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POTENTIAL SITE SUITABILITY ANALYSIS OF SMALL HYDROPOWER PLANT IN IRANG RIVER CATCHMENT, MANIPUR, INDIA: A GEO-SPATIAL AND MCDM APPROACH

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A*bstract*—India being one of the leading developing country where 80% of its energy or power supply are produced by fossil fuel: coal, oil and solid biomass. Using of fossil fuel-based power led to environmental degradation and to reduce it an alternative power source is required. Amongst the alternate source, Hydropower is the most suitable source for power supply. Hydropower is one of the oldest renewable power sources where it generates power from the flow of water by converting its gravitational flow or potential energy of water source into electricity. Due to roughness and inaccessible of terrain of the study area, the use of conventional method becomes almost impossible. With the help of new innovative methodologies and techniques of Remote Sensing (RS) and Geographic Information System (GIS) this study has been carried out. In this study nine geo-spatial inputs are used to find the site suitable for small hydropower (SHP) project. The multi criteria decision making (MCDM) techniques is used to evaluate the input's weights. After the weight is obtained for each input, it is overlaid according to its weight using overlay tool to obtained the site suitable for SHP project. The outcome of this study allows spotting identification of SHP potential zone.

***Keywords*— Fossil Fuel, Environmental Degradation, Remote sensing, Geographic Information System, Geo spatial, Multi criteria decision making (MCDM).**

I. INTRODUCTION

India being one of the leading developing country its power consumptions increases drastically since 2000 due to more establishment of industries, increase population growth etc. 80% of India's power supply is supplied through fossil fuel-based system which lead to environmental degradation such as Global warming The growing concern over environmental degradation caused by fossil fuel-based system, environmental problems with nuclear fuel-based systems and the ever-rising shortage of power have highlighted the need for the development of new and alternate sources of energy sources (1). Hydroelectricity represents the alternative to fossil fuels which has less concern for environmental degradation or atmospheric pollution compare to fossil fuel generation. Amongst the alternate source, Hydropower is the most suitable source for power supply. Hydropower is one of the oldest renewable sources which provides 17% of world's electricity that generates power from the flow of water by making a diversion or by constructing a dam. The principle of hydropower is by converting the kinetic movement of water's flow into electricity where no consumption of water take place. Hydropower is a method of sustainable energy production

Advantages or Benefits of Hydropower:

- Clean fuel source, as water is the source of hydropower. As a result, the air won't be contaminated.
- Domestic energy supply, enabling each state or province to generate its own energy without relying on foreign fuel sources.
- Hydropower creates reservoirs that offer recreational opportunities, such as fishing, swimming, and boating.
- Compared to fossil fuels, renewable energy sources are more dependable and cost-effective.
- Provides flood control. Irrigation and water supply.

Hydro power projects are classified according to their sizes (large, small, and mini-scale) and their purposes (single or multi-purpose). In India, hydro power plants of 25MW or below capacity is classified as small hydro, which have further been classified into micro (100kW or below), mini (101kW-2MW) and small hydro (2-25MW) segments (2). India's first hydropower plant, with a 130kW capacity, was built at Darjeeling, West Bengal, in 1897. In 1902, a plant with a 4500kW capacity was built in Mysore, Karnataka. A modest mini- and micro-hydropower project with a 6781.81MW capacity was also launched.

To site the suitable zone for small hydropower using the conventional method is difficult due to high terrain profile of the area or due to inaccessible terrain and needs huge man power. Using the newly developed software such as Remote sensing (RS) and Geographic Information System (GIS) offer an easy approach to evaluate and can substantially overcome the limitations of conventional methods.

II. STUDY AREA

Manipur is a state in North-Eastern India, a sub- Himalayan range. It is bounded by Nagaland to the North, Mizoram to the South, Assam to the west and Myanmar to the East. The state lies at a latitude of 23°83'N–25°68'N and longitude of 93°03'E–94°78'E. The total area of the state is 22,327 square kilometres. The capital lies in an oval-shaped valley of approximately 2,000 km2, surrounded by mountains, at an elevation of 790 metres (2,590 ft) above mean sea level (MSL). The rivers are distributed in four basins which are the Barak river basin to the west, the Manipur river basin in the central, the Yu river basin in the east and the Liyai river basin in the north.

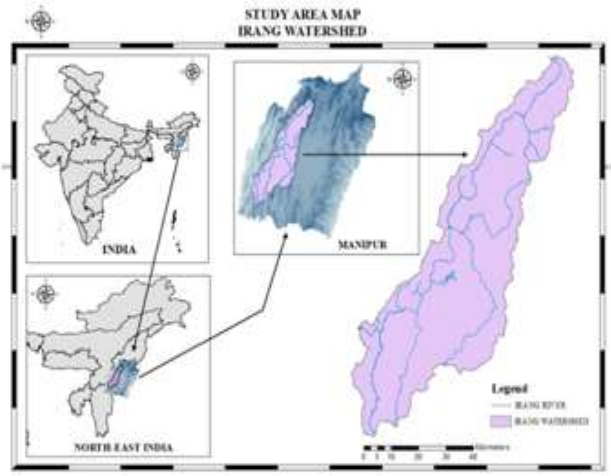

Fig. 1. Study Area map

The study area lies in the Barak river basin which is the largest and longest river of Manipur having a catchment area of 9041 sq.km which is 40.5% of the state and yields 364 million litres per day. It rises from the northern part of the state and flows south-westwards through the western hills. The Barack separates the western hills of Manipur from the Barail Range. Its main rivers and tributaries are the Irang river, Makru river, Tuivai river and Jiri river. Zoning of the site for hydropower potential is done at Irang river one of the main tributaries of Barak river. Irang river is the most important tributary of the Barak river having a catchment area of 3564 square kilometres. It rises from the northern part of the western hills with an elevation of around 2300 meters and separates Tamenglong District and Churachandpur District. Irang river flows at a length of around 230 km approximately where some of the rivers also fall into the Leimatak river. Further south it is joined by the north flowing river called Tuivai then Jiri river where it forms the inter-state boundary between Manipur and Assam. It flows westwards towards the Cachar plains where it is known as Surma and finally it falls into the Brahmaputra in Bangladesh

III. MATERIALS AND METHODS

1. MATERIALS

The identification of suitable site for small hydropower were conducted using nine different geo spatial inputs such as Digital Elevation Model (DEM) or Elevation, Flow Accumulation, Stream Order, LULC, Slope, Discharge, Soil, Lineament Density and Drainage Density. The brief description of the input is given below:

A. **Watershed Delineation**

To obtain the watershed of Irang river, digital elevation model (DEM) layer and stream line of Irang river generated from DEM using hydrological tool in ArcGIS is used. The watershed of Irang river is delineated by using GIS tool. A total of 25 sub basin is obtained for Irang watershed.

B. **Digital Elevation Model (DEM)**

ALOS PALSAR imagery with 12.5m resolution was downloaded from Alaska Satellite facility and it is mosaic using arcGIS tool. The acquired DEM is then reprojected from GCS coordinate system to Projected Coordinate System, Universal Transverse Mercator (UTM). Afterward the study area DEM was extracted using fore mentioned watershed boundary delineated using GIS. Further, the extracted study area DEM is used to generate stream order, flow accumulation, slope, drainage density and lineament density.

C. **Flow Accumulation layer**

The flow accumulation map was extracted from the above DEM using hydrological assessment tool. First, the DEM was hydrologically corrected with fills/sinks. Then by using the hydrological corrected DEM, flow direction of the study area is obtained and finally by using the flow direction map, flow accumulation map is acquired.

D. **Stream Order layer**

The stream order of Irang river is generated using Strahler method (1957). According to Strahler method, the stream order increases when stream of same order intersect. The intersection of two first order links will create a second order links and intersection of two second order links will create third order and so on. It is also generated using hydrological assessment tool in ArcGIS.

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E. Land Use Land Cover (LULC)

The LULC map provides the information to understand the current landscape. For this study, a sentinel satellite imagery of 10m resolution was downloaded from United States Geological Survey (USGS) and by using band 12, band 4 and band 3 a False Colour Composite (FCC) image is formed. Later it is mosaic using arcGIS. Then from the mosaic sentinel image, the study area is extracted using the watershed shapefile which attained from running through ArcSWAT tool. The LULC map of the study area was prepared using supervised classification approach. The image is classified to get five different patterns i.e., Vegetation, Barren Land, Agriculture, Settlement and Water body.

F. Slope layer

The slope map is the representation of surface gradient. It shows whether the surface of the particular are is gentle or steep. The slope map is generated using the above extracted DEM of Irang catchment area using surface tool in arcGIS. The range of the slope of Irang catchment area varies from 0 to 797.58%. The slope is calculated in terms of percentage for this study area.

G. Discharge

Discharge is the amount of water flowing through a channel. For this particular study, to obtained the discharge map rainfall data from January 2021 to December 2021 was downloaded from Climate Prediction Group, Indian Meteorological Department Pune, Maharashtra website using the study area's latitude and longitude. After acquiring the rainfall data, through Hydrological Response Unit (HRU) analysis in arcSWAT tool the required discharge data of each sub basin of Irang watershed and discharge map is obtained.

H. Soil layer

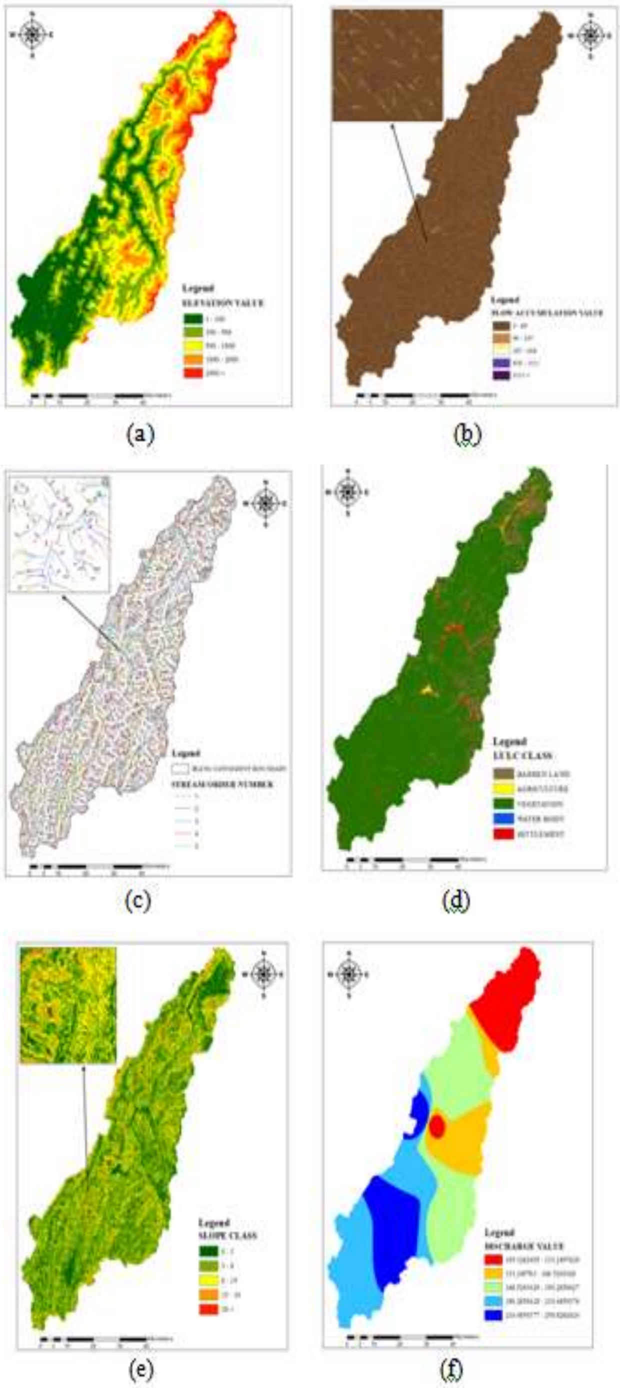
Soil map is the geographical representations showing variation of soil types and soil properties. For this study, the world soil map of scale 1:5000000 of Harmonized world soil database (HWSD) was downloaded from FAO (Food and Agriculture Organization) website and is extracted to get the study area using extraction tool in arcGIS. The study area's soil map is also used to obtained the above discharge map.

I. Lineament Density layer

The lineament density was defined as the total length of all the recorded lineaments divided by the area under consideration. First the geo spatial DEM data is used to extract Hillshade data then lineament density is obtained from it. The unit of lineament density is square kilometre.

J. Drainage Density layer

Drainage density is defined as channel length per unit watershed area that reveals the number of channels in a watershed. The drainage density map is generated from digital elevation model (DEM) using hydrological assessment tool and line density tool in ArcGIS



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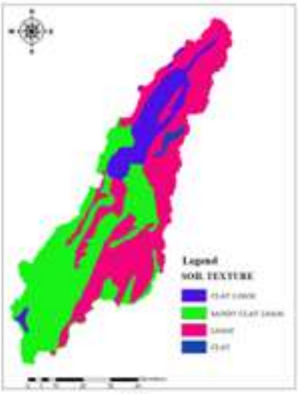

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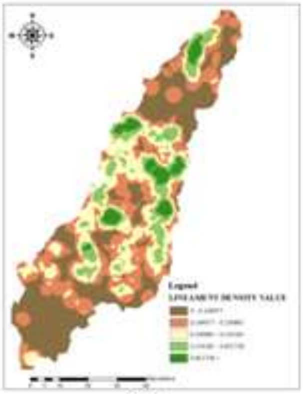

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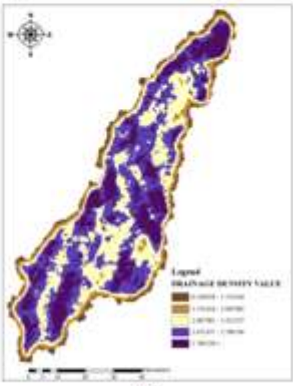

(i)

Fig. 2. (a) Digital Elevation Model (b) Flow Accumulation map (c) Stream Order map (d) LULC map (e) Slope map (f) Discharge map (g) Soil map (h) Lineament Density map (i) Drainage Density map

2. METHODS

After all the input parameter is acquired, it is reclassified into five ranks: 1 – Very Low, 2 – Low, 3 – Moderate, 4 – High, 5 – Very High. After the reclassification process, weights of each parameter are been determined using Analytical Hierarchy Process (AHP) which is one of the multi-criteria decisions making (MCDM) techniques. Finally, with the procure weights it is then overlaid using weighted overlay tool in arcGIS to get the site suitable for hydropower project.

A. Analytical Hierarchy Process (AHP)

AHP is a methodical approach based on both psychology and mathematics for organising and analysing complicated choices. It is a method used in multi-criteria decision-making (MCDM). When expert's references are used to estimate the relative magnitudes of components through pair-wise comparisons, it offers an accurate method for quantifying the weights of decision criteria. A fundamental scale of importance is used to perform the comparisons and show which aspect is more significant or dominating than another. The parameters were weighed in a square matrix framework by giving all the diagonal value as 1. The AHP correlation grid's eigenvalue and matching right eigenvector were then used to determine the weighting of these parameters.

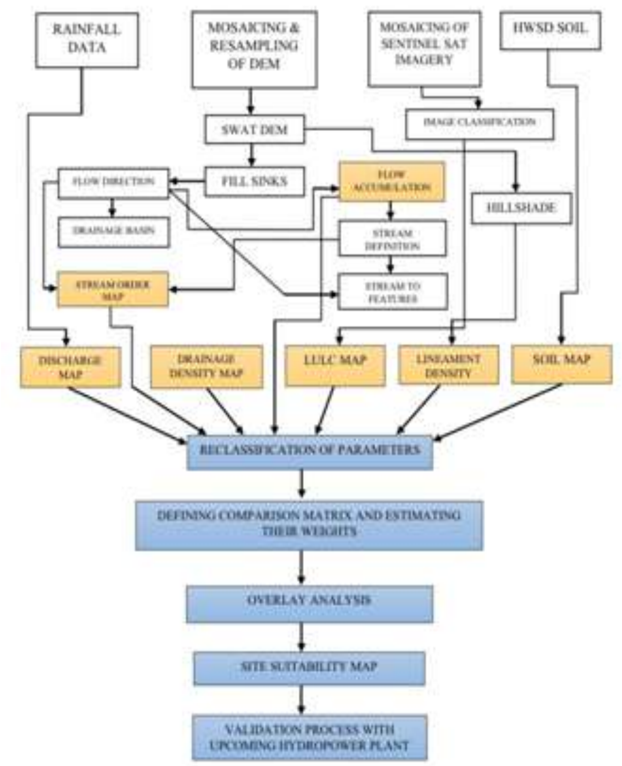

Fig. 3. Flow chart of GIS process

Table -1 Pair wise comparison matrix

	I	II	III	IV	V	VI	VII	VIII	IX
I	1	3	3.5	3	3.5	4	4	5	6
II	0.333	1	3	3.5	3	4	4	4	4
III	0.333	0.333	1	3	3	3	3	3	3
IV	0.333	0.286	0.333	1	2	3	2	3	3
V	0.25	0.333	0.333	0.5	1	2	3	3	2
VI	0.222	0.25	0.333	0.333	0.5	1	2	2	2.5
VII	0.2	0.25	0.333	0.5	0.333	0.5	1	3	2
VIII	0.167	0.25	0.333	0.333	0.333	0.5	0.333	1	2
IX	0.167	0.25	0.333	0.333	0.5	0.4	0.5	0.5	1

I – Stream Order; II – Flow accumulation; III – Discharge; IV – Drainage density; V – Slope; VI – Soil; VII – LULC; VIII – Lineament density; IX - Elevation

B. Determination of weights of input parameters

After having a comparison matrix, normalized eigen vector of the matrix is being computed. To obtain the normalized eigen vector, first the value in each column is being added together and the total sum of the column is obtained then each element or value of matrix in each column is being divided by the total sum. The value received is the normalized relative weight. The sum of each column should be 1.

Table -2 Estimation of weights

0.333	0.504	0.37	0.24	0.25	0.217	0.201	0.2	0.235
0.111	0.168	0.315	0.28	0.21	0.217	0.201	0.163	0.156
0.111	0.056	0.105	0.24	0.21	0.163	0.151	0.122	0.117
0.111	0.048	0.035	0.08	0.14	0.163	0.1	0.122	0.117
0.083	0.056	0.035	0.04	0.07	0.107	0.151	0.122	0.078
0.074	0.042	0.035	0.026	0.04	0.054	0.1	0.081	0.098
0.067	0.042	0.035	0.04	0.02	0.027	0.05	0.122	0.078
0.055	0.042	0.035	0.026	0.02	0.027	0.016	0.04	0.078
0.055	0.042	0.035	0.026	0.04	0.022	0.025	0.02	0.039
1	1	1	1	1	1	1	1	1

Once the normalized relative weight is obtained, the normalized principal eigen vector is achieve by averaging across the rows multiplied by the reciprocal of total numbers of inputs parameters i.e., 9. The normalized principal eigen vector is also called priority vector. The sum of all elements in priority vector should also be 1. The priority vector obtained is the weights of each input parameters and is expressed in term of percentage.

Table -3 Determined Weights of the parameter

PARAMETER	WEIGHT (%)
Stream Order	29
Flow Accumulation	20
Discharge	14
Drainage Density	10
Slope	8
Soil	6
LULC	6
Lineament Density	4
Elevation	3

C. **Overlay Analysis**

By summing the weight values of each characteristic and taking into consideration nine contributing factors, a weighted index overlay analysis was used to construct a possibly appropriate hydropower potential site map for the Irang watershed. With the help of the overlay tool in the ArcGIS Arc Map 10.4 platform, the information for each influencing element was collected and analysed.

IV. RESULTS AND DISCUSSION

All input characteristics are categorised into five appropriateness classifications for the hydropower potential project site: Very Low, Low, Moderate, High, and Very High. It has been demonstrated that areas with lower elevations have greater potential than those with higher elevations. The overlay's results indicate that, with the exception of the northern part of the watershed, where the elevation is fairly high and the area has a mountainous topography, the majority of the site is appropriate for the construction of a hydroelectric plant. The reclassified map is shown below:

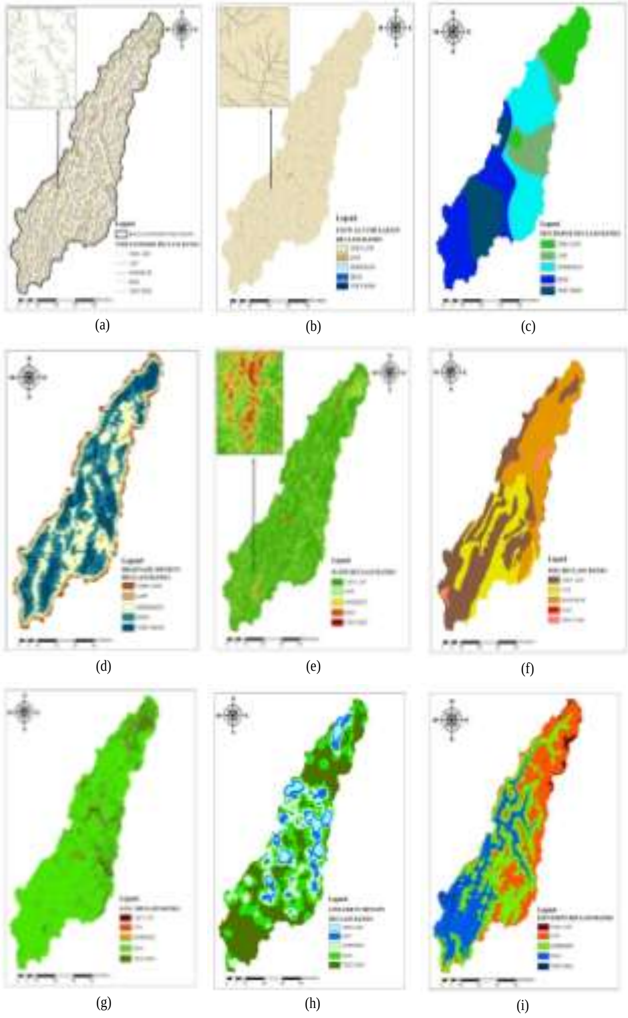

Fig. 4. Reclass map (a) stream order (b) flow accumulation (c) discharge (d) drainage density (e) slope (f) soil (g) LULC (h) lineament density (i) elevation

The north-eastern part of the watershed falls into a high terrain zone which is above 2000m which shows that it is not suitable for setting up hydropower project and to verify the correctness of the overlay result, validation was carried out utilising the forthcoming hydropower project undertaken by the government of Manipur. The results and forthcoming government projects for building hydropower plants place all of them in the moderate and high zones, verifying our methodology and research. This study was carried out and verified in order for additional dams or impending hydroelectric projects to be taken into consideration in highly and moderately appropriate places, in order to maintain and satisfy the Irang's river water demands, and in light of sustainable development. The validation map is shown in the figure below.

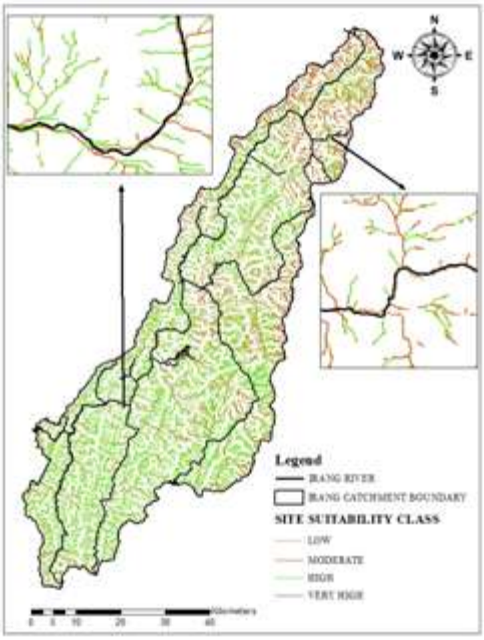

Fig. 5. Site Suitability map

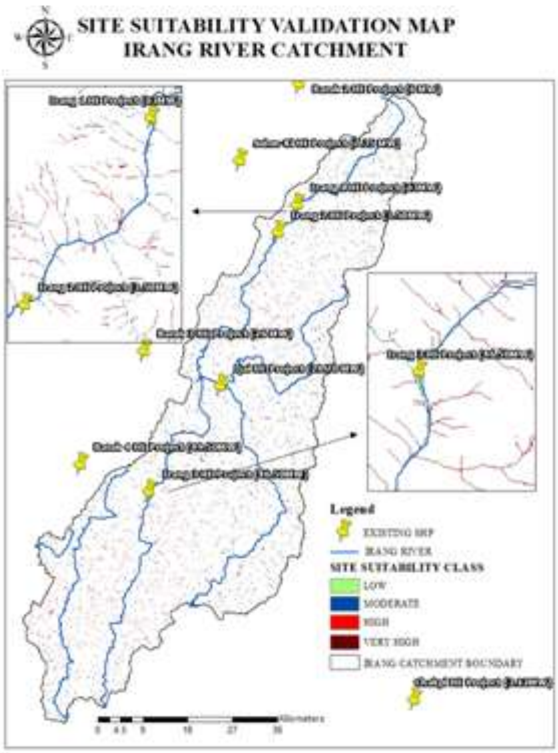

Fig. 5. Validation map

V. CONCLUSION

Electricity is one of the most essential requirements for human being and Manipur has a lengthy history of electricity shortages despite having abundant hydropower potential. The abundant hydel resources must be methodically used in order to address the requirement for electricity. Because it is a renewable energy source that is unbounded and does not generate pollution. With this study the potential site for establishing hydropower plant secure. The Irang watershed was investigated using a geographic information system (GIS) and multi-criteria decision analysis methods where nine impacting geospatial elements, including stream order, flow accumulation, discharge, drainage density, slope, soil, land use/cover, lineament density, and elevation were used. The suitability maps were created using the weights from the decision-making algorithms and GIS. According to the output results, it is suggested that low elevation terrain which is the southern part and central part of the watershed is thought to be the optimum location for developing hydropower plants or dam construction and the northern part of the watershed falls into a high terrain zone of above 2000m which shows that it is unsuitable for establishing hydropower plant. Finally, with the upcoming government hydropower project it is being re-check where it shows that all the upcoming project falls under moderate zone and high zone. The findings of this study can serve as some guidance for other studies in this area, making it simple for them to choose the most appropriate method for choosing hydropower sites.

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