Solar Farm Site Selection:
A Multi-Criteria Analysis of the Isle of Wight

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Contents

List of Figures

List of Tables

Abstract

Site selection for utility-scale solar farms is an issue of critical importance, partially due to the high demand for land with growing populations. The primary aim of this research is to determine the most suitable location for a solar farm on the Isle of Wight, which is imperative due to the ‘Eco-Island’ initiative, aiming to be completely energy self-sufficient by 2020. Firstly, the use of hard constraints in a Boolean based multi-criteria analysis determined 3.2% (12.26km2) of land is suitable. Soft constraints were then applied to this suitable land, weighted according to preference. The electrical generation capacity of the two ‘most suitable’ sites is compared, alongside local land features to determine the final location, and the potential contribution of this final site to achieving the Eco-Island initiative is quantified. GIS has proven to be invaluable to the site selection process due to its ability to process and display data.

Introduction

Since the industrial revolution, the increase in fossil fuel consumption has led to greater greenhouse gas emissions, namely CO_2 and CH_4 (Cáceres, 2017). This anthropogenic forcing has long been of global concern, resulting in an emphasis on reducing emissions through the development and utilisation of renewable energy sources (Sahu, 2015; Hubbert, 1949).

There are many sources of renewable energy, whereas in the UK, solar PV still has considerable growth potential as it is considered to have the greatest generation capacity (Stoker, 2017). Despite this, there is a distinct absence of literature surrounding siting a solar farm in the UK. This report uses a case study approach to address this current gap in literature via the following aim and objectives:

Project Aim:

- To determine the most suitable location for a solar farm on the Isle of Wight.

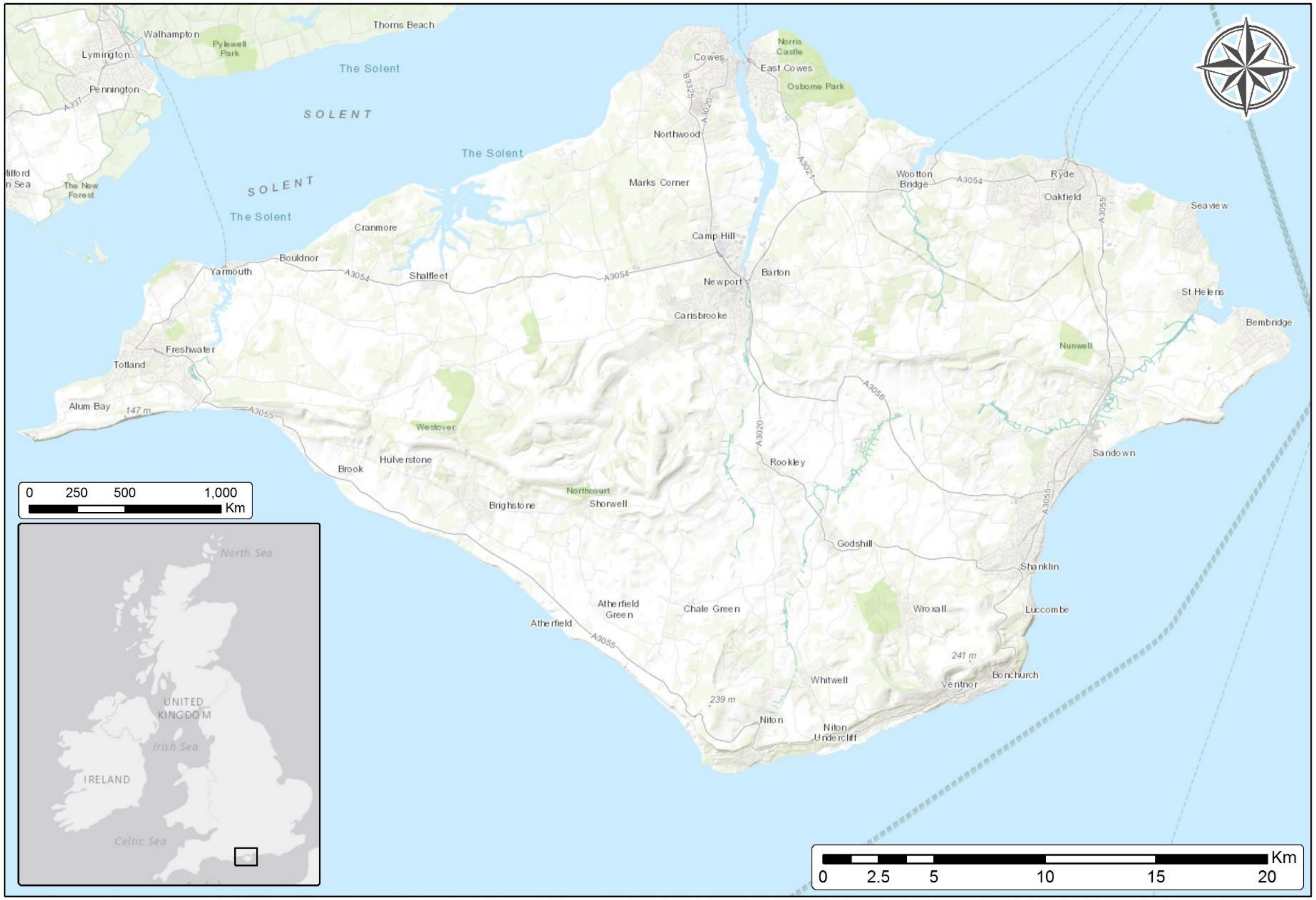
Project objectives:

- Produce suitable constraints in accordance with literature and government guidelines.
- Use appropriate data sources to undertake multi-criteria analysis.
- Assess the validity of our 'suitable area' output in relation to approved solar farm locations.
- Apply weighted overlay to determine the preferred locations.
- Estimate electricity generation potential of suitable locations.

Case Study Location

The long-term feasibility of solar technology in the UK is considered sceptical because of common public perception that inadequate amounts of solar radiation are received (BRE National Solar Centre, 2013). However, this argument is unsubstantiated, throughout an average year the UK benefits from ~60% of the solar radiation received at the equator (Hive Energy, 2015). The introduction of government incentives has led to a massive increase in the deployment of solar photovoltaic technologies in the UK, culminating with 12,561 megawatts (MW) of installed capacity across 928,870 installations as of September 2017 (Cherrington et al., 2013; Smith et al., 2014; Westacott and Candelise, 2016; BEIS, 2017).

The Isle of Wight (figure 1) is the largest island in England, with an area of 380km^2 (ONS, 2016). A 2011 BBC News report stated that each year, the island consumes 600GWh of electricity provided from the mainland. However, the 'Eco Island' initiative states the Isle of Wight has a goal of utilising their renewable energy potential to become completely energy self-sufficient by 2020. The location of the Isle of Wight is favourable for solar technologies, as Southern England receives the greatest amount of solar radiation in the UK (Burnett, Barbour and Harrison, 2014). This report therefore addresses a gap in literature with a case study of the Isle of Wight which is directly relevant to the islands 'Eco Island' initiative.



Basemap Source: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 1: Location of the Isle of Wight, Sources within map.

Literature Review

A vast amount of literature has been published in relation to solar radiation, photovoltaic (PV) technology, criteria, and methods for undertaking site selection analysis. The following chapter will provide an overview of this literature.

Solar Radiation

Dubayah and Rich (1995) suggest three principal sources of solar radiation; direct, diffuse, and reflected (figure 2). The ArcGIS Solar Analyst model calculates the total solar radiation from inputs of both direct and diffuse radiation, however in accordance with other solar transmission models, does not include reflected radiation. This is as reflected radiation is anisotropic, and subsequently fluctuates depending on sky angle and atmospheric conditions (Aguayo, 2013; Gastli and Charabi, 2010).

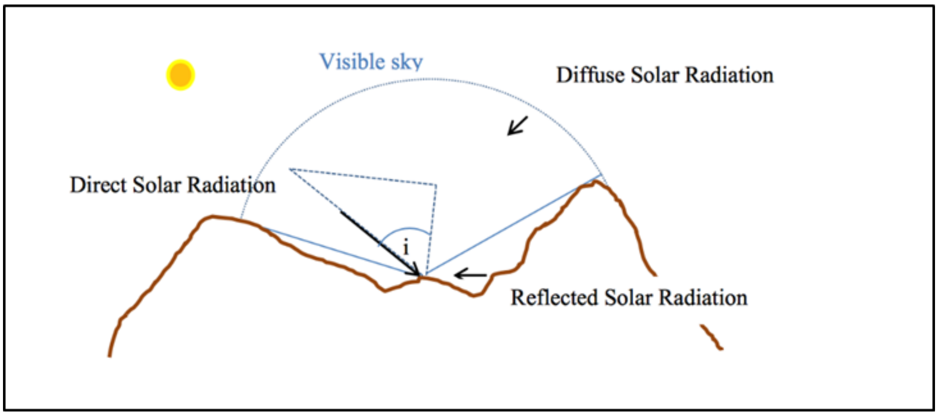


Figure 2: How different solar radiations are recieved and influenced by topography. Adapted from Dubayan and Rich (1995) by Aguayo (2013).

The ArcGIS Solar Analyst model is widely used throughout literature due to its compatibility with DEM layers. It encompasses local variant factors such as atmospheric effects, site latitude and elevation, orientation, slope and aspect, seasonal and daily variations in sun angle, and obscurities caused by shadows of surrounding topography. (Al Garni and Awasthi, 2017; Aguayo, 2013; Charabi and Gastli, 2010).

Solar Photovoltaic Technology

Solar photovoltaic technology is a renewable form of electricity generation (Wiginton, Nguyen and Pearce, 2010). The use of semi-conducting materials, such as Crystalline silicon (c-Si), ensures that an electrochemical process (‘photovoltaic effect’) takes place as the PV cell (solar panel) receives sunlight, generating an electrical current (Parliament. House of Commons, 2015; Li, 2013; Saga, 2010).

There are many variations of photovoltaic systems. For example, small scale devices can provide power for a remote device such as a calculator (Fairley, 2002). At the domestic scale, solar panels capable of generating several Kilowatts of electricity are installed on the rooftops of homes, whilst hundreds of megawatts can be generated at utility scale solar farms (Palmer et al., 2017; Parliament. House of Commons, 2015; Varma, Rahman and Vanderheide, 2015). Furthermore, smaller scale and more rural systems tend to be standalone systems, meaning they are not connected to the countries’ utility grid (Kaundinya, Balachandra and Ravindranath, 2009), whilst, for economic reasons, utility scale solar farms are typically ‘on-grid’ (Azoumah et al., 2010).

There are many positives and negatives associated with solar PV as an energy source. These are summarised below in table 1. The lack of greenhouse gas emissions produced during operation, coupled with the abundance of Silicon in the Earth's crust present distinct advantages for the technology (Tsoutsos, Frantzeskaki and Gekas, 2005; Woditsch and Koch, 2002). The economic viability of Silicon extraction facilitates a long-term future for solar PV as further utilisation and replacement of PV modules at the end of their life cycle will not overly stress the supply (Lo Piano and Mayumi, 2017). Once operational, PV cells require limited maintenance due to having no moving parts (Li, 2013). Should the demand for solar generated electricity increase, the technology is completely scalable as solar panels can be retrofitted to existing solar farms, increasing their electrical generation potential (Lewis, 2015). In addition, such expansions could be temporary as solar farms are reversible, allowing the previous land-use to be re-instated (National Assembly for Wales, 2015).

At all scales, the greatest drawback associated with the technology is the initial cost, but there is a clear decrease in the price of solar projects, with Gallagher (2017) predicting a 27% decline by 2022. Another concern, specifically for large solar farms, is the potential environmental damage caused by construction and visual pollution to local residents (Natural England, 2011). As light hits a PV cell, a potential reflection hazard (glint and glare) is a cause for concern, especially in relation to aircraft pilots and automobile drivers (Anurag et al., 2017). Despite this, a report to identify the risk of glint and glare posed to the Duxford aerodrome and the M11 Motorway from a proposed solar farm in Cambridgeshire concluded very limited impact (Pager Power, 2015).

Table 1: Advantages and disadvantages of solar PV technology.

Advantages	Disadvantages
Abundant raw material	Initial cost
Low maintanence	Construction damage
Scalability	Glint/glare
Reversible	Visual pollution
No waste / GHG emissions	

Site Selection Criteria

Locating a geographical area of land which is not only suitable, but most appropriate for a specific use is a multi-industry problem. The literature represents this with a multitude of site selection studies aiming to find optimal locations for a broad range of uses, including a landfill (Wang et al., 2009), hospital (Soltani and Marandi, 2011), and a new oyster farm (Cho et al., 2012) for example.

When locating the most suitable site for a solar farm, multiple factors are taken into consideration (table 2). Although, the relative importance of each factor is not consistent within literature, it is irrefutable that the amount of solar radiation is the most important factor to be considered when siting a solar farm (Noorollahi et al., 2016; Perpiña Castillo, Batista e Silva and Lavalle, 2016). This is because the electricity generation potential of a solar farm is determined by the amount of solar irradiation received, which is directly affected by geographical characteristics such as the slope and aspect of the land (Jerez et al., 2015). The amount of land required to site a solar farm is, and will continue to be a problem, leading Chiabrando, Fabrizio and Garnero (2009) to the conclusion that it is not a feasible technology of the future. Specifically, the issue arises when agricultural production suffers due to solar farm developments (Parliament. House of Commons, 2015). In the UK, this has led to associated government incentives such as feed in tariffs and the Renewables

Obligation scheme being vastly reduced to limit future projects (DEFRA, 2014). However, some believe the funding cuts are non-founded, with a 2014 RSPB policy briefing stating there is no evidence that solar farms have displaced agricultural production. In response to the funding cuts, AEE Renewables plc (2015) calculated that 0.5% (70,750ha) of the combined land mass of England and Wales would be required to generate 10% of total electricity consumption, inferring the required land area and associated impacts on agricultural production of solar in the UK will be negligible.

Proximity to the electrical grid is considered extremely important as with greater transmission distance, the energy loss and transmission costs increase (Li, 2013; Janke, 2010). As aforementioned, absence of official consensus exists on the exact distance, with methodologies being adapted to their respective study region. For example, in a regional study of Cyprus, Georgiou and Skarlatos (2016) deemed 2km as the maximum suitable distance to the grid, whilst up to 5km was considered appropriate in a provincial scale study in Turkey by Ayday (2016).

The literature is also divided on the importance of a transport network when siting a solar farm. The principal benefit of being close to a major road is the ease of site access for workers and vehicles during the construction phase (Li, 2013). Both Charabi and Gastli (2011) and Janke (2011) promote road importance as repairs will be required during operation. Conversely, Li (2013) considers the potential repairs to be so infrequent, it can be considered negligible. However, neither of the abovementioned studies represent the importance of roads with a high priority weighting. This may be due to ease of access, which also increases the risk of criminal damage or theft, such as is being investigated by Hampshire police, following thefts across six solar farms in the county (Lennon, 2017).

It has been demonstrated above that from an economic standpoint, it is beneficial for the proximity of a solar farm to be closer to the utility grid and major roads. However, the visual pollution local residents experience has to be considered (Watson and Hudson, 2015). In a study of Cyprus, Georgiou and Skarlatos (2016) set a minimum distance of 50m from major and minor roads to minimise visual pollution, whilst a 100m buffer was applied to roads in a study of Turkey (Uyan, 2013). In the UK, concerns of growing visual pollution were partially responsible for the discontinuation of Basic Payment Scheme (BPS) funding for land parcels containing solar panels (Rural Payments Agency, 2017). Conversely, in a renewable energy assessment of West Oxfordshire, it was stated that appropriate use of natural visual barriers, such as hedges can alleviate any visual impact of a solar farm because of the small height of the panels (LDA Design, 2016). In agreement, Kaygusuz (2009) concluded solar farms cause minimal visual pollution, especially compared to more intrusive wind farms. Moreover, solar technologies also display the favoured public acceptance due to being less visually intrusive, as documented in a study of Greece by Tampakis et al. (2009).

Table 2: Summary of constraints.

Reference	Study Location	Constraints Considered
Janke (2010)	Colarado, USA	Solar radiation Transmission line proximity Urban areas Population density Road proximity Landcover Federal lands
Uyan (2013)	Turkey	Urban areas Land use Road Proximity Slope Transmission line proximity
Watson & Hudson (2015)	UK	Agricultural land class Historical areas Landscape designations Urban areas Wildlife designations Aspect Slope
Noorollahi et al. (2016)	Iran	Solar radiation Average temperature Transmission line proximity Road proximity Urban areas Elevation Slope Land use Cloudy days Relative humidity Dusty days
Georgiou & Skarlatos (2016)	Cyrprus	Elevation Slope Viewshed Land value Road proximity Transmission line proximity Solar radiation

Site Selection Methods

To aid the site-selection decision-making process, Multi Criteria Decision Analysis (MCDA) methods are used widely across literature (Watson and Hudson 2015; Wang et al., 2009). It encompasses both multi-attribute (MADA) and multi-objective (MODA) decision analysis. MADA assumes a predetermined and restricted quantity of alternatives, whereas, MODA is continuous with regards to it measuring the most desired outcome within multiple feasible outcomes. (Malczewski, 2006).

Furthermore, the incorporation of GIS with MCDA has become increasingly utilised because much of the information concerned with site selection is spatially dependent and GIS offers the facility to manage and display this data (Noorallahi et al., 2016; Li, 2013). Due to their mutually beneficial relationship, Watson and Hudson (2015) state the use of GIS-MCDA for solar farm siting allows electrical generation to be maximised, whilst keeping potential negative effects to a minimum. In doing so, Algarni and Awasthi (2017) state that GIS-MCDA enables a more reliable site selection decision to be made.

There are many different methods of undertaking MCDA which include, but are not limited to, Weighted Sum (Aras, Erdoğmuş and Koç, 2004; Renn, 2003), Elimination and Choice Translating Reality (ELECTRE) (Sánchez-Lozano et al., 2014; Roulet et al., 2002), Preference Ranking Organisation Method for Enrichment Evaluation (PROMTHEE) (Haralambopoulos and Polatidis, 2003), Grey Relation Method (Wang et al., 2008) and by far the most widely used in literature, the Analytic Hierarchy Approach (AHP) (Doljak and Stanojević, 2017; Watson and Hudson, 2015; Chatzimouratidis and Pilavachi, 2007; Mohsen and Akash, 1997. Although less common, some studies use a combination of the previously stated methods. Such as the use of ELECTRE to validate the results of the AHP and TOPSIS method, as seen in Sánchez-Lozano, García-Cascales and Lamata (2015).

This chapter provided an overview of literature surrounding the topic of solar farm site selection. The factors and methods that are considered within literature are discussed, along with the lack of consensus on their relative importance and appropriateness. It is concluded the lack of uniformity is due to the broad range of study region within the literature and the differing geography, politics and demographics as a result.

Methodology

The following chapter will outline the methodology used in this site selection study. Firstly, data pre-processing will be outlined, then the GIS analysis, and finally, solar radiation in the context of calculating the electrical output of a site.

Data pre-processing

A Digital Elevation Model (DEM) was the first data set required. Firstly, multiple tiles of 2m resolution LIDAR were downloaded and combined using the 'mosaic to new raster' tool to produce a seamless raster. However, it soon became apparent that the LIDAR data set was incomplete, with many NoData voids present. To combat this, several void-filling methods were considered, such as the focal statistics tool available in the Spatial Analyst extension of ArcGIS, but this was deemed inappropriate due to the size of one particular void.

As an alternative, a complete, 30m resolution SRTM dataset was downloaded for the Isle of Wight and the following conditional syntax was used in the Raster Calculator:

$$Con(IsNull(LIDAR\_DEM), SRTM\_DEM, LIDAR\_DEM)$$

Equation 1: Raster calculator syntax.

This syntax only replaces NoData in the LIDAR DEM with the equivalent pixel values from the SRTM dataset, leaving the present data unaffected, maintaining a greater resolution across most of the dataset. This process is outlines below in figure *3*.

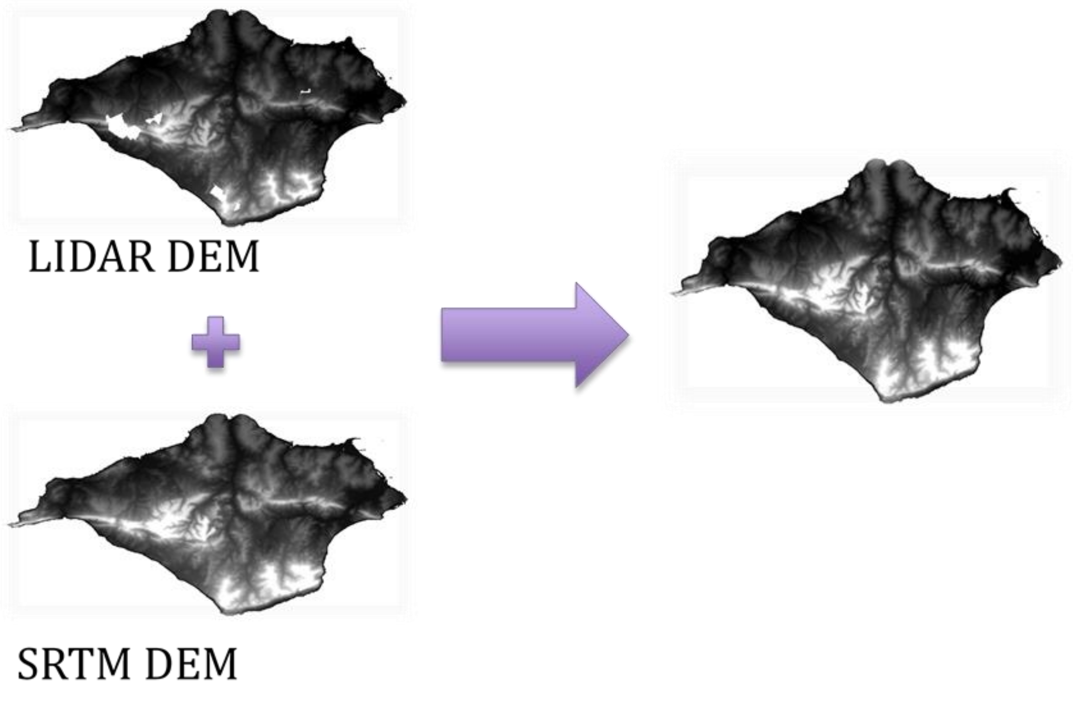


Figure 3: Outlining DEM preparation. Sources: Edina Digimaps (2017), United States Geological Survey (2010).

GIS Analysis

The ESRI ArcGIS suite was used to spatially analyse all the necessary datasets associated with siting a solar farm on the Isle of Wight. Below, table 3 summaries the data.

Table 3: Summary of data sets used in the analysis.

Data Set	Organisation	Description	File Type
LIDAR DEM	Edina Digimaps	2m resolution Digital Elevation Model	Raster
Land Cover Map (2015)		Land cover map of the U.K.	Vector
SRTM 30m	United States Geological Survey	30m resolution Digital Elevation Model	Raster
SSSI's	Natural England	Sites of Special Scientifc Interest	Vector
Agricultural Land Classification		Agricultural Value of Land	Vector
Ancient Woodland		Areas of Ancient Woodland	Vector
AONB's		Areas of Outstanding Natural Beauty	Vector
OS Open Roads	Ordnance survey	British Road Network	Vector
OS Open Rivers		British river network	Vector
Solar Farms	Renewable Energy Planning Database	Operational Solar Farms on Isle of Wight	CSV

Both aspect and slope were derived from the DEM using the relevant surface analysis tools. The analysis is split into two sections, MADA for hard constraints via the Boolean method, which is a selection process as opposed to a design process, considering only hard constraints. Secondly, MODA has been used for soft constraints via the weighted overlay toolset.

Hard constraints are criteria of which the solar farm site must comply to. Initially all chosen layers had to be converted from their original data type to a raster dataset, whereby the dataset was coded using a Boolean approach to 1 – where the layer area does meet the criteria, or 0 - where the layer area does not meet the criteria. This was mainly done using the polygon to raster tool, and then subsequently reclassified accordingly. Following this process, all outputs were then multiplied together within the raster calculator tool to give the resulting pixels on the Isle of Wight which fall within the hard constraints. The method above is summarised below in figure 4 using an ArcMap model.

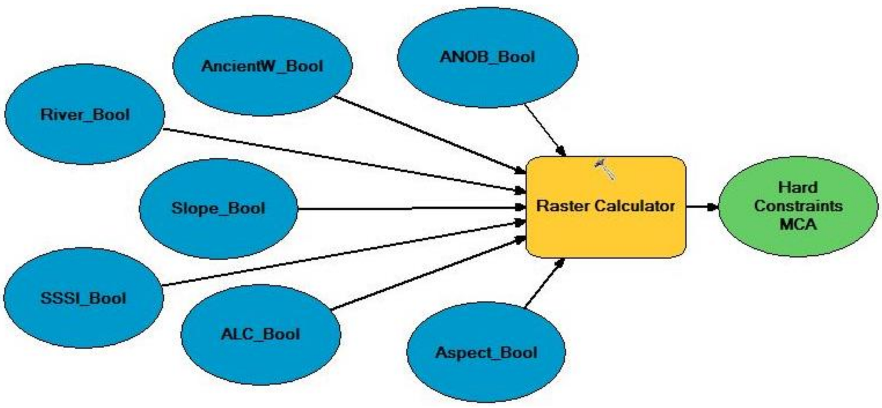


Figure 4: Model Builder output for the raster calculator process.

Once ‘suitable’ land had been determined, soft constraints were considered (table 4*)*.These Soft constraints are a range of criteria based on preference for each selected layer. Initially Euclidean distance buffers were derived from both the road and the urban area layers, alongside slopes within 5%, agricultural land class and aspect, the layers were converted from feature class to raster, and reclassified. From the reclassification the preferences per layer were applied and each layer is further weighted as seen below in table 4. Where importance for placement is as follows: distance to roads, agricultural land class, topographic slope and an equal lowest weighting for distance to urban areas and topographic aspect.

Table 4: Summary of weighting applied to soft constraints.

Layer	Weighting	Range	Preference
Roads	45%	0 - 50	Restricted
		50 - 300	1st
		300 - 800	2nd
		800 - 1500	3rd
		1500 - 2280	4th
Urban areas	10%	0 - 50	Restricted
		50 - 300	1st
		300 - 800	2nd
		800 - 1500	3rd
		1500 - 2060	4th
Agricultural Land Classification	30%	Urban	Restricted
		Non agricultural	Restricted
		Grade 2	Restricted
		Grade 3	3rd
		Grade 4	2nd
		Grade 5	1st
Slope	15%	0% - 1%	1st
		1% - 2%	2nd
		2% - 3%	3rd
		3% - 4%	4th
		4% - 5%	5th
		> 5%	Restricted
Aspect	10%	Flat	2nd
		North	Restricted
		Northeast	Restricted
		East	Restricted
		Southeast	2nd
		South	1st
		Southwest	2nd
		West	Restricted
		Northwest	Restricted
		North	Restricted

Solar radiation

ESRI's ArcGIS Solar Analyst extension was used in combination with the Isle of Wight DEM to produce a raster layer representing an estimation of (ASI) annual solar irradiation received within the Isle of Wight in 2016. After extracting individual pixel values for estimated annual solar irradiation (MW/m2 /year), the sum of ASI for the two most favourable site locations was obtained. This stipulated the total amount of sun radiation each potential PV solar farm would have received in 2016 (Table 5).

Table 5: Classification of parameters used in generating energy output. Adapted from Charabi and Gastli (2010).

Parameter	Definition	Units
GP	The electric power generation potential per year	GWh
SR	The solar radiation received per unit horizontal area	GWh/km^2/ year (to calculate annual electricity production)
CA	The calculated total area	Km^2
AF	The area factor, indicates what fraction of the calculated areas are solar exploitable	Unitless
N	The efficiency with which solar system converts sunlight into electricity	Unitless

The sum of each potential farm's ASI was used to calculate the electric power generation per year (GP). Many different methods were considered when calculating the potential energy output for the two most suitable sites available (Aguayo, 2013; Dubey, Sarvaiya and Seshadri, 2013; Skoplaki and Palyvos, 2009). However, the methodology implemented in Charabi and Gastli (2011) was deemed most applicable to this project. This was carried out by applying the parameters in table 4 to the equation below:

$$GP = SR \ x \ CA \ x \ AF \ x \ n$$

Equation 2: Formula as provided by Charabi and Gastli (2011).

Results

The following section will outline the results from the analysis undertaken using the methodology stated in the previous chapter.

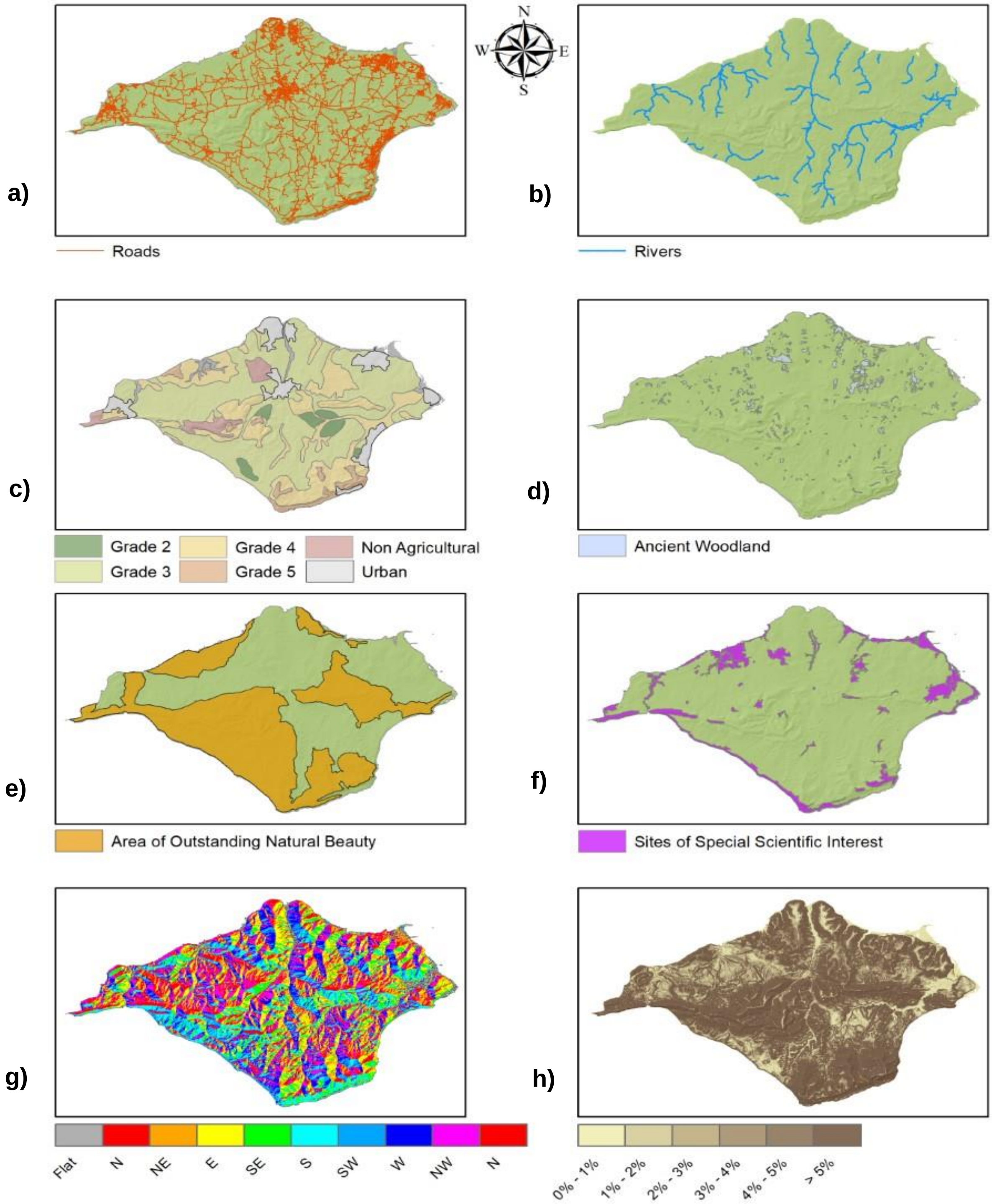


Figure 5: All initial data sets used to begin creation of hard constrain layer and soft constraint layer.
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Figure 5 displays the initial data sets used in the analysis and their spatial extent on the Isle of Wight study region. A comprehensive road network can be seen across the island with obvious clustering as can be seen in 5a, along with the river network in 5b. The agricultural land values are displayed in 5c, ranging from grade 2 (high agricultural value) to grade 5 (low agricultural value). Environmentally important areas are shown in figures 5d, 5e and 5f which present the spatial extent of ancient woodland, areas of outstanding natural beauty and sites of special scientific interest respectively. Furthermore, 5g and 5h are derived from the void-filled LIDAR DEM, displaying the aspect (orientation) and slope <=5%.

Multi-criteria analysis

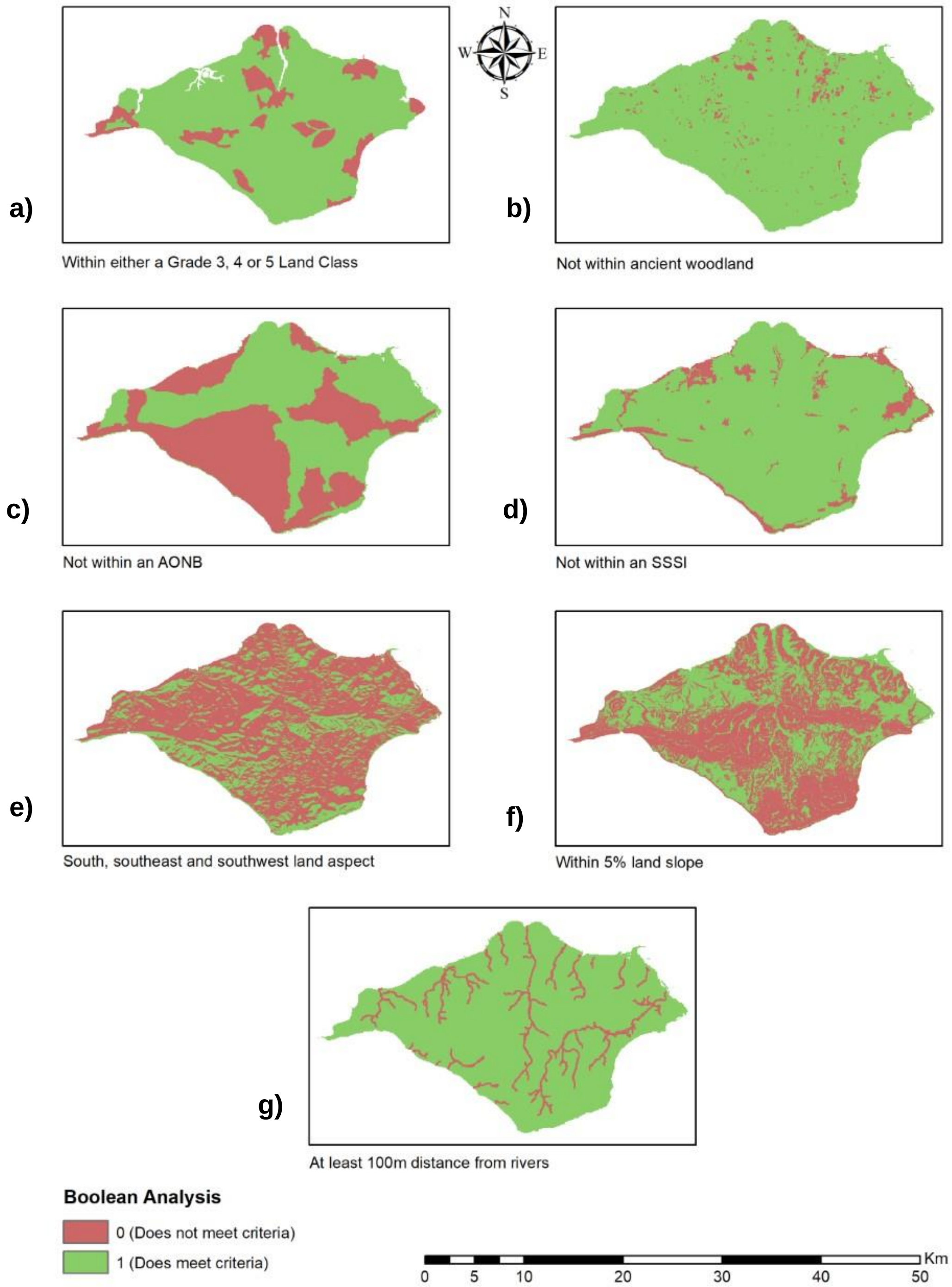

Figure 6: Boolean analysis of hard constraints.
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Figure 6 displays the results of carrying out a Boolean based multi-criteria analysis. The area in green represents meeting the criteria for that specific layer in question, and any area in red does not meet the criteria, and thus is automatically not a possible site for a solar farm. For example, figure 6a displays the agricultural land classes 3, 4 and 5 as green and therefore represents meeting the analysis criteria. Moreover, 6c presents the area of land not listed as an AONB, but as can be seen above, a substantial area of land is protected. Once individually determined, these layers were combined to produce figure 7, which can be seen below.

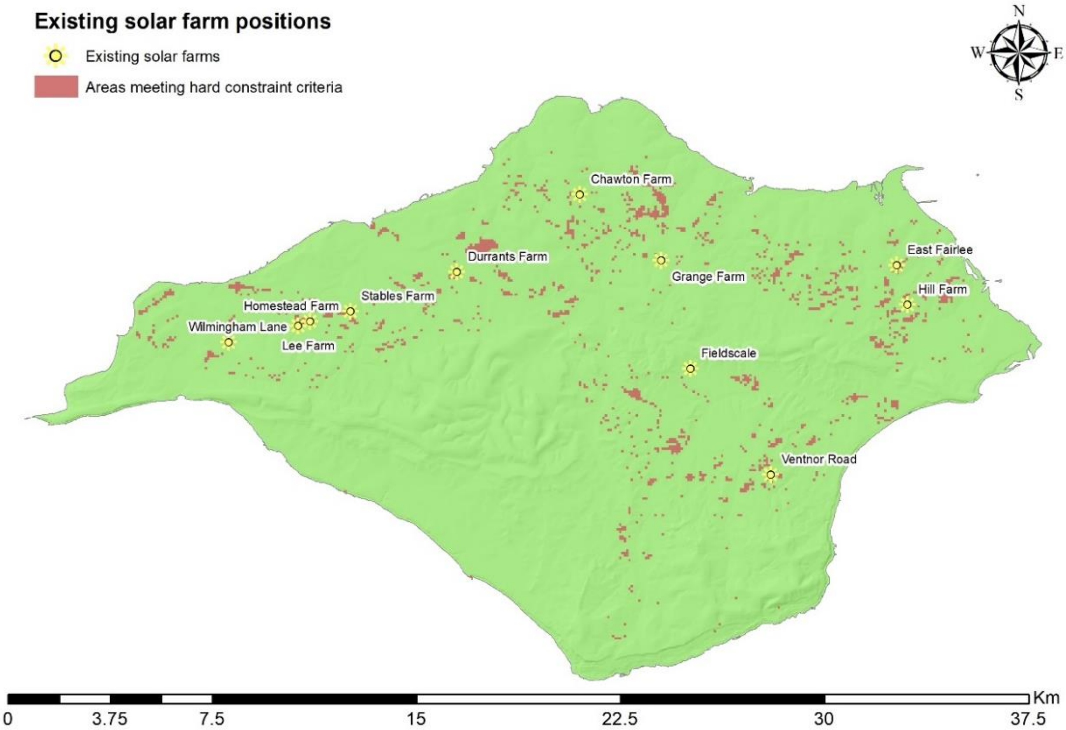

Figure 7: Distribution of solar farms in comparison to the hard criteria areas. Contains REPD data.

As Above, figure 7 is the output result of the Boolean multi-criteria analysis and depicts the area of land our analysis deemed suitable for siting a solar farm in red. This suitable land amounts to 12.26Km^2, 3.2% of the islands surface area. As a test of our model, the centroid coordinates of the operational solar farms on the island were downloaded from the Renewable Energy Planning Database (REPD) and overlaid on top of our suitable area. As can be seen, 1/11 solar farms are within the 'suitable area', whilst 10/11 solar farms are negligibly close to the suitable/not suitable boundary. The greatest distance a centroid point is away from the boundary is 402m (table 6). However, this test figure demonstrates the relative credibility behind the analysis.

Table 6: Solar farm distances to hard constraint area, where distance is 0 the farm lies within the area.

Site Name	Installed Capacity MW	Distance to criteria
Durrants Farm	4.5	163
Lee Farm	5	63
Stables Farm	1.5	41
Wilmingham Lane	7.01	402
Chawton Farm	3.2	305
Ventnor Road	4.8	58
Hill Farm	10.2	235
East Fairlee	7.25	65
Grange Farm	6	231
Homestead Farm	10.7	0
Fieldscale	10.62	82

Weighted overlay

Figure 8 below represents the weighted overlay ‘soft constraints’ which include flat, Southeast, South and Southwest of the aspect classes, Slopes between 0% and 5%, Euclidean distances from between 0m and 2,060m from roads, Euclidean distances from between 0m and 2,280m from urban areas and agricultural land classes from grade 3 to 5.

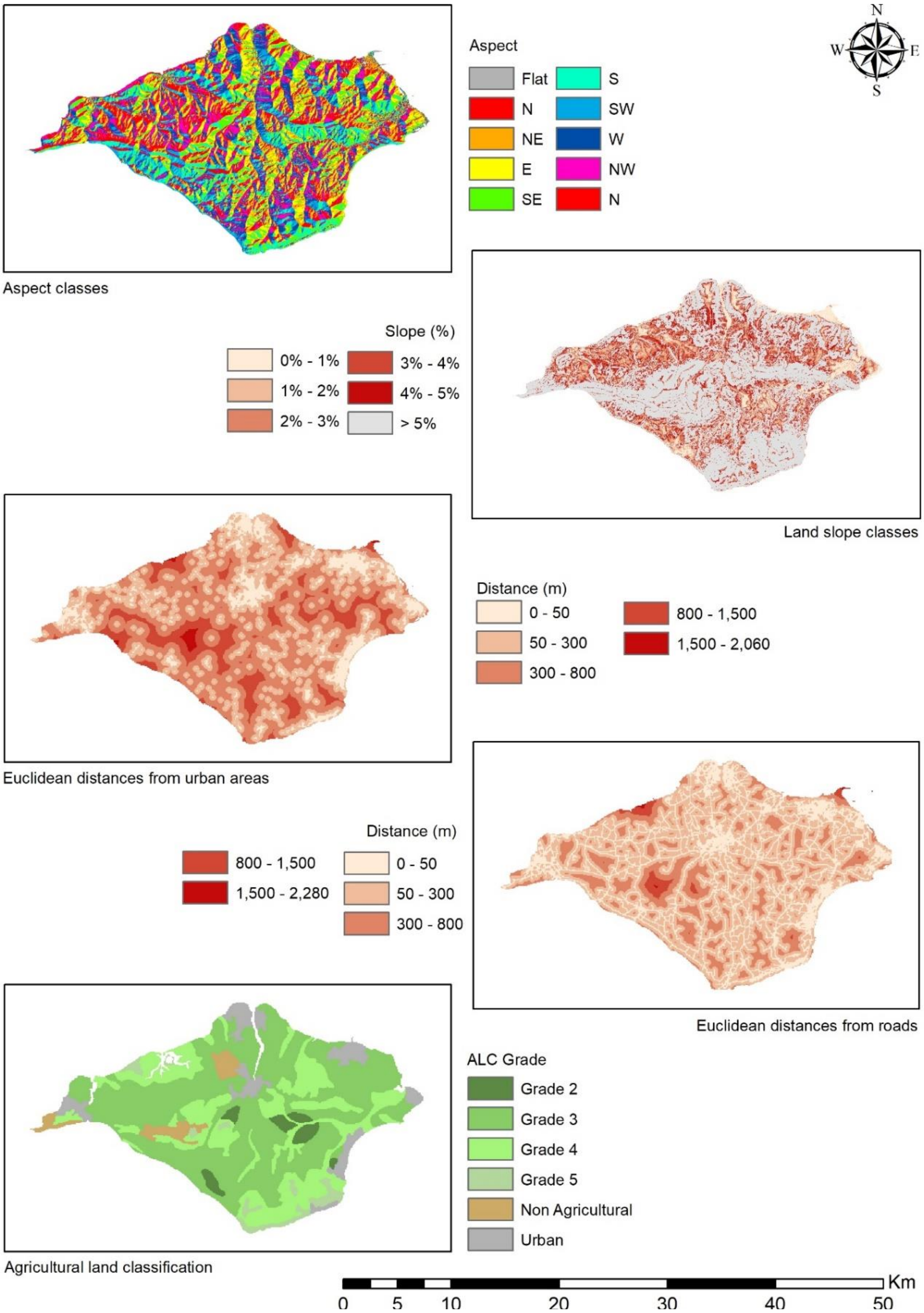

Figure 8: Weighted overlay input layers, for soft constraint analysis.

The result of the outputs of the weighted overlay and the Boolean multi criteria analysis can be seen below figure 9, where only polygons with an area larger than the existing solar farms on the Isle of Wight are being considered. This boundary size has been determined as 0.13km^2, in order to result in possible solar farm sites bigger than those currently in operation. The two polygons shown in figure 9 are the result of this filtering. Site one is situated North West of Newport while the second site is positioned to the South East of the town.

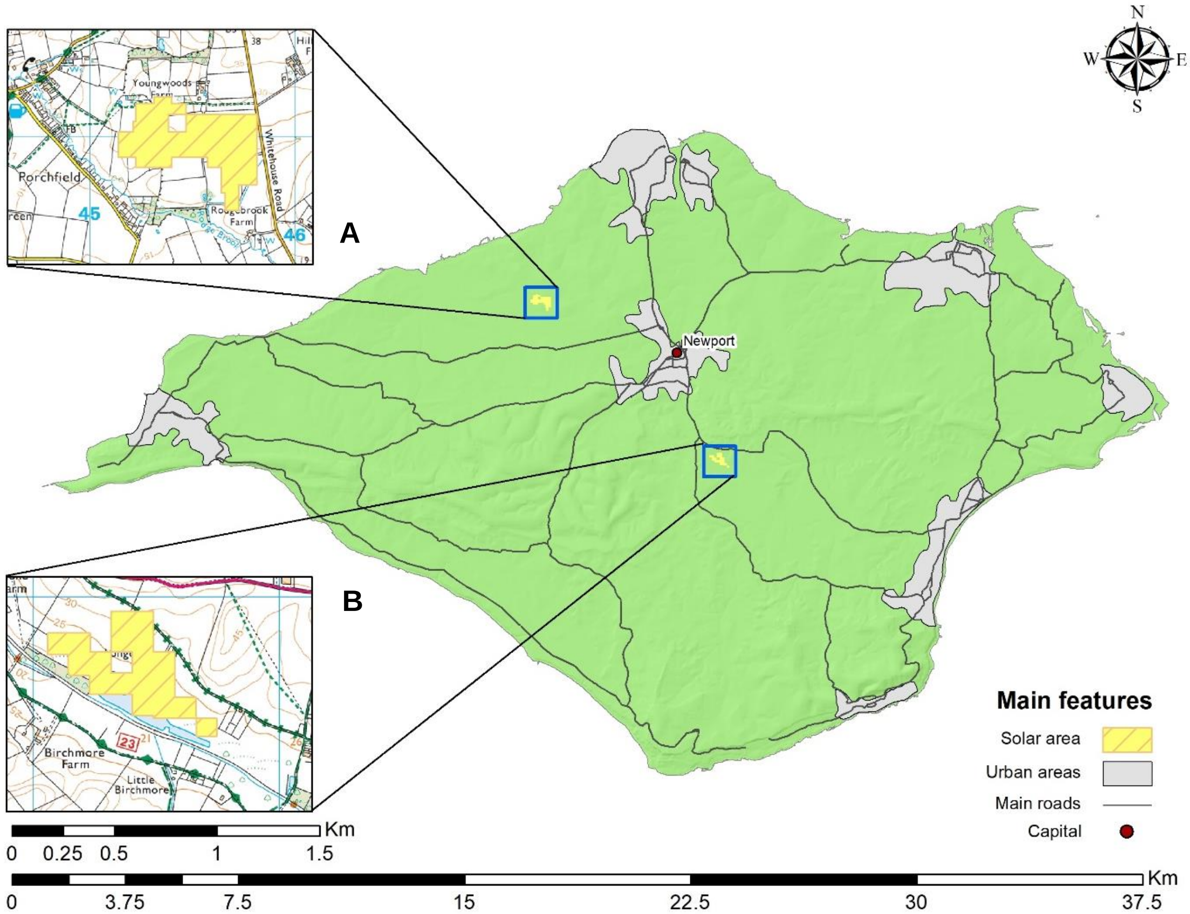

Figure 9: Final two site options, after both hard and soft constraint analysis.
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There are two main differences between site A and site B, including size and resulting solar energy potential, and the local land features of each site. Due the larger size of site A, given in table 7 below, the solar energy potential is greater than that of site B. Also, while both sites are outside the 100m river buffer considered in figure 6g, site B is positioned on a flood plane to an adjacent water body, illustrated in the OS basemap featured in figure 9.

Table 7 displays the data from Table 5 configured in Equation 2, and the resultant calculated energy output. The results show that the potential Site A would have produced the greater GP over the year of 2016 of 42729.5MWh/km^2/year, in comparison to Site B which would have produced 22430.6MWh/km^2/year.

Table 7: Input and results of calculated energy output.

	Parameters				**Energy output**	
Site	SR (GWh/km^2/year)	CA (km^2)	AF	n	GP (GWh/km^2/year)	GP(MWh/km^2/year)
A	2720.24105	0.187	70%	12%	42.72954641	42729.54641
B	2007.75141	0.133	70%	12%	22.4305988	22430.5988

Furthermore, comparable energy data has been calculated using the ratio 10,000sq ft:1MW proposed capacity (Solar mango, 2017), yielding proposed capacity results of 20.1MW for site A and 14.3MW for site B. When considered these main differences between the sites, it has been decided that site A will be most appropriate for the solar farm development.

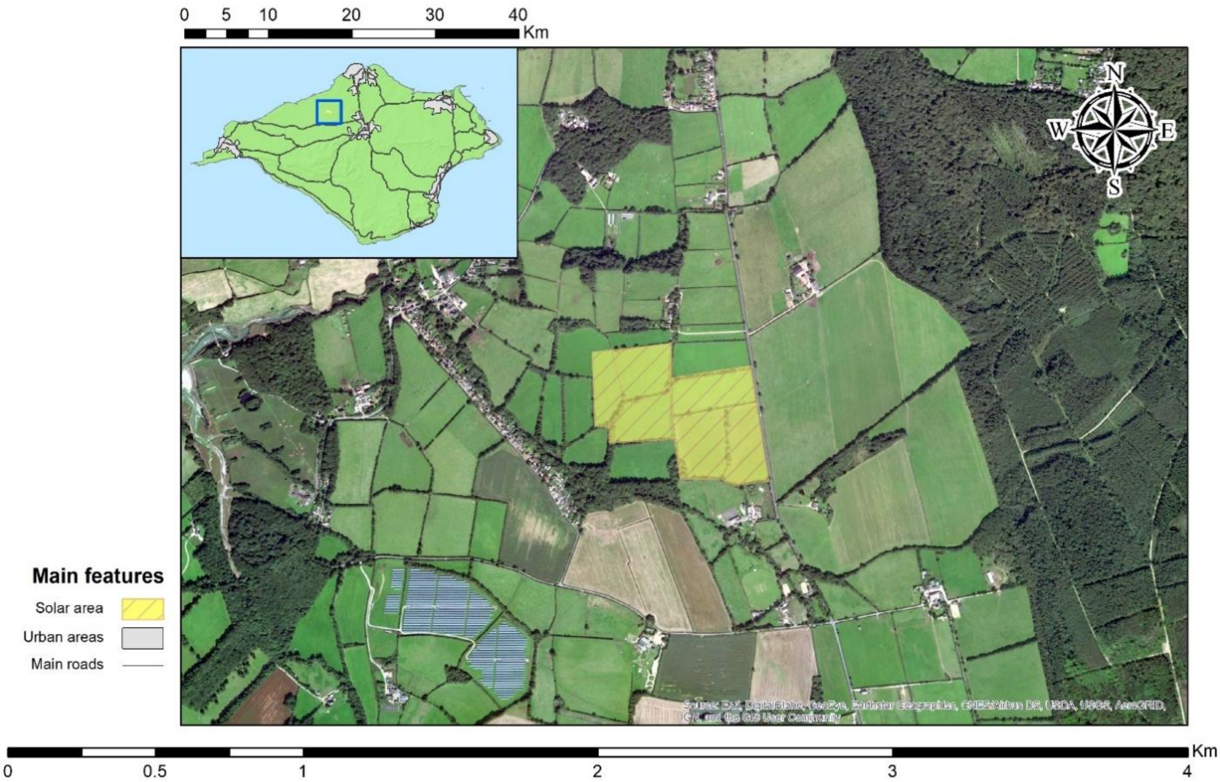

Figure 10: Final solar farm site map, using an expected area of use polygon.

The final site is represented above in figure 10, showing the expected area of use, with regards to field boundaries in the vicinity. The area and energy output information has been contained above in table 7.

Discussion

The aim of this research was to locate the most suitable location for a solar farm on the Isle of Wight. The first section of this chapter will address the use of solar radiation as a constraint in this analysis, followed by a validation of the obtained results. The appropriateness of siting a solar farm will then be addressed. Lastly, the potential contribution towards achieving the Eco-Island initiative will be quantified.

Solar Radiation as a Constraint

There is an overwhelming body of literature stating solar radiation is the most important factor to be considered in solar farm site selection (Noorollahi et al., 2016; Perpiña Castillo, Batista e Silva and Lavalle, 2016). However, solar radiation is not the principal factor taken into consideration in this study. This is because the use of ESRI's solar analyst calculated the radiation to be adequate across the whole island, with negligible variation, which is supported by the spatial distribution of operational solar farms on the island. This reduced variation over the relatively small study region displayed the inappropriateness of the solar radiation factor at this level (assuming enough is received for electricity generation). It was determined that solar radiation is much more appropriate in larger scale studies, due to the variation that would occur over large distances. Example study regions include Europe (Perpiña Castillo, Batista e Silva and Lavalle, 2016), Colarado, USA (Janke, 2010) and Iran (Noorollahi et al., 2016), which all apply solar radiation as the principal constraint. On the contrary, studies of smaller geographical regions including Konya, Turkey (Uyan, 2013) and Southern England (Watson and Hudson, 2015) did not consider solar radiation variation in their site selection studies.

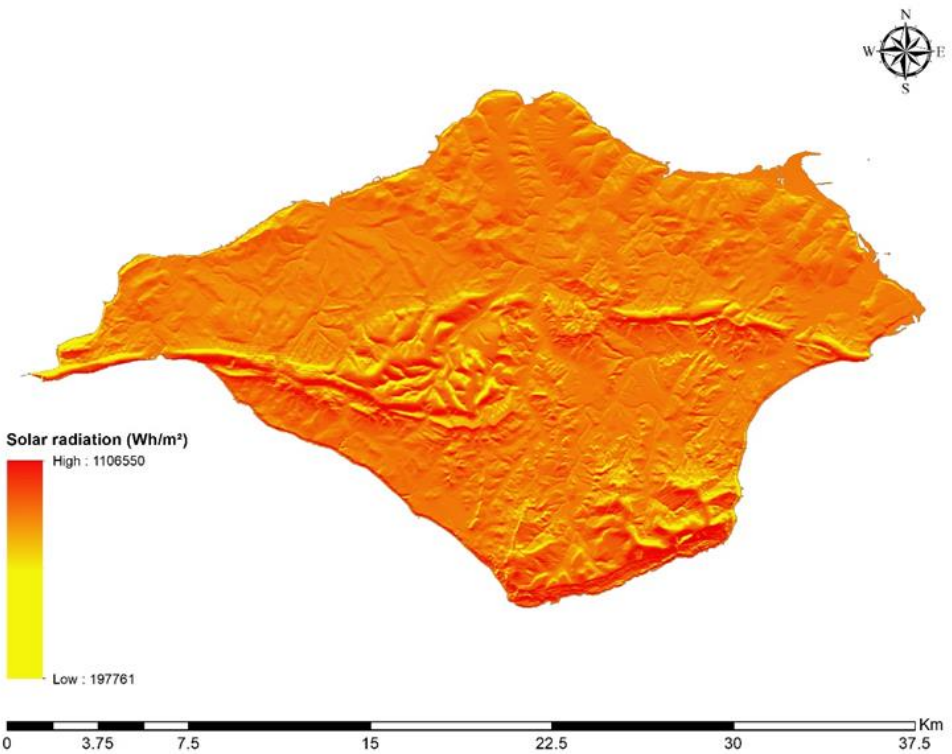

Figure 11: Displays relative uniform solar radiation.

Results Validation

It should be noted that the results of this analysis are directly based upon the criteria used and different constraints would have yielded different results. What the authors deemed 'optimal' criteria, others may not, which is demonstrated by inconsistency in constraints throughout literature. The absence of official criteria associated with siting a solar farm in the UK is due to the local planning authorities deeming individual constraints more, or less appropriate in their respective county. This effect is exemplified when studying regions in other parts of the world.

In an attempt to validate the results in the analysis, the 12.26km^2 of land deemed suitable for a solar farm was cross referenced by centroid points of operational solar farms (figure 7). Only one existing solar farm is within the 'suitable area' as found by this analysis. However, all points are exceptionally close (<0.5km). The difference between existing solar farms and this analysis can be attributed to differences in criteria, resolution of data sets used and ultimately, differences in criteria used in the planning stages of the operational solar farms.

The presentation of our final selected site in figure 10 demonstrates the real-world suitability. The land is of lower agricultural value, suitable for building and not obstructed in any way. Moreover, the site has an existing hedge around the extremities to minimise visual pollution. The final site is also highly accessible by vehicle for construction purposes, due to the nearby road.

Appropriateness of a Solar Farm

Despite the availability of other renewable energies, this analysis focuses on solar. The rationale being that there are eleven operational solar farms currently on the island. However, the appropriateness of solar in the county is much more substantiated. Table 8a and 8b, adapted from the Renewable Energy Planning Database (REPD) presents a comparison of technologies on the Isle of Wight. It is evident that solar farms are prevalent across the region, whilst far less onshore wind farms are granted planning permission. All but one wind farm has been rejected. Cheverton Down, the only wind farm to successfully gain planning permission had its development abandoned in the early stages. The small size of the island, and its close-knit community, may have considerable influence over whether a project is granted planning permission. It can be inferred that the local residents favour solar technology over wind, explaining the trends in successful planning applications. This inference would be in accordance with the previously mentioned Tampakis et al. (2009) study of Greece.

Table 8: Provide a summary of operational solar farms (a) and onshore wind farm applications for the Isle of Wight (b).

Operational Solar Farms		
Site Name	Installed Capacity (MW)	Operational Since
Durrants Farm Solar	4.5	01/07/2011
Lee Farm	5	31/07/2012
Stables Farm	1.5	07/08/2012
Wilmingham Lane Solar Farm	7.01	14/03/2013
Chawton Farm Solar Farm	3.2	22/03/2013
Ventnor Road Solar Park	4.8	23/03/2013
Hill Farm Solar Park	10.2	30/05/2014
East Fairlee	7.25	12/02/2015
Grange Farm	6	13/03/2015
Homestead Farm	10.7	15/12/2015
Fieldscale	10.62	15/04/2016

Refused Onshore Wind Farms		
Site Name	Proposed Capacity (MW)	Planning Permission Refused
Cheverton Down*	1.2	-
Wellow Wind Farm	12	02/11/2006
Cheverton Down Re-submission	3.9	04/12/2009
Cheverton Down Farm Re-submission	9	22/12/2009
Vectis wind farm	12.5	23/07/2012
Camp Hill Wind Farm	6	18/12/2014

**Cheverton Down - Planning permission granted 20/11/2002. Development Abandoned.*

Contribution towards Eco-Island Initiative

In the results section, a crude estimation for the proposed capacity of the final site is 20.1MW, this is supported by the calculated generation potential of 4729.5MWh/km^2/year. The proposed capacity approximately double the largest installed capacity any operational solar farm on the island, currently 10.7MW at Homestead Farm (table 8a). Although ambitious, this result is in accordance with the size of our selected site which is, again, approximately double the area of Homestead Farm. Following this, it is possible to determine the contribution that the proposed solar farm will have in regard to the island achieving their 'eco-island' initiative of being completely energy self-sufficient by 2020. The Isle of Wight Council (2017) states that currently, the electrical consumption of the island is 575GWh and to achieve self-sufficiency, a theoretical installed capacity of 170MW would be required to meet this demand. Based on the final site proposed capacity, it is evident that it would make significant progress towards achieving this goal, producing 11.77% of the required 170MW installed capacity. Furthermore, this would result in a 28% increase in the contribution of solar technologies towards accomplishing this goal.

The annual electrical consumption of a house in the UK is 3,300kWh (Solar trade, 2016). Based on this, the 20.1MW proposed capacity of site A, roughly equates to powering 6090 homes, 9% of the dwellings on the island (Isle of Wight Council, 2011). Moreover, based on a calculation from Solar trade (2016), Site A would also mitigate an estimated 6643 tonnes of CO_2 emissions, compared to if the equivalent power was generated via fossil fuels. It should be noted that different fossil fuels do not produce uniform amounts of CO_2, and this is a simplified quantification of the potential benefits of the proposed solar farm. This also further quantifies the substantial contribution site A could have towards the islands' 'green credentials'.

Based on current statistics, it is unlikely that the eco-island initiative will be achieved in the original time scale. However, the island has accumulated significant capacity for renewable energy generation over recent years, which is something that mainland UK would benefit from. Regardless of the timescale, it is very likely that the eco-island initiative will be achieved, especially when recently approved technologies are taken into consideration. For example, St. Catherine's Race is an approved site for a tidal barrage with a proposed capacity of 30MW (REPD, 2017). Although construction is yet to begin, planning permission was granted July 20th, 2016. If this development comes to fruition, it will significantly shorten the time until the eco-island initiative is achieved.

Conclusion

Summary of Key Findings

The integration of GIS-MCA has been critical in performing this analysis. The initial analysis determined that 12.26km^2 of land on the Isle of Wight to be a suitable for a solar farm. The addition of weighted soft constraints into the analysis revealed the two most suitable sites; A and B. These sites were 0.187km^2 and site B, 0.133km^2, with a respective proposed capacity of 20.1MW and 14.3MW. This greater electrical generation potential of site A was the principal reason it was chosen as the most suitable location on the island. It should be noted that the results obtained are a direct result of the specific criteria used in the analysis.

It can be concluded that the results of this research address the project objectives. The validity of the results was tested in comparison to existing solar farms with the 'suitable area' output from the initial MCA. It is recognised that the proposed electrical generation and associated powered homes and emissions saved was conducted is an approximation. Despite this, the results still display the significance that the future development of site A could have towards the Isle of Wight achieving their Eco-Island initiative.

Limitations and recommendations for further study

There is a broad agreement within literature that proximity to the electrical grid is a major parameter to be considered when siting a solar farm because of the direct economic impact of long distance transmission (Li, 2013; Azoumah et al., 2010; Janke, 2010). Unfortunately, this analysis was not able to take proximity to the national grid into consideration. The national grid infrastructure open data only covers mainland England and despite personal communication with the company, the data for the Isle of Wight was not available. However, the large spatial distribution of operational solar farms on the island, coupled with the fact our final selected site has a solar farm in the near vicinity, it can be assumed that adequate infrastructure exists.

As our analysis focussed on a utility scale solar farm, a recommendation to future research would be to conduct a comprehensive analysis, assessing the electricity generation potential of island wide deployment of domestic scale solar panels, onto rooftops and existing infrastructure. Perhaps, a similar framework performed by Gooding et al. (2013) in their assessment of feasible PV potential based upon available roof-top area.

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