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RESEARCH ARTICLE

SITE SELECTION OF SOLAR FARMS FOR DISTRICT MALAKAND USING ANALYTICAL HIERARCHY PROCESS (AHP)

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ABSTRACT

The energy deficiency of the modern world can only be overcome by the proper utilization of the renewable energy resources. Pakistan and specially Khyber Pakhtunkhwa (KPK) province is facing major energy problems, to reduce these problems one of the option is to install solar farms in different areas of the KPK province. This research paper, deals with site selection for solar farm in Malakand Division. There are many sites in Malakand Division, but selection of the most suitable site for the solar farm is important because it needs investment in millions. The Analytical Hierarchy Process (AHP), is used by which Shergarh, Skha kot, Dargai, Malakand, Batkhela and Thana were alternatives. Eight factors were considered, namely Quality of Terrain, Land's Price, Security, Weather, Local Transmission Capacity, Proximity to transmission lines, Agricultural concern and Population. After strong brain storming, surveys (related to the data collection of different factors) and meetings with different government officials and local area people's. The calculations were based on AHP and finally it was concluded that THANA with weight (0.1927) is the most suitable site for the solar farm to be installed. In future work it is suggested to use Multiple Criteria Decision Analysis (MCDA) integrated with Geographic Information System (GIS) to select a suitable and feasible site and then compare the results.

INTRODUCTION

Energy is the biggest and vital challenge for the mankind they are facing in twenty-first century. Before industrial revolution there were non-renewable sources used for the energy production called fossil fuels i.e. coal, natural gas and petroleum. These resources were vital for the usage of each sector of life in the human society. But as the fossil fuel resources are stored energy accumulated during hundreds of millions of years and is being very rapidly depleted by excessive exploration. So, the fossil fuel resources are limited and will be vanished soon. On the side if we look at the limited availability of the fossil fuel it will lead to higher prices. In the next 25 years, the Global demand will be increased by 49% (Kaiser *et al.,* 2013). And as result the demand is expected to be increased from 86 million barrels/day in 2007 to 104 million barrels/day in 2030 (Kaiser *et al.,* 2013). As majority of the World's energy supply is generated from fossil fuels, and it has an extraordinary impact on the World ecology, economy and climate. The price of oil and other fossil fuels are increased very quickly in the recent years so most of the world countries have developed new policies to reduce the cost of energy and pollution of the Globe (Panwar *et al.,* 2011). Due to the increasing prices and decreasing the level of the fossil fuel resources also due to the environment hazard, Renewable energy is emerging so rapidly and had taken the attention of each nation.

Renewable energy sources are those resources that can be used to produce energy again and againe.g. solar energy, wind energy, biomass energy, geothermal energy etc.

Renewable energy sources are environment friendly and have almost negligible impact as compare to other energy resources. On the other hand, non-renewable energy sources are finite and someday it will be depleted while the renewable energies are infinite and will not be depleted forever (Urmee *et al.,* 2009). From all the renewable energy sources, solar energy has got the most attention in the decade of 1970s. And is the center of much emotion and pressure. Many people regard it as the solution for the reduction of nuclear and fossil fuels and for clean environment. Solar energy can provide all type of energy needs i.e. chemical, electrical, and thermal and even transportation fuels. Albeit so many uses of the solar energy it is very diffuse undependable and cyclic, so therefore it needs

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systems and components that can concentrate and gather it in a good manner so that it may be converted to any of the above forms efficiently (Power plant technology by el-wakil chapter 13). Although the solar energy is totally free but there is an initial cost which must be considered. One of the most difficult jobs is to choose a suitable site for the solar farms as due to the site selection different Non-Government organizations (NGO's) and Government organizations are being in a puzzle state. As because investment in billions is required for the installation of a solar farm, if a solar farm is installed in such a place where it would not be so much efficient, it will be a huge disaster and will not only decimate us financially but will also barren the cultivable land and will affect other localities as well. So, it is necessary to select the most suitable site for the solar farm. Since the choice of plant destinations has a solid connection dispatch with the plant's security which ought to meet the meteorology prerequisite, financial aspects necessity, environment and society necessity (Yun-na *et al.,* 2013). Determination of an appropriate site depends on an arrangement of criteria for the most part contingent upon the nearby states of its encompassing surroundings. This reality applies on the issue of site determination for appropriate sun oriented areas. The fluctuating barometrical conditions (mists, clean, poisons) additionally change the accessibility of sunlight based illumination inside years and even days. Environmental conditions not just lessen the amount of insolation achieving the Earth's surface additionally influences the insolation quality by dispersing and retention of approaching light and modifying its range. While normal insolation information offer an understanding into sun oriented vitality potential on a local scale, locally important conditions, for example, encompassing territory may fundamentally impact the sunlight based vitality potential in a site (Hofierka and Cebecauer, 2008). What's more, some financial and social criteria take an interest in the assessment of the terrains. Case of such criteria is the vicinity of the chose site to power transmission lines or changing over stations and the closeness to principle streets or populated territories (Arran-Carrion *et al.,* 2007).

The areas with the most astounding sun powered assets are not generally achievable locales for sun oriented homesteads. An assortment of components assumes a part in the site choice of sun oriented homesteads. They can be classified into: monetary, environmental, and so forth figures (Van Haaren and Fthenakis, 2011). Multi-criteria Evaluation (MCE) is generally utilized as a spatial examination instrument in vitality assessment and natural fields. It is in this manner conceivable to give an ideal system to the coordination of the natural, financial, and social elements that influence arrive reasonableness for a specific purpose. Among the different MCE procedures that can be connected to the assessment of land reasonableness, is the Analytical Hierarchy Process (AHP) strategy (Saaty, 1980) (Saaty, 1990 & 2008) such technique speaks to anissue by method for the various leveled association of criteria, and a while later uses correlations with set up weights for criteria and inclination scores for classes of various criteria, considering client judgment (Aydin *et al.,* 2010). As of late, multi criteria assessment (MCE) strategy have turned out to be progressively prominent as a device for various destinations race thinks about. MCE techniques were created in the 1960s to help for basic leadership. MCE is an idea which has wide use in many fields, as per the writing.

In Baton Rouge, Louisiana 70803, U.S.A. the Analytical Hierarchy Process is used to look at the judgments of 126 experts inside reviewers with respect to the significance of 14 elements (called red flag) that may flag the potential for monetary misrepresentation inside a business association (John, 1968). In New Jersey, the AHP is used for different decision making approach to computer software evaluation. Another review was actualized in the Antalya region of Turkey, which is helpful for astronomical site observatory offices with its fitting atmosphere properties and climate conditions. (Koc-San *et al.*) In Jordan the analytical hierarchy process (AHP) is used for the comparison of different electricity power production options. (Bilal *et al.,* Likewise, the AHP is used in so many fields for complex decision making throughout the world (Hauser David *et al.,* 1994; Patrick and Sonia 1999; Yalcin Ali, 2007). The decision taken through AHP is very efficient and can be accepted easily. By the help of AHP we can solve difficult and complex problems, and is being used for such analysis for the last of so many decades.

MATERIALS AND METHODS

a) Analytical Hierarchy Process: (AHP) (Saaty, 1990 & 2008)

AHP is the most important and useful method in making decisions where there are more than one alternatives. AHP isadopted when there is a decision to be taken in selecting an alternative among conflicting, inappropriate and quantitative or qualitative alternatives. All the calculations are carried out using excel spread sheet, (Khwanruthai BUNRUAMKAEW, Kardi. AHPis consisting of different steps, i.e. it is a stepwise procedure. All the steps are described as:

Step1 (Hierarchy Building): In the first step the problem is decomposed into Goal, criterion, sub-criterion and alternatives. This is the most important and critical step in analyzing the results, it helps in comparison of the alternatives and criterion with the goal. An example of simple hierarchy is shown in the fig 1.1.

Step2 (Pair wise comparison): In this step the criterion are compared with each other based on goal, while then all the alternatives are compared with each other based on each criterion. In this step a specific weight is assigned based on the importance for the specific alternative or criterion. Different weights and their meanings are explained in the table 1.

Table 1.

The Fundamental Scale for Pairwise Comparisons		
Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment moderately favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities of 1.1, 1.2, 1.3, etc. can be used for elements that are very close in importance.		

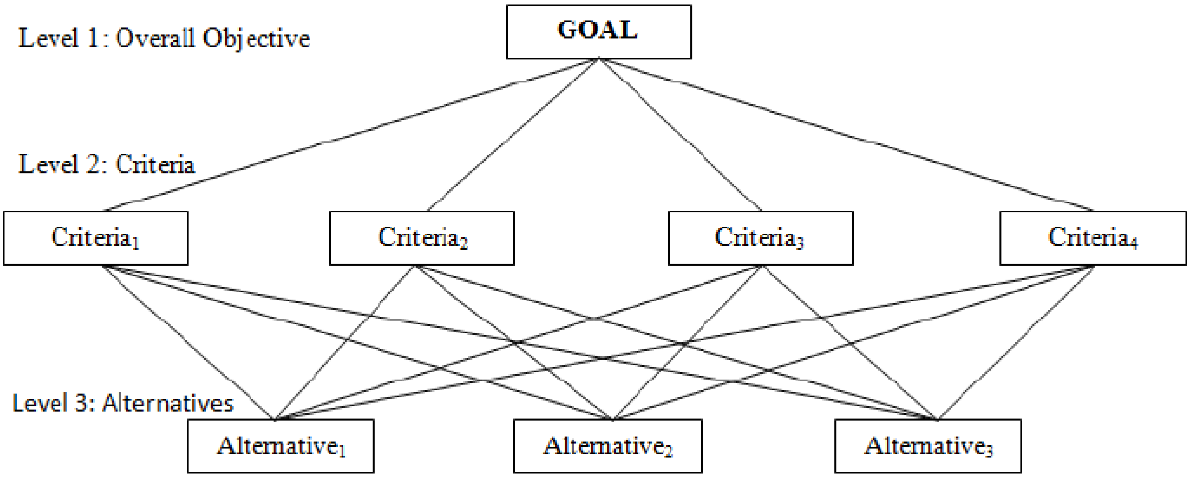

Figure 1. Hierarchy model

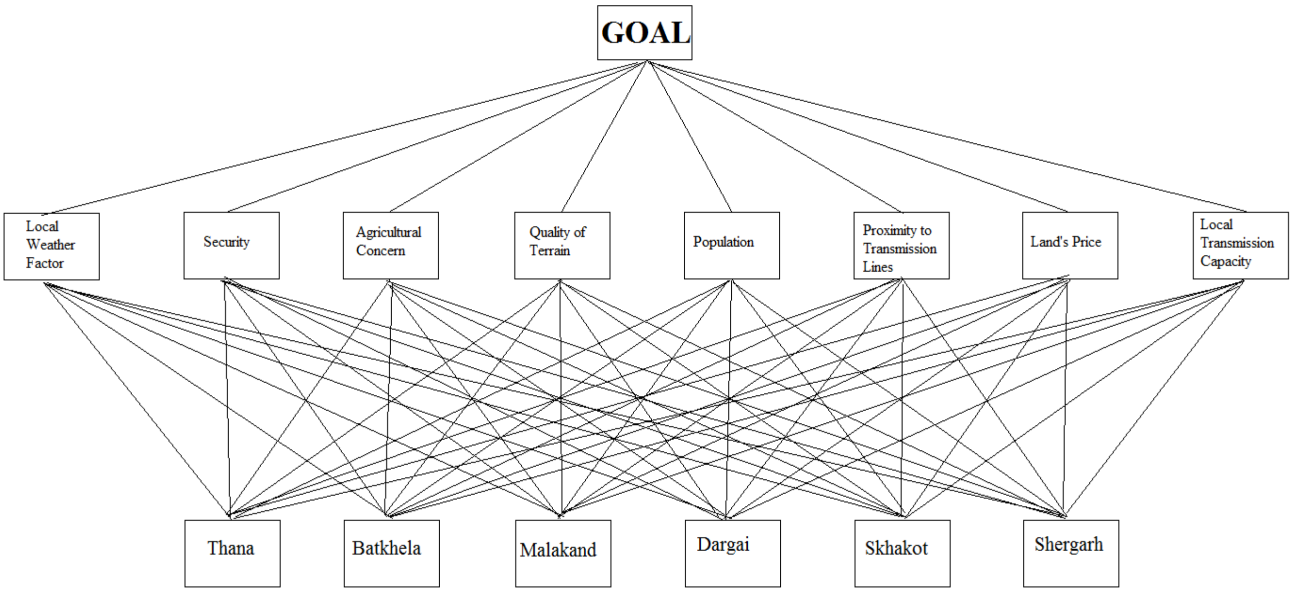

Figure 2. Hierarchy

In the comparison matrix, the values in the principal diagonal will be equal to unity, while the upper triangular matrix will be established by giving specific values to the respective factor, the lower triangular matrix will be the reciprocal of the upper triangular matrix.

Step 03 (Normalization of the matrix): In this step the comparison matrix is normalized by dividing all the entries of the square matrix by the respective column sum.

Step 04 (Eigen/Priority vector): In this step finding the average across each row gives us the priority vector for each factor. In this step the alternative with higher weight is selected as the best choice.

Step 05 (Consistency analysis): In this step, we do consistency analysis for finding whether the preference ratings were consistence or not. (Saaty L.Thomas, 1990 & 2008) In this analysis there are three steps involved

i. Consistency index

For consistency index, we have find the principal Eigen value (λ_{max}), which is obtained by the product of the priority vector with the reciprocal of the respective value of the principal diagonal in the priority matrix.

$$CI = (\lambda_{max} - n)/(n-1)$$

Where 'n' is the number of alternatives.

ii. Random index (RI)

Now as we calculated the consistency index but the main problem is that to which appropriate value should we compare this index? So, for that Prof. Saaty proposed a table which is given by.

Table 2. Random index with respect to the number of alternatives (Saaty Thomas, 1990 & 2008)

N	1	2	3	4	5	6	7	8	9
R.I	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.49

Table 3. Priority vector for the factors based on Goal

Goal	QT	LP	S	W	LTC	PTL	AC	P	Priority Vector
QT	1	0.333	0.2	0.111	0.2	0.166	0.142	0.125	0.019
LP	3	1	0.333	0.166	0.25	0.2	0.166	0.142	0.032
S	5	3	1	0.2	0.5	0.25	0.2	0.166	0.054
W	9	6	5	1	7	5	3	2	0.325
LTC	5	4	2	0.142	1	0.333	0.25	0.25	0.068
PTL	6	5	4	0.2	3	1	0.5	0.333	0.114
AC	7	6	5	0.333	4	2	1	0.5	0.162
P	8	7	6	0.5	4	3	2	1	0.223

Consistency index = 0.136, Random index = 1.41, Consistency Ratio = 0.097

Where QT stands for quality of terrain, LP stands for land's price, S stands for security, W stands for weather, LTC stands for local transmission capacity, PTL stands for proximity to transmission lines, AC stands for agricultural concern and P stands for population.

Table 4. Comparison of alternatives based on weather

WEATHER	Thana	Batkhela	Malakand	Dargai	Skhakot	Shergarh	Priority vector
Thana	1	0.333	0.2	0.143	0.125	0.111	0.027
Batkhela	3	1	0.5	0.333	0.2	0.143	0.056
Malakand	5	2	1	0.333	0.25	0.167	0.085
Dargai	7	3	3	1	0.333	0.25	0.149
Skhakot	8	5	4	3	1	0.5	0.269
Shergarh	9	7	6	4	2	1	0.415

Consistency index = 0.083, Random index = 1.12, Consistency Ratio = 0.074

Table 5. Agricultural concern and Eigen vector *Average = Eigen vector

AgriculturalConcern	Thana	Batkhela	Malakand	Dargai	Skhakot	Shergarh	Priority vector
Thana	1	6	8	3	2	0.5	0.255
Batkhela	0.166	1	3	0.5	0.2	0.143	0.052
Malakand	0.125	0.333	1	0.2	0.125	0.111	0.026
Dargai	0.333	2	5	1	0.333	0.25	0.094
Skhakot	0.5	5	8	3	1	0.333	0.190
Shergarh	2	7	9	4	3	1	0.383

Consistency index = 0.062, Random Index = 1.12, Consistency Ratio = 0.055

i. **Consistency Ratio:** Now the comparison between the consistency index and the random index is called consistency ratio. If the value of the consistency ratio is less than or equal to .10 or 10 % then it is called as consistent otherwise inconsistent (Saaty, 1990 & 2008).

CR = CI/RI

Step 06 (Synthesizing the final priority): In this step priorities of each criterion with respect to goal is multiplied with the priority of each alternative with respect to that criterion. After which all the results for each alternative will be added, the result of which are known as the global priority/rating, the alternative with the higher value will the preferred alternative.

Data and Methodology

Location of Study

The study area of the current research project is named as Malakand Division. Malakand division is situated in the Khyber Pakhtunkhwa province of Pakistan. Malakand is situated at 34.57° North latitude, 71.93° East longitude and 844 meters' elevation above the sea level. In this project six locations of Malakand division are under considerations which are: Shergarh, Skhakot, Dargai, Malakand, Batkhela, and Thana.

As moving from Peshawar city towards Malakand division, first Shergarh falls in the way, after which Skhakot and so on as of the order of given above.

Hierarchy: The first step in the AHP is the hierarchy building; hierarchy for the current research work was built in Paint (software) following the standard procedure [16][17]and is shown in figure 1.2.

Figure 1.2 (Hierarchy)

Data Collection

The data related to different alternatives were collected from different organizations (Pakistan Metrological Department Peshawar, Census department Peshawar, Director of agriculture & Statistical officer Dargai, and Geology department UOP), observation and evaluation through site visits and meeting with different area peoples and experts. After successful data collection, we could assign different weights to the alternatives based on importance. The calculations based on the data collected is presented in results and discussion section.

RESULTS AND DISCUSSION

Comparison of the criterions with respect to the goal: The comparison of the criterion with respect to the goal is carried out in excel spread sheet following the standard procedure also

Table 6. Priority vector based on Population

Population	Thana	Batkhela	Malakand	Dargai	Skhakot	Shergarh	Priority vector
Thana	1	0.5	8	6	3	4	0.278
Batkhela	2	1	9	7	4	5	0.403
Malakand	0.125	0.111	1	0.333	0.143	0.2	0.027
Dargai	0.166	0.143	3	1	0.25	0.333	0.050
Skhakot	0.333	0.25	7	4	1	2	0.145
Shergarh	0.25	0.2	5	3	0.5	1	0.097

Consistency Index = 0.085, Random Index = 1.12, Consistency Ratio = 0.076

Table 7. Priority vector based on Security

Security	Thana	Batkhela	Malakand	Dargai	Skhakot	Shergarh	Priority vector
Thana	1	5	3.00	0.5	8	6	0.292
Batkhela	0.2	1	0.333	0.2	3	3	0.081
Malakand	0.333	3	1	0.333	6	5	0.166
Dargai	2	5	3	1	9	7	0.385
Skhakot	0.125	0.333	0.167	0.111	1	0.5	0.030
Shergarh	0.167	0.333	0.2	0.143	2	1	0.045

Consistency Index = 0.071, Random Index = 1.12, Consistency Ratio = 0.064

Table 8. Priority vector based on Proximity to transmission lines

Proximity to Transmission lines	Thana	Batkhela	Malakand	Dargai	Skhakot	Shergarh	Priority vector
Thana	1	0.5	9	3	7	5	0.305
Batkhela	2	1	7	3	6	5	0.366
Malakand	0.111	0.143	1	0.143	0.5	0.25	0.030
Dargai	0.333	0.333	7	1	5	3	0.171
Skhakot	0.143	0.167	2	0.2	1	0.5	0.047
Shergarh	0.2	0.2	4	0.333	2	1	0.079

Consistency Index = 0.085, Random Index = 1.12, Consistency Ratio = 0.076

Table 9. Priority vector on the basis of Local Transmission Capacity

Local Transmission Capacity	Thana	Batkhela	Malakand	Dargai	Skhakot	Shergarh	Priority vector
Thana	1	5	0.5	3	6	7	0.288
Batkhela	0.2	1	0.333	0.5	3	5	0.107
Malakand	2	3	1	5	7	9	0.391
Dargai	0.333	2	0.2	1	4	6	0.139
Skhakot	0.167	0.333	0.143	0.25	1	2	0.046
Shergarh	0.143	0.2	0.111	0.167	0.5	1	0.029

Consistency Index = 0.095, Random Index = 1.12, Consistency Ratio = 0.085

Table 10. Priority vector on the basis of Quality of Terrain

Quality of Terrain	Thana	Batkhela	Malakand	Dargai	Skhakot	Shergarh	Priority vector
Thana	1	3	7	6	0.333	0.5	0.201
Batkhela	0.333	1	4	3	0.25	0.286	0.099
Malakand	0.143	0.25	1	0.5	0.125	0.143	0.031
Dargai	0.167	0.333	2	1	0.2	0.25	0.053
Skhakot	3	4	8	5	1	2	0.368
Shergarh	2	3.5	7	4	0.5	1	0.247

Consistency Index = 0.079, Random Index = 1.12, Consistency Ratio = 0.070

Table 11. Priority vector based on Land's Price

Land Price	Thana	Batkhela	Malakand	Dargai	Skhakot	Shergarh	Priority vector
Thana	1	4	7	0.333	5	0.5	0.192
Batkhela	0.25	1	3	0.2	2	0.25	0.074
Malakand	0.143	0.333	1	0.111	3	0.125	0.048
Dargai	3	5	9	1	7	2	0.390
Skhakot	0.2	0.5	0.333	0.143	1	0.2	0.038
Shergarh	2	4	8	0.5	5	1	0.256

Consistency Index = 0.112, Random Index = 1.12, Consistency Ratio = 0.099

Table 12. Weights of the factors w.r.t goal and of the alternatives w.r.t the factors

Factors	Weights of the factors w.r.t Goal	Weights of the alternatives w.r.t all the factors					
		Thana	Batkhela	Malakand	Dargai	Skhakot	Shergarh
QT	0.019	0.200	0.099	0.031	0.053	0.368	0.247
LP	0.032	0.192	0.074	0.048	0.390	0.038	0.256
S	0.054	0.292	0.081	0.166	0.385	0.030	0.045
W	0.325	0.027	0.056	0.084	0.149	0.269	0.415
LTC	0.068	0.288	0.107	0.391	0.139	0.045	0.029
PTL	0.114	0.305	0.366	0.030	0.172	0.047	0.079
AC	0.162	0.254	0.051	0.026	0.094	0.190	0.382
P	0.223	0.277	0.403	0.027	0.050	0.145	0.097

Where QT stands for quality of terrain, LP stands for land's price, S stands for security, W stands for weather, LTC stands for local transmission capacity, PTL stands for proximity to transmission lines, AC stands for agricultural concern and P stands for population.

Table 13. Products of the weights and their summation

Product of weights					
Thana	Batkhela	Malakand	Dargai	Skhakot	Shergarh
0.0038	0.0019	0.0006	0.0010	0.0071	0.0047
0.0062	0.0024	0.0016	0.0126	0.0013	0.0080
0.0159	0.0044	0.0090	0.0209	0.0017	0.0139
0.0088	0.0181	0.0275	0.0485	0.0875	0.0145
0.0196	0.0073	0.0266	0.0095	0.0031	0.0282
0.0349	0.0418	0.0035	0.0196	0.0054	0.0034
0.0414	0.0084	0.0043	0.0153	0.0309	0.0129
0.0620	0.0902	0.0059	0.0112	0.0324	0.0856
∑= 0.1927	∑= 0.1746	∑= 0.0791	∑= 0.1386	∑= 0.1694	∑= 0.1714

the priority vector is shown (Saaty Thomas, 1990 & 2008), the summary of which is shown in Table 3.

Comparison of alternatives with respect to the criterions

All the alternatives are compared with each other based on each criterion.

Weather

Weather is the major factor concern with the solar farm, to categorize all the alternatives based on weather; we got some data from the Pakistan Meteorological department (PMD) Peshawar. The data was consisting of data related to humidity, temperature, rainfall and wind speed. Based on which we assigned weights to all the alternatives, the summarized form of which is shown in table 4. Based on whether Skhakot is the most suitable site whose priority vector is 0.296 for the solar farm, because as we move away from Peshawar the intensity of sunlight and other parameters are going to decrease (observation from the data given by PMD) as required for a solar farm.

Agricultural concern

The agricultural related data is obtained from the office of Agricultural officer Dargai Pakistan. Based on which the alternatives are categorized and the priority/Eigen vector is shown in the table 5. Similarly, for all other criterions the priority/ Eigen vector is shown in Table 6 - Table 12, and the respective consistency ratio below each table.

Synthesizing final priority

The final step is to synthesize the overall priority, following the standard procedure (Saaty, 1990 & 2008) in this step we are going to multiply the weights of the all the alternatives (relative to the factors) with that of the relative weights of the factors w.r.t goal, presented in the foregoing tables. The results are shown in the Table 1.12 and 1.13. From the Table 1.13 it is clearly shown that the most preferable and appropriate site for the solar farm is termed as THANA with overall weight of 0.1927. Based on the overall consideration we must select THANA for the installation of a solar farm.

Future work

Instead of AHP if we select a site considering only one factor let weather then the best site for the solar farm would be "Shergarh" which is not feasible at all. In this current research work we consider eight different factors that are affecting the solar farm efficiency. At the end, we came to the conclusion that "THANA" is the best choice for installing a solar farm in Malakand Division. Now a day's Multiple Criteria Decision Analysis (MCDA) integrated with Geographic Information System (GIS) is used widely for the selection of sites (Arran-Carrion *et al.,* 2007; Van Haaren *et al.,* 2011; Koc-San *et al.,* Bilal *et al.* Hauser David, 1994; Yalcin Ali, 2007; Akgun and Bulut, 2007). The future work of this research project is that we have to select a suitable and feasible site by the MCDA integrated with the GIS and then compare the results of both the methods.

REFERENCES

Akgun, A., Bulut, F. GIS-based landslide susceptibility for Arsin–Yomra (Trabzon, North Turkey) region. Environ. Geol. 51, 1377–1387, 2007

Arran-Carrion, J., *et al.*2007.Environmental Decision-Support Systems for Evaluating the Carrying Capacity of Land Areas: Optimal Site Selection for Grid-Connected

Photovoltaic Power Plants. *Renewable and Sustainable Energy Reviews,* 12; 2358-2380.

Aydin N.Y., *et al*. 2010. GIS-Based Environmental Assessment of Wind Energy Systems for Spatial Planning: A Case Study from Western Turkey. *Renewable and Sustainable Energy Reviews,* 364–373.

Bilal A. Akash, RustomMamlook, Mousa S. Mohsen, Multi-criteria selection of electric power plants using analytical hierarchy process

F S Patrick, C K Sonia. 1999. Final contractor selection using Analytical Hierarchy Process.

Hauser David, Tadikamalla Pandu, 1994; revised August 1994. The Analytic Hierarchy Process in an uncertain environment: A simulation approach

John M. Hassell Department of Accounting, College of Business Box 19468, University of Texas at Arlington Arlington, TX 760190468, U.S.A. An empirical examination of the sensitivity of the analytic hierarchy process to departuresfrom recommended consistency ratios.

Kaiser, P., Unde, R.B., Kern, C., Jess, A. 2013. Production of liquid hydrocarbons with CO2 as carbon source based on reverse water–gas shift and Fischer-Tropschsynthesis. ChemieIngenieurTechnik:489–99.

Kardi, T, Analytic hierarchyprocess (AHP) tutorial.

Khwanruthai BUNRUAMKAEW (D3), *Division of Spatial Information Science Graduate School of Life and Environmental Sciences, University of Tsukuba (March 1st, 2012).*How to do AHP analysis in Excel.

Koc-San, D., B.T. San, V. Bakis, M. Helvaci, Z. Eker. Multi-Criteria Decision Analysis integrated with GIS and remote sensing for astronomical observatory site selection in Antalya province, Turkey.

Panwar, N.L., Kaushik, S.C., Kothari, S. 2011. Role of renewable energy sources in environmental protection: are view. *Renewable and Sustainable Energy Reviews;* 85(4):15(3)1513–24.

Power plant technology by el-wakil chapter 13

Saaty L. Thomas, 1990. How to make a decision: The Analytic Hierarchy Process.

Saaty L. Thomas, 2008. Decision making with the analytic hierarchy process.

TeknomoKardi, ANALYTIC HIERARCHY PROCESS (AHP) TUTORIAL

Urmee, T., Harries, D., Schlapfer, A. 2009. Issues related to rural electrification using renewable energy in developing countries of Asia and Pacific. Renewable Energy; 34(2):354–7.

Van Haaren, R., Fthenakis, V. 2011. GIS-based wind farm site selection using spatial multi-criteria analysis (SMCA): Evaluating the case for New York State*. Renewable and Sustainable Energy Reviews,* 3332–40.

Yalcin Ali. Accepted 19 January 2007. GIS-based landslide susceptibility mapping using analytical hierarchy process and bivariate statistics in Ardesen (Turkey): Comparisons of results and confirmations

Yun-na, W., Yi-sheng Y, Tian-tian F, Li-na K, Wei L, Luo-jie F.2013. Macro-site selection of wind/solar hybrid power station based on ideal matter-element model. *Electrical Power and Energy Systems,* 50:76–84.

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