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Solar energy potential assessment using GIS

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Abstract

Renewable energy resources are those having a cycling time less than 100 years and are renewed by the nature and their supply exceeds the rate of consumption. Renewable energy systems use resources that are constantly replaced in nature and are usually less polluting. In order to tap the potential of renewable energy sources, there is a need to assess the availability of resources spatially as well as temporally. Geographic Information Systems (GIS) along with Remote Sensing (RS) helps in mapping on spatial and temporal scales of the resources and demand. The spatial database of resource availability and the demand would help in the regional energy planning. This paper discusses the application of geographical information system (GIS) to map the solar potential in Karnataka state, India. Regions suitable for tapping solar energy are mapped on the basis of global solar radiation data, and this analysis provides a picture of the potential. The study identifies that Coastal parts of Karnataka with the higher global solar radiation is ideally suited for harvesting solar energy. The potential analysis reveals that, maximum global solar radiation is in districts such as Uttara Kannada and Dakshina Kannada. Global solar radiation in Uttara Kannada during summer, monsoon and winter are 6.31, 4.40 and 5.48 kWh/sq.m, respectively. Similarly, Dakshina Kannada has 6.16, 3.89 and 5.21 kWh/sq.m during summer, monsoon and winter.

Keywords: Solar energy, Potential, GIS

1. Introduction

Energy generated by the sun is radiated outwards in all directions, and only two thousand-millionths of it is intercepted by the earth as light and infrared (heat) radiation. The intensity of the sun's radiation (irradiance) at the top of the earth's atmosphere at the mean distance of the earth from the sun is roughly constant (solar constant) with an observed value of 1366 Watts/m^2 ± 0.3%. However, on average, only about half of this energy reaches the earth's surface [1].

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The total quantity of short wave radiant energy emitted by the suns disc as well as that scattered diffusively by the atmosphere and cloud, passing through a unit area in the horizontal in unit time is referred generally as global solar radiation. Monitoring the daily global solar radiation will help in assessing the total solar energy at any location considering diurnal and seasonal variations. The global solar radiation reaching the earth's surface is made up of two components, direct and diffuse. The sum of the direct and diffuse components reaching a horizontal surface is global radiation. Direct radiation is the part, which travels unimpeded through space and the atmosphere to the surface; and diffuses radiation is the part scattered by atmospheric constituents such as molecules, aerosols, and clouds. In simple terms, direct radiation causes shadows, and diffuse is responsible for skylight [1].

Approximately 30% is reflected back to space, and clouds, dust, and "greenhouse" gasses such as water vapor, carbon dioxide, and ozone absorb the remaining 20%. The annual global radiation in India varies from 1600 to 2200 kWh/sq.m which is comparable with radiation received in the tropical and sub-tropical regions. The equivalent energy potential is about 6,000 million GWh of energy per year [2].

1. 1. Characteristic of the solar radiation

Solar radiation is made up of electro-magnetic waves (Es), which travels from the sun to the earth with the speed of light (c). Wavelength (λ) of the wave is related to the frequency (υ), and is given in Eq. 1.

$$C = \upsilon \lambda \tag{1}$$

The electro-magnetic waves of solar radiation (Es, cal/min) emitted into the space and its part intercepted by the earth (Ee, cal/min) is given by:

$$Es = 4\pi r_o^2 I_o \tag{2}$$

$$Ee = 4\pi r_o^2 I_o \tag{3}$$

where, r_o, r_e, I_o are the mean distance between sun and earth, the radius of the earth, and solar constant, respectively.

The part of solar radiation intercepted by the earth depends mainly on the insolation of the earth's outer atmosphere.

1. 2. Insolation at the outer atmosphere

Insolation is the rate at which energy reaches the earth surface. It is the absorption of solar radiation by the earth surface [3]. If the earth were represented as a sphere, then at the equator a horizontal surface at a point immediately under the sun would receive 1.36 kW/sq.m continuously. Horizontal surface on the same longitude but different latitude would receive correspondingly less. The earth rotates about an axis, which is inclined at an angle $(23^{1/3})^o$ to it. This modifies the solar radiation to give rise to a seasonal variation of solar radiation and due to this, more radiation falls on the polar region in the summer than at the equator. An important feature is the absence of seasons at the tropics and the extremes of 6 month summer and 6-month winter at the poles.

Another feature of significance is the 12 hour day, 12 hour night in the tropics compared to the shorter night/longer day summer cycle in temperate areas and the reverse in the winter. Other than the insolation at the outer atmosphere the atmosphere inside the earth surface also has an effect on radiation.

1. 3. Effects of the earth's atmosphere

It is seen that about 30% of the incident solar radiation is reflected by the atmosphere, a further 20% is absorbed on passing through the atmosphere and the remaining arrives to the earth's surface, where as 2% is reflected and the remaining is absorbed. For the most favored region the average flux density is as high as 300w/sq.m the average for the tropics is about 250w/sq.m and in more temperate region the figure is about half this value. In order to study the effects of solar radiation on the earth, it is necessary to determine the amount of radiation reaching the earth's atmosphere and surface.

1. 4. Global solar radiation

The quantity of short wave radiant energy emitted by the sun passing through a unit area in the horizontal in unit time is referred generally as global solar radiation (G) [4]. The computation of daily sums of global solar radiation at sites where no radiation data's are available, can be done through various probable relationships among the parameters such as from (a) sunshine and cloudiness, (b) extra terrestrial radiation allowing for it's depletion by absorption and scattering in the atmosphere. There is a relationship between solar radiation received on earth's surface and sunshine. Hence earlier researchers like Kimball (1919), Ångström (1924) and others used sunshine data for solar radiation estimation [5].

The statistical relation formulated between the daily duration of sunshine N and the daily total global solar radiation G is of the form,

$$(G/G_o) = a + (1\text{-}a)\ (n/N) \qquad (4)$$

where, G_o is daily global solar radiation with cloud free atmosphere, a is mean proportion of radiation received on a completely overcast day, and N: maximum possible duration of sunshine (with solar elevation < 5^o), h.

Due to the difficulties in the precise evaluation of Go in the above equation, Go was replaced by the extra terrestrial radiation (ETR) on a horizontal surface, and the relation is given by,

$$(G/ETR) = a + b\ (n/N) \qquad (5)$$

where, ETR is extra terrestrial radiation, kWh / m^2 / day. ETR on a horizontal surface for any place for any day / month can be estimated by the following relation,

$$ETR = 10.39\ K\ (\cos\varphi\cos\delta\sin\omega + \omega\sin\varphi\sin\delta) \qquad (6)$$

10.39 is solar constant (assumed equal to 1.36kw/sq.m. x 24/π), K is correlation factor for varying earth sun distances, φ is Angle of latitude, δ is angle of declination and ω is sun set hour angle in radians.

To compute (n/N) at a place where only cloud cover data are available with out mean sun shine data the inverse relation between the sunshine n/N and cloud cover C is used, which is given by,

$$C = 1 – (n/N) \quad (7)$$

Since (n/N') is used for deriving G the relation between (n/N') and C is given by,

$$1 – (n/N') = 1C + 0.310 + 0.476C^3 + 0.100C^4 \quad (8)$$

where, N' is maximum possible duration of sunshine (with solar elevation >= 5^o), h. Hay correlated n/N' with G'/ETR, where G' is the global solar radiation that first strikes the ground before undergoing multiple reflections. The numerical relation between G and G' is given by,

$$G – G' = GR[(0.25n/N') + 0.60(1-n/N')] \quad (9)$$

where R is surface albedo.

The statistical relation now takes the form:

$$(G'/ETR) = a + b(n/N') \quad (10)$$

Different relations of global solar radiation is obtained by considering the influence of climatological multi variates like mean temperature Tm, relative humidity RH, specific humidity SH, rainfall R, and ratio of minimum and maximum temperature ψ. They are,

$$(G'/ETR) = m_1 + m_2 (n/N') +m_3 (n/N')^2 \quad (11)$$

$$(G'/ETR) = c_1 + c_2 (n/N') + c_3 Tm \quad (12)$$

$$(G'/ETR) = d_1 + d_2 (n/N') + d_3 \psi \quad (13)$$

$$(G'/ETR) = g_1 +g_2 (n/N') +g_3 Tm + g_4 RH \quad (14)$$

$$(G'/ETR) = k_1 + k_2 (n/N') + k_3 Tm + k_4 RH + k_5 R \quad (15)$$

$$(G'/ETR) = e_1 +e_2 (n/N') + e_3 \psi + e_4 SH \quad (16)$$

$$(G'/ETR) = f_1 + f_2 (n/N') +f_3 Tm + f_4 SH \quad (17)$$

$$(G'/ETR) = h_1 +h_2 (n/N') + h_3 Tm + h_4 SH + h_5 R \quad (18)$$

Specific humidity (SH) is used instead of RH to take care of the relatively large variation in RH and is given by

$$SH= RH (4.7923 + 0.3647Tm + 0.55Tm^2 + 0.0003Tm^3) \quad (19)$$

where RH is relative humidity; f_1, f_2, f_3, and f_4 are empirical constants, which vary with geographical location, respectively.

1. 5. Diffused solar radiation (D)

It is the part of short wave radiation scattered by the atmosphere reflected diffusely and transmitted by clouds and passing through unit horizontal area in unit time [4]. For average conditions, D can be determined with reasonable accuracy from G and ETR through a linear regression equation connecting D/G in one hand and G/ETR on the other [5]. The general regression equation is of the form,

$$(D/G) = c + d(G/ETR) \qquad (20)$$

where, D is diffused solar radiation, c is regression constant and d is regression constant, always negative.

To secure better accuracy D should be replaced by D' and G by G', where D' is given by,

$$D' - D = G\,R\ [(0.25\ n/N') + 0.60\,(1-n/N')] \qquad (21)$$

The linear regression equation used to derive D takes the form,

$$D'/G' = c + d\,(G'/ETR) \qquad (22)$$

1. 6. Direct Solar Radiation (I_H)

It is the quantity of solar radiation emitted from the solid angle subtended by the visible disk of the sun and passing through a unit area in horizontal in units of time [4].

$$I_H = G - D \qquad (23)$$

2. Literature review

Iziomon and Mayer evaluated global solar radiation for lowland and a mountain site with data from 1991 to 1994. Tested models were broadly categorised as cloud-based (Kasten) and sunshine-based (Ångström–Prescott, Garg and Garg, Sivkov). Adjustable parameters in the models were determined. Observed monthly mean values of solar radiation G and those estimated using Kasten model agreed within 2.5% for the lowland site and 13% for the mountain site. Root mean square errors of estimated hourly values of G using Kasten model appreciated significantly with fractional cloud cover N (particularly for N>4 octals). Monthly mean values of G estimated using Ångström–Prescott model agreed with observation within 2.5% for the lowland site and 3.4% for the mountain site. The effect of air mass, latitude and water vapour terms on the Ångström–Prescott relation has also been investigated. In general, Ångström–Prescott as well as Garg and Garg models yielded the least RMSE (<0.047) for the study sites and are thus recommended for estimating G for an arbitrary location [6].

Ali Rahoma analyzed global index and diffuse fraction for clear-sky conditions using direct, global, and diffuse solar radiations (cloudless) taken over a one year period at Helwan. The results highlight the need for routine instantaneous surface meteorological data to compute global and diffuse radiations on a horizontal surface in the absence of any other radiation measurements. The spectral composition of the global solar-radiation was found to be 4.3% UV band, 32.5% band range 250–630 nm, 13.74% red band, 52.75% infrared band and 29.7% diffuse solar-radiation The spectral distribution of direct solar-radiation ratio of the extraterrestrial solar radiation was found to be: 0.69% green and blue band, 47.5% yellow and orange band 45% red band, and 52.7% infra-red band [7].

Shafiqur Rehman, et al adopted a geostatistical technique consisting of (i) data collection, (ii) univariate analysis, (iii) experimental variogram calculations and model fitting, (iv) estimation using kriging, and (v) plotting contour maps for the estimation of solar radiation in Saudi Arabia. Variogram models are fitted to measured variograms for each month of the year. Estimates obtained for 1500 grid points (30 × 50) with resolution of 55 × 33 km, were used to plot monthwise solar radiation contours. The error analysis showed that the mean percent errors to vary between 0.5% and 1.7%. This technique could be used for the spatial estimation of solar radiation on regional and continental scales [8].

Ahmet Aksakal and Shafiqur Rehman, presents the actual global solar radiation on a horizontal surface in the Arabian Gulf Coast near the city of Dhahran, based on monthwise high resolution, real time solar radiation and meteorological data for a year. Hourly, daily, and monthly statistics of solar radiation was made from the one-minute averaged recorded values. The highest measured daily, and monthly mean solar radiation was found to be 351 and 328 W/m^{-2}, respectively. The highest one-minute averaged solar radiation values up to 1183 W/m^{-2} were observed in the summer season, from May–September. The highest hourly solar radiation value was recorded as 1053 W/m^{-2} in the middle of June [9].

Ramachandra and Subramanian., estimated the solar radiation for Uttara Kannada district based on the solar radiation and climatological data got from IMD, Pune, for Karwar, Honnavar, Shirali, Mangalore, and Goa. The computed and measured values of global solar radiation agrees with the range of 2 –5 % for most months the computed and the estimated values are with in the range of ± 5%. Karwar has a global solar radiation range of 5.5 – 6.5 kWh/sq.m for January–May and 4 - 5 kWh/sq.m during July–September, while in Honnavar it ranges from 5.47–6.5 kWh/sq.m for January–May and minimum during July–September. The study demonstrates that good solar energy potential is available in this region during most months of the year. The amount of solar energy that could be harnessed by utilizing 5% of the wasteland as collector area is found to be of the order of 95.72 million units (MkWh) annually [10].

3. Objective

Objective of this study is to analyze spatially solar energy potential in Karnataka State, India.

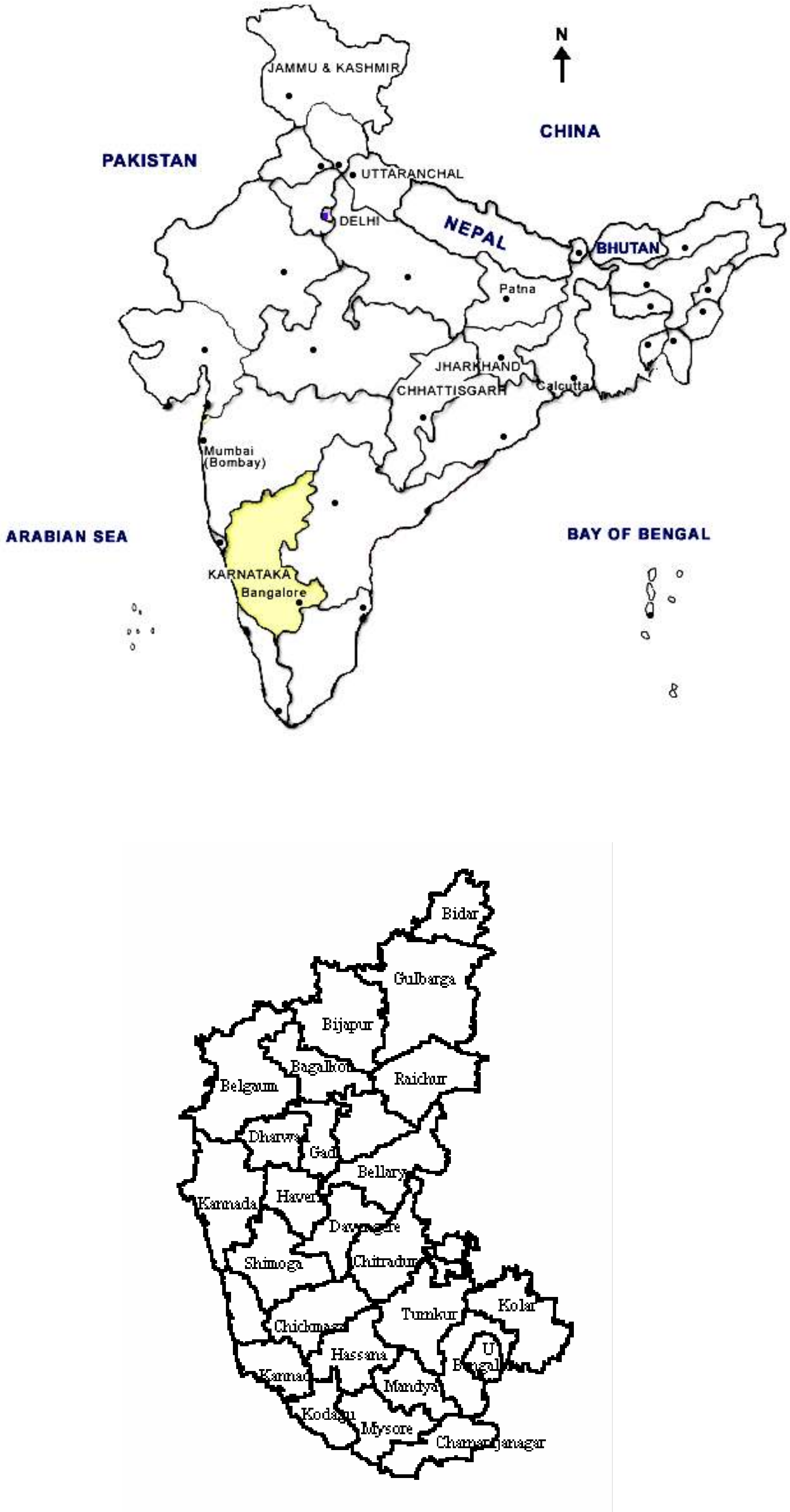


Fig. 1. Study area: Karnataka State, India.

4. Study area

The study was carried out for Karnataka state, India based on the data compiled for various locations. The State of Karnataka is confined roughly within 11°31' North and 18°45' North latitudes and 74°12' East and 78 ° 40' East longitude and lies in the western central part of peninsular India (Fig. 1). It is situated on a tableland where the Western and Eastern Ghat ranges converge into the Nilgiri hill complex. Karnataka's total land area is 1,91,791 sq. Km. It accounts for 5.35 percent of the total area of the country (32.88 lakh sq. Km) and ranks eighth among major States of the country in terms of size. For administrative purpose the state is divided into 27 districts, which are sub divided into 175 taluks.

5. Methodology

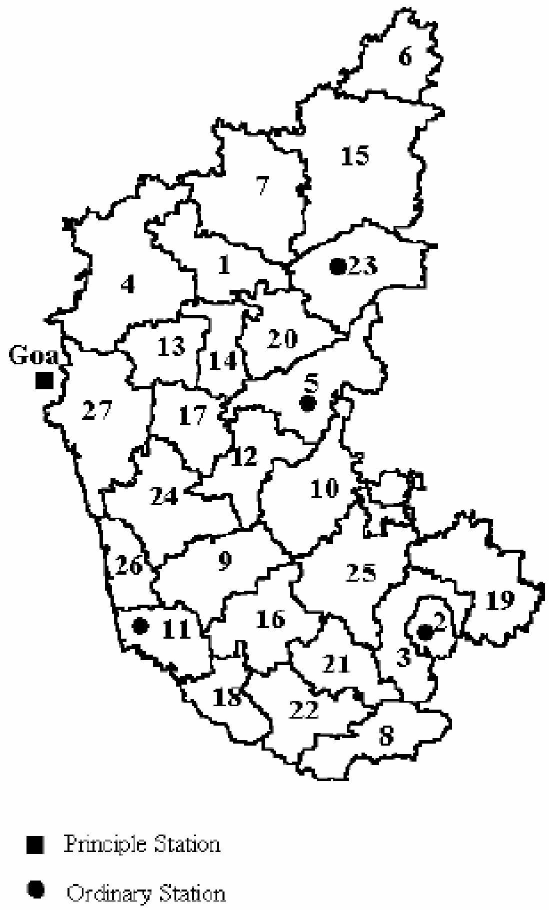
Stations where measurements of global solar radiation were available, data was used directly and for locations where the data was not available indirect methods were used. They are as follows,

1. From extra terrestrial radiation, allowing for its depletion by absorption and scattering by atmospheric gases, dusts, aerosols and clouds. This is theoretically based and requires some approximation of the absorbing and the scattering property of the atmosphere (given in Eq. 6).
2. From other meteorological elements, such as duration of sunshine and cloudiness using regression technique (Eqs. 9, 10 and 20). This method is empirical based, and the form usually used involves actual and potential hours of sunshine, which gives the regression constants for global and diffused solar radiation at the particular location or site

For practical purpose it is convenient to divide the entire radiation regime within the earth's atmosphere into two parts, the solar or the short-wave radiation and the terrestrial or long-wave radiation. To derive the detailed solar radiation climatology of a region and to estimate its solar energy potential, it is necessary to collect extensive radiation data such as daily global solar radiation, daily diffused solar radiation, sunshine hours, and maximum sunshine hour etc. of highest accuracy at a larger number of stations covering all the climatic zones of the region. In the absence of actual measured data, radiation data can be computed from other meteorological parameters to provide necessary data coverage for the region [5].

5. 1. Estimation of solar energy in Karnataka

India Meteorological Department (IMD) collects climatological data in all districts of Karnataka while solar radiation data is collected in stations of Bangalore, Mangalore, Bellary, and Raichur. Fig. 2 shows the meteorological stations in Karnataka. These are ordinary stations equipped for continuous recording of global solar radiation and sunshine. Since not all the districts have solar radiation monitoring station, the values for such districts were estimated using the data collected from the neighboring station (with solar radiation data). The climatological parameters such as relative humidity, sunshine hours, and mean temperature for calculating global solar radiation was collected from IMD, Pune for meteorological stations in Karnataka located at Bangalore (ordinary radiation station), Mangalore (down ward radiation measured), Bellary (under crop weather observation), and Raichur (co-operation ordinary radiation station).



District_name	AREA_SQKM!	District_id
Bagalkote	6,594	1
Bangalore	2,190	2
Bangalore Rural	5,815	3
Belgaum	13,415	4
Bellary	8,419	5
Bidar	5,448	6
Bijapur	10,475	7
Chamarajanagar	5,685	8
Chikmagalur	7,201	9
Chitradurga	8,388	10
Dakshina Kannada	4,843	11
Davanagare	6,018	12
Dharwad	4,230	13
Gadag	4,657	14
Gulbarga	16,224	15
Hassan	6,814	16
Haveri	4,851	17
Kodagu	4,102	18
Kolar	8,223	19
Koppal	8,458	20
Mandya	4,961	21
Mysore	6,269	22
Raichur	5,559	23
Shimoga	8,465	24
Tumkur	10,598	25
Udupi	3,596	26
Uttara Kannada	10,291	27

Fig. 2. Meteorological stations in Karnataka.

Regression relations between radiation with sunshine duration and climatological parameters was found out for Bangalore, Mangalore, Raichur, Bellary districts (in Karnataka) and Goa based on 25 years of data collected from Goa, 20 years data from Mangalore, 12 years data from Bellary and 7 years data from Raichur. It is found that computed values of solar radiation agree within 5-10% of the observed values.

With the knowledge of relationship between global radiation with sunshine duration and climatological parameters at Mangalore, Bangalore, Bellary, Raichur, and Goa interpolation was done to determine global solar radiation in other districts of the State, where solar radiation data is not available. Climatological mean monthly data of temperature, hours of sunshine, relative humidity etc., for all the districts were analysed and used to estimate solar radiation for all districts in Karnataka.

Thus, solar radiation for Kolar, Tumkur, Mysore, Mandya and Chamrajnagar were estimated based on the relation derived from Bangalore station, as Bangalore is closer to these districts. Similarly values for Udupi, Shimoga, Chikmagalur, Hassan and Kodagu were estimated based on the relation derived from Mangalore station. Relation derived from Bellary station was used in Haveri, Gadag, Davangere, Koppal, and Chitradurga and that from Raichur station were used in Bidar, Gulbarga, Bijapur, and Bagalkote. Since Uttara Kannada, Dharwad, and Belgaum were closer to Goa, global solar radiation was estimated based on the regression relationship derived for G' and climatological parameters of Goa. The station in Goa is a principal radiation station, where there is continuous recording of global, diffused solar radiation and sunshine.

The solar energy potential is truly enormous, and the amount that can be readily accessed with existing technology greatly exceeds the world's primary energy consumption. In determining the realistic potential of solar energy conversion systems, it is quite evident that we have to consider the availability of solar energy associated with time such as daily variation due to day and night cycles, seasonal changes due to the earth's motion around the sun, and variation due to local weather condition. With the detailed investigation of solar energy availability and changes at various places in Karnataka, the potential that could be harnessed to meet the community energy needs in the immediate future can be known.

Due to the dilute nature of solar energy flux at the earth's surface large collecting surfaces are required in many applications. This makes it necessary to look at the land use pattern of the region and also at the land availability for harnessing solar energy.

The average monthly global solar radiation is calculated using Eq. 17. Based on the R^2 value and the least value of standard error of the y estimate, empirical formula consisting of specific humidity and mean temperature is the best relationship compared to others.

$$(G'/ETR) = f_1 + f_2\,(n/N') + f_3\,Tm + f_4\,SH \quad (17)$$

where, Tm is mean temperature and SH is specific humidity (given by Eq. 19).

The resulting global solar radiation is further classified based on seasons as:

– Global solar radiation during summer (February–May)
– Global solar radiation during monsoon (June–September)
– Global solar radiation during winter (October–January)

6. Results, analyses and discussion

6.1. Solar radiation in Karnataka

Karnataka receives global solar radiation in the range of 5.1–6.4 kWh/sq.m during summer, 3.5-5.3 kWh/sq.m during monsoon, and 3.8–5.9 kWh/sq.m during winter. The analysis reveals that, maximum global solar radiation is in districts such as Uttara Kannada, Dakshina Kannada etc. The study identifies that Coastal parts of Karnataka with the higher global solar radiation is ideally suited for harvesting solar energy.

Global solar radiation in Uttara Kannada during summer, monsoon and winter are 6.31, 4.16 and 5.48 kWh/sq.m respectively. Similarly, Dakshina Kannada has 6.16, 3.89 and 5.21 kWh/sq.m during summer, monsoon and winter. Where as Mandya district has minimum global solar radiation of 5.41, 3.45, 3.73 kWh/sq.m during summer, monsoon and winter. The results were implemented in GIS to obtain maps showing district wise variation of global solar radiation. Fig. 3 shows the district wise variation of global solar radiation during summer, Fig. 4 during monsoon, and Fig. 5 during winter.

6. 2. Present status in Karnataka

Though successive governments have installed 700 PV pumps, 26,000 PV domestic lighting units, 800 PV based TV and community units and 30,000 PV powered street lights, which together generate some 530 kW, a great deal needs to be done to deliver Photo Voltaic on a large scale. Table 1 gives the district wise utilization of solar lanterns, home lights, and street lights (1996–2002).

Many bulk applications of energy (like cooking and heating) need only a low-grade energy source, and hence it makes sense to make solar thermal devices available to households on a large scale. However, the installation of solar water heating devices appears to have slowed down, even though major savings can be achieved through the use of solar passive systems for heating and cooling buildings, apart from the few isolated architectural experiments, not much has been achieved in this area [11].

The total number of industrial and commercial systems installed in the state is around 150 in the range 1000 liters per day (35 systems), 1000 to 5000 LPD (72 systems), 10000 LPD (10 systems). Assuming that the system is used effectively for 225 days in a year the amount of equivalent electrical energy saved annually is 6 million units. In Bangalore city alone 4.2 lakh All Electric Houses (AEH) consume electricity for water heating. The amount of electrical energy that can be saved by installing solar water heaters is approximately 1.8 million units. The generation capacity required to meet their demand is 250 MW, which will cost the state Rs. 380 crore. But for installing the solar heating to All Electric Homes (AEH) in Bangalore city would cost Rs. 250 crore.

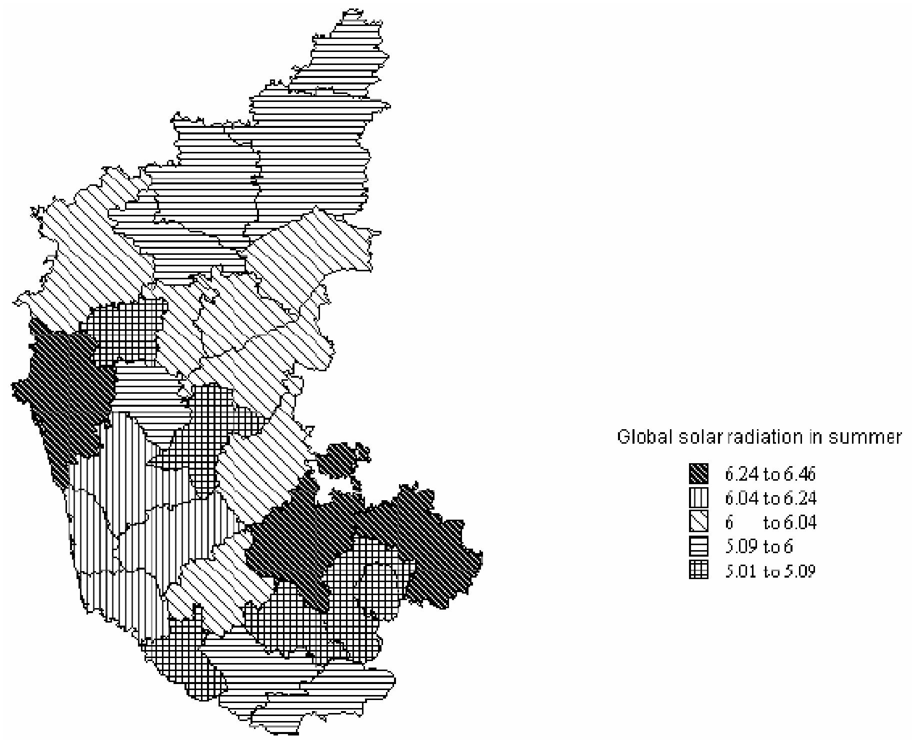


Fig. 3. District wise distribution of global solar radiation during summer.

The cost of domestic water heater is between Rs. 8000 and Rs. 10000. Government of India provides a subsidy of Rs. 3000 to each person who goes for it. Solar heaters save about 50 to 75 kWh of energy per month per household. By educating people about solar energy through mass media substantial saving in electric energy and fuel wood could be achieved. The reasons for low-level market penetration are high capital cost of the system, inadequate fund for disbursement of subsidy, absence of attractive financial package for buyers and lack of awareness of the technology.

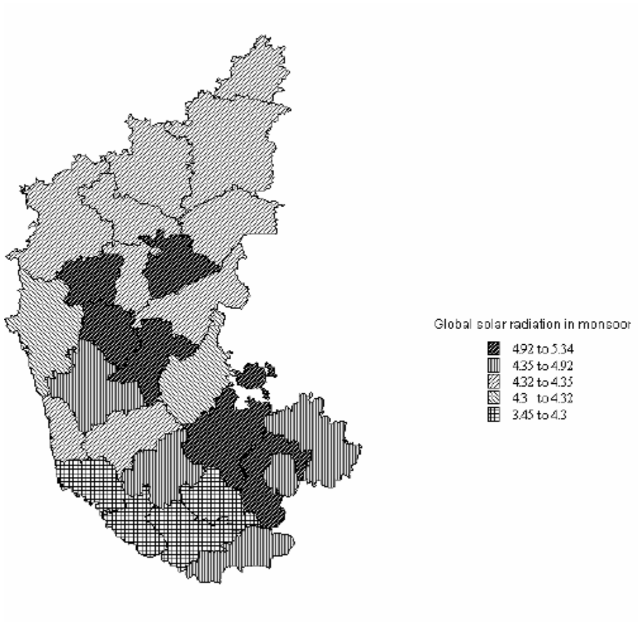


Fig. 4. District wise distribution of global solar radiation during monsoon.

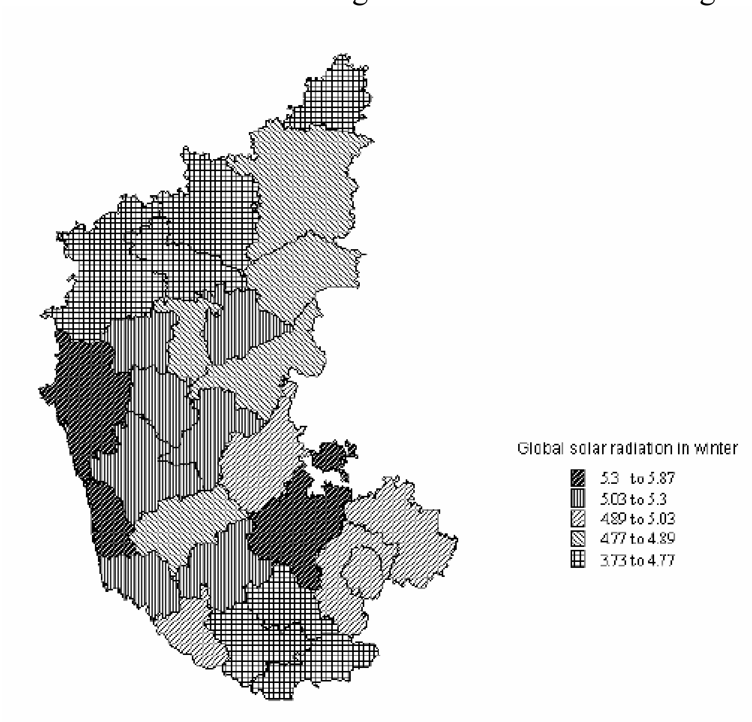


Fig. 5. District wise distribution of global solar radiation during winter.

Table 1. District wise utilization of solar lanterns, home lights, and street lights

District	Lantern	Home light	Street light
Bangalore (urban)	2517	286	63
Bangalore (rural)	–	–	–
Belgaum	74	8	0
Bellary	148	3	15
Bidar	16	3	50
Bijapur	21	8	10
Bagalkote	4	31	5
Chikmagalur	291	220	76
Chitradurga	151	38	0
Davangere	19	9	6
Dakshina kannada	172	1981	68
Udupi	3	346	0
Dharwad	25	43	53
Gadag	8	9	0
Haveri	282	201	0
Gulbarga	23	5	0
Hassan	244	147	11
Kodagu	802	96	22
Kolar	169	25	0
Mandya	21	0	5
Mysore	1771	80	50
Chamrajnagar	176	11	21
Raichur	5	1	0
Koppal	10	13	0
Shimoga	142	271	0
Tumkur	57	3	19
Uttara Kannada	36	84	0

Source: Karnataka Renewable Energy Development Limited.

7. Conclusions

Solar energy is a clean, pollution free, and renewable source of energy. Development of this source of energy requires an accurate detailed long-term knowledge of the potential taking in to account seasonal variations. The region of the earth between the latitude of 40°N and 40°S is generally known as the solar belt and this region is supposed to be with an abundant amount of solar radiation. Karnataka being located between 11°40' and 18°27' north latitude and the geographic position favors the harvesting and development of solar energy. Karnataka receives global solar radiation in the range of 3.8–6.4 kWh/sq.m. Global solar radiation during monsoon is less compared to summer and winter because of the dense cloud cover. The study identifies that coastal parts of Karnataka with the higher global solar radiation is ideally suited for harvesting solar energy.

This study has demonstrated that Geographic Information Systems (GIS) helps in mapping on spatial and temporal scales of the resources and demand. The spatial database of resource availability and the demand would help in the regional energy planning. GIS provided the means for identifying, and quantifying the factors affecting the available solar energy potential. In addition to this, it also provided the flexibility to enrich the database, on which decisions are based, with spatial data and additional restriction on resource availability.

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References

[1] http://www4.tpgic.com.au/users/eafc/solarm/solrad.htm
[2] Feller G. Serious megawatts. India Building large-scale solar thermal capacity. Rajasthan, India. www.ecoworld.org/ energy/articles/articles2, 2003.
[3] Hunt VD. Energy dictionary, Van Nostrand Reinhold Company Inc., New York, pp.230-246, 1979.
[4] Mani A. Handbook of Solar Radiation Data for India, Allied Publisher Private Limited, New Delhi, pp. 1–88, 1980.
[5] Mani A. Solar Radiation over India, Allied Publisher Private Limited, New Delhi, pp. 1-79, 1982.
[6] Iziomon MG, Mayer H. Assessment of some global solar radiation parameterizations. J Atmospheric Solar-errestrial Physics 2002;64:1631–1643.
[7] Rahoma UA. Clearness index estimation for spectral composition of direct and global solar radiations. Applied Energy 2001;68:337–346.
[8] Rehman S, Saleem GG. Spatial estimation of global solar radiation using geostatistics. Renewable Energy 2000;21:583–605.
[9] Aksakal A, Rehman S. Global solar radiation in Northeastern Saudi Arabia. Renewable Energy 1999;17:461–472.
[10] Ramachandra TV, Subramanian DK. Potential and prospects of solar energy in Uttara Kannada, district of Karnataka State, India. Energy Sources 1997;19:945–988.
[11] http://www.indianpurchase.com/magonline/e-power/current/article1.htm

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