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PRELIMINARY FRAMEWORK FOR WIND FARM SITING AND SIZING: A CASE OF MUSTANG DISTRICT, NEPAL

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BACKGROUND

High cost of licensed micro-siting software, lack of reliable ground based wind resource data and difficulty in assessing geographically morphed areas of the country makes it challenging for project developers in Nepal to perform preliminary siting and tangible evaluations of wind farms.

This study elaborates a minimum cost framework to identify feasible wind farm sites as part of pre-project development assessment. The methodology follows overlaying key parameters such as elevation profile, transportation routes, land usability and geographical terrain to generate potential wind project zones. The study framework considers three Wind Turbine Generators (WTG) with different rated power capacities and blade lengths to provide flexible and site-specific energy yield estimates. Finally, a self-developed spreadsheet turbine sizing and yield calculator toolkit combines secondary wind resource data of the project site and power curves of WTGs to calculate the wind farm size and energy yield for all turbine options. The final output will also have considered wake effect losses by adopting a commercially accepted park-effect turbine placement thumb rule.

The presentation is based on a case study for Mustang District — an area well known for rich wind resource in Nepal.

OBJECTIVE

1. Develop a master overlay within a selected study area by overlaying various critical project siting parameters such as accessibility, elevation profile, land use profile and transportation route.
2. Identify multiple prospective wind farm zones within the master overlay by considering secondary indices such as population centers, long term economic benefit from the project etc.
3. Develop a layout for wind farm by considering the wake effect factor.
4. Conduct energy yield estimates of each zone by using secondary wind speed data, wind turbine power curves of selected WTGs suitable for the project area; identify zones with higher yield factors.
5. Make comparison between multiple prospective wind farm sites.

METHODS

1. Extract segments of Elevation, Slope and Land Use profiles of desired project area; superimpose those extracted maps against the transportation route extract to produce a master overlay of the project area.
2. Locate multiple project zones within the master overlay based on micro-level manual technical inputs and socio-economic indices of the area.
3. Divide each zone into calculable surface areas whose axis is determined by the direction of wind given by Wind Rose for that zone.
4. Wake Effect Consideration: Calculate the total number of wind turbines within the project area using 5Dx3D Model.
5. Obtain site specific Mean Wind Speed value (at 100m Height) and roughness value. Evaluate these values at WTGs hub height (80m in this case) using the logarithmic law expression.
6. Based on the Mean Wind Speed data at Hub Height, Power Curve of the Wind Turbines and Wind Direction Factor, estimate the total size of wind farm considering each WTG, average Energy Yield of each WTG and hence the Capacity Factors (CF) for the farms.

RESULTS: A CASE OF MUSTANG DISTRICT

Identifying Prospective Wind Farm Zones in Mustang

Elevation Profile of Mustang

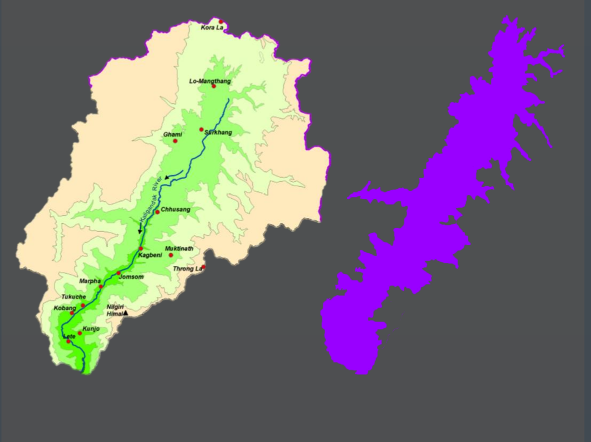

Fig: Extracted Segment with Altitude <4000 masl

Elevation above 3500-4000 masl due to the rapidly decreasing air density index decreases the wind power density

Slope Profile of Mustang

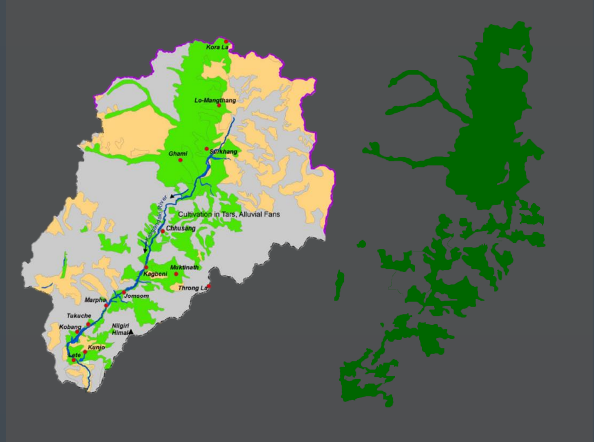

Fig: Extracted Segment with Slope <15°

High inclined slope profiles are economically unfeasible due to high capital mounting and land development

Land Use Profile of Mustang

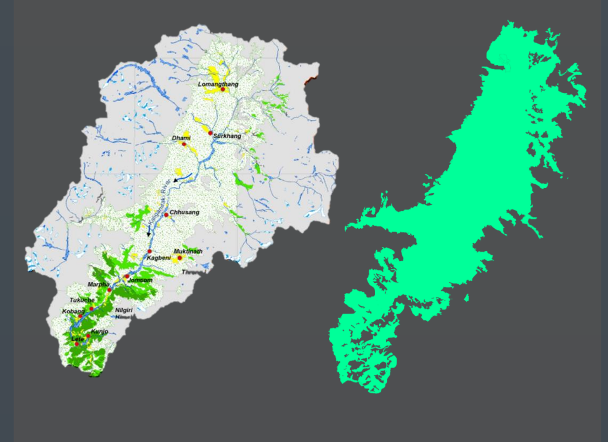

Fig: Extracted Segment with Usable Land Area

Only barren land, cultivation land, bushland, edge of river, sandy and grassland areas have been considered

Generate Common Overlay

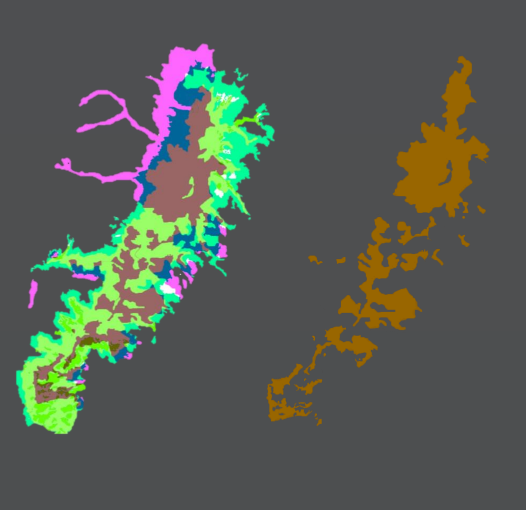

Fig: Common Segment after Superimposing Elevation, Slope and Land Use profiles

Transportation Route Map of Mustang

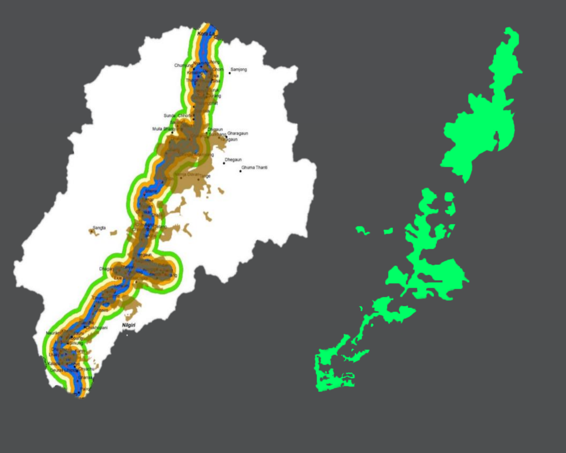

Fig: Generating Master Project Overlay

Only the areas located within 4km from the closest roadway network have been considered

Identifying Cluster of Project Zones

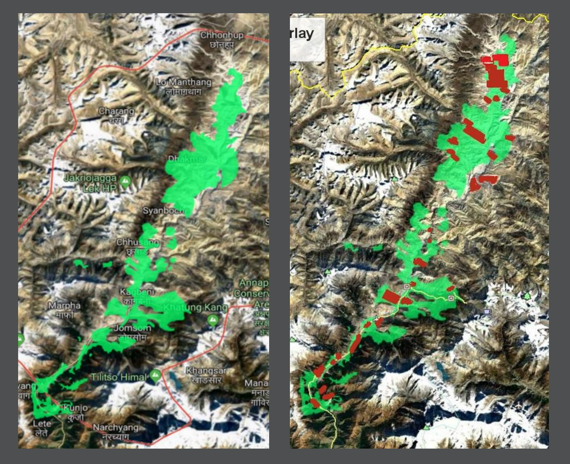

Fig: Transferring Master Overlay to Satellite Geographical Map of Mustang

38 Project Zones were Identified as Suitable Locations for Developing Large Scale Wind Farms

Selection of Wind Turbine Generators (WTGs)

Rational for Selection of WTGs

- It is important to choose the right specification of the wind turbines that match the wind resource profile of the site
- Looking from the point to economy of scale and production capabilities, larger WTGs always prevails in commercial wind farms compared to the smaller WTGs
- However, poor transportation infrastructure is a principal challenge in developing wind projects in Mustang; therefore, the study has chosen three varieties of large scale WTGs that have blade lengths of ≤40m

Specifications	Enercon E53/800	Leitwind LTW80/1000	Acciona AW1500/77
Rated Power	800kW	1MW	1.5MW
Rated Average Wind Speed	12.5m/s	10.5m/s	11.1m/s
Blade Length	26.5m	40m	38.5m
Rotor Diameter	52.9m	80m	77m

Table: Technical Specifications of the Selected WTG Types

Consideration of Wake Effect for Wind Farm Layout

- Wake Effect: Wind turbines extract energy from the wind but downstream there is a wake from the wind turbine, where wind speed is reduced; this aggregates influence on the energy production of entire row of WTGs
- As a rule of thumb, WTGs are spaced 5 to 9 rotor diameters apart in the prevailing wind direction, and 3 to 5 diameters apart in the direction perpendicular to the prevailing winds

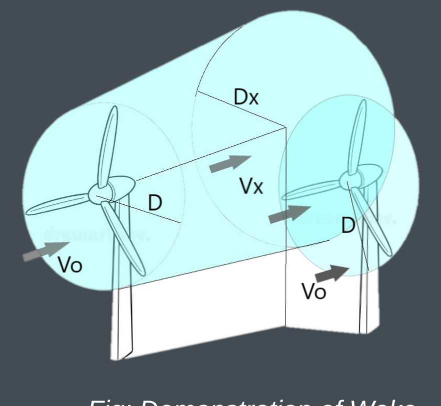

Fig: Demonstration of Wake Effect in Trailing WTG

- Therefore, the study considers a conservative spacing of 5D x 3D (where D is the rotor diameter) to reduce the effect of wake hence in turn giving the wind farm layout

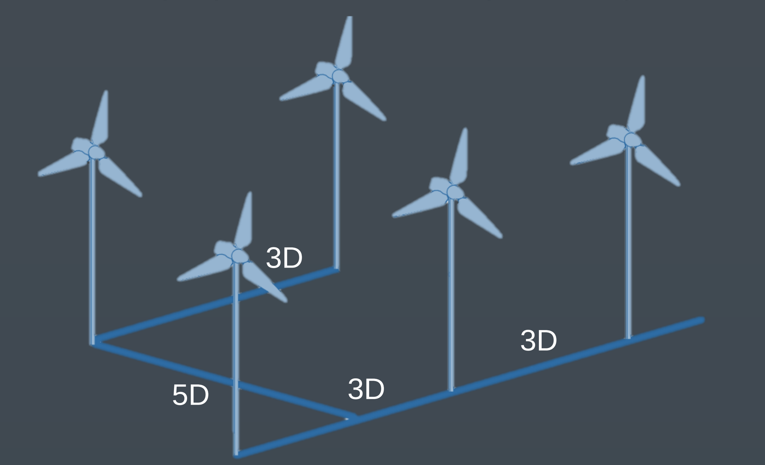

Fig: 5D x 3D WTG Placement Model to Lessen the Effect of Wake

Calculation of Energy Yield at Zone 20: Tangbe

Demonstration of the sizing model is performed here for a one of the identified zones, selected at random.

Step 1: The zone is sub-divided in three quadrilaterals and given dimensions

Step 2: Based on the 5Dx3D Model, total number of WTGs is evaluated for each WTG type

Step 3: Based on secondary wind resource data from Global Wind Atlas (GWA), wind speed at hub height was calculated; likewise the wind direction factor is calculated towards the most prominent direction

Step 4: Based on no. of WTGs, Wind Speed at Hub Height, Power Curve of respective WTGs and Wind Direction Factor, the daily energy yield of the wind farm was calculated in a self-created excel sizing tool

L1	L1'	L2	L2'	L3	L3'
897m	564m	1066m	637m	884m	1103m

Enercon E53/800		Acciona AW1500/77		Leitwind LTW80/1000	
No.	MW	No.	MW	No.	MW
56	44.8	24	36	24	24

Fig: Area of Zone 20 and calculated no. of WTG

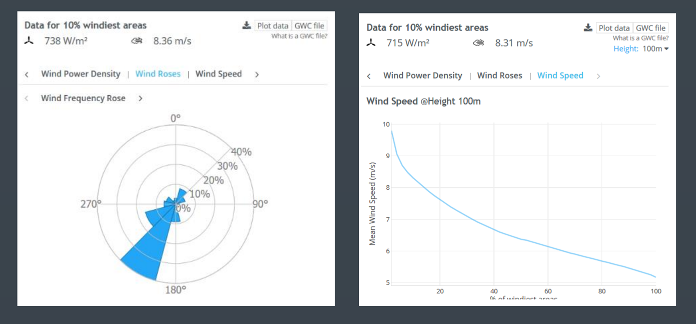

Fig: Satellite base wind resource at Zone 20 from GWA

Enercon E53/800		Nordex/Acciona AW1500/77		Leitwind LTW80/1000	
MWhr /day	Capacity Factor	MWhr /day	Capacity Factor	MWhr /day	Capacity Factor
289.01	26.88%	440.32	50.96%	251.04	43.58%

Fig: Wind Farm Capacity and Energy Production at Zone 20 for all WTG types

CONCLUSIONS

1. A low-cost preliminary evaluation model is essential in identifying and screening multiple large/utility scale wind project sites without financially burdening project developers.
2. The assessment model presented here provides project implementers a rudimentary solution for siting potential wind project locations by taking into account the physical characteristics, and infrastructural limitations of the project area and sizing the project by interpreting technical factors such as wake effect and resource potential for multiple choices of WTGs.
3. The tool also allow users to compare between the selected WTGs in terms of energy yield which is important in deciding the plant configuration.
4. Using this model the total wind power capacity for entire Mustang district was devised as following:

Enercon E53/800			Acciona AW1500/77			Leitwind LTW80/1000		
MW	GWhr/ Day	Capacity Factor	MW	GWhr/ Day	Capacity Factor	MW	GWhr/ Day	Capacity Factor
1227	6.908	29.56%	1138	11.160	48.20%	676	5.774	42.96%

Fig: Total Installed Capacity and Energy Production for all WTG types in Mustang District

5. As seen in Mustang, the total rated installed capacity is not always proportional to the energy production of WTGs. This is because each WTG is best suited to an area with particular wind resource. Therefore, this tool also quantifies the importance of selecting site specific WTG in terms of higher yield factor and not the rated installed capacity.

REFERENCES

- Danish Wind Industry Association. (2003, 6 1). The Park effect. Retrieved from windpower.org
- EWEA. (2009, March). Wake Effect. Retrieved from Wind Energy- THE FACTS
- K.C, K., Poudel, K. R., Paudel, N., Pokharel, R. P., & Koirala, S. (2014). Resource Mapping Report-2014, Mustang District. District Development Committee, Mustang
- SWERA. (2008). Solar and Wind Energy Resource Assessment in Nepal (SWERA): Final Report (GIS PART). Khumaltar, Lalitpur, Nepal: Alternative Energy Promotion Center Government of Nepal Ministry of Environment, Science and Technology
- Nepal Renewable Energy. (2010, June 25). Retrieved from nepalrenewableenergy.com
- Laudari, R., Sapkota, B. K., & Banskota, K. (2015). Assessment of Economic Viability of Wind Energy in Nepal: A Case Study of Ten Sites. IOE Graduate Conference, (pp. 169-179)
- Global Wind Atlas
- Acciona AW-77/1500. Retrieved from wind-turbine-models.com
- Leitwind LTW80 1000. Retrieved from wind-turbine-models.com
- Enercon E-53. Retrieved from wind-turbine-models.com

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