Wind farm Site Suitability Selection using Multi-Criteria Analysis (MCA) and Spatial Modeling

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Abstract

Since the decade of the 1970s Jamaica's economy like that of many countries without indigenous sources of fossil fuels has suffered from the inflated and fluctuating prices of petroleum products. Latterly, such economies have had to grapple with the negative environmental consequences of using fossils, notably climate change and global warming.

The strategic response therefore, was to encourage the development of renewable energy resources (RES) namely wind, solar and hydropower. This is in spite of the absence of an enabling legislative environment. This study makes a contribution to the extant body of knowledge on the location of suitable sites for wind farms in Jamaica. The method pivots on the use of a deterministic GIS model and is supported by multi-criteria decision making and Analytical Hierarchy Process (AHP). The model selected 113 optimal sites that were further optimised by filtering out small non-contiguous areas. Finally, future research of this type can be advanced more seamlessly if issues relating to data quality, data accessibility and ground truthing are resolved.

Keywords: GIS model, multi-criteria analysis, analytical hierarchy process, geo-visualisation

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INTRODUCTION

1.1: Background

Since the first oil crisis of the early 1970s Jamaica and many other petroleum importing countries have been attempting to diversify their energy sector. The ultimate objective is to reduce its dependence on imported petroleum (Ministry of Mining and Energy, 2009). The significant increase in the price of fuel has virtually wiped out all the cash reserves of the countries and has impacted on the quality of health, education and transportation, inter alia.

During the period of the 1970s and 1980s the reduction in consumption of petroleum was in and of itself the challenge to be addressed by conservation and the use of renewable energy sources (RES). In the current disposition where concerns of global warming and climate change are topical, the interest centres more on a reduction in dependence on fossils fuels.

The concerns of governments are therefore twofold: how to manage expenditure where the portion demanded to import fossil fuels is constantly increasing, and how to manage expanding demands for infrastructural repairs, dislocation and loss of life caused by unpredictable and devastating weather systems, direct consequences of consuming fossil fuels.

Jamaica’s response to the first energy crisis was the establishment of the Petroleum Corporation of Jamaica (PCJ) which was mandated to drive the country’s oil exploration efforts. This was subsequently expanded to include energy conservation and improving efficiencies, and to drive the use of renewable energy sources.

1.2: Energy and the Jamaican Economy

The Green Paper entitled “The Jamaica Energy Policy 2006-2020” summarises the relationship between energy and the Jamaican economy as follows (Ministry of Energy and Mining , Jamaica, 2006):

- Excessive dependence on imported primary energy;
- Low energy supply self-sufficiency due to a lack of indigenous energy resources, and low utilization of available sources, namely wind, hydro, solar and biomass;
- High petroleum consumption that is concentrated in alumina, power generation and transport sectors (per capita energy consumption has increased by 50% since the early 1990s);
- Rising share of oil products in the import energy supply mix relative to crude oil (the latter share has fallen from 42.5% in 1990 to 23.5% in 2004);
- Low levels of the refinery utilization, operating below 60% since 1983; and
- High systems losses in the electricity industry, which has been deteriorating since 2001 and which reached 20% in 2004.

1.2.1: Jamaica’s Energy Policy

The energy policy was promulgated in 1995 with several objectives (Ministry of Mining and Energy, 2009) two of which are particularly relevant to this study:

- diversify the energy base and encourage the development of indigenous energy resources where economically viable and technically feasible; and ensure the security of energy supplies;

- Minimize the adverse environmental effects and pollution caused by the production, storage, transport and use of energy, and minimize environmental degradation as a result of the use of fuel wood.
- Jamaica consumes about 60,000 barrels of oil per day but the decade between 1999 and 2009 saw a marginal decline in imports of 1.5%, i.e. from 23.6 to 22.1 million barrels per annum. Despite these statistics fossils fuels/petroleum fuels dominated the energy mix at 91% with only 9% contributed by renewable (Figure1.1). The policy however advocates for an increase to 12.5% and 20% for renewables in 2015 and 2030 respectively.
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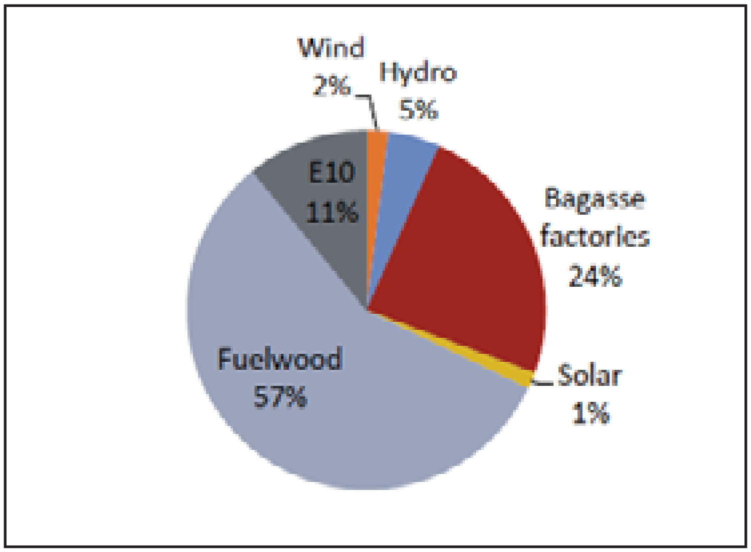

- Figure 1.1 Renewable energy contribution to Jamaica's energy mix (Ministry of Mining and Energy, 2009)

1.2.2: Wind Farm Development in Jamaica

Integral to the diversification of Jamaica's energy mix is the development of wind farms. Two currently operate on the island: Wigton Wind Farm Ltd a wholly owned subsidiary of the Petroleum Corporation of Jamaica (PCJ) with facilities near Rose Hill in

Manchester that produces 38.7 MW; the other at Malvern/Hermitage in St Elizabeth which has a capacity of 3 MW and is owned and operated by the island's main electricity generating company, the Jamaica Public Service Company Ltd (JPS).

Figure 1.2. Location of Jamaica's wind farms

1.3: Statement of Problem

Jamaica like many other non-producing oil importing countries are dependent on the high priced commodity to fuel its industrial, domestic and other sectors important to the proper functioning of the economy. The high price of fossil fuels along with price instability are significant issues when they are considered alongside the environmental effects of using fossil fuels e.g. global warming and climate change. These issues make the need to develop Jamaica's renewable energy sources (RES) more urgent.

1.4: Research Objectives

1. To identify the criteria that will select the most suitable sites for the location of wind farms.
2. To determine the level of influence (weight) associated with each criterion.
3. To develop a GIS based model to determine site suitability for wind farms.
4. To determine the most suitability sites for wind farms in Jamaica.

2.0: Literature Review

2.1: Wind farm location criteria

Baban and Parry (2001) resorted to the use of questionnaires targetting public and private sectors in the UK , to identify criteria , policies and factors used to determine suitable areas for locating wind farms. The responses to the four main questions are relevant to the instant study:

1. The question that asked about the criteria used to locate new areas for suitable farms returned: physical, economic, environmental impact, resource, visual and planning considerations.
2. Factors or constraints considered when trying to find suitable areas for locating wind farms, returned proximity to residential areas, noise, nuisance, shadow flicker, greenbelt, topography, ecology, agricultural land classification, conservation areas, distance from electricity gridlines, by the responding local authorities. The private consultancies on the

other hand, returned: wind speed , prevailing wind, terrain, adjacent terrain, vegetation, proximity to residential areas, noise and appearnce.

Of note the local authorities were not concerned about the very important factor of wind speed

3. The question that addressed government regulating policies used to locate wind farms returned: planning policy and pollution.
4. A specific question relating to optimum wind speed and direction, terrain type, distance from settlement, roads noise and aesthetics returned: 7 to 15 m/s optimum terrain described as round, hilly or flat, ideal adjacent terrain described as smooth, no change, or inclined, maximum grade slope 10%, and minimum distance from urban centres ranged from 500 to 5000 metres.

   The criteria developed by Baban and Parry (2001) consisted of a number of constraint factors including topography, wind speed and direction, landuse/landcover, access, population, hydrology and ecology. These constraint factors and their corresponding criteria were highlighted as physical, planning, economic, environment or resource consideration (Baban, 2004). These were found to be suitable for the Caribbean region, specifically Trinidad and Tobago which was regarded as an area of information poverty. Jamaica would also qualify as an area of information poverty and would also exhibit other geograpghical similarities to Trinidad and Tobago.

Belay (2009) focussed on Adis Ababa, Ethiopia and following consultations with the literature and stakeholder of wind resources in Ethiopia identified the following criteria (Table 2.1) :

Table 2.1 Site selection Criteria (Belay, 2009)

Item	Criteria
1	The proposed site should be on a slope less than 10%.
2	The proposed sites should be on bare (open area) followed by agricultural land.
3	The proposed sites should be found no more than 5 kilometres distance from the main road for transport acessibility.
4	To make the wind farm economical, the proposed sites should be located not more than 5 kilometres away from the National grid (electric transmission line).
5	Geological structures which are good from the geological engineering point of view and not easily affected by erosion are required.
6	The proposed sites should be located not less than 2 kilometres from towns.
7	Wind duration should be considered as a factor

The study recognised the need for wind duration as a factor to be considered in siting turbines but was omited from this study due to the unavailabilty of this data. This factor was also not considered by (Baban & Parry, 2001) for Trinidad and Tobago nor considered for Jamaica in any previous work. It is worthy of note than Baban (2004) recommends the same approach of (Baban & Parry, 2001) for developing wind farms in the Caribbean. However he was cautious by citing Sparks et al., (1996) which states that as a general rule, locating wind farms, in addition to being economically viable, should not have a significant impact on the local environment in terms of visual and noise intrusion, electromagnetic interference and possibly wild life collisions.

Table 2.2 presents the criteria recommended for Jamaica by Loy and Coviello (2005) against those actually considered for the implementation of Wigton Wind farm (Renewable Energy Systems Ltd, 2002). The latter include two additional criteria: environmental impact assessment and Surface roughness (which induces turbulence). The availability of wind resources is of paramount importance and so the local wind resource assessment was conducted at the Wigton site since 1996 seven years prior to the start of construction, in order to give a reliable long term scenario of wind speed at the site. The long term wind speed was estimated at 8.3 m/s at a hub height of 40 m. The wind resource assessment also indicated that wind speed would be in the range of 4-14 m/s blowing from the east or south east the majority of the time. Low turbulence is a characteristic of this site and has an inverse relationship with wind speed; that is, highest turbulence at lowest wind speeds, when it will have a minimal effect on the wind turbines (Renewable Energy Systems Ltd, 2002). Renewable Energy Systems Ltd (2002) also suggests that a lower wind regime turbine could be considered for the site based on the measurements were it not for the island’s location within a hurricane zone.

When the separation criteria of proximity to settlements, proximity to roads, proximity to airports and radar , and the avoidance of line of sight between television, radio and microwave transmitters/receivers were considered, Wigton was determined to be one of the few land areas where all can be satisfied (Renewable Energy Systems Ltd, 2002). Good access to site is important to facilitate construction activities and a separation distance of 50 m was applied. The planning authorities placed a 5 km radius safe guard from long range radar stations, while a line of site with transmission and microwave transmitters/receivers paths were identified and avoided (Renewable Energy Systems Ltd, 2002)

Renewable Energy Systems Ltd (2002) notes that the grid connection can be a limiting factor on the development of wind farms either due to the distance to connection points or where the grid line is incapable of accepting the new capacity. For its implementation Wigton connected a 11 km overhead link to a sub-station at Spur Tree. The location of Wigton Wind Farm sought to avoid a conflict with the location and boundary of nationally designated and environmentally sensitive areas. The only designated land use for the site was bauxite mining which did not pose a conflict (Renewable Energy Systems Ltd, 2002).

Topography and local geography can provide a challenge for site access. There are several locations in the eastern section of the island , for example Blue and John Crow Mountain ranges that have recorded good wind resources (Simmonds & Johnson, 2012) but would be significantly constrained by steep slopes, rough and complex terrain, along with the constraints imposed by their location in environmentally sensitive areas. Jackson (2009) notes the erection of turbines at Wigton on knolls to maximise exposure to the highest winds and to limit the impact of surface roughness.

Geology and soil type are important for construction activities associated with the installation of the turbines. The White Limestone group which dominates the island's geology, outcrops close to the surface and allows for road construction, foundation excavation with a modest amount of topsoil and backfilling (Renewable Energy Systems Ltd, 2002). The environmental impact assessment associated with Wigton stated that the cabling between the turbines and the sub-station would be underground but as Jackson (2009) noted this was abandoned for the overhead 69 KV lines due to unsuitable clay soils.

Table 2 .2 Criteria used for wind farm site selection in Jamaica (adapted from Loy and Coviello , 2005 and Renewable Energy Systems Ltd, 2002)

No.	Criteria generic to Jamaica	Criteria Specific to Wigton
1	Wind speed	Wind speed
2	Accessibility by trucks or other transport means for the supply of turbines	Environmental impact
3	Land ownership and sufficient land space for wind farms	Proximity (& distance from) to population centres
4	Proximity to high voltage transmission grid	Proximity to the JPS electrical distribution grid
5	The topography at the site and in the vicinity	Site area large enough to accommodate about 25 wind turbines
6	The required distance from dwellings	Access for construction of the wind farm
7	Suitability of soil conditions and foundations	Land ownership
8		Surface roughness – no major obstacles causing excessive wind turbulence
9		Soil conditions suitable for foundation construction

2.2 : Site Suitability analysis

Land use suitabilty analysis is a tool used to identify the most suitable places for locating future land uses. Suitabilty techniques enable planners and decision makers to analyse the interaction among three types of factors : location, development actions and environmental elements (Collins et al, 2001). Among others, analysts are able to map the most suitable site for a specific development proposal (Collins et al. 2001) such as the location of a wind farm or hydropower plant. Land suitability anaysis techniques may be used to solve two problems : it can identify the most suitable and alternative use for a tract of land (location) for a specific type of use (Collins et al., 2001). The focus of this study is on the latter.

Mendoza (1997) describes site suitabiity asessment as inherently a multicriteria problem that examines evaluation/decision problem involving several factors and presents this generic model

$$S = f(x_{1,} x_{2, \ldots\ldots,} x_n)) \qquad (6)$$

Where S = suitability measure ; $x_{1,}\ x_{2,\ \ldots\ldots,}\ x_n$ = are the factors affecting the suitability of the site/land. These factors include physical, environmental and socioeconomic (Baban & Parry (2001); Belay (2009) and Balance et. al.(2000).

The integration of multi- criteria methods of suitability assesments and allocation methods into GIS systems offers both the spatial capabilities of GIS and the analytical power of formal multicriteria decision making tools. This renders GIS a convenient and powerful platform for performing land suitability analysis and allocation (Mendoza, 1997).

Mendoza (1997) proposed the following generalised equation:

$$S = {}^{n}\sum c_j\ x_j \qquad (7)$$

Where x_j = are the factors affecting suitability ; c_j = are the parmetres associated with each factor. The “ parametres” or “weights’ represent the realtive importance or degree of influence of each factor to the overall measure of site suitability. The magnitude of each weight is determined from information obtained from experts, users and stakeholders who are most informed about the site and its suitability for potential land uses.

2.3: Analytical Hierarchy Process

Multi-criteria decision making involves the use of multiple factors (criteria) each contributing to some extent in arriving at a final decision. It is this “some extent” consideration that needs to be quantified so that the contribution of each factor (criterion) to the overall decision making process may be determined. This is possible via the Analytic Hierarchy Process (AHP). Saaty (2008) defines this as a theory of measurement through pair wise comparison and relies on judgment of experts to derive priority scales. The pair wise comparison scales are made using a scale of absolute judgments that represents how much more one factor exerts its influence relative to another (Saaty, 2008). Figueira et al. (2005) describes this as a mathemetical science, which we use to gather most of our information for decision making.

3.0: GIS METHODS FOR SITING WIND FARMS

3.1: Study Design

This is a quantitative study using geographic information systems application and tools, and Analytical Hierarchy Process (AHP). This chapter sets out the methods and procedures undertaken to execute this study. It also provides an overview of the fundamental concepts, theories and equations on which the operations are based.

3.2: Research Variables

The research aims to predict the location of suitable areas for wind farms in Jamaica. This is the dependent variable and will be measured against independent variables (criteria): average wind speed, land cover/ land use, surface roughness, topography, geology, distance from main roads, distance from the electricity grid, distance from settlements. This is illustrated in figure 3.1

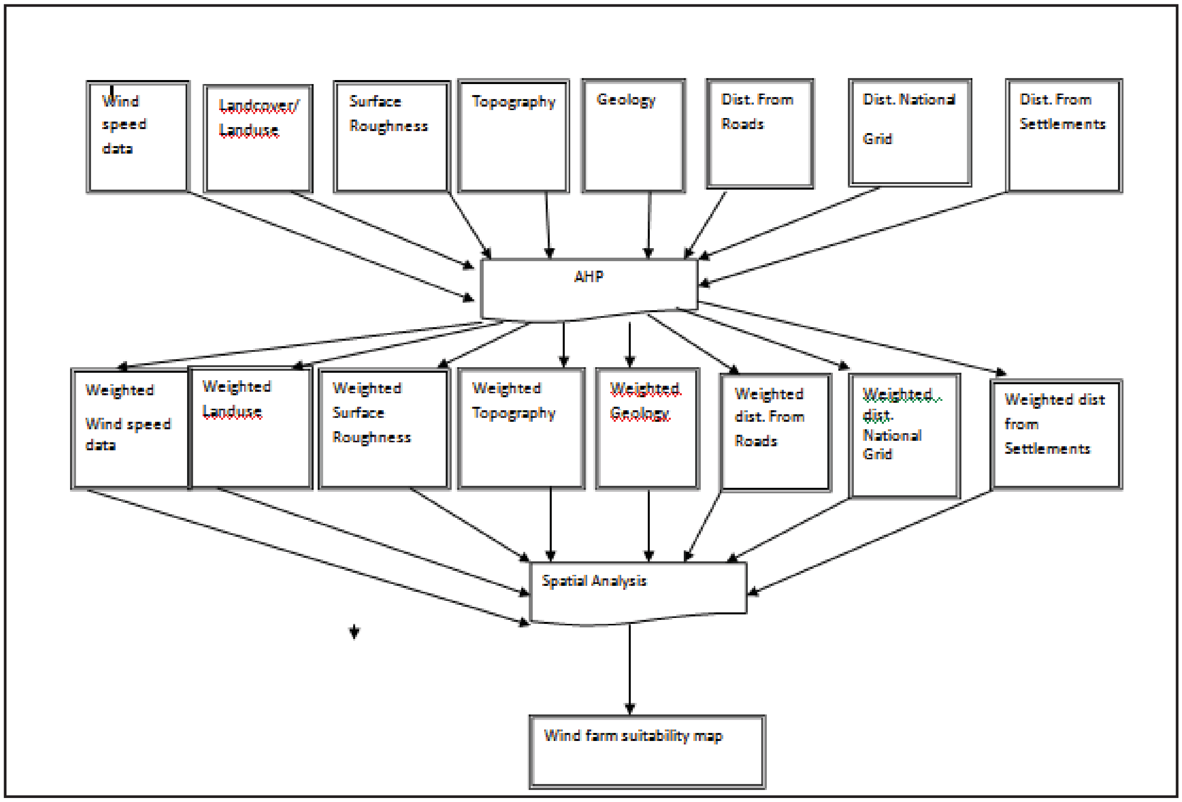

Figure 3.1. Conceptual model for wind farm site suitability assessment.

3.3: Data Collection

Five experts were drawn from the following areas: academia, land management, urban and regional planning, sustainable energy and wind farm development. Each participant was asked to select from a list of criteria/factors extracted from the literature the eight most relevant ones. The results were reconciled based on the frequency of responses and entered in a matrix. The participants were then required to exercise their expert judgment in a pair wise comparison of the criteria. On completion of this stage the responses were entered in the AHP software application from http://www.isc.senshu-u.ac.jp/~thc0456/EAHP/AHPweb.html. Only the data from experts that satisfied the criteria of CR < 0.1 were used. The derived weights were then averaged for input in to the weighted overlay tool. Other datasets were acquired from various sources and prepared as shown in Figure 3.2

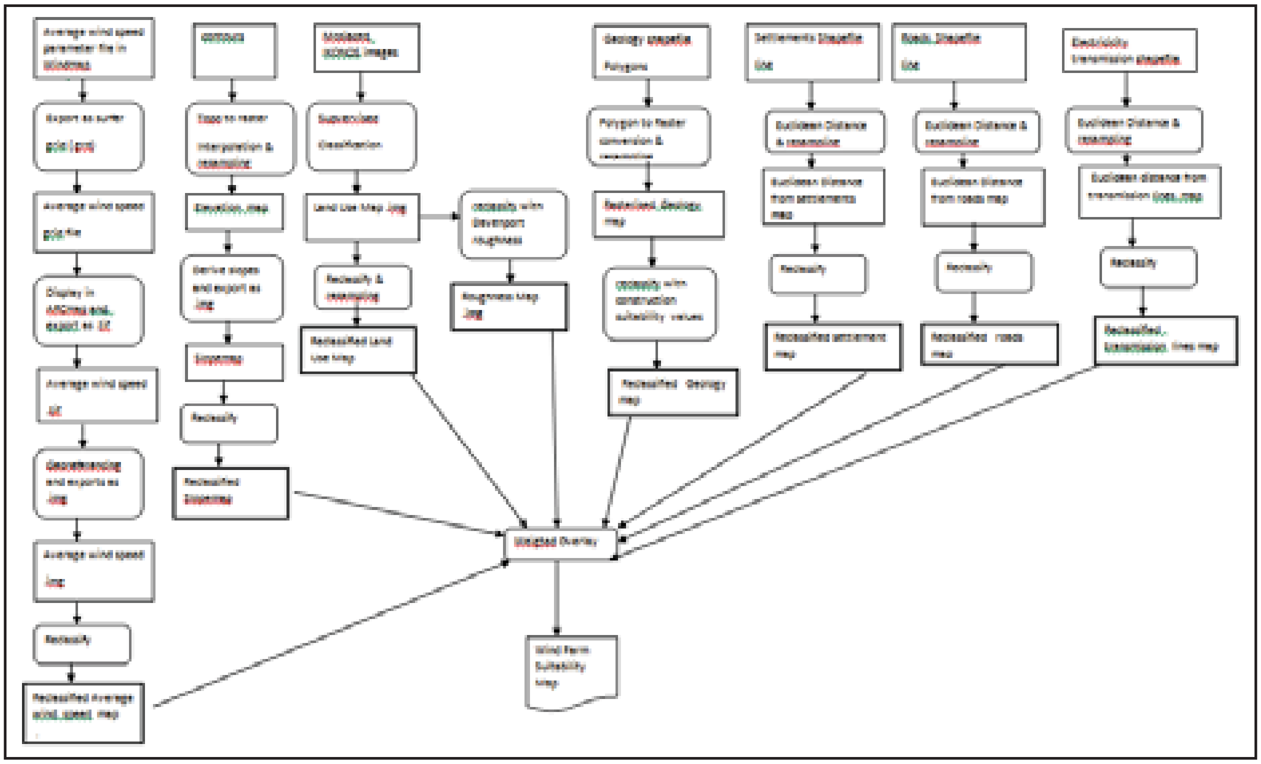

Figure 3.2. Wind farm site suitability work flow diagram

3.4: Pilot Testing and Stakeholder Consultation

This process began with the circulation of a list of site selection criteria to available expert stakeholders for selection and comments. Two face to face meetings were conducted to facilitate a discussion on the selection of the relevant criteria to be included in the AHP matrix in preparation for piloting. The pretesting of the matrix used to conduct the pair wise comparison was done by a group of faculty members and graduate students at the University of Technology, Jamaica. This allowed for the uncovering of deficiencies not apparent from a simple review (Wiersma, 2000) and allowed the researcher to gain familiarity and confidence in the use of the chosen AHP software.

Apart from meetings with individual experts that participated in the AHP the researcher availed himself of two opportunities to present the results. Friday May 4th to the management of Wigton Wind farms Ltd and Friday July 14th at a Wigton Wind Farm Ltd/ Inter-American Development Bank organised workshop. The latter was very broad based with participants from the government, industry and academia. Both proved useful in terms of garnering information useful to the project.

4.0: Results

Five specific research objectives were to be achieved to bring this research to a satisfactory conclusion as itemised in section 1.4.

4.1: Site Selection Criteria.

The literature (Loy & Coviello, 2005, Renewable Energy Systems Ltd, 2002, Baban & Parry, 2001) prescribes an exhaustive list of factors that are used in a multi-criteria evaluation of this type (Table 2.2). However, due to the unavailability of datasets, limitations in the number of parameters that can be captured by the AHP software ($2 \leq n \leq 9$ for http://www.isc.senshu-u.ac.jp/~thc0456/EAHP/AHPweb.html) and lack of consensus by the experts, it was agreed that the ones most relevant to Jamaica and hence appropriate for the study are shown in Table 4.1:

Table 4.1 Criteria weighting results from Analytical Hierarchy Process

Criteria	Weight %
Wind speed	37
Slope\terrain	13
Geology	8
Proximity to roads	14
Proximity to transmission lines	13
Land use	8
Surface roughness	5
Proximity to settlements	2

4.2: The weight associated with each factor

This objective was met by processing the pair-wise comparison values determined by each expert participating in the AHP. Five of six of the experts invited responded to the invitation to participate in the interview. They represented diverse backgrounds such as land management, urban and regional planning, engineering, sustainable energy and wind farm development. Their role was to evaluate the influence of each factor by pair-wise comparison to facilitate the implementation of the AHP process so that the percentage influence of each factor (weight) in determining the suitability of sites for wind farm are ascertained. The results of those experts' opinions which were deemed consistent and reliable are also presented in Table 4.1.

4.3: The structure and configuration of the GIS- based mode

The graphical representation used is shown in Figure 4.1 and comprises 30 variables and 17 processes. The number of variables and processes used in the model will vary based on the properties of the original datasets, conversion and transformation required to make them suitable for acceptance by the weighted overlay tool. The string of tools that precede the weighted overlay tool may also include others that would serve to further optimise the site suitability selection.

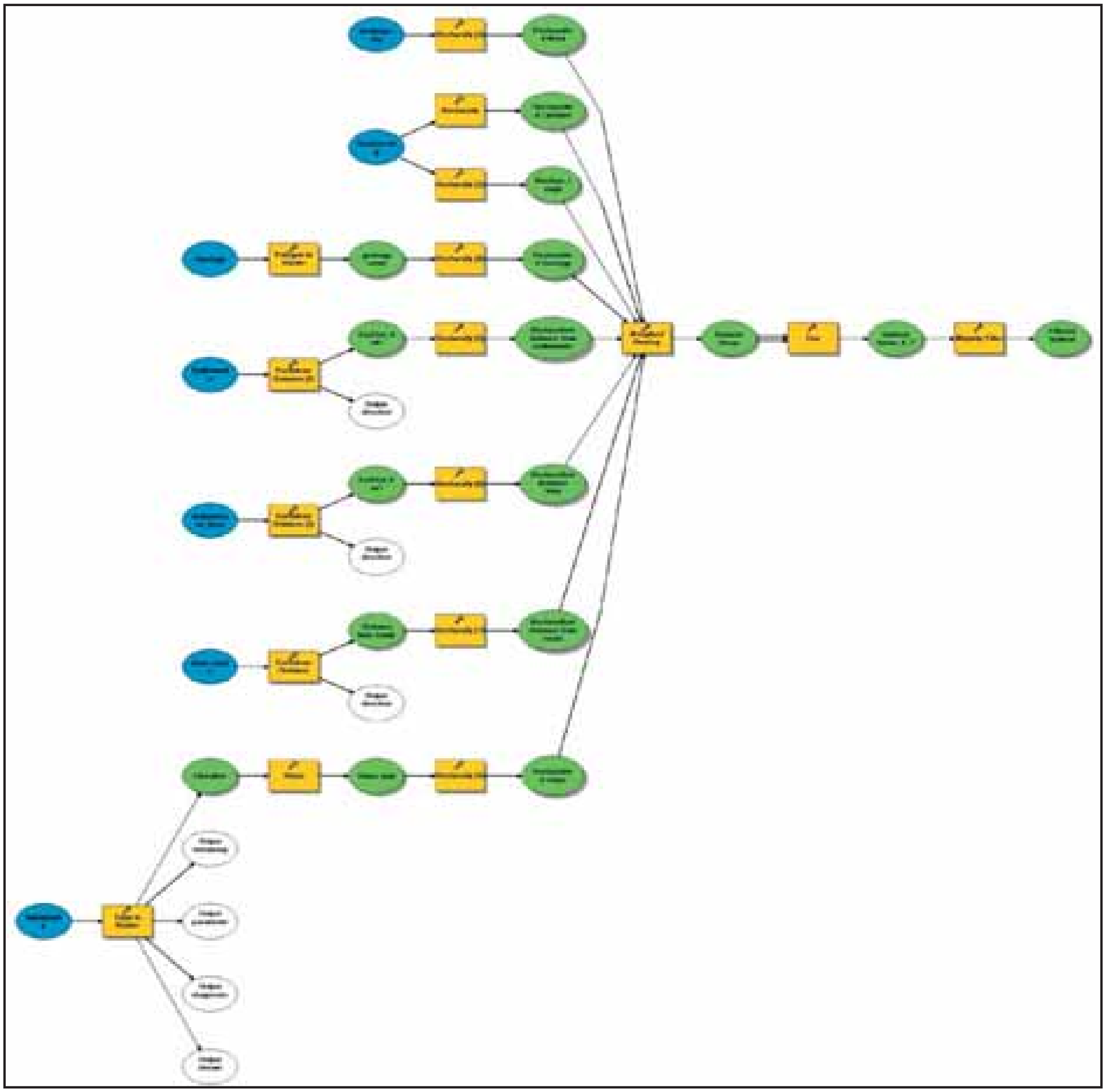

Figure 4.1. Wind farm site suitability model

4.4: ArcGIS Model Builder Output- Suitability Classification of Sites

Figure 4.2 shows the output of the ArcGIS Model Builder. The sites are categorised from least suitable with a suitability value of zero to most suitable with a value 7. Further analysis has unearthed a number of sites belonging to each suitability category (Table 4.2). Sites that are classified as of moderate to high suitability (6) and those that are the most suitable (7) are further categorised as optimal areas (Figure 4.3).

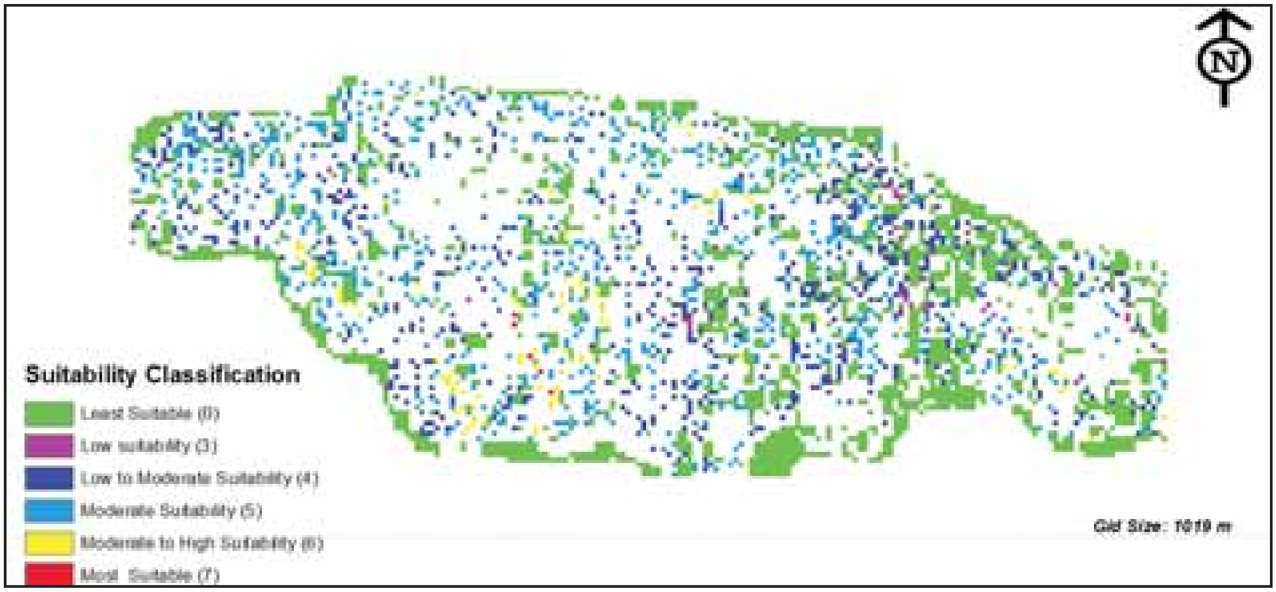

Figure 4.2. Suitability classification of sites for wind farm location

Table 4.2. Number of sites per suitability value/class.

Suitability value\class	Number of sites	Percent of total sites
0	2123	56.2
1	0	0
2	0	0
3	49	1.3
4	689	18.2
5	801	21.2
6	108	2.85
7	7	0.19

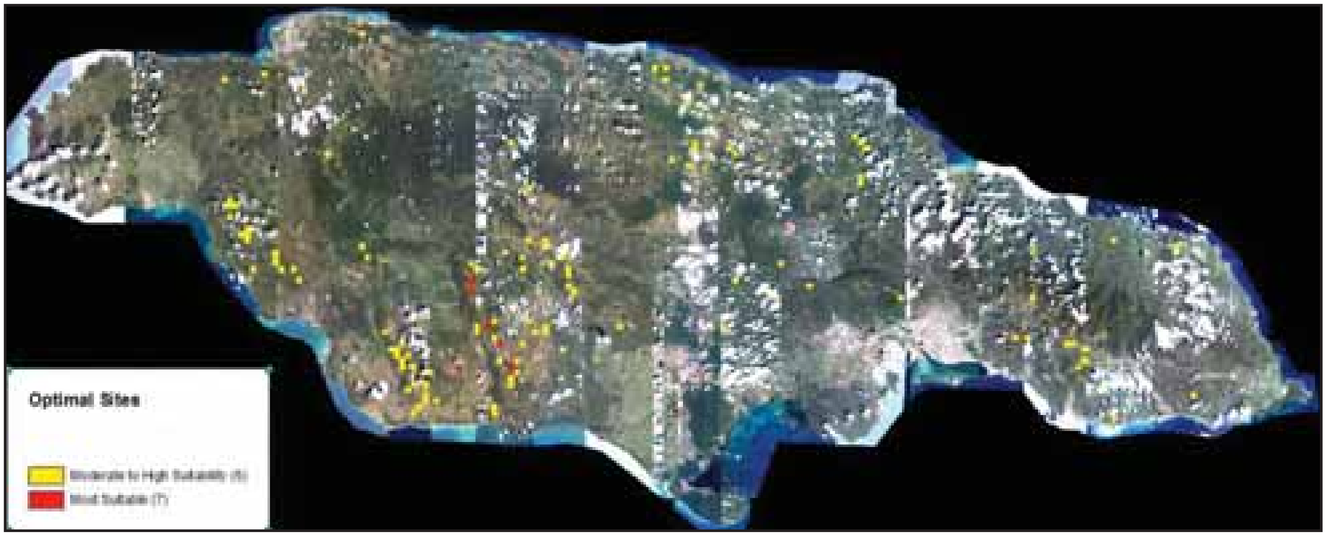

Figure 4.3. Location of optimal sites for wind farms.

Figure 4.3 shows 113 sites classified as optimal areas. Many of these sites are only of one grid cell (approximately 1 km^2) in area. Whilst these may be suitable for small operations, to satisfy the requirement of minimum size (Ministry of Mining and Energy, 2010) and to reduce the effect visual intrusion occasioned by the presence of too many sites, the larger ones are considered more appropriate. Sites of at least five square kilometres are filtered out and presented in Figure 4.4.

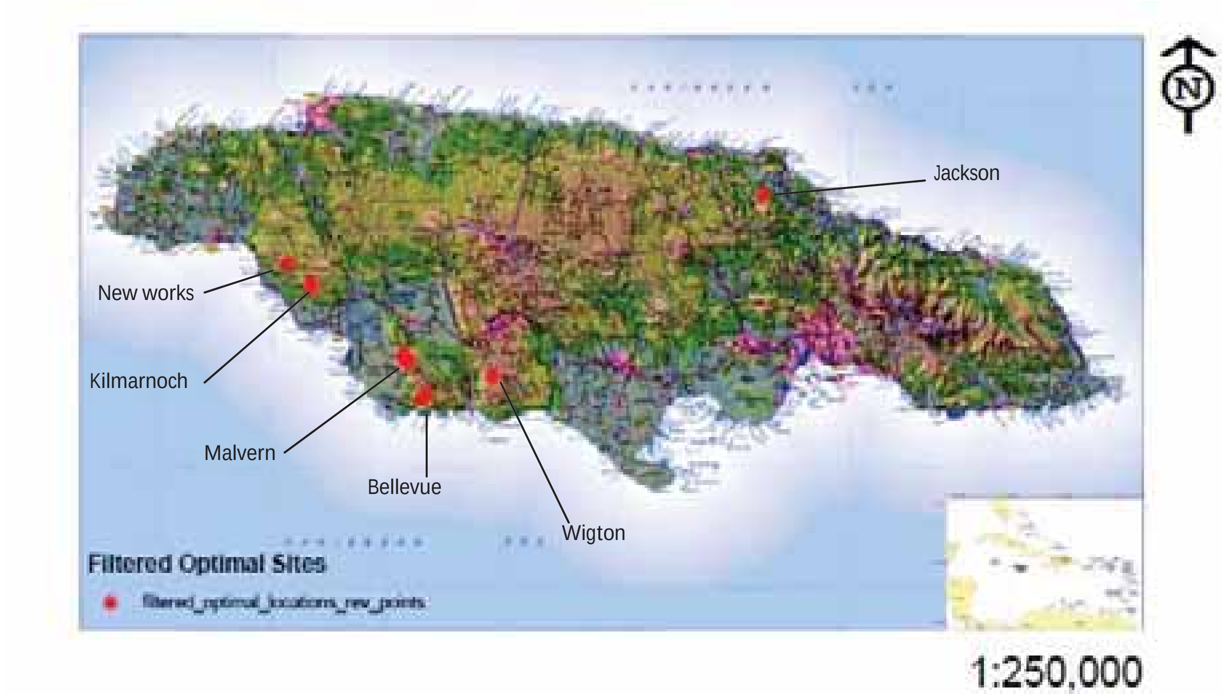

Figure 4.4 Filtered optimal areas

Figure 4.4 shows the filtered optimal sites grouped into 6 clusters based on their proximity to each other and their location in the same general area. The clusters are named after the main settlement in which they are located, namely: Kilmarnoch, Malvern, Bellevue in the parish of St. Elizabeth, New Works in Westmoreland, Jackson in St. Mary and Wigton in the parish of Manchester. These 6 clusters comprise 10 sites (Figure 4.5).

FID	Shape	POINTID	GRID_CODE	Location
0	Point	1	6	Jackson, St Mary
1	Point	2	6	New Works, Westmoreland
2	Point	3	6	Kilmarnoch, St. Elizabeth
3	Point	4	6	Kilmarnoch, St. Elizabeth
4	Point	5	6	Malvern, St. Elizabeth
5	Point	6	6	Malvern, St. Elizabeth
6	Point	7	6	Malvern, St. Elizabeth
7	Point	8	6	Wigton, Manchester
8	Point	9	6	Bellvue, St. Elizabeth
9	Point	10	6	Bellvue, St. Elizabeth

Figure 4.5 Attribute table of filtered optimal sites

Figure 4.2 shows the location of sites within suitability categories 0 to 7. The higher the suitability value the more suitable the site. Categories 6 and 7 account for 2.85% and 0.19 % of the sites respectively. These classes were filtered out and designated optimal sites. The question may be asked: why classes 6 and 7? Why not include class 5? Why not only class 7? These are all appropriate questions, but it remains a judgment call by the researcher and the experts to determine the minimum threshold value for optimum suitability. The consensus was therefore to include only those sites classified as moderate to highly suitable and most suitable.

Sites were further optimised based on size and the extent and to which single cell (pixel) locations were contiguous. The sites selected in the instant case were those that had a majority of eight cells contiguous and considering that all datasets were resampled to the coarsest resolution (1019 metres) the minimum area chosen by the filtered optimal sites is therefore approximately 5 $km^{2.}$ Other options are available in this Majority Filter tool: the choice of four neighbours, and a replacement threshold of half allows for four filtering options. These could be manipulated to match technical, financial or regulatory requirements, where size is an important consideration. Commercial operations will require large sites for example Wigton Wind Farm occupies an area of 2.76 km^2 (Jackson, 2009) but generates only 38.7MW which accounts for approximately 2% of the island's generation mix (Potopsingh, 2009). Smaller off the grid operations may however opt for smaller areas such as the Jamaica Public Service Company's site at Malvern which occupies only fourteen hectares with installed capacity of 3 MW (Environment and Engineering Managers Limited, 2009)

4.5: Sensitivity Analysis of the Model

Sensitivity analysis is a perquisite for model building (Chen et al. 2009) along with other methods of accuracy assesment. The separation criteria of proximity to electricity grid, roads and settlements were the subject of analysis. The calculate tool from the General toolset of the

Data Mangement toolbox was introduced in the model at the Euclidean Distance tool for all three parameters. The model was re-run for +10% and -10% for each parameter and produced the follwing results: The combined cell total for suitabilty classes 6 and 7 decreased by 17.6% from 108 to 89. This was also the case for proximity to settlements, however proximity to electricity grid showed a 26.85 % change.

The method of direct recognition was also used to qualitatively assess the accuracy (Aronoff, 2005) of two outputs of spatial analysis. The digital Elevation model (DEM) and the slope map were overlain by a layer of drainage features to determine conformance with topgraphic characteristics (Figure 4.6 and 4.7). No instances of drainage features flowing against slopes or in the wrong direction was observed. The quality of the two products were hence deemed to be good.

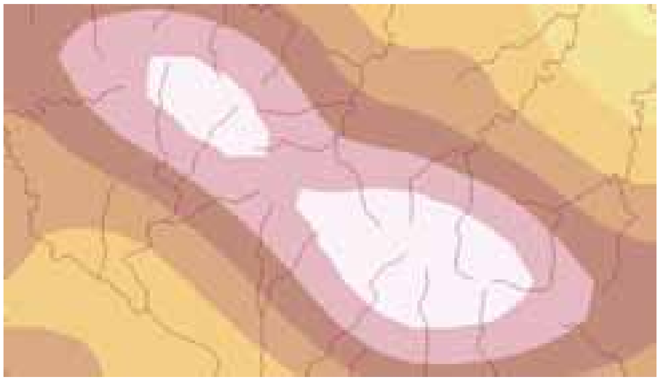

Figure 4.6. Drainage features overlaying a DEM.

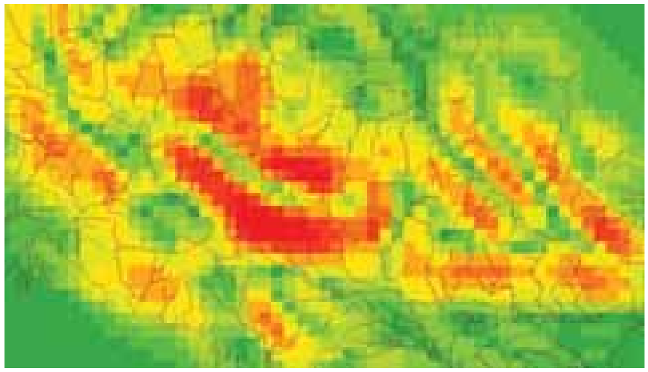

Figure 4.7. Drainage features overlaying slope map

The Petroleum Corporation of Jamaica has designated four sites as wind potential sites (Figure 4.8): Green Castle, St. Mary, Wigton and Blenheim, Manchester and Spur Tree, Manchester (Jackson, 2009, Potopsingh, 2009). Malvern in St. Elizabeth is a proven site being the location of the first wind turbine to generate electricity in Jamaica (Wright R. M., 1996). It currently has installed capacity of 3.0 MW using four (4) 7.5 kW turbines (Environment and Engineering Managers Limited, 2009). Wigton Wind Farm is the larger of the two operations with a capacity of 38.7 MW (Ministry of Mining and Energy, 2010). Figure 4.8 compares the locations of the optimal sites with those designated as potential sites including those currently with installed capacity. With the exception of Green Castle in the parish of St. Mary and New Works in Westmoreland all the other sites were approximately co-located with those sites deemed to be of potential by other methods.

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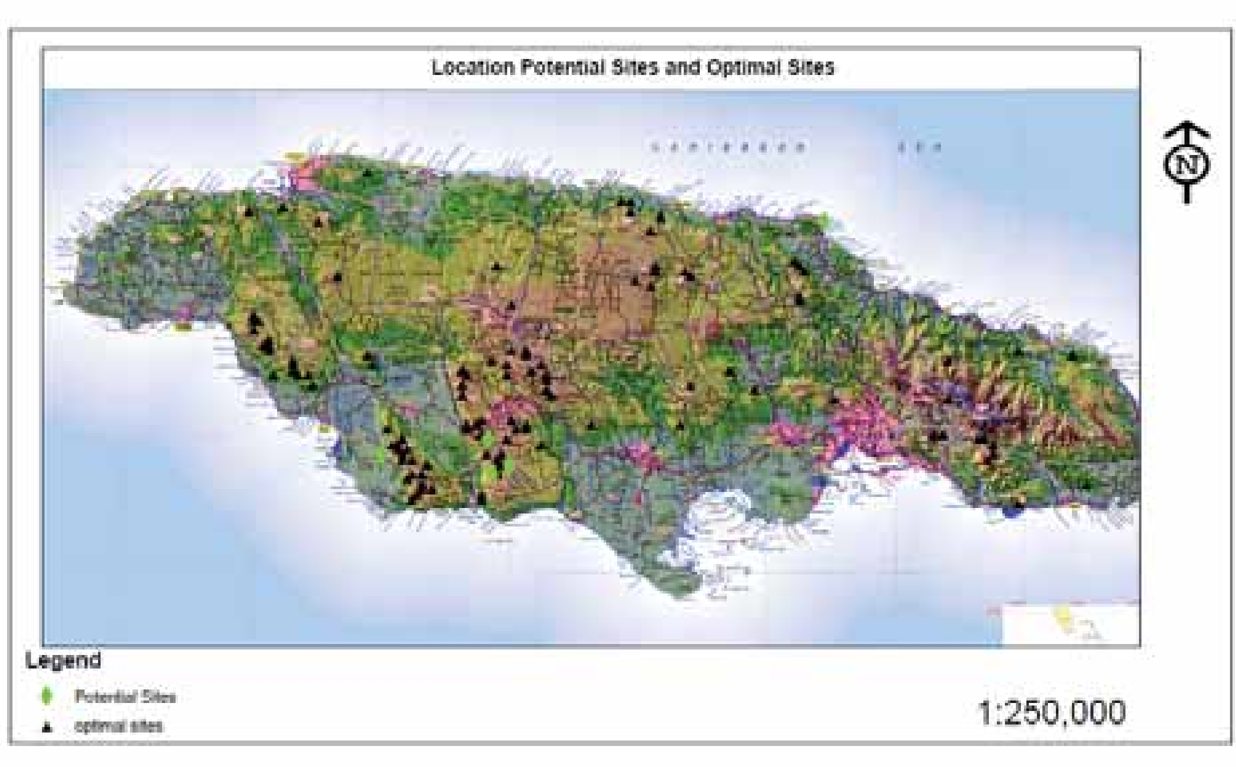

Figure 4.8. Comparing the location of optimal sites and potential sites

5.1: Conclusions

In conclusion, the study set out to determine the effectiveness of using spatial analysis tools and Model Builder in ArcGIS to determine the location of suitable sites for wind farms in Jamaica.

In summary, these were achieved as follows:

1. The key criteria/factors (Table 2.2) necessary to "fuel" the model developed (Figure 4.1) were identified with the help of the literature and the views of expert stakeholders.
2. The weighted overlay tool is one of the key components of the model and required the weights (Table 4.1) which were derived from expert stakeholders using the AHP method of Saaty (2008).
3. Development of the spatial model relied on the conceptual model (Figure 3.1), the work flow diagram (Figure 3.2), ArcGIS Model Builder template and several ArcGIS Spatial Analysis tools.
4. Categorisation of Jamaica's land area ranging from least suitable to most suitable was predicted by the model; and
5. This was in reasonable agreement with sites predicted by other methods (Jackson 2009; Potopsingh 2009). This along with a sensitivity analysis (Chen et al. 2009), and a visual inspection (Aronoff, 2005) of two model parameters served to validate the model.

While confidence can be expressed in the information and information products documents (IPD) generated by this research limitations of data quality, data accessibility and ground truthing requires caution in their interpretation and use.

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