Estimate Electricity Production from Solar Energy Potential using GIS Techniques

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***Abstract*—Pakistan is in the grip of serious energy crises that is badly affecting all sectors of the economy and the various segment of the society. With an energy shortfall of approximately 8,500 MW in the country [1] ,ever dwindling gas reserves, and unfavorable balance of payments in oil imports, it is imperative to enhance production of energy from all indigenous sources giving top priority to sources of renewable energy. Pakistan possesses tremendous potential for generating renewable energy from solar potential. Renewable energy can play a unique role by supplementing the existing energy resources at local level and providing the desired diversity in power generation sources for uninterrupted supply and provide economical ways to produce electricity. The prime objective of this research was to identify potential for solar energy farms in sindh area by incorporating various environmental, economic, and physical parameters. Physical parameters like solar irradiance , environmental constraints like presence of natural reserves, agricultural lands , coastlines ,lakes and wetlands areas and planning and economic constraints criteria like acceptable aspect, slope and proximity to transmission lines were taken into account for each source of energy based on literature review and national legislations and guidelines. In this study a GIS based methodology for estimated electricity production from solar energy potential was developed for sindh province. Individual satisfaction degrees for each alternative location with respect to the identified technical and environmental objectives as well as economical feasibility criteria were calculated using analytical hierarchy process (AHP) for solar potential. Then these individual satisfaction degrees were aggregated in to over all performance indexes which were used to determine priority maps for solar energy generation facilities and estimates electricity production from suitable areas.Since there was no specific study conducted in site suitability for renewable energy farms in sind, this study will be useful for decision makers and investors to look in to the possibility for installation for PV solar energy systems.**

***Keywords*—Multi-criteria Decision Analysis; Analytical hierarchy process (AHP); Alternate Energy; Renewable energy farms**

I. Introduction

In the era of globalization, a rapidly increasing demand for energy and dependency of countries on energy indicate that energy will be one of the biggest problems in the world in the next century [2]. This requires for renewable sources of energy. Fortunately, by virtue of Pakistans location and natural endowments, many technologically feasible alternate energy resources, like solar and wind ,are available to meet the countrys growing energy requirements [3]. Renewable energy (Solar and Wind) projects is one of the most possible ways for sustainable energy development. Since the cost is important factor in renewable energy projects, the project feasibility should be done before construction. Selecting the site for wind turbine and photovoltaic system is a typical process involving not only technical requirement, but also physical, economical, social, environmental and political requirements that may result in conflicting objectives. Such complexities needs use of Geographical Information System and Multi-criteria decision making. The study area of this research covers Sind province of Pakistan as shown in Fig: 1.

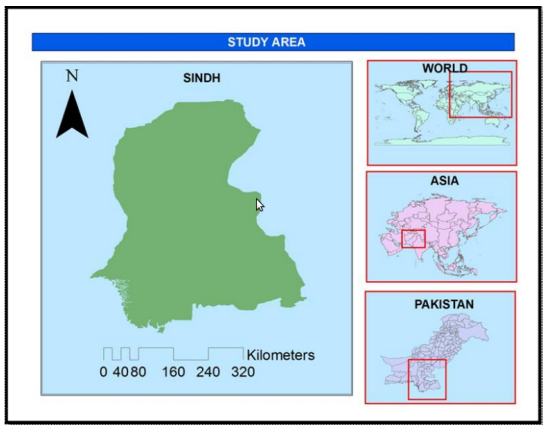

Fig. 1. Study Area

II. Site Selection for Alternate Energy

A. Site Selection Process

Site selection for photo voltaic system requires consideration of a comprehensive set of factors and balancing of multiple objectives in determining the suitability of a particular area for a defined land use [4]. The selection of suitable sites involves a complex process drawing from physical, demographical, economic, policies, and environmental constraints. The current decision making process has advance methods for handling multi-criteria problems while considering the physical suitability conditions.

B. Site Selection Tools

Geographic information systems and Multi-criteria decision making techniques have been used in finding site suit-

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ability areas . A brief description of these decision making tools are shown below .

C. Geographic Information Systems (GIS)

A GIS is a computerized system that helps in maintaining data about geographic space [5]. Although often described as a decision support system, there have been some supporting modules for site selection based on various area conditions, and conflicting objectives.

D. Multi Criteria Decision Making (MCDM)

Multi criteria decision analysis is a tool which is used for decision making used different weighing schemes to assigned weights to different criteria used in your analysis. Multi-criteria decision methods used to solve various site selection problems.

E. The Analytical Hierarchy Process (AHP)

The most important factor in MCDM is how to establish weights for a set of criteria according to importance. Location decisions such as the ranking of alternative communities are representative multi-criteria decisions that require prioritizing multiple criteria [4]. The analytic hierarchy process (AHP) is a logical framework that helps analyzer to improve the understanding of complex decisions by making hierarchical structure of the problem. The incorporation of all relevant decision criteria, and their pairwise comparison allows the decision maker to determine the trade-offs among objectives. AHP allows decision makers to solve complex problems

F. Pairwise Comparisons Method

The Pairwise comparisons method was developed by Saaty (1980) in the context of the Analytical Hierarchy Process (AHP). This method involves pairwise comparisons to create a ratio matrix. As input, it takes the pairwise comparisons of the parameters and produces their relative weights as output

III. METHODOLOGY

The research was performed in two phases ,the first focused on the development of a method by which people could obtain the suitable areas for the location of solar farms in the investigated areas Site selection of solar system is depend upon direct solar radiation ,slope, Aspect, natural reserves and most importantly its required large area for the deployment of solar panel arrays [6] . The criteria in this study were selected with the help of literature review and Pakistan government regulations.Flow chart of methodology is shown in Fig: 2

A. GIS Data

To find out the suitable sites for solar energy , there are eight spatial data layers of input for overlaying in ArcGIS10.1 with GIS extension modules; Image Analysis, Spatial Analyst and 3D Analyst. Some details of input data are shown in Table:I

GIS Data	Description	Data Source
Layer 1	Solar energy potential	NASA surface meteorology database
Layer 2	Transmission grid	Google Earth
Layer 3	Slope	Digital Elevation Model
Layer 4	Aspect	
Layer 5	Urban areas	LANDSAT 4,5 image Data
Layer 6	Vegetation areas	
Layer 7	Barren areas	
Layer 8	Road Network	

TABLE I
DETAIL OF GIS INPUT DATA

Intensity of importance	Definition
1	Equal importance
2	Equal to moderate
3	Moderate importance
4	Moderate to strong
5	Strong
6	Strong to very strong
7	Very strong
8	Very strong to extremely strong
9	Extreme importance

TABLE II
WEIGHING SCORES

B. Weighing Criteria

Weighing scores for each criterion is derived from analytic hierarchy process (AHP), by directly comparing importance of one criterion to another criterion. Rules for defining the score are shown in Table:II

Summary of weighing scores for each criterion of PV panel site selection are shown in Table:III

Criterion	Solar	Aspect	Slope	Barren	Vegetation	Urban	Road	Grid	Weights
Solar	1	4	3	4	5	4	5	3	0.30
Aspect	0.25	1	2	4	5	5	5	3	0.20
Slope	0.333	0.5	1	4	5	3	5	3	0.17
Barren	0.25	0.25	0.25	1	2	3	3	2	0.09
Vegetation	0.2	0.2	0.2	0.5	1	2	3	2	0.06
Urban	0.25	0.25	0.333	0.333	0.5	1	3	2	0.06
Road	0.2	0.2	0.2	0.333	0.333	0.333	1	2	0.04
Grid	0.333	0.333	0.333	0.5	0.5	0.5	0.5	1	0.04
Total									1.00

TABLE III
WEIGHING SCORES FOR SOLAR FARMS SITE SELECTION

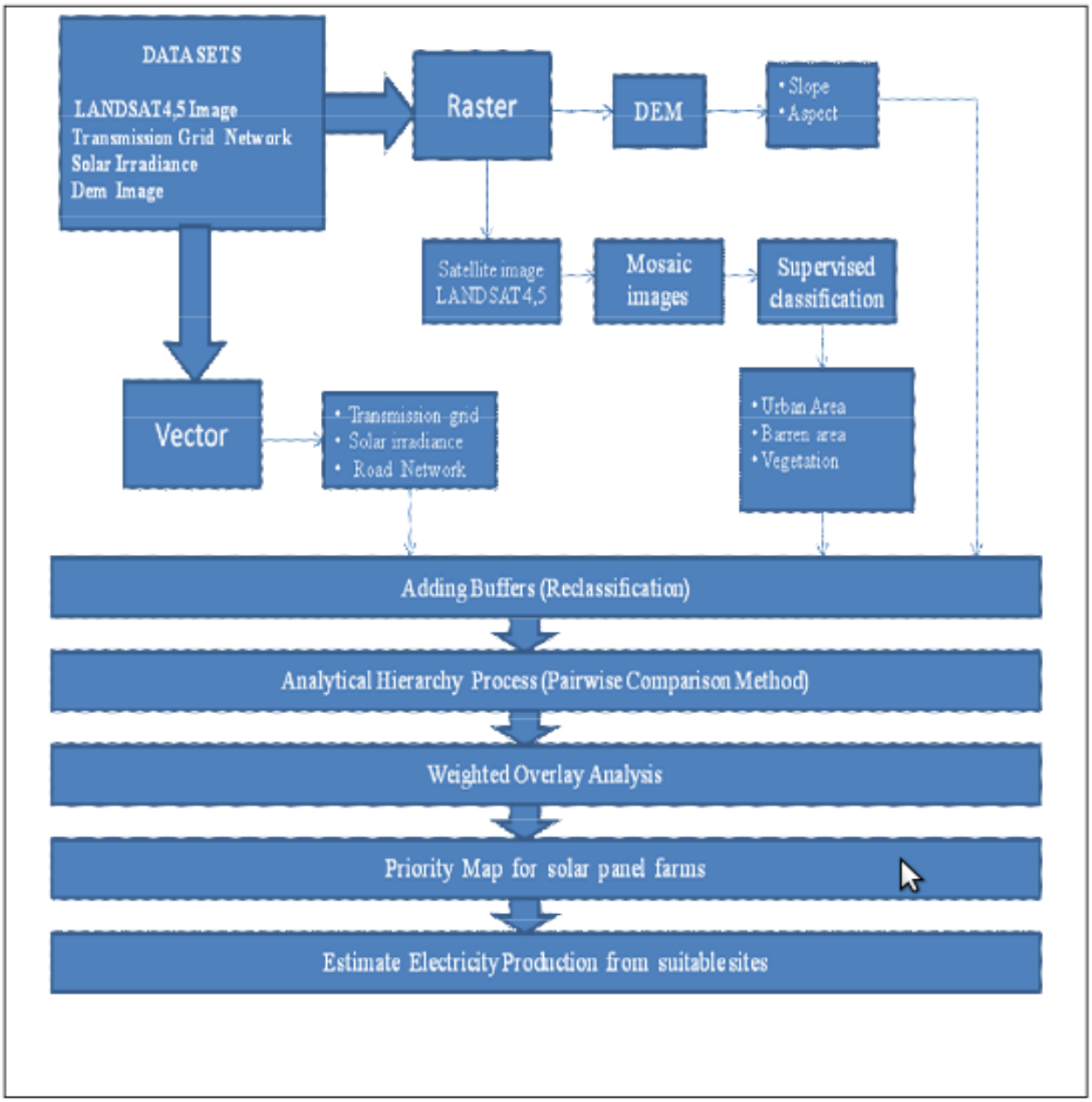

Fig. 2. Flow Chart (Methodology)

C. Suitability function

In this study perform a GIS Spatial analysis and 3D analysis using ArcGIS10.1 which represented as sets of spatial processes, such as buffer, classification, and overlay techniques such as weighted overlay . Each of the input criteria is assigned a weight influence based on its importance, then the result successively multiplying the results by each of the constraints. This process is often used in site suitability studies where several factors affect the suitability of a site. Then the GIS overlay process can be used to combine the factors and constraints in the form of a weight in overlaying process. The result is then summed up producing a suitability function (F) as described by the formula.

$$F = \prod_{I=0}^{I=N} (wi * Mi) \tag{1}$$

D. PV Panel Energy Calculation

Estimated power generated by solar panel array on suitable areas can be calculated with the help of the equation given below

$$E = A * r * H * PR \tag{2}$$

E = Energy in kilo watt-hour/Annual
A = Total solar panel area in square km
r = Solar Panel Yield

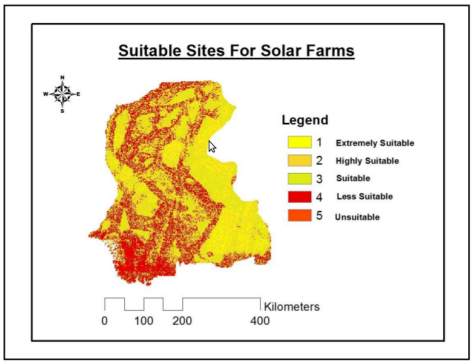

Fig. 3. Suitability Sites For Solar Farms

Suitability	Area (Square km)	Energy (Kwh/Ann)	Power Generated (MW)
Extremely Suitable	257.78	12730672	1909.6
Highly Suitable	9902.5	203327593	30499
Suitable	51289.21	261627504	39244.12

TABLE IV
ESTIMATED POWER GENERATION OF SUITABLE LOCATIONS

H = Average Annual Irradiance
PR = Performance Ratio , coefficient for losses

There are many type of losses associated with solar panel

- Inverter losses
- Temperature losses
- DC cables losses
- AC cables losses
- Shadings

IV. RESULTS OF SYUDY

The results from the study, shows Suitability areas for solar farms are depicted in Fig: 3:

The areas covered by the suitable locations and estimated power production with the help of solar panel array are given in table:IV

V. CONCLUSION

However, analyzing data for appropriate zones for the PV solar panel installation .In this study had higher weights of the data on the effectiveness of solar irradiance and on Aspet than other factors. This shows that the extremely suitable, class1, and the high suitable, class 2, areas were found in Barren zones..Moreover, for the engineering and construction possibilities in this study area, the areas steeper than 15are considered as exclusion zones. After analyzing data for pv panel installation in this study.The results shows that extremely and highly suitable class of solar farms suitability map has enough area for solar panel array and could generate large amount of electricity which is useful to cover present shortfall.

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