiation ($kWh/m^2/day$)	
	2016	2017
January	5.78	4.75
February	5.67	5.39
March	5.00	5.83
April	4.12	6.02
May	4.42	6.16
June	5.57	6.24
July	6.13	6.26
August	6.24	6.26
September	6.26	6.26
October	6.26	6.27
November	6.26	6.27
December	6.26	6.27

4.4 Mapping of solar potential

The statistical analysis of solar potential is represented in Table 4.7 with maximum, minimum, average, and standard deviation of monthly mean solar potential. It can be noted that solar potential in AP and TS varies from 6.68 to 3.31 kWh/m^2day. April has maximum solar potential 6.68 $kW\ h/m^2day$ and minimum solar potential is available in August as 3.13 kWh/m^2day (Table 4.6). Solar radiation variation is less in April as it has the least standard deviation of 0.09 and high in August with high standard deviation of 0.37. As observed, there is sufficient solar energy available in AP and TS, especially in the months of March, April and May.

Table 4.7. Statistical presentation of monthly mean solar radiation within AP and TS.

Month	Solar radiation potential kW h/m^2 day			
	Max.	**Min.**	**Ave.**	**SD**
1	5.26	4.70	4.95	0.16
2	6.11	5.49	5.76	0.18
3	6.55	6.03	6.33	0.12
4	6.68	6.30	6.54	0.09
5	6.59	5.94	6.22	0.18
6	5.18	4.25	4.82	0.25
7	4.67	3.40	4.19	0.31
8	4.75	3.31	4.17	0.37
9	5.00	4.08	4.59	0.24
10	5.09	4.26	4.65	0.25
11	5.01	4.05	4.66	0.26
12	4.84	4.15	4.61	0.17

The predicted monthly mean solar radiation from the optimum ANN model, for January to December, was analyzed and mapped using GIS approach. ArcGIS 10.0 software was used in the present work for mapping of solar radiation. The yearly and monthly mean maps of solar radiation in the form of contour were developed. The interval of the contour is taken as 0.1 kWh/m^2 day. The contours are iso-lines and solar radiation value is constant along the contours. Figure 4.9 shows the yearly average map of solar radiation. It can be observed from Figure 4.9 that the yearly average solar radiation is high in the West region and less towards the East region.

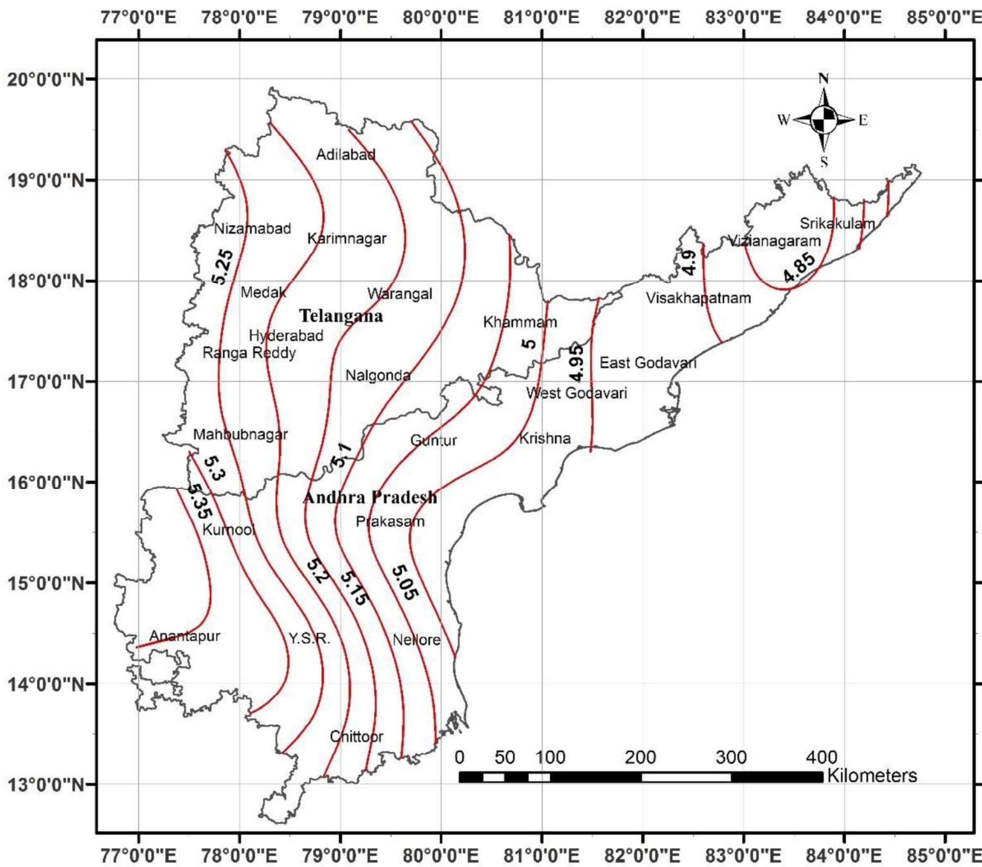


Figure 4.9. Contour map of yearly average solar radiation (kWh/m^{2}day) within AP and TS.

The contour maps are generated for each month to study the variation in solar radiation, which is presented in Figure 4.10 to Figure 4.15. The maps can provide better visualization of solar potential within the study region in each month. These maps can be further zoomed-in to get the value of solar radiation at local level for each month, which can help to find the ideal regions with higher solar potential for setting-up solar fields. It is found from the maps (Figures 4.10 to Figure 4.15) that solar potential varied widely across regions and from month to month.

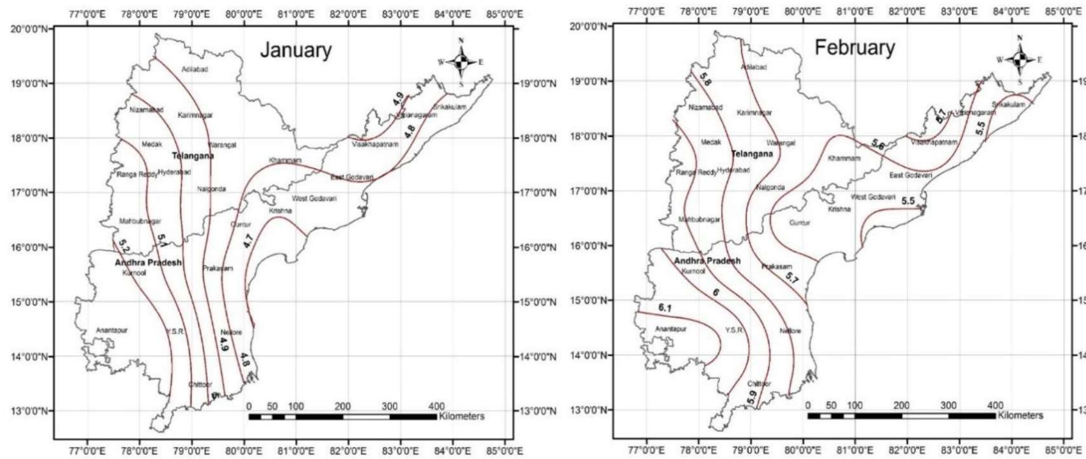


Figure 4.10. Contour map of solar radiation (kWh/m^{2}day) for AP and TS (January and February).

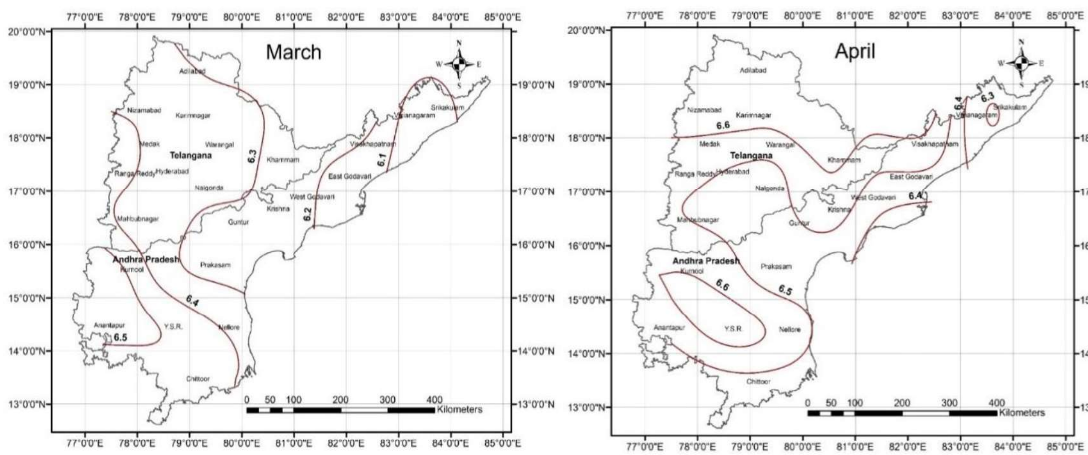


Figure 4.11. Contour map of solar radiation (kWh/m^{2}day) for AP and TS (March and April).

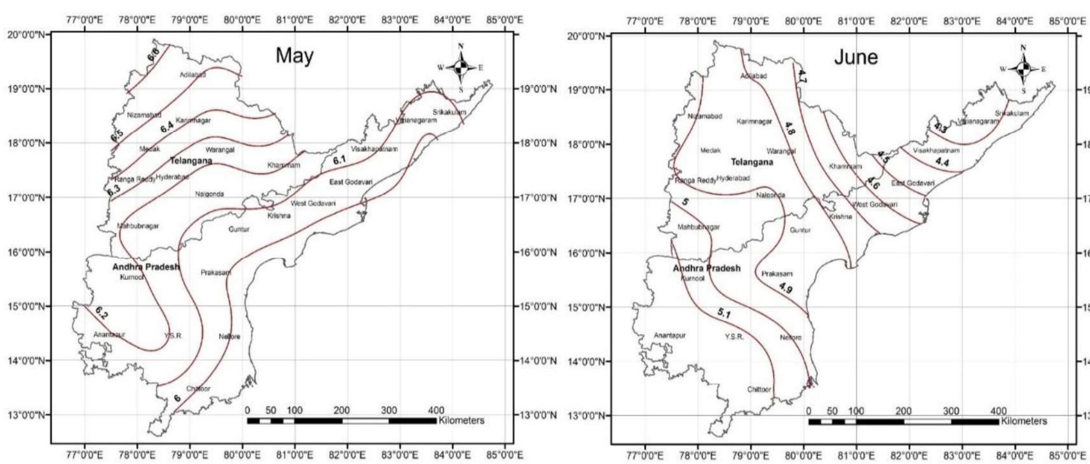


Figure 4.12. Contour map of solar radiation (kWh/m^{2}day) for AP and TS (May and June).

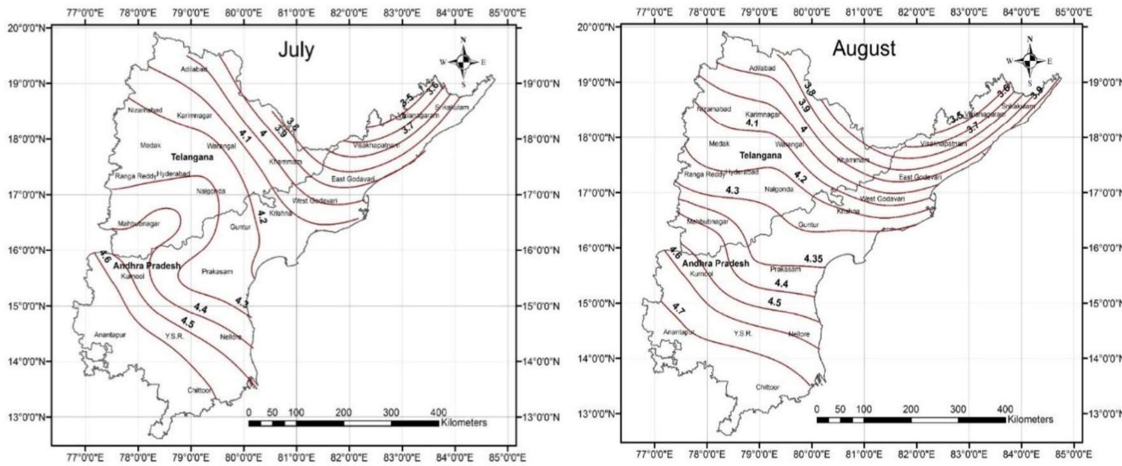


Figure 4.13. Contour map of solar radiation (kWh/m^{2}day) for AP and TS (July and August).

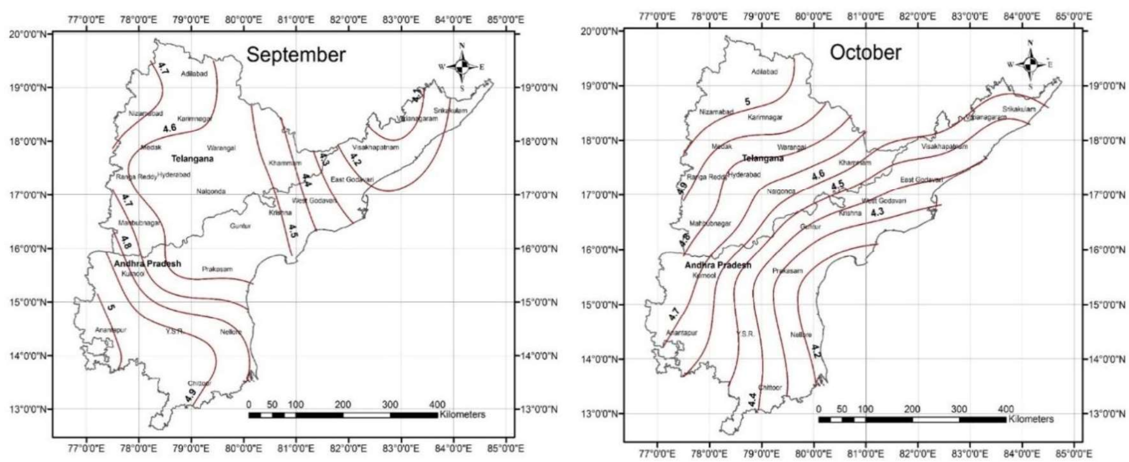


Figure 4.14. Contour map of solar radiation (kWh/m^{2}day) for AP and TS (September and October).

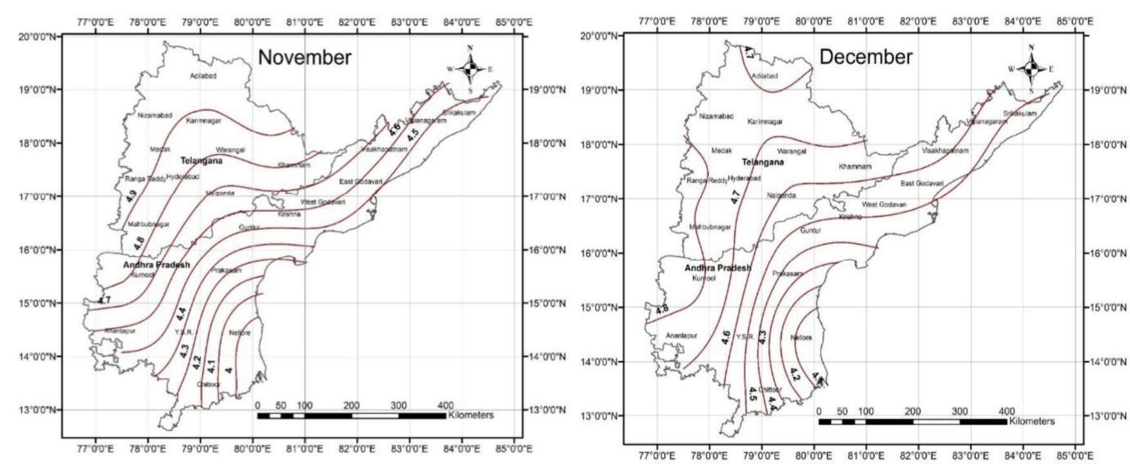


Figure 4.15. Contour map of solar radiation (kWh/m^{2}day) for AP and TS (November and December).

4.5 Land use and land cover estimation

Regions with higher solar potential are identified using yearly and monthly maps of solar radiation. Figure 4.16 shows regions with higher solar potential.

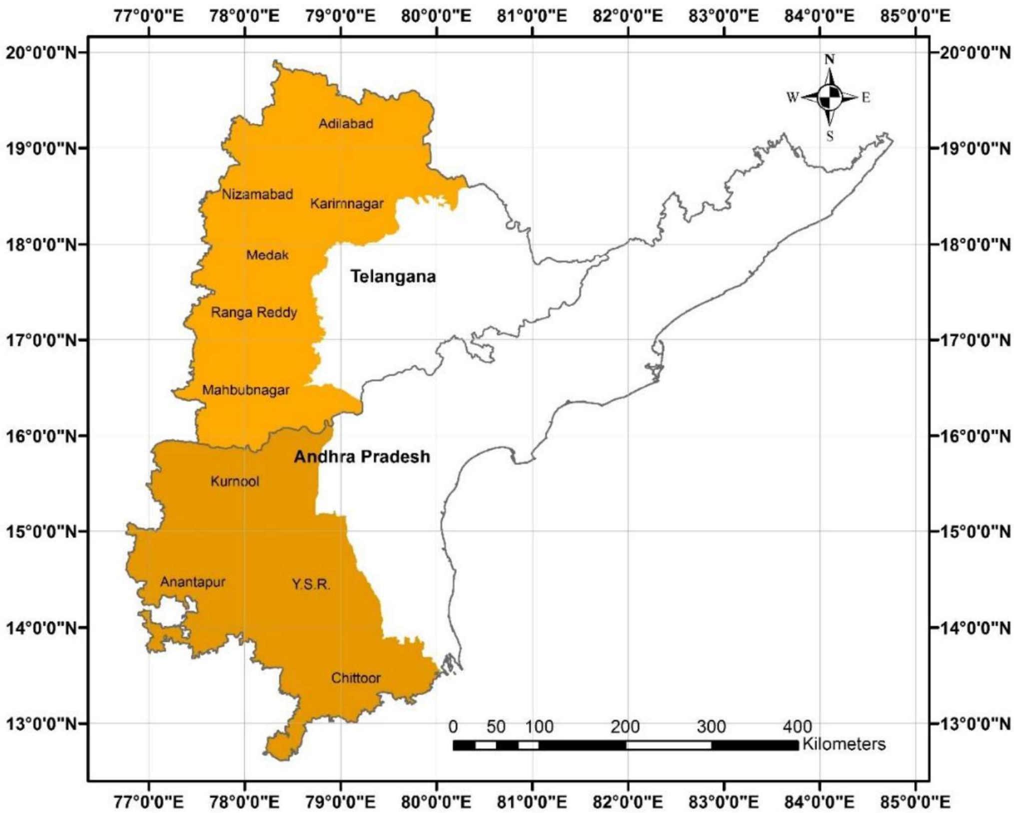


Figure 4.16. Region with higher solar potential within AP and TS.

Kurnool, Anantapur, YSR, Chittoor districts in AP and Adilabad, Nizamabad, Karimnagar, Medak, Ranga Reddy, Mahbubnagar districts in TS, which are located in the West region have high solar radiation. The western region of AP has solar radiation in the range of 4 to 6.6 kWh/m^{2}day. This region has higher solar radiation compared to the western region in TS in March, April, May, November and December. The western region in TS receives solar radiation in the range of 4.4 to 6.6 kWh/m^{2}day. This region has higher solar radiation as compared to the western region in AP, in January, February, June, July, August, September and October.

Land Use and Land Cover (LULC) analysis is carried out to estimate the ideal area available and their locations for setting-up solar fields. Remote sensing map with a resolution of 100 m x 100 m is obtained from NASA earth data center and analyzed using GIS approach. The data is obtained for India and analyzed to calculate district wise availability of different types of land within AP and TS. Remote sensing map shows land distribution in sixteen different types, which are further classified into six categorizes as discussed in Chapter 3 (Section 3.6). Among all types of land, ideal land for setting-up solar fields is built-up and barren land, as shown in Figure 4.17. Distribution of different types of land in ten districts, which receive higher solar radiation as presented in Table 4.8. Ranga Reddy district has the highest built-up area of approx. 1180 km^2 and Anantapur district has highest barren land of 502.5 km^2. Considering built-up and barren land together, Ranga Reddy district has the highest area (1214 km^2) available for setting-up solar fields.

It is generally assumed that 80% of barren land can be considered for setting-up solar fields. Rest 20% goes in for pathway and side walk along with some peripheral space. On the other hand, solar panel installation in built-up area has some limitations. In the present analysis, any man-made structure is considered built-up area. However, all land in this category is not suitable for roof-top PV system. The ratio of suitable area to the total built-up area is defined as Building Footprint Area Ratio (BFAR). The BFAR varies from 0.3 to 0.9 for different types of man-made structures (Singh and Banerjee, 2015). A practical average value of BFAR is taken to be 0.6. The effective area for roof-top PV installation can be obtained from the Building Footprint Area (BFA), using PV Area (PVA) factor. The PVA factor is defined as the ratio of effective PVA and BFA. The PVA factor needs to be obtained since the complete BFA cannot be utilized for PV installation. There are several factor which reduces the effective area for PV installation, such as (i) shading due to neighboring structures and some part of the structure itself, (ii) use of BFA for other purposes and (iii) irregular shape of BFA which make some portion not suitable for PV installation. The PVA factor for India is considered 0.3 (Singh and Banerjee, 2015). Considering BFA ratio and PVA factor, the overall reduction coefficient would be 0.18. Therefore, the available built-up area in Ranga Reddy district will reduce to approx. 212 km^2

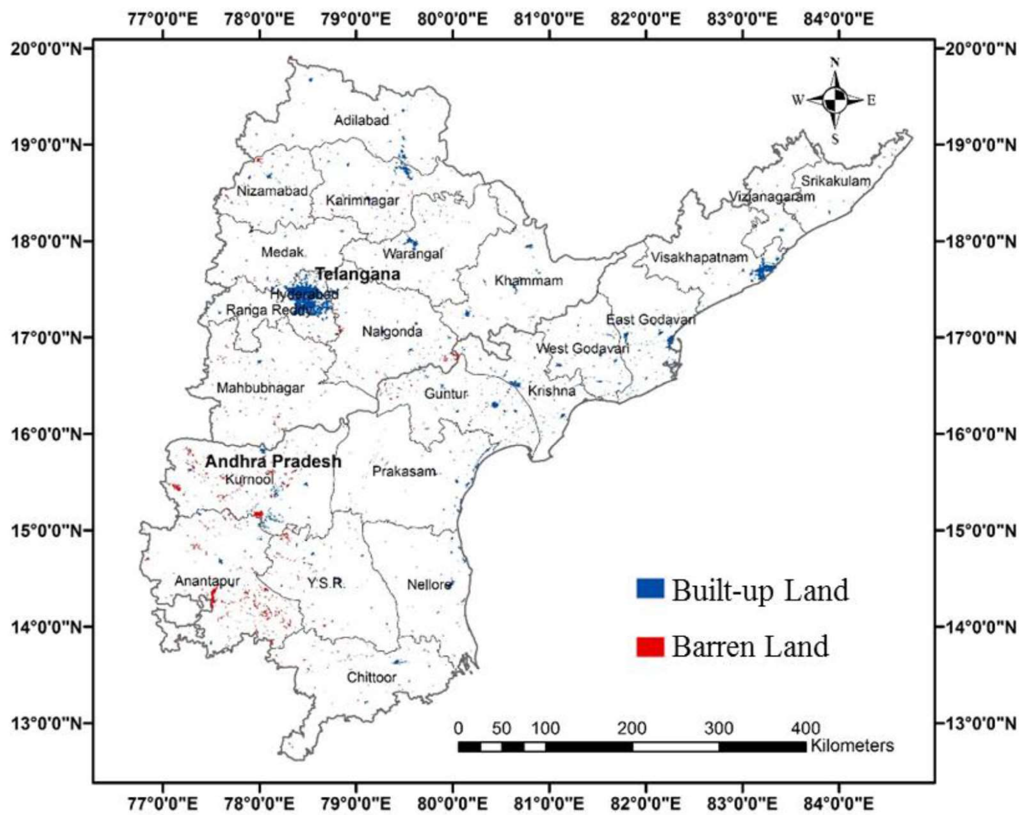


Figure 4.17. District wise built-up land and barren land within AP and TS.

Table 4.8. Area estimation of different types of land in the districts with higher solar potential in km^2.

LULC	Adilabad	Anantapur	Chittoor	Karimnagar	Kurnool	Mahbubnagar	Medak	Ranga Reddy	YSR
Built-up land	119.90	73.53	74.15	184.34	267.16	70.19	101.86	1179.92	72.99
Barren land	7.89	502.50	74.32	40.80	338.28	89.31	15.74	34.03	115.74
Broadleaf forest	19.81	424.78	2925.75	0.00	2286.44	1921.67	0.00	282.05	3283.44
Crop land	7511.65	13414.06	6766.07	8409.73	11377.13	12715.90	7401.96	4269.29	5781.31
Mixed forests	1332.60	1478.28	1438.03	436.61	779.56	818.75	359.23	211.58	1846.89
Shrubland	357.04	1357.14	1500.08	600.25	1209.28	537.02	813.22	510.60	2158.02
Fallow land	1318.98	1214.69	1876.04	158.76	772.83	1539.01	442.13	953.10	1042.49
Wasteland	26.62	53.26	31.27	6.32	41.84	7.48	0.73	0.00	10.05
Water bodies	72.58	721.42	316.09	132.34	724.59	695.58	72.80	148.47	749.24
Plantations	21.36	37.31	152.68	2.31	13.15	6.84	48.65	72.59	99.67
Grassland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.79	0.00
Needleleaf forest	5253.86	0.00	0.00	1929.42	0.00	0.00	511.63	42.97	0.00

4.6 Summary

The ANN based predictive model is developed and optimized for estimation of solar potential within AP and TS. The predicted solar radiation is analyzed and mapped using GIS approach. Contour maps are plotted for yearly mean and monthly mean solar radiation. These maps give a better visualization of solar potential at local level within AP and TS, which will help the decision maker to identify ideal locations for solar power generation. In addition, regions with higher solar potential are identified using yearly and monthly contour maps. Land use and land cover analysis is carried out to estimate the available ideal area for setting-up solar fields in regions of higher solar radiation.

Next chapter discusses the optimal utilization of resources: Wind and Solar.