PREDICTION OF THE SUITABILITY OF LOCATIONS FOR WIND FARMS USING FLEX EXPERT SYSTEM

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ABSTRACT

Wind-generated electricity has the ability to provide electricity to homes and businesses without causing air pollution or depleting non-renewable resources, unlike electricity generated by coal, natural gas, and oil (fossil fuels). Wind farm developments are mostly not common with the local populations and as a result, many factors have to be taken into consideration before such development can take place. This paper presents a Forward Chaining Flex knowledge-base for locating Wind Farms. Such factors as energy production, visual and sound impact for the local community, the number of wildlife species in the area and their population sizes, a geological survey to determine ground stability and a hydrological survey to show the effect of the development on local rivers and water sources, are arranged in a decision tree and consequently built into a knowledge-based system using the Flex expert system shell. Sample outputs from the developed Flex expert system show that a location might be ruled out as 'completely unsuitable', 'ideal' or a 'second best' choice.

Keywords: Wind farms, Flex knowledge-base, Expert systems, Decision tree

INTRODUCTION

Wind-generated electricity, also known as wind power, has the ability to provide electricity to homes and businesses without causing air pollution or depleting non-renewable resources, unlike electricity generated by coal, natural gas, and oil (fossil fuels). Furthermore, because wind power has no fuel costs (that is, wind power depends on the energy of the wind), its operating costs are lower than the costs for power produced from fossil fuels, although its capital costs are greater. Wind power relies on frequent, strong winds to turn the blades of power-generating turbines (United States Government Accountability Office, 2004).

In testing whether a location is suitable for a wind farm, some factors are usually considered (United States Government Accountability Office, 2004), (Colby, etal, 2009) as indicated in the decision tree in Fig. 1. The outcome of a hydrology survey is always checked; the development may interfere with water courses, by eroding land or causing flooding from run-off (as the turbines need concrete footings, reducing the volume of land to soak up water). If that test is passed, a further test for suitability is used which involves determining the level of energy production possible at the site.

Next, a test is made of the diversity of wildlife inhabiting the site – that is, counting the number of different bird species in the nearby area. However, some birds are scarcer than others, resulting in a greater need for conservation (and hence rejecting any sort of development). The broad categories of birds are indicated in the table below, along with a simple means of producing a score from counts of the different numbers of invertebrate species. An assessment of whether the location is suitable is based on the total score derived from the formula (N * S), where N is the number of distinct species (they could be Endangered, Scarce and Common species) and S is the scoring weight. The scoring weights for the species are 3, 2 and 1 respectively. The location is considered not to be damaging to

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wildlife if the score is greater or equal to 20; it is considered a second best quality location if the score is between 10 and 20; it is considered damaging to wildlife if the score is less than 10.

Table 1. Birds Diversity Scoring System

Level of scarcity	**Number of distinct species (N)**	**Scoring Weight (S)**	**Weighted score (N * S)**
Endangered		3	
Scarce		2	
Common		1	
			Total Score =

The scoring system might be misleading because based on the formula, suppose we have 0 number of endangered, 2 Scarce and 20 common, the score is 24, meaning that the obvious conclusion is that a wind farm will not be damaging to wildlife but it is also obvious that one of the species is not represented. This implies that a high score might be produced by the individual components of the formula. The mere fact that diversity and sizes of birds populations change seasonally and with migration patterns and the capacity of a site to provide the necessary food and habitat for birds can also vary from year to year, then having a low score does not always mean that the placement of a wind farm would significantly damage the wildlife..

Following the wildlife diversity test, a further four tests may be required. A check of visual impact is next. If the location is close to inhabited areas, then a check of sound impact is also required. Then the result of a geological survey is tested, to determine whether the ground is sufficiently stable to support a heavy turbine. Lastly, a check for sound is made, to consider whether the noise of the turbines is likely to carry to inhabited areas.

Expert Systems

Expert Systems (ES) (Negnevitsky, 2005), (Hopgood, 2001), (Callan, 2003) are systems that are designed to simulate the behaviour of a human expert as he or she attempts to solve some complex problem in a particular domain. They are computer systems that encapsulate specialist knowledge about a particular domain of expertise and are capable of making intelligent decisions within that domain. Areas successfully tackled so far within the expert systems framework include medical diagnosis, geological exploration, organic chemistry, fault-finding in electronic equipment, and the insurance industry. In fact, any area in which human experts solve problems is a potential area for the use of expert systems. The most popular expert systems are rule-based systems. Rules can represent relations, recommendations, directives, strategies and heuristics (Negnevitsky, 2005).
A rule-based expert system consists of five components – the knowledge base, the database, the inference engine, the explanation facilities, and the user interface (Negnevitsky, 2005). The knowledge base contains the domain knowledge useful for problem solving. The knowledge is represented as a set of rules and each rule specifies a relation, recommendation, directive, strategy or heuristic and has the IF (condition) THEN (action) structure. When the condition part of a rule is satisfied, the rule is said to fire and the action part is executed. The database includes a set of facts used to match against the IF (condition) parts of rules stored in the knowledge base. The inference engine carries out the reasoning whereby the expert system reaches a solution. The inference engine links the rules given in the knowledge base with facts provided in the database and uses two main strategies to operate – the forward chaining strategy and the backward chaining strategy.
The inference engine must decide when the rules have to be fired. The two main ways in which rules are executed are the forward chaining and the backward chaining. Forward chaining is a data-driven reasoning which means that rules are selected and applied in response to the current fact base. The reasoning starts with the known data and proceeds forward with that data. Forward chaining is also a method of gathering information and then concluding from it whatever can be concluded. Backward

chaining is the goal-driven strategy. In backward chaining, an expert system has the goal and the inference engine attempts to find the evidence to prove it.
A computer cannot encode the full complexity of the factors and the often uncertain information involved in developing Windy-ES. Consider for instance, the wildlife diversity and sizes change enormously over time, and the information from geological surveys can be quite inaccurate, leading to changes in the exact location for the wind farm once development begins. These changes should be taken into account in site selection because rules cannot capture the thought processes of an expert (Callan, 2003)**.** This is in agreement with what (Negnevitsky, 2005) said in his book: "In general, rule-based expert systems do not have the ability to learn from the experience. Unlike a human expert, who knows when to 'break the rules', an expert system cannot automatically modify its knowledge base, or adjust existing rules or add new ones. The knowledge engineer is still responsible for revising and maintaining the system." Deciding on what constitutes some of the factors involved (especially the hydrology survey, geology survey and the diversity of wildlife) is quite subjective, so the knowledge represented is not particularly deep.

The key to the success of an expert system is the validity and completeness of the knowledge possessed by the system. Most often, it is assumed that the knowledge itself is readily available and could be expressed explicitly but this assumption is not always the case as can be seen in the Flex knowledge-based expert system for locating the wind farm, mainly due to the complexity of the factors and the uncertain information. Thus, the rules that describe the domain are not known and the problem is not expressible explicitly in terms of rules, facts or relationships such as expressing wildlife migration pattern and land stability as rules.

Disadvantages of Expert Systems

Some of the limitations of Expert Systems include the following (Kock, 2003):

- Expert Systems cannot apply common sense in making decisions. They only rely on the rules.
- Experts do not realise when they reach their limits. They may recommend inappropriate actions.
- Knowledge acquisition is not readily available. Another reason for this problem is that experts tend to be unreliable when it comes to describing their own reasoning processes. This may be as a result of deliberate resistance from the domain experts. Also experts tend not to spend enough time analysing their own behaviour and processes.
- The domain of expertise is usually narrow. An expert system is designed for a specific purpose and is not useful for another purpose.
- Expert systems may be costly to develop because of the time of human experts and other people involved in the process.
- Expertise is very difficult to extract from humans.
- Lack of trust by end users may be a hindrance to expert system's use.
- Knowledge transfer is subject to a host of perpetual and judgemental biases.
- The work of rare and expensive knowledge engineers is required, and
- Most experts have independent means of checking whether the conclusions are reasonable.

MATERIALS AND METHODS

Decision Trees

A decision tree (Callan, 2003) is a way of relating a series of inputs to an output (usually representing something you want to predict) using a series of rules arranged in a tree structure. One famous algorithm used for the decision tree learning is ID3 (Callan, 2003), which uses the Training Set to decide which attribute is the most important in dividing the cases into the different outcomes. This attribute is then placed at the top of the Decision Tree, and the process repeats to find the next most important attribute along each branch. Choosing the best attribute uses a measurement from Coding and Information Theory, called entropy. The description of the ID3 algorithm is given by (Kock, 2003)

Flex Expert System

For the Flex knowledge-base for locating wind farms, the forward chaining (rules) strategy was used. We need to first gather information and then tries to infer from it whatever can be inferred. The Flex Expert System Shell will be used. Flex describes knowledge in terms of *production rules* (that is, *if-then* statements), which has proved the most popular approach to encapsulation expert knowledge. Such rules, despite appearing simple, enable relatively complex connections to be made between individual pieces of 'knowledge', thereby solving apparently difficult problems. The rule consists of two parts – the IF part called the antecedent (condition) and the THEN part called the consequent (conclusion or action). In general, a rule can have multiple conditions joined by the keywords AND (conjunction), OR (disjunction) or a combination of both (Negnevitsky, 2005). The condition of a rule contains two parts – the object (linguistic object) and its value. The object and its value are linked by an operator. Such operators used in Flex programs are *is, are, are not, becomes and includes*. However, expert systems can also use mathematical operators to define an object as numerical and assign it to the numerical value (Callan, 2003)**.** Also similar to a rule antecedent, a consequent combines an object and a value connected by an operator. The operator assigns the value to the linguistic object.
Figure 1 shows the Decision Tree for assessing local suitability that will eventually be used to produce the corresponding knowledge-base. Based on the decision tree provided, some production rules are constructed. A location might be ruled out as completely unsuitable, ideal or a 'second best' choice (which may be used if no other sites can be found, but there may be difficulties, construction-based or political, to overcome). In many cases a result can be determined without performing all the tests.

Each node is an attribute in the decision tree (corresponding to an object in Flex), and the arcs from the node specify the different values that attribute can take (Callan, 2003). In this case, every attribute can take at least two values. Following one line of values, the path taken represents a specific case of attribute values that lead to an outcome for that case – a decision in which we are interested. As an example, consider the leftmost path, which is equivalent to the following rule:

```
rule best_location
    if [ the outcome of a hydrology survey is 'no hydrological effect'
    or the outcome of a hydrology survey is 'minimal hydrological effect']
    and the level of energy production possible is 'high energy'
    and the number of different bird species in the nearby area >= 20
    and the visual impact of the proposed wind farm is 'very distant visual impact'
    and the result of a geology survey is 'stable geological effect'
    then decision becomes 'Accept as best quality location.'
```

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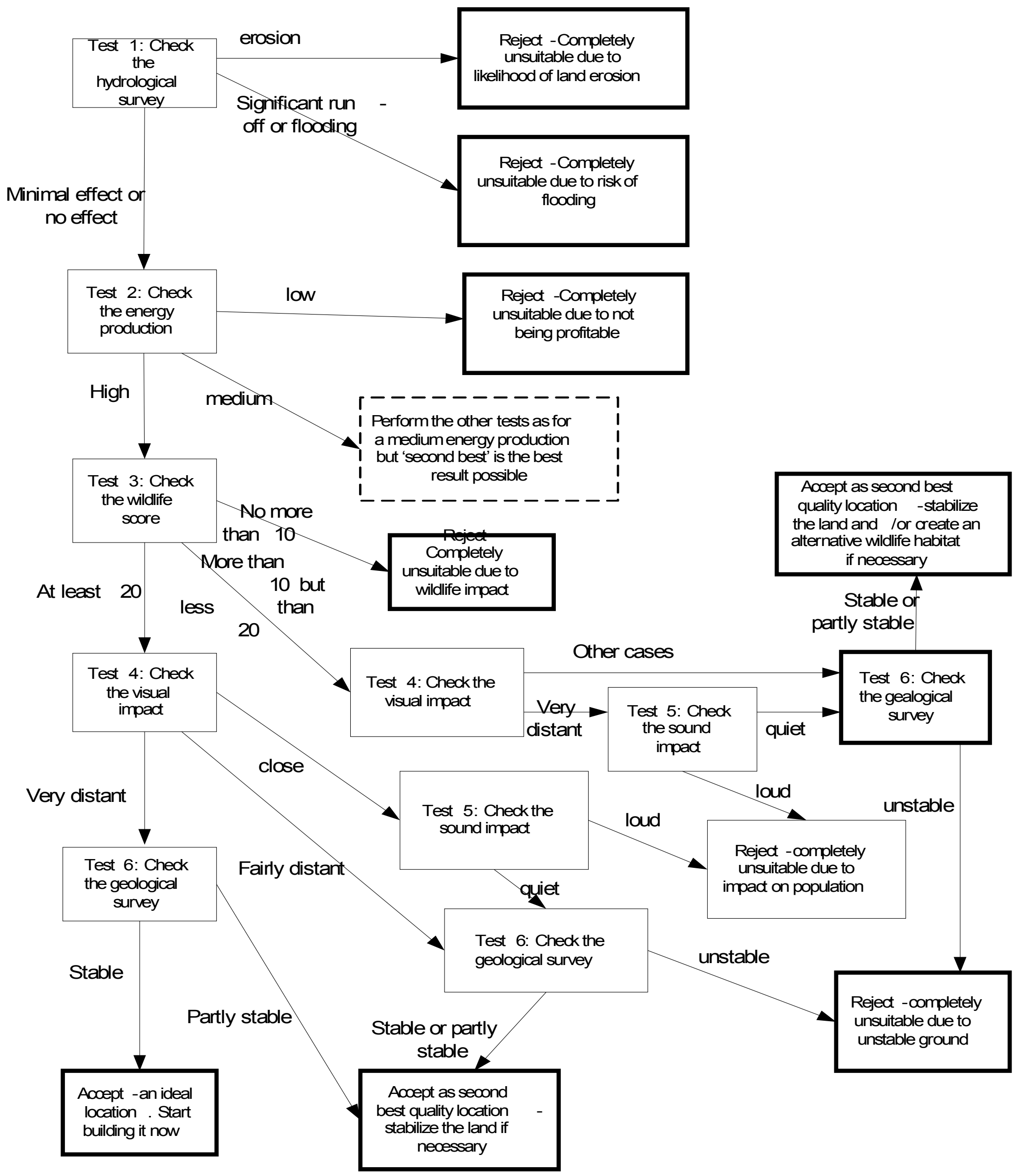

Figure 1: The decision tree for assessing local suitability

General Structure Of The Developed Expert System

The structure of a (forward chaining) Flex knowledge-base for locating a wind farm has the following parts which will be typed in this order:

- /* gather all the necessary information */

Here we construct rules to check what we don't already know and include questions to ask for these values. We gather all the information we need about the different tests to be conducted to ascertain suitability of site for a locating a wind farm. Also a set of questions are given to the user to supply answers with. In the case of the wildlife score, the user enters a number while in other cases, the user chooses from among group of options from the dialogue box. The following program segment illustrates this:

```
group hydrology_test 'no hydrological effect', 'minimal hydrological effect', 'erosion', 'flooding', 'significant run_off'.

question the outcome of a hydrology survey
        what is the hydrological effect of the site? ;
        choose from hydrology_test ;
        because knowing the hydrology effects help determine the suitability of site .

group energy_test 'low energy', 'medium energy', 'high energy'.

question the level of energy production possible
        what is the energy level of the proposed site? ;
        choose from energy_test ;
        because knowing the energy level help determine the suitability of site .

group visual_test 'close visual impact', 'fairly distant visual impact', 'very distant visual impact'.

question the visual impact of the proposed wind farm
        what is the actual visual impact of the site? ;
        choose from visual_test ;
        because knowing the visual impact of the site help determine suitability of site.

group geology_test 'stable geological effect', 'partly stable geological effect', 'unstable geological effect'.

question the result of a geology survey
        what is the geology survey on the site ;
        choose from geology_test ;
        because knowing the geology survey really help determine the suitability of site .

group sound_test 'loud sound impact', 'quiet sound impact'.

question the effect of sound impact on the populace
        what is the sound impact on the populace? ;
        choose from sound_test ;
        because knowing the sound impact help determine the suitability of site .

question the number of different bird species in the nearby area
        please enter the wildlife score ;
        input number ;
        because knowing the scores help determine suitability of site .
```

- /* rules to determine the value of the object sought */

There are nine rules written to determine the value of the decision to be taken, that is, whether to accept as best quality location, accept as second best quality location, or to reject site completely. The first rule has ‘Accept as best quality location’ as the decision, the second to the eighth rule have ‘accept as second best quality location’ and the ninth rule has ‘reject site completely’ as the decision. The full production rules are included in Appendix 1.

If there are no matches, then a default case is created that instantiates decision and advice to something sensible as illustrated in the following program segment:

```
rule unknown_tests
        if decision is unknown
        then decision becomes 'not known'
        and advice becomes 'Check the various tests and try again.'
        and output_advice .
```

- /* set up how the program starts and output */
  1. Ruleset: The ruleset simply refers to the rule base of the expert system (Windy-ES), that is, the production rules produced from the given decision tree. The full production rules are provided in Appendix 1.

  2. Action to invoke the ruleset: The action ‘decide’ invokes the ruleset, windy_ES, we have defined. The first line of ‘ruleset’ statement specifies that all the nine rules are to be included. The second line specifies that rules are to be visited in the order in which they are written because forward chaining strategy was used in the flex program. In order to avoid Flex firing a single rule repeatedly, the third line specifies that if a rule has been used, that it should not be used again. The last rule (concerning restart) specifies that Flex should not use previous answers to instantiate objects each time the program is run, but that it should ask the questions again, so the user can enter different answers each time the questions are asked. The last line simply tells Flex to forget what was typed in the previous session. The following program segment illustrates this:

```
ruleset windy_ES
        contains all rules ;
        select rule using first come first served ;
        update ruleset by removing each selected rule ;
        initiate by doing restart .
```

  3. Actions to output to the Console window: The flex program is started by typing in ‘*decide .*’ in the Console window. The action ‘*decide*’ invokes a ruleset (windy_ES), and then calls another action , ‘output_advice’ to write the ‘decision’ and ‘advice’ on the console window, as illustrated by the following program segment:

```
action decide
    do invoke ruleset windy_ES .

action output_advice
    do nl
  and write('A possible decision is: ')
    and write(decision)
    and nl
    and tab(2)
    and write('You are advised to ')
    and write(advice)
    and nl
    and nl .
```

Below is a screen shot obtained from the console window when the Flex program is run for the first time, showing the general structure of the expert system (Windy-ES):

```
| ?- template        hydrology_test
```

```
template    energy_test
template    wildscores
template    visual_test
template    sound_test
template    geology_test
group       hydrology_test
question    hydrology_test
group       energy_test
question    energy_test
group       visual_test
question    visual_test
group       geology_test
question    geology_test
group       sound_test
question    sound_test
question    wildscores
rule        best_location
rule        secondbest_location1
rule        secondbest_location2
rule        secondbest_location3
rule        secondbest_location4
rule        secondbest_location5
rule        secondbest_location6
rule        secondbest_location7
rule        reject_location
rule        unknown_tests
ruleset     windy_ES
action      decide
action      output_advice
```

RESULTS AND DISCUSSION

Analysis of the Flex Expert System

Templates definitions are used at the start of the Flex program to allow object and action names to be hidden from part of the program except in the template definition. Using template definitions also make the programs easier to read, as illustrated by the following program segment:

```
template hydrology_test
        the outcome of a hydrology survey .

template energy_test
        the level of energy production possible .

template wildscores
        the number of different bird species in the nearby area .

template visual_test
        the visual impact of the proposed wind farm .

template sound_test
        the effect of sound impact on the populace .
```

Kock, 2003
template geology_test
the result of a geology survey .

The rules are written in a way that by calling the output actions as soon as the 'decision' object is successfully instantiated, multiple decisions and corresponding advice are output. We also try to establish a kind of natural dialogue between the system and the user by making inference engine to ask questions only when the questions are necessary to make decisions.

DISCUSSION

A typical consultation would invite the user to input details about the location being considered, and would output an assessment of suitability, including details of actions necessary or reasons for rejecting it as unsuitable. The expert system should try to ask only questions that still seem relevant – following on from answers given by the user – to produce a natural dialogue. The Flex program should allow for a more natural dialogue to take place. Take for instance, when the user enters all the information satisfying the first rule 'rule accept_location', Flex still ask the user to enter the 'sound impact of the turbine' which is not part of the first rule. If the user enters 'quiet sound impact' to the question, the first rule will still fire but if the user enters 'loud sound impact' the first rule ('accept_location') and the last rule ('reject_location') will fire. One way of resolving this problem should be to include Test 5 (that is, Check the sound impact) in all the rules since having a quiet sound impact is a good indication that a land is suitable for locating the wind farm and having a loud sound impact indicates alter rejection of site. This approach can also be a good way of improving the decision tree. Again, more specific rules will avoid this. The ordering of the rules is also very important.

The general working of the system can be explained by looking at some sample outputs obtained when the Flex Expert System in Appendix 1 was run for the various conditions in the production rules. For instance, when the outcome of a hydrology survey is 'no hydrological effect' or the outcome of a hydrology survey is 'minimal hydrological effect, and the level of energy production possible is 'high energy', and the number of different bird species in the nearby area >= 20, and the visual impact of the proposed wind farm is 'very distant visual impact' and the result of a geology survey is 'stable geological survey' then output becomes:

0.025 seconds to reconsult_rules windy farm project.ksl [f:\]
| ?- decide.

A possible decision is: Accept as best quality location.
You are advised to accept as an ideal location and start building now.

Congratulations yes

CONCLUSION

The use of Flex expert system shell in the development of a knowledge-base expert system for locating a wind farm has been considered. Flex has proved to be an excellent tool for developing rule-base expert systems by representing knowledge in the form of production rules (IF – THEN statements). The developed expert system (Windy-ES) also got a share of the general problems of expert systems, especially the problem of encoding (because of the complex nature of factors involved and uncertain information) and the problem of knowledge acquisition. Decision tree learning (using ID3 algorithm) and Inductive learning should be adopted for the overall improvement of the decision tree used in the development of the model.

APPENDIX 1 – Flex Expert System for Locating Wind farms

/* Flex knowledge-base for locating Wind Farms */
/* using forward-chaining (rules). */

/* To allow object names to be hidden from part of the program except in the template definition, and for the programs to be more readable, templates definitions are used */

```
template hydrology_test
        the outcome of a hydrology survey .

template energy_test
        the level of energy production possible .

template wildscores
        the number of different bird species in the nearby area .

template visual_test
        the visual impact of the proposed wind farm .

template sound_test
        the effect of sound impact on the populace .

template geology_test
        the result of a geology survey .
```

/* questions to be called by the rules */

```
group hydrology_test 'no hydrological effect', 'minimal hydrological effect', 'erosion', 'flooding', 'significant run_off'.

question the outcome of a hydrology survey
        what is the hydrological effect of the site? ;
        choose from hydrology_test ;
        because knowing the hydrology effects help determine the suitability of site .

group energy_test 'low energy', 'medium energy', 'high energy'.

question the level of energy production possible
        what is the energy level of the proposed site? ;
        choose from energy_test ;
        because knowing the energy level help determine the suitability of site .

group visual_test 'close visual impact', 'fairly distant visual impact', 'very distant visual impact'.

question the visual impact of the proposed wind farm
        what is the actual visual impact of the site? ;
        choose from visual_test ;
        because knowing the visual impact of the site help determine suitability of site.
```

```
group geology_test 'stable geological effect', 'partly stable geologicaeffect', 'unstable geological effect'.

question the result of a geology survey
        what is the geology survey on the site ;
        choose from geology_test ;
        because knowing the geology survey really help determine the suitability of site .

group sound_test 'loud sound impact', 'quiet sound impact'.

question the effect of sound impact on the populace
        what is the sound impact on the populace? ;
        choose from sound_test ;
        because knowing the sound impact help determine the suitability of site .

question the number of different bird species in the nearby area
        please enter the wildlife score ;
        input number ;
        because knowing the scores help determine suitability of site .

/* Rules about tests and decisions. */
/* By calling the output actions as soon as the */
/* 'decision' object is successfully instantiated, */
/* multiple decisions and corresponding advice are */
/* output. Our choice of where to call output */
/* actions can determine how many answers we output */
/* in a foward-chaining program. */

rule best_location
        if [ the outcome of a hydrology survey is 'no hydrological effect'
        or the outcome of a hydrology survey is 'minimal hydrological effect']
        and the level of energy production possible is 'high energy'
        and the number of different bird species in the nearby area >= 20
        and the visual impact of the proposed wind farm is 'very distant visual impact'
        and the result of a geology survey is'stable geological effect'
        then decision becomes 'Accept as best quality location.'
        and advice becomes 'accept as an ideal location and start building now.'
        and output_advice
        and write ('Congratulations') .

rule secondbest_location1
        if [ the outcome of a hydrology survey is 'no hydrological effect'
        or the outcome of a hydrology survey is 'minimal hydrological effect']
        and the level of energy production possible is 'high energy'
        and the number of different bird species in the nearby area >= 20
        and the visual impact of the proposed wind farm is 'very distant visual impact'
        and the result of a geology survey is 'partly stable geological effect'
        then decision becomes 'accept as second best quality location1.'
        and advice becomes 'Stabilize the land if necessary.'
        and output_advice .

rule secondbest_location2
        if [ the outcome of a hydrology survey is 'no hydrological effect'
```

```
        or the outcome of a hydrology survey is 'minimal hydrological effect']
        and the level of energy production possible is 'high energy'
        and the number of different bird species in the nearby area >= 20
        and the visual impact of the proposed wind farm is 'fairly distant visual impact'
        and [ the result of a geology survey is 'stable geological effect'
        or the result of a geology survey is 'partly stable geological effect' ]
        then decision becomes 'accept as second best quality location2.'
        and advice becomes 'Stabilize the land if necessary.'
        and output_advice .

rule secondbest_location3
        if [ the outcome of a hydrology survey is 'no hydrological effect'
        or the outcome of a hydrology survey is 'minimal hydrological effect']
        and the level of energy production possible is 'high energy'
        and the number of different bird species in the nearby area >= 20
        and the visual impact of the proposed wind farm is 'close visual impact'
        and the effect of sound impact on the populace is 'quiet sound impact'
        and [ the result of a geology survey is 'stable geological effect'
        or the result of a geology survey is 'partly stable geological effect' ]
        then decision becomes 'accept as second best quality location3.'
        and advice becomes 'Stabilize the land if necessary.'
        and output_advice .

rule secondbest_location4
        if [ the outcome of a hydrology survey is 'no hydrological effect'
        or the outcome of a hydrology survey is 'minimal hydrological effect']
        and the level of energy production possible is 'high energy'
        and [ the number of different bird species in the nearby area > 10
        and the number of different bird species in the nearby area < 20 ]
        and the visual impact of the proposed wind farm is 'very distant visual impact'
        and the effect of sound impact on the populace is 'quiet sound impact'
        and [ the result of a geology survey is 'stable geological effect' ]
        or the result of a geology survey is 'partly stable geological effect'
        then decision becomes 'accept as second best quality location4.'
        and advice becomes 'Stabilize the land and/or create an alternative
        wildlife habitat if necessary.'
        and output_advice .

rule secondbest_location5
        if [ the outcome of a hydrology survey is 'no hydrological effect'
        or the outcome of a hydrology survey is 'minimal hydrological effect']
        and the level of energy production possible is 'high energy'
        and [ the number of different bird species in the nearby area > 10
        and the number of different bird species in the nearby area < 20 ]
        and [ the visual impact of the proposed wind farm is 'close visual impact'
        or the visual impact of the proposed wind farm is 'fairly distant visual impact' ]
        and [ the result of a geology survey is 'stable geological effect'
        or the result of a geology survey is 'partly stable geological effect' ]
        then decision becomes 'accept as second best quality location5.'
        and advice becomes 'Stabilize the land and/or create an alternative
        wildlife habitat if necessary.'
        and output_advice .
```

```
rule secondbest_location6
        if [ the outcome of a hydrology survey is 'no hydrological effect'
        or the outcome of a hydrology survey is 'minimal hydrological effect']
        and the level of energy production possible is 'medium energy'
        and the number of different bird species in the nearby area >= 20
        and [ the visual impact of the proposed wind farm is 'close visual impact'
        or the visual impact of the proposed wind farm is 'fairly distant visual impact'
        or the visual impact of the proposed wind farm is 'very distant visual impact' ]
        and the effect of sound impact on the populace is 'quiet sound impact'
        and [ the result of a geology survey is 'stable geological effect'
        or the result of a geology survey is 'partly stable geological effect' ]
        then decision becomes 'accept as second best quality location6.'
        and advice becomes 'Stabilize the land if necessary.'
        and output_advice .

rule secondbest_location7
        if [ the outcome of a hydrology survey is 'no hydrological effect'
        or the outcome of a hydrology survey is 'minimal hydrological effect']
        and the level of energy production possible is 'medium energy'
        and [ the number of different bird species in the nearby area > 10
        and the number of different bird species in the nearby area < 20 ]
        and [ the visual impact of the proposed wind farm is 'very distant visual impact'
        or the visual impact of the proposed wind farm is 'fairly distant visual impact'
        or the visual impact of the proposed wind farm is 'close visual impact' ]
        and [ the result of a geology survey is 'stable geological effect'
        or the result of a geology survey is 'partly stable geological effect' ]
        then decision becomes 'accept as second best quality location7.'
        and advice becomes 'Stabilize the land if necessary.'
        and output_advice .

rule reject_location
        if the outcome of a hydrology survey is 'erosion'
        or the outcome of a hydrology survey is 'significant run-off'
        or the level of energy production possible is 'low energy'
        or the number of different bird species in the nearby area =< 10
        or the result of a geology survey is 'unstable geological effect'
        or the effect of sound impact on the populace is 'loud sound impact'
        then decision becomes 'reject site completely.'
        and advice becomes 'reject site completely - unsuitable due to likelihood of land
        erosion, risk of flooding, not being profitable, negative wildlife impact,
        negative impact on population or unstable ground.'
        and output_advice
        and write ('Sorry about that') .

/* If there are no matches, then create a 'default' */
/* case that instantiates decision and advice to */
/* something sensible. */

rule unknown_tests
        if decision is unknown
        then decision becomes 'not known'
        and advice becomes 'Check the various tests and try again.'
        and output_advice .
```

```
/* Set up how the program starts and outputs. */

ruleset windy_ES
        contains all rules ;
        select rule using first come first served ;
        update ruleset by removing each selected rule ;
        initiate by doing restart .

action decide
        do invoke ruleset windy_ES .

action output_advice
        do nl
        and write('A possible decision is: ')
        and write(decision)
        and nl
        and tab(2)
        and write('You are advised to ')
        and write(advice)
        and nl
        and nl .
```

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