APPLICATION OF GEOMATICAL SCIENCE TO CHARACTERIZE SOLAR RADIATION IN CUIABA, MATO GROSSO, BRAZIL, THROUGH SRTM DIGITAL ELEVATION MODEL

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ABSTRACT: The sun is the primary source of energy and influence ecologic, social and economic aspects of humanity. The aim of this work was to use the remote sensing and geographic information systems for solar radiation prediction based on Cuiaba, Brazil digital elevation model. SRTM data was used as source of information for solar radiation estimates in Cuiaba, Mato Grosso, Brazil. Algorithms of Solar Analyst were used in a geographic information system to estimate global, diffuse, direct radiation and its duration in the year of 2009, according to altitude variability. The adopted methodology enabled to visualize the spatial variability of solar radiation in Cuiaba. Based on zonal tabulation spatial analysis, areas with higher solar radiation values corresponded with areas with higher solar radiation duration. Generally, higher elevations received more insolation than lower elevations.

KEY-WORD: Solar energy, spatial variability, remote sensing, GIS.

INTRODUCTION: The suns are the primary source of energy and influence ecologic, social and economic aspects of humanity. In a local scale the latitude and topography are the principal factors that influence the distribution of radiation. The analysis of the slope orientation of a given area is an effective tool to evaluate the degree of sunlight and moisture level which they are exposed, allowing the indication of potential areas for solar radiation usage.

Several models have been proposed for generation of global radiation, usually, solar radiation estimation methods are based on ground measures obtained from dispersed radiometric networks. Interpolation and extrapolation techniques, applied to the measured data, are performed to estimate the solar radiation at points located away from the stations (BATLLES et al., 2008) for example, the radiation estimated by empirical equations starting from the simple Angström linear-regression formula and with the computer-program can provide the immediate and accurate values for the solar components for any site in the country (MOHAMAD, 2004). The random nature of global solar radiation is included in all proposals, but the way of implementing this in a model varies significantly (EHNBERG & BOLLEN, 2008).

Spatial radiation models can be categorized into two types: point specific and area based. In the both types, the local effect of complex topography can influence in the estimated needing a specific solutions as empirical relation for the usual methods. The Solar Analyst is a comprehensive geometric solar radiation modeling tool with a fast and effective algorithm that permits accurate calculation of topographic influences on solar radiation over local and landscape scales (FU & RICH, 1999).

NASA Shuttle Radar Topography Mission (SRTM) has provided Digital Elevation Models (DEMs) for approximately 80% of the earth's land surface. The SRTM mission provided the

most complete high resolution digital topographic database of the Earth. However, only 3 arc sec data are available for most scientific research (EHSANI & QUIEL, 2008).
Considering that complex environmental and agricultural problems require solutions of geomatics that combine knowledge, techniques and methodologies from different sources, for decision support improvement, it has been even more necessary to use those methodologies to optimize resources for environmental impact assessments and to reduce costs in quality control programs. Thus, the aim of this work was to use remote sensing and geographic information systems for solar radiation estimates in Cuiaba, Mato Grosso, Brazil, using SRTM digital elevation model.

MATERIAL AND METHODS: The study was conducted in the Cuiaba municipal district, Mato Grosso state, located in the southern part of the Brazilian (16°S, 56°W, average altitude 179 m). The tropical semi-humid climate in the region is characterized by annual average temperatures between 22 and 25°C and annual precipitation of 1400 mm in the urban areas of Cuiaba and Varzea Grande (ZEILHOFER et al., 2009). The Cuiaba River and its principal affluent are responsible for about 63.9% of the total volume used for public water supply in the watershed, which corresponds to withdrawals of about 1.4 m^3s^{-1}, without considering rural water supply along the river. In the cities of Cuiaba and Varzea Grande the quotas of water supply guaranteed by the Cuiaba River are higher, 95 and 82% respectively (ZEILHOFER et al., 2006).
Topographic parameters (slope, aspect, and elevation) were derived from a digital elevation model (DEM) for the basin. The SRTM data are currently distributed by USGS seamless ftp server (ftp://e0srp01u.ecs.nasa.gov/srtm/version2/SRTM3/). The 3.0 SRTM version 2.0 data are the result of substantial post processing efforts of the NGA and exhibits well defined water bodies and coastlines and the absence of spikes and wells (single pixel errors), although some areas of missing data (‘voids’) are still present. The version 2 directory also contains the vectorized coastline mask used by NGA in the editing, called SRTM Water Body Data (SWBD), in shapefile format. The data are distributed in a geographic (Lat/Long) projection, with the WGS84 horizontal datum and the EGM96 vertical datum and are currently available from the CGIAR-CSI SRTM database. In this study 3 arc sec DEM of version 3.0 SRTM data (~ 90 m) with geographic projection acquired from CGIAR-CSI GeoPortal database was used. That was re-projected to UTM grid with WGS84 Datum (Figure 1).

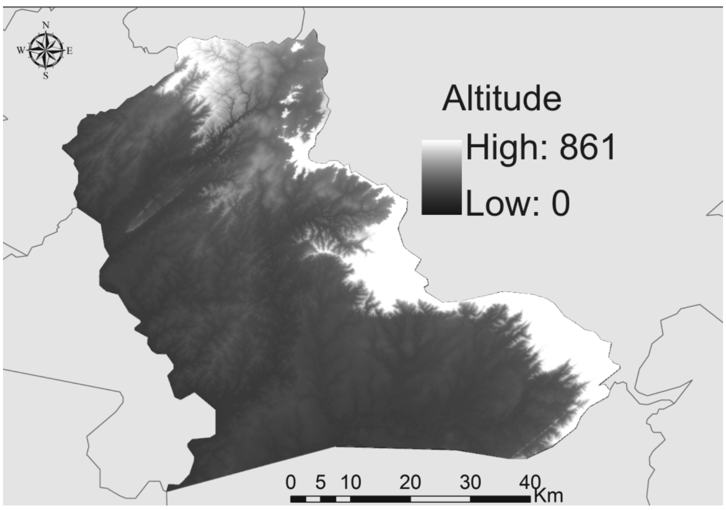


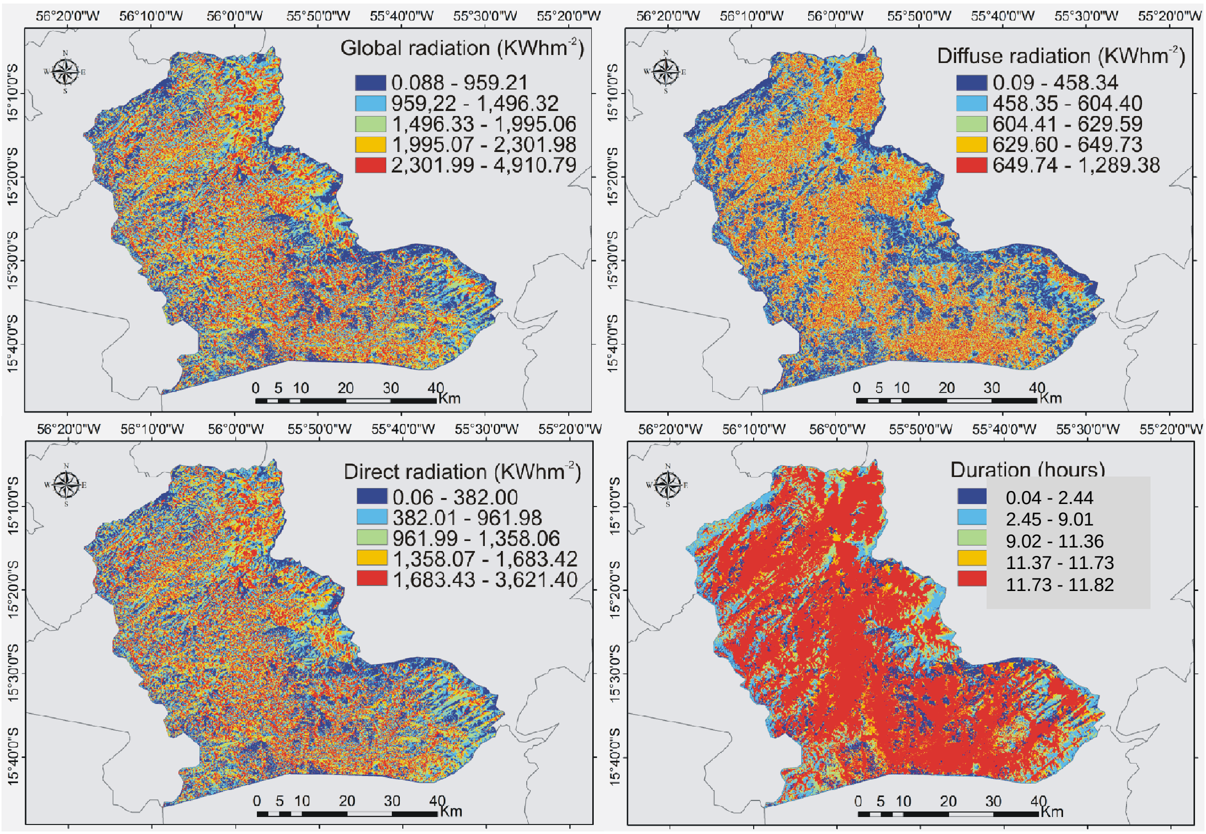
Figure 1. Digital elevation model (DEM) SRTM of Cuiaba, Mato Grosso, Brazil, with 90 m spatial resolution, adopting GCS WGS84 coordinate system.

The Solar Analyst is a comprehensive geometric solar radiation modeling tool. It calculates insolation maps using digital elevation models (DEMs) for input. Highly optimized algorithms account for the influences of the viewshed, surface orientation, elevation, and atmospheric conditions. The incoming solar radiation model account atmospheric condition, elevation, surface orientation and influences of surrounding topography (Fu and Rich, 1999).
Direct solar radiation is calculated based on gap fraction, sun position, atmospheric attenuation and ground receiving surface orientation for each sunmap sector that is not completely obstructed and implemented a simple transmission model which starts with the solar constant and accounts for atmospheric effects based on transmittivity and air mass depth
Global, diffuse, direct radiation and its duration in 2009 were calculated for each pixel of 90 m spatial resolution of the SRTM digital elevation model. After that, quantile tecnhique was applied to the data to define 5 classes of intensity of global, diffuse, direct radiation, its duration and digital elevation model. The area (Km^2) of each class of each map was determined. Zonal tabulation spatial analysis was performed to determine the variation of radiation and its duration inside each class of the digital elevation model.

RESULTS AND DISCUSSION: The adopted methodology enabled to visualize the spatial variability of solar radiation in Cuiaba. Zonal tabulation spatial analysis enabled to determine areas of solar radiation according to classes of altitude (Table 1).
Table 1. Areas (Km^2) derived from zonal tabulation spatial analysis of altitude and global, diffuse, direct radiation and its duration.

Variable interval	Altitude (m)				
	0-191	191-213	213-245	245-363	363-861
Global radiation (KWh m^{-2})					
0.089 - 959.21	103.8	108.2	133.5	133.5	202.5
959.22 - 1,496.31	144.7	133.9	131.6	143.5	160.8
1,496.31 - 1,995.06	144.7	144.6	134.7	137.0	140.9
1,995.07 - 2,301.98	157.5	162.2	144.9	135.1	98.4
2301.99 - 4,910.79	163.8	159.0	142.3	135.3	77.6
Diffuse radiation (KWh m^{-2})					
0.009 - 458.34	97.2	100.4	126.0	133.0	230.1
458.35 - 604.40	101.5	110.7	127.8	122.9	174.7
604.41 - 629.57	167.4	166.1	153.0	143.1	108.8
629.58 - 649.73	164.7	161.4	143.2	148.6	91.0
649.74 - 1,289.38	183.6	169.2	137.0	136.6	75.5
Direct radiation (KWh m^{-2})					
0.06 - 382.00	113.1	115.8	132.5	132.7	178.3
383.00 - 961.98	137.0	127.7	133.5	148.0	175.2
961.99 - 1,358.07	140.9	139.8	129.5	130.0	139.9
1,358.07 - 1,683.42	146.1	152.8	139.7	132.7	105.7
1,683.43 - 3,621.4	177.3	171.8	151.8	140.7	81.2
Duration (h dia^{-1})					
0.04 - 2.44	44.3	56.4	78.8	73.0	88.9
2.45 - 9.01	64.3	40.9	38.8	57.0	150.2
9.02 - 11.36	52.1	55.3	61.1	60.2	123.0
11.37 - 11.73	57.1	69.7	82.0	68.2	75.6
11.73 - 11.82	496.6	485.5	426.2	425.8	242.6

Generally, higher elevations received more insolation than lower elevations (Figure 2). However, there was reduction of radiation area under higher values of radiation in the highest altitude interval. It suggests that the aspect of terrain could cause major influence in radiation than altitude values. FU & RICH (2002) studying applications of solar radiation model in agriculture and forestry using Solar Analyst also observed relations of soil temperature, insolation and elevation in order to provide information to understand fine-scale patterns across the landscape. Studies must be done to validate the obtained results using climatic stations at Cuiaba municipal district and to evaluate the potential of using solar radiation in buildings of Cuiabá city.



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