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ECOSENSITIVE LOCATING STRATEGY OF INLAND WIND POWER PLANTS IN SOUTH KOREA

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Abstract

Mountain ridge lines in Korean peninsula are regarded as ecologically important zones. Inland wind power energy source distribution pattern overlaps the mountain ridge line zone. Inland wind power plant siting in Korea shows conflict between ecological importance and renewable energy production policy. Geographical barrier mapping method and random walker simulation may help to cooperate renewable energy industry and environmental impact assessment process in South Korea.

Key words: *ecosensitive locating strategy, wind power plant, geographical barrier mapping, travelling probability, random walker simulation*

I. INTRODUCTION

South Korea is changing its energy plan to use more renewable energy for an effort of reducing Green House Gas(GHG) emission. The portion in energy mix of South Korea in 2012 was 0.61%(476.7MW/78,483MW total capacity, MOTIE, 2014). 2nd Basic Energy Plan of South Korea issued in the early 2014 sets the goal of renewable energy increase upto 11% in 2035.

Inland and offshore wind power generation is one of the most important renewable energy sources in Korea. However, locating inland wind power plants (WPP's) is not so easy to proceed. The difficulties may arise from refusal of accepting destruction of local ecological system due to the site leveling of wind power sites and construction of approach roads

For South Korea have many mountainous regions , construction of approach road for inland WPP include new road construction in ecologically well preserved area and in the steep slop area to go up to mountain ridge area where the WPP's will be located from 200 to 300m below. And the width of the road varies from 5m in the straight course to 40-50m in a very steeply curved area (Fig. 3). The heights of newly excavated artificial slope faces at the roadside are more than 10 m even to 20m high, which are relatively larger when we consider the small dimension of the road itself. In addition, mid-sized animals cannot cross the road where the roadside slope is more than 1m high. Eventually the locating of inland WPP site may produce long range of geographical barriers that may obstruct travelling of animals through.

II. MOUNTAIN RIDGE LINES IN KOREA AND DISTRIBUTION OF WIND POWER POTENTIAL.

There are important mountain ridge lines in Korean peninsula. Most important one is called "Baekdu Daegan", literally it means 'the Great mountain ridge line derived from Mt. Baekdu', located at the northen part of Korean peninsula' (called here as BDDG for a convenience, Fig. 1). Second most important ridge line, which was derived from Baekdu Daegan is called as "Jeonggan". Actually these lines are water divide line and regarded as an ecologically important zone in Korean peninsula. Baekdu Daegan has been regarded as a backbone of Korean peninsula traditionally. South Korea legislated law to conserve Baekdu Daegan zone. Almost all the development projects are not permitted in the zone. Geographical distribution pattern of wind energy potential is considerably overlapped to mountain ridge line (Figure 1 and 2). This brings problems when wind power plant development is actively expanded.

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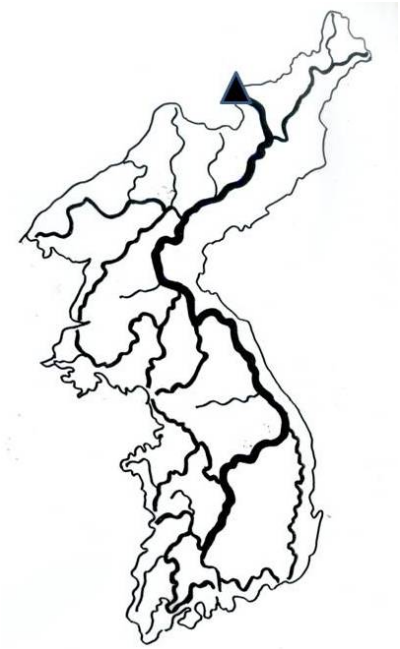


Fig. 1 Important mountain ridge lines in Korean peninsula. Heavy line is Baekdu Daegan, Great mountain ridge line. Mt Baekdu is located at the northern end of this line, at national boundary between China and North Korea (traiangle in the map). Horizontal (eg. lateral) width of Korean peninsula is about 200km.

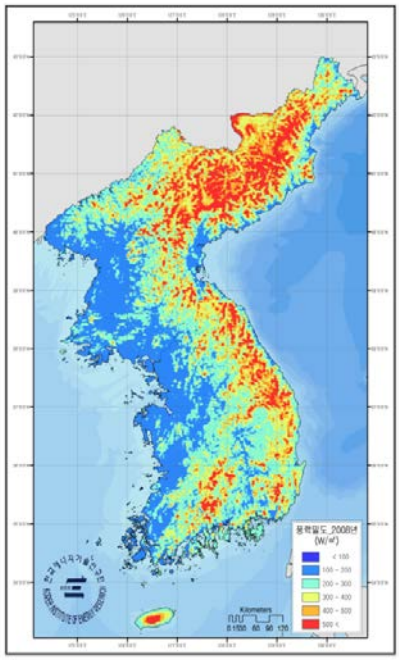


Fig. 2 Wind density map of Korean peninsula (2008). Major wind source pattern overlaps BDDG zone and the other major mountain ridge lines.

Source: New and Renewable Energy Data Center (http://kredc.kier.re.kr/kier/)

However, there is a general consensus among Korean people about protecting BDDG zone and would not utilize the area as WPP sites even though the law permits locating the facilities even in the zone because there are traditional emotions of refusal of destruction on BDDG by the construction activities. But the conflicts between

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'green (ecology)' and 'green (renewable energy)' in locating inland WPP's are still present in the other mountain ridge lines in the peninsula.

III. GENERAL PROBLEMS IN LOCATING INLAND WIND POWER PLANTS

Kim (2008) assessed the wind resource potential of South Korea and he evaluated the implementation potential estimates in South Korea corresponds to 12.5GW; the inland implementation potential as 4.6GW and offshore potential, 7.9GW. He rated that the implementation potential roughly equals to 1/8 of geographical potential and to 2% of theoretical potential. However the other suggestion shows larger potential capacity, eg. inland implementation potential as 8.2GW (Lee, 2014).

There are many cases of conflicts when there were attempts to locate WPP's in the major mountain ridge lines other than BDDG (Jeonggan and the other ridge lines). That is because there is not an acceptable strategy for selecting WPP site, strategy of producing renewable energy at the cost of minimum ecological destruction. Process of reconciliation of related policies are still in progress between two relevant ministries, Ministry of Trade Industry and Energy (MOTIE) and Ministry of Environment (MOE), hoping to conclude to make sustainable solutions.

It can be estimated that about 90 to 110 sites would be necessary to accommodate fully the emplacement potential of wind power, one site generally assumed to accommodate 40 to 50 MW wind power facilities. Major environmental problems related to inland WPP site are ecological disturbances, impacts of very low frequency noise, opposition of citizens who lives near the proposed site.

Endeavour of conservation of most important species distributed in the area.

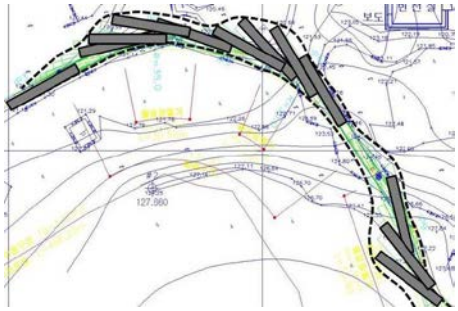


Fig. 3 Diagramatic illustration that shows the variation of width of approach road because of the length of trailer cargo for transportation of compartments(35-50m). The width of the road varies from 5 to 50m.

Locating of wind power site in South Korea requires;

1) The place where good wind energy sources are distributed
2) The place where separation distance of more than 1km can be obtained from places of residence
3) The place where the avoidance could be obtained in consideration of distribution of important species and of habitats of endangered species

Table 1 shows the summary of environmental problems and strategic alternatives. Strategic alternatives require acceptance of unavoidable and important impacts and change of attitude to respond to energy needs by accepting environmental disturbances. Optimum alternatives are applying best possible mitigation measures. Remarks in the column 'Impact Unavoidable' are generally agreed assessment results. The arrow at the column is marked to signify the necessity of an effort to change strategy for accommodating WPP to ecologically well-preserved area.

Table 1 Summary of environmental impacts derived from inland wind power plants construction and operation and their corresponding sustainable solutions. Right most columns show possibilities of avoidance and mitigations (rearranged from data of Kim (2014)).

Environmental Impacts	Mitigatable Impacts	Impacts Unavoidable		Method of mitigation or other solution
Landscape Distant view	Mitigatable Acceptable			
Landscape Near view			Unavoidable Remarkable	Separation
Low frequency Noise	Mitigatable Remarkable			
Destruction of forest ecosystem	Mitigatable Remarkable	<-	Unavoidable Remarkable	Accept impacts Apply best of mitigation
Destruction of major ecological axis	Mitigatable Remarkable	<-	Unavoidable Remarkable	Accept impacts Apply best of mitigation
Disorder in Animal habitats and Animal Migration Obstacles	Mitigatable Remarkable	<-	Unavoidable Remarkable	Accept impacts Apply best of mitigation
Bird strikes	Mitigatable Remarkable	<-	Unavoidable Remarkable	First Avoid locating Feedback after monitoring
Impact from Access road Construction	Mitigatable Remarkable	<-	Unavoidable Remarkable	Accept impacts Apply best of mitigation
Induced developments	Partly mitigatable Acceptable			Planning control

IV. EIA SYSTEM IN SOUTH KOREA

Figure 4 shows environmental impact assessment process of South Korea.

1st, Project proponent submits documentation of wind power project (WPP) with Environmental Impact Statement (EIS).

2nd, Approving agency (MOTIE) start to consultation of EIS with MOE

3rd, MOE request KEI and other specialist groups for reviewing of EIS

4th, KEI and other specialist groups present consultation details through technical review and suggestions

5th, MOE give consultation opinions to Approving agency (MOTIE)

6th, Approving agency give construction permit with stipulation regarding environmental protection and impact mitigation

Delay of approval process frequently happens because of disqualified data and/or environmental refusal due to ecological importance of the proposed area. These difficulties raise problems in wind power industries significantly. One of the major problems are related to lack of ecologically sensitive siting.

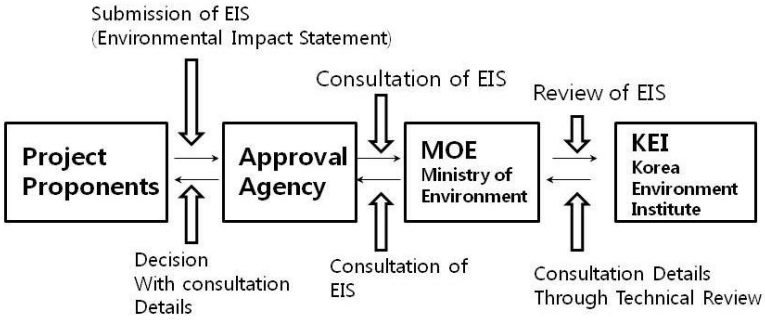


Fig. 4 EIA consultation process in South Korea

V. Method of siting in an ecologically sensitive area

To improve this process sustainably and efficiently, Kim (2014) suggested the revised process of environmental consultation. Fig. 5 summarized the suggestion. Main point of the suggested process is an approving process of site suitability before documentation process begins. It can be done by ecologically reliable and complete site surveying. It is believed to be quite easy to comprehend and acceptable from both WPP industries and environmental specialist groups.

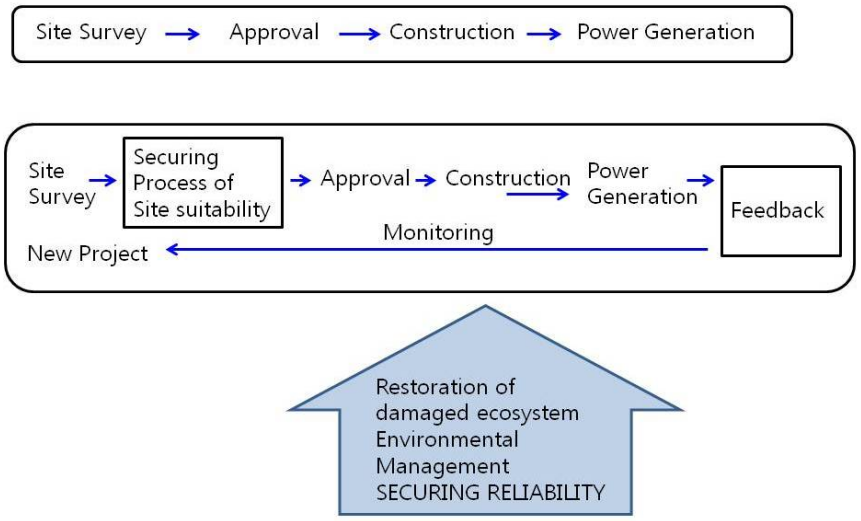


Fig. 5 Securing site suitability and increasing predictability of site licensing (Kim, 2014). Above diagram is a preexisting process. Diagram below is a new suggestion for both ecologically and industrially acceptable**.**

Ecologically reasonable siting method was suggested by Lee et al. (2012). They suggested Habitat Suitability Index, which can be derived with the use of GIS. They analyzed distribution of habitat and designated habitat suitability index, where water, road and ground coverage and slope were considered. The results seems to be useful in Environmental Impact Assessment, however the method is not easy to adopt because it takes much time and expenses to prepare the results. Kim (2005) and Kim and Ko(2013) suggested employing geographical barrier mapping for an aid tool of siting.

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VI. GEOGRAPHICAL BARRIER MAPPING

'Geographical barriers' are 'artificial and natural barriers that can block the travel of animals' (Kim, 2005). Kim (2005) proposed preparation of geographical mapping in environmental impact statement for a tool of ecologically sensitive siting. He emphasized that it is quite simple to draw in the field and the results on the map leads to comprehensive and intuitive conclusions to understand distribution characteristics of barriers and degree of difficulties of animal migration in a certain area. Applying geographical barrier map to a construction plan will give informations about change in geographical barriers before and after construction. This mapping is useful for both project proponent and reviewer of EIA report.

The examples of geographical barriers are concrete wall, wired wall, artificial facilities such as houses, buildings, heavy traffic roads, artificial slope faces at the end of leveled area. Combined elements such as a guard rail along the road combined with roadside slope, open concrete conduit combined with steep slope etc. work also as geographical barriers. Figure 6 shows digramatic illustration of a geographical map. Siting alternatives are designated as A and B in the figure. Site B is more acceptable than site A because site A will work as an additional geographical barrier and will block the ecological corridor compared to site B.

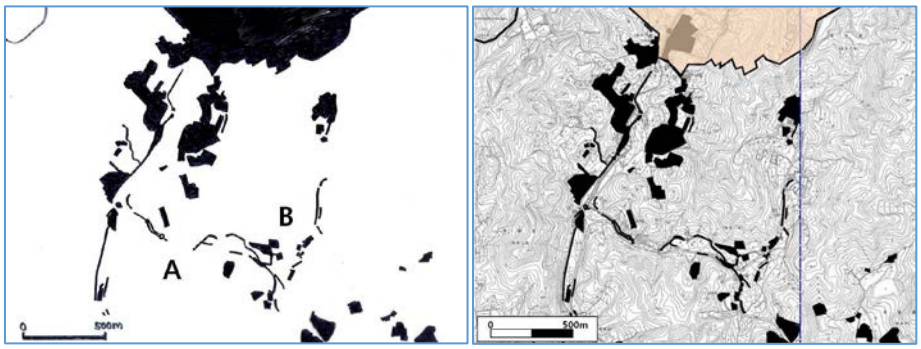


Fig. 6 An example of geographical barrier map. Left one shows geographical elements such as roads, water course, banks, various buildings and urban area overlapped on a geographical map. Right one shows only distribution of geographical barriers (adopted from Kim and Ko, 2013**).**

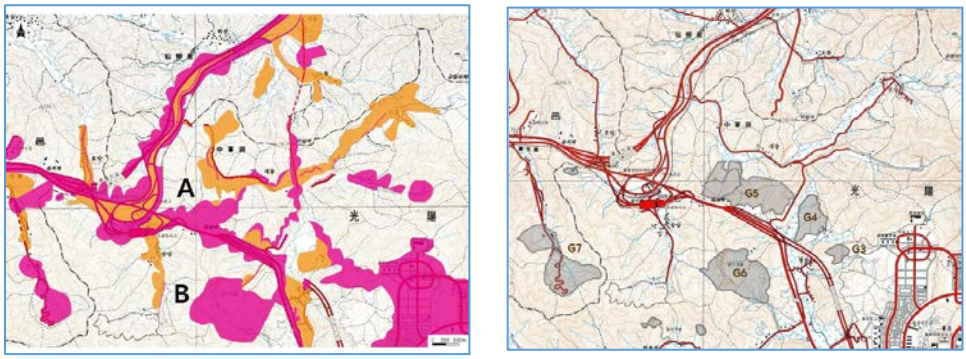


Fig. 7 An example of geographical barrier map. Left one shows roads, urban area and excavation sites of earth materials. Right one emphasizes distributions of geographical barriers (colored area). Horizontal width of the map is about 8 km (adopted from Kim, 2005).

The figure 7 shows other example of geographical barrier mapping. When we consider expanding excavation site to supply more earth material around this region, selecting site A is more ecosensitive than to choose site B because the site A is already isolated by surrounding barriers.

Generally, terminology 'permeability' is used to describe transmissability of fluid through porous media, such as rock, sediment, soil etc. In this study, the term 'permeability' is adopted to describe 'travelling easiness of animals in the field of various geographical barriers.' Diagram in Fig.8shows simplified concept of permeability as a travelling probability of animals in the field. Kim (2013) suggested random walker simulation to estimate change in possibility of animal passage before and after construction of some facilities or road when these work as geographical barriers. The simulation results could be used like permeability of a media.

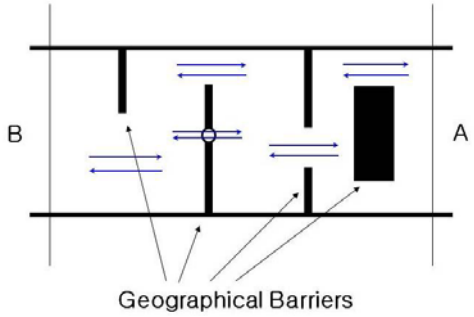


Fig. 8 A conceptual diagram that shows travelling probability of animals in the field where various geographical barriers are located. General term 'permeability' is adopted to express easiness of migration of animals like fluid transmissibility in porous media. The horizontal arrow represent moving directions, circle in the center of diagram represents a type of ecological corridor such as small ecobridge. (Modified from Kim, 2005).

When an animal travels from A to B, travelling easiness may be dependent on locations, numbers and dimensions of geographical barriers. The travelling easiness of an area can be defined as 'travelling probability' like permeability of a porous media for fluid travel.

VII. LOCATING STRATEGY USING RANDOM WALKER SIMULATION: A SUGGESTION

It is quite important how much closely arrange WPP sites along a mountain ridge line for more energy production. Figure 9 explains ecosensitive locating strategy of WPP sites. But the information of setting intervals seems to be uncertain. Kim and Ko(2013) suggested employing random walker simulation to understand travelling probabilities where series of barriers are located. Random walker simulations were accomplished with various interval settings from 5 to 25 km. Fig 10 shows simple model of random walker simulation for locating multiple WPP's along a mountain ridge line. The results are listed in Table 2. It is suggested to use of random walker simulation method to optimize ecosensitive locating of WPP and other ecosensitive locating projects.

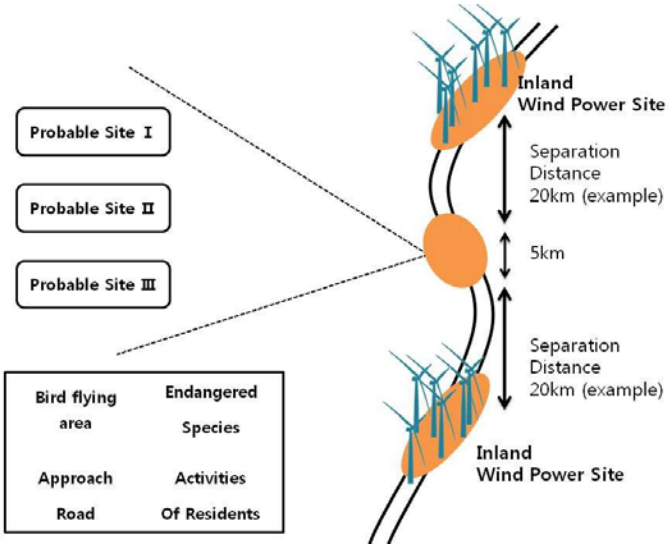


Fig. 9 Digrammatic explanation of progressive locating strategy between preexisting WPP sites. In situ alternatives of site I, II, III are assumed. Major items to be surveyed are listed at the left corner of diagram.

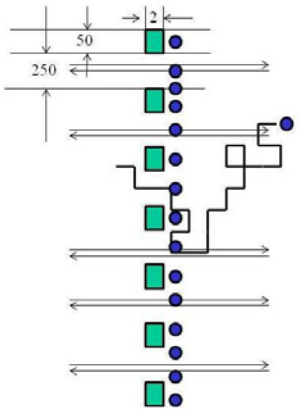


Fig. 10 Simple model for simulation of inland wind power plants along a mountain ridge line. 1 unit the figure designated 0.1km. This model assumes locating 7 sites with some open distance between them. Simulation results with various interval settings are presented in Table 2.

Table 2 Variation of permeabilities and travelling probabilities according to various wind power plant layout. One site of wind power plant is regarded as geographical barrier of 5km long. Number of random walkers: 1,000. Number of steps: 1,000. 10 step corresponds to 1km. Number of Sites of Wind Power Plant: 7. Total length of interval includes 7 sites of plants and 6 open distance among the sites. The numbers are average of repeated results**.**

Distance between each site of Wind Power Plants(km)	Total length of interval (km).	Permeability Geometric travelling probabilities (%)	Travelling Probability (Results of random walker simulation)(%)
5	65	46.2	64.1
6	71	50.7	67.5
7	77	54.5	68.3
8	83	57.8	70.0
9	89	60.7	72.2
10	95	63.2	76.0
15	125	72.0	79.4
25	185	81.3	86.6

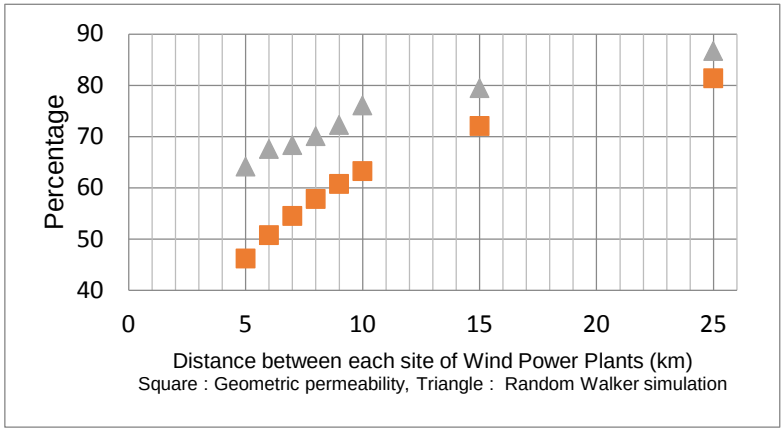


Fig. 11 Results of random walker simulation with various intervals (horizontal axis) and percentage of walkers that passed through the barriers (vertical axis). Triangles are random walker simulation results (travel probabilities) and squares are calculated germetrical travel probabilities (permeabilities).

VIII. CONCLUSION

Korean peninsula is uniquely sensitive to protect major ridge lines as a ecologically important zone. Siting of inland wind power plants along the mountain ridge lines encountered strong refusals ecologically. Geographical barrier mapping is useful to understand and estimate environmental situations comprehensively. It could be used as one of the most useful tools in environmental impact assessment. Ecosensitive strategy of project siting is suggested and examples of the strategy is explained by applying to locating problems of inland wind power plants in South Korea. Random walker simulation method is useful to evaluate and understand degree of travelling easiness. Sustainable development could be accomplished with the help of these methods.

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