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Where is wild in Glasgow's Southside? A test of the applicability of relative wildness mapping to suburban Scotland

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Abstract

Urban wildness refers to natural ecosystems within built-up areas that are subject to minimal human interference. It can provide huge social benefits and contribute to more liveable towns and cities. Focused on the societal benefits, the aim of this study was to test the applicability of relative wildness mapping (RWM) to suburban Scotland with an attempt to identify where is wild in Glasgow's Southside. RWM adopts a spatial definition of wildness based on the wilderness continuum that allows wildness to be understood as relative and defined using continuous geographical variables. This study used variables measuring naturalness, untouchedness, remoteness, and ruggedness. The results lead to the conclusion RWM is capable of pinpointing wildness within a suburban landscape and mapping variations of wildness across a suburban landscape. The relative wildness map distinguished six locations containing a sizeable area of high relative wildness within Glasgow's Southside: Bull Wood, North Wood, Big Wood, Dams to Darnley Local Nature Reserve and the Waulkmill Glen Site of Special Scientific Interest, the Cart and Kittoch Valleys Site of Special Scientific Interest, and the northwest corner of Pollok Golf Course. A survey of the locations revealed they are mainly dense native woodland, are generally subject to minimal land management, score highly for ecological wildness and greenness, and, between them, provide the three elements of a psychologically oriented definition of wilderness (direct contact with nature, periods of solitude, and inherent physical challenges). And a comparative analysis to determine the urban habitat type composition of the wildest and least wild areas revealed the wildest areas are dominated by woodland, almost entirely unpaved, and made up of a relatively small amount of artificial vegetation, while the least wild areas are more or less exclusively a combination of paved land, vacant lots/fringe vegetation, and artificial vegetation. The study also revealed Glasgow Southside's wildest areas are well protected. 99.9% of the wildest 1%, 98.2% of the wildest 5%, and 96.6% of the wildest 10% is covered by at least one designation and therefore under some form of special protection.

Keywords

Geography

GIS

Urban wildness

Relative wildness mapping

Suburban Scotland

For Maeve and my boys

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List of abbreviations

ASCII	American Standard Code for Information Interchange
BAE	British Aerospace
BBC	British Broadcasting Corporation
BNG	British National Grid
CAKV	Cart and Kittoch Valleys
CWN	Contact with nature
DTD	Dams to Darnley
DTM	Digital terrain model
DSM	Digital surface model
FC	Football Club
FV	Fringe vegetation
GB	Great Britain
GCS	Geographic coordinate system
GIS	Geographic information system(s)
IPC	Inherent physical challenges
LNR	Local Nature Reserve
MCE	Multi-criteria evaluation
MSc	Master of Science
NOVAFs	Number of visible artificial features
NW	Northwest
PAWS	Plantations on Ancient Woodland Sites
PCS	Projected coordinate system
PGC	Pollok Golf Course
POS	Periods of solitude
RWM	Relative wildness mapping
SEPA	Scottish Environmental Protection Agency
SINC	Site of Importance for Nature Conservation
SSLI	Site of Special Landscape Importance
SSSI	Site of Special Scientific Interest

STV	Scottish Television
TPO	Tree Preservation Order
UNESCO	United Nations Educational, Scientific and Cultural Organization
UK	United Kingdom
UKCEH	UK Centre for Ecology & Hydrology
VL	Vacant lot
WG	Waulkmill Glen

1. Introduction

Urban wildness refers to areas within built-up areas that exhibit qualities of wilderness, such as natural ecosystems (e.g., forests, woodlands, grasslands, and wetlands), self-regulation, and a degree of separation from human activity. It can provide enormous social benefits and contribute to more liveable towns and cities (McKinney et al., 2018). It can provide places for active recreation (Konijnendijk, 2005; Dvorak and Borrie, 2013), aesthetic enjoyment (Van den Berg and Koole, 2006), and interactions with nature (Zefferman et al., 2018) that are otherwise often unavailable in urban environments. It can improve health and wellbeing by encouraging physical activity and allowing psychological restoration (Kaplan and Talbot, 1983; Bowler et al., 2010; Shanahan et al., 2015). And it can provide children with opportunities for unstructured play, letting them imagine a world not ordered by adults (Kahn, 1997; Cloke and Jones, 2005; Louv, 2005).

It is therefore important to increase and promote the opportunities for experiencing wildness in built-up areas. While none of Scotland's towns or cities are far from a quality natural setting, urban dwellers tend to visit natural settings for just a few days or weeks a year, regardless of whether or not they are nearby (Cheesbrough et al., 2019). Urban wildness represents everyday wild: wildness that can be visited and benefitted from spontaneously and effortlessly whenever the opportunity arises.

A key part of this endeavour is mapping the geographical extent and intensity of existing urban wildness. The principal geographic information system (GIS) approach to mapping wildness is relative wildness mapping (RWM). RWM adopts a spatial definition of wildness based on Lesslie and Taylor's (1985) wilderness continuum, a scale of environmental modification from paved to pristine that allows wildness to be understood as relative and defined using continuous geographical variables that identify the wildest and least wild locations and everything in between (Carver et al., 2012). RWM of Scotland, like RWM in general, has focused on landscapes with relatively little human influence, on areas such as the Cairngorms and Loch Lomond and The Trossachs national parks (see Carver et al. (2012)). However, several recent studies

suggest it could also be useful for landscape planning within intensively used anthropogenic landscapes (see Müller et al. (2015), Müller et al. (2018), and Aznarez et al. (2022)). These studies are able to demonstrate RWM as capable of pinpointing areas in anthropogenic contexts that are relatively wild on the ground.

A relative wildness map of Scotland was created in 2014 on behalf of Scottish Natural Heritage (now NatureScot; NatureScot, 2023). Being a national map, it covers Scotland's anthropogenic landscapes. However, being a national map, it also covers large areas of genuine wild land, meaning anything remotely urban is very much confined to one end of the wildness spectrum, making urban wildness hard to distinguish. Furthermore, due to data availability and computational costliness, it is based upon analysis performed entirely at 25 m or 50 m spatial resolution. These spatial resolutions are more or less incapable of identifying small, fragmented pockets of high relative wildness that can be so beneficial in urban environments.

It is necessary to identify those pockets of high relative wildness and determine what they are and whether or not they are protected, particularly within the suburbs of Scotland's towns and cities, where the majority of Scots live and thus where the social benefits of any local wildness are most widely felt. Developed in collaboration with Scottish Government, the aim of this study is to test the applicability of RWM to suburban Scotland with an attempt to identify where is wild in Glasgow's Southside, a large sprawling area south of the River Clyde with a landscape that is very much suburban. While technically RWM can be applied to any given area and produce relative results, it is currently unknown whether it will produce meaningful results when applied specifically to suburban Scotland and suburban landscapes in general. It will be interesting to see what kind of areas are scored as most (and least) wild. To test whether RWM is applicable to suburban Scotland, this study will answer the following four research questions:

1. Where in Glasgow's Southside are areas of high relative wildness located?
2. Are these locations potential urban wildness areas?
3. Which urban habitat types make up the wildest and least wild areas of Glasgow's Southside?

4. Are the wildest areas protected?

The structure of the thesis is as follows. Section two, the background section, expands on some of the above. Section three introduces the study area, then, section four, the method section, presents and justifies the method. Section five, the results section, presents the results, addressing the four research questions in turn, then, section six, the discussion section, interprets the results and their implications, reflects on the method, and suggests how the results might be applied. Section seven concludes.

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2. Background

2.1. The health challenges of urbanisation and health benefits of nature contact

Urbanisation brings with it particular health challenges. The relatively sedentary lifestyles of urban dwellers and the easy access in urban areas to low-cost, high-fat food can lead to overweight and obesity, which in turn can lead to diabetes, heart disease, stroke, and certain cancers (Dye, 2008). Urban areas are also associated with higher rates of mental health problems (Peen et al., 2010), with noise, crowding, and demanding occupations just three of the many urban stressors (van den Berg et al., 2016; Cheesbrough et al., 2019).

There is a wealth of evidence contact with nature can improve health and wellbeing (Bowler et al., 2010; Ward Thompson and Aspinall, 2011; Hartig et al., 2014), and a great deal of research that highlights the critical role the provision of urban nature plays in fostering healthy urban populations (Shanahan et al., 2015; van den Berg et al., 2016). The variety of health benefits resulting from contact with nature is quite remarkable. Correlational evidence exists for improved immune function (von Hertzen et al., 2011), cognitive ability (Berman et al., 2008), self-reported wellbeing (Dallimer et al., 2012), and self-perceived general health (Maas et al., 2006), as well as for reduced stress (Grahn and Stigsdottir, 2003; Van den Berg and Custers, 2011), risk of poor mental health (Dallimer et al., 2012), allergies (Hanski et al., 2012), respiratory illness (Lovasi et al., 2008), all-cause mortality (Mitchell and Popham, 2008), and mortality from cardiovascular disease (Donovan et al., 2013).

2.2. The transformative power of urban wildness

Experiences in urban wildness hold the same potential benefits as those in more ordinary urban greenspaces such as parks and gardens (Cheesbrough et al., 2019). However, evidence suggests a different, deeper dimension (Knecht, 2004), one that can be both inspirational (Fredrickson and Anderson, 1999) and transcendent (Williams and

Harvey, 2001). For example, Cheesbrough et al. (2019) used photovoice interviews to explore the perceived health and wellbeing effects of visits to the city of Edmonton's Natural Area Parks. The authors describe Canada's Natural Area Parks as urban wildness: neither landscaped park, nor wilderness, but something in between, and as spaces fully bounded by city structures and processes, but where nature takes its own course with only minimal management. The research participants described visits to the parks as transformative. They spoke of being in a different world, somewhere they could experience the absence of human influence and the presence of natural processes. Quiet, fresh air, wildlife, ruggedness, natural beauty, and environments in flux each contributed to their sense of being somewhere else. The participants valued the feeling of being away, away from work and stress and from the traffic and busyness of the city. Key to this was the quiet and sense of being enveloped by nature. The participants reported visits to the parks were beneficial to their health and wellbeing because they offered a holistic experience. Each visit simultaneously encouraged physical activity, reduced stress, induced relaxation, enhanced emotional and spiritual health, and created and sustained connections with nature. The physical proximity of the parks to participants' homes was a major motivation to engage in physical activity, and the physically challenging topography of the parks intensified participants' physical exercise. Many of the participants believed physical activity within the parks helped release stress and promote relaxation. The parks also provided solitude for contemplation. Many of the participants spoke of a spiritual component of their visits. And finally, a number of participants noted how being in the parks enhanced connections with others. The parks were a place for families to interact without distraction and they prompted chance encounters that in turn prompted stronger ties and social cohesion.

2.3. Relative wildness mapping

2.3.1. The wilderness continuum

RWM is the primary GIS method of mapping wildness. At its core is a spatial definition of wildness based on the wilderness continuum concept introduced by Lesslie and Taylor (1985). The wilderness continuum (figure 1) is a scale of wilderness quality that

reflects both the degree of human modification and the degree of naturalness and remoteness. Absolute pristine ecological wilderness sits on one extreme of the spectrum, and on the other end sits completely human-controlled town and city centres and indoor settings such as shopping malls (Lesslie and Taylor, 1985; Carver et al., 2012; Lesslie, 2016).

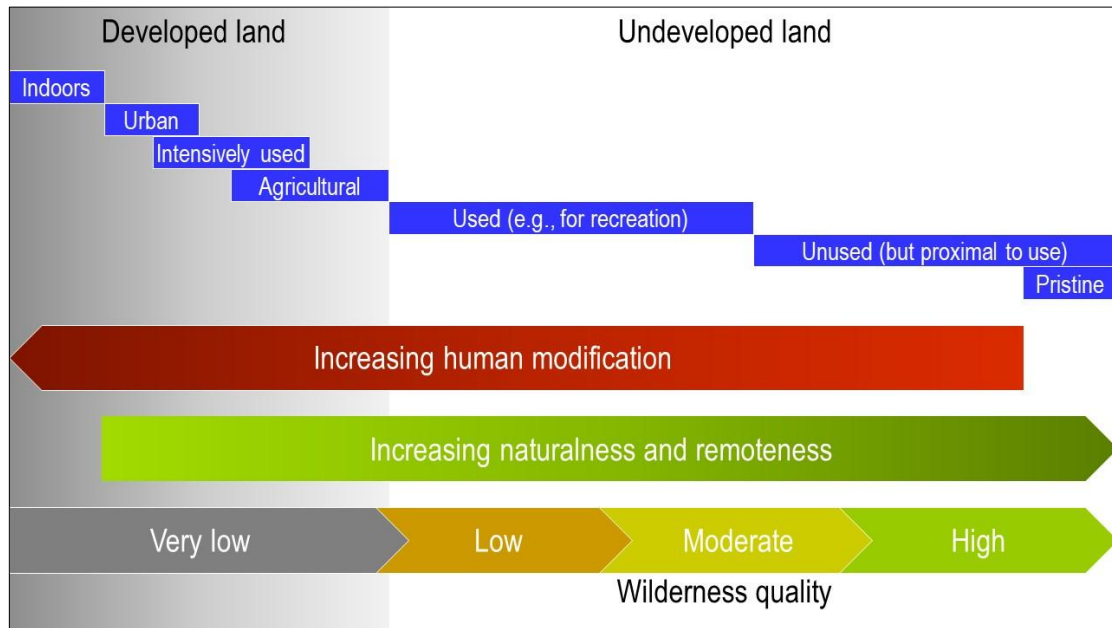


Figure 1: *The wilderness continuum (adapted from Lesslie and Taylor (1985))*

The continuum concept generates debate concerning the point along the continuum at which wilderness can be said to exist (Lesslie and Taylor, 1985; Carver, 1996; Dawson and Hendee, 2009; Carver and Fritz, 2016). However, Nash (1993, p. 1) is right to highlight that “one man’s wilderness is another’s roadside picnic ground” as he sidesteps formal definition by asserting “wilderness is what men think it is.” A landscape is more likely to be perceived as wilderness if it possesses those key attributes of impactful wilderness listed in the previous section, but precisely how those attributes are interpreted depends upon factors including individuals’ lifestyle, cultural background, and past experiences (Ittelson et al., 1974; Flanagan and Anderson, 2008). Our understanding of these perceptions is improved by wilderness perception surveys. Such surveys have been carried out in a number of countries, including Norway (Vistad and Vorkinn, 2012), the Netherlands (Van den Berg and Koole, 2006), the United States (Flanagan and Anderson, 2008; Larkin and Beier, 2014), and Scotland (Market

Research Partners, 2008; MVA Consultancy and Research Now, 2012), and their results are frequently used in RWM studies to inform the weighting of different wildness indicators and to explore how individual perceptions affect spatial patterns and distribution of wilderness quality.

2.3.2. Continuous geographical variables

The continuum concept imagines wildness as both relative and scalable and in doing so allows RWM studies to define wildness with continuous geographical variables that identify the wildest and least wild locations and everything in between (Carver et al., 2012). Different studies use different combinations of variables, but most of those carried out in the last ten or so years use a combination that measure the extent and intensity of each of four basic attributes of wildness: (1) naturalness, (2) untouchedness, (3) remoteness, and (4) ruggedness (including Carver et al. (2012), Müller et al. (2015), Radford et al. (2019), and Zoderer et al. (2020)). These four attributes were identified by Scottish Natural Heritage (2002) and first operationalised by Carver et al. (2012) to map relative wildness within Scotland's national parks. They align closely with the three elements of Fredrickson and Anderson's (1999) psychologically oriented definition of wilderness (the provision of direct contact with nature, periods of solitude, and inherent physical challenges) and several key attributes of impactful wilderness (e.g., absence of built form or social influence, opportunity for solitude, and rugged landscape presenting physical challenge (Knecht, 2004)).

2.3.3. GIS-based multi-criteria evaluation

Whichever variables are chosen to measure wildness, they are almost always combined using weighted linear combination as part of a GIS-based multi-criteria evaluation (MCE) model (Cao et al., 2019). A GIS-based MCE model transforms and combines geographic information (e.g., indicators of wildness) with value judgements (e.g., perceptions of wildness) to obtain information for decision making (Carver, 1991; Malczewski and Rinner, 2015). The weighted linear combination allows variables to be weighted by their relative importance and it is this that lets RWM studies incorporate the results of expert and/or wildness perception surveys into their analysis. The result

of this combination is measures of perceived wildness across space that describe the continuum of the human modification of the studied landscape and the physical nature of its terrain (Carver et al., 2012).

2.3.4. Applications of relative wildness mapping

This approach to mapping wildness has been implemented for more than 30 years across a range of spatial scales. There are worldwide assessments (McCloskey and Spalding, 1989; Sanderson et al., 2002), continental assessments (e.g., of Europe (Fisher et al. (2010))), national assessments (e.g., of China (Cao et al., 2017), Iceland (Ølafsdóttir and Runnström, 2011), Austria (Plutzer et al., 2016), the United States (Aplet et al., 2000), the United Kingdom (Carver et al., 2002), and Scotland (NatureScot, 2023)), and local assessments (e.g., of the South Western Carpathians (Măntoiu et al., 2016) and the Dolomites UNESCO World Heritage Site (Orsi et al., 2013)). The vast majority of these studies include or focus on natural, untouched landscapes. However, several recent studies have shown it can also assist landscape planning within intensively used anthropogenic landscapes.

Müller et al. (2015) were the first to apply RWM to an anthropogenic landscape. They applied it to Denmark, which is heavily farmed, densely populated, and according to Fisher et al.'s (2010) continental assessment, one of the least wild areas of Europe. With orthophoto checks and a ground truthing exercise, the study demonstrates RWM can produce meaningful results when applied to such a context. However, this is a national assessment, and while Denmark can be considered an anthropogenic landscape within the European context, it is of course a landscape that contains more and vaster wild spaces than a typical town or city. This, coupled with a relatively low resolution of analysis, means, while both revealing and promising, it is no test of the applicability of RWM to a context as anthropogenic as a discrete urban environment.

Narrowing their focus, Müller et al. (2018) apply RWM to Aarhus Municipality (to ultimately test for a relationship between urban wildness and urban biodiversity). Aarhus Municipality spans an area of almost 500 km² and includes the city of Aarhus and some rural communities. The city of Aarhus is Denmark's second largest city with

over 300 000 inhabitants. With orthophoto checks and a ground truthing exercise performed entirely within the city centre, this study demonstrates RWM can capture variations in urban wildness that can also be perceived on the ground. A subsequent statistical analysis confirms high mapped wildness scores correspond to natural settings and low mapped wildness scores correspond to settings under heavy human influence (with just a small amount of unexplained variation). These findings are supported by those of Aznarez et al. (2022), the only other recorded application of RWM to an anthropogenic landscape. They apply it to the Basque city of Vitoria-Gastiez (to ultimately test for relationships between urban wildness, urban habitat quality, and urban biodiversity). Their results may not be as rigorously tested as those of Müller et al. (2015) and Müller et al. (2018), but they are equally encouraging. High mapped wildness scores correspond to hills, foothill forests, wetlands, and areas within urban greenspaces, while low mapped wildness scores correspond to commercial, residential, and industrial zones. While this is all very promising, it is evidence derived from just two studies. It is not undeniable evidence RWM is universally applicable to urban environments, nor is it, of course, evidence RWM is applicable specifically to suburban landscapes or suburban Scotland. In addition, Muller et al.'s (2018) RWM analysis covered some rural communities and one would assume Vitoria-Gastiez (Aznarez et al., 2022) is in many ways a very different place to Glasgow. For these reasons, the applicability of RWM to suburban Scotland cannot be assumed and must be tested.

3. Study area

Glasgow's Southside – defined here as the Glasgow City Council area south of the River Clyde – has an area of about 64 km². There is no truly wild land within that area, not in a true ecological sense (i.e., a pristine landscape devoid of any human influence). The 42 national Wild Land Areas recognised by NatureScot (2023) are all some way from Glasgow. Instead, there are over 220 000 people residing in residential areas such as Pollokshields, Shawlands, Cathcart, Cardonald, and Castlemilk (see figure 2). There are schools, colleges, offices, factories, and docks, pubs, cafes, restaurants, and shops, libraries, museums, churches, and mosques. There are police stations, fire stations, recycling centres, sewage works, and underground stops. There are the headquarters of BBC Scotland and STV (the buildings labelled L1 and L2 in figure 3). There is Glasgow Science Centre and Silverburn Shopping Centre (the buildings labelled L3 and L4). And there are two hospitals: the New Victoria and the Queen Elizabeth (the buildings labelled L5 and L6). Two football stadiums: Ibrox and Hampden (the stadiums labelled L7 and L8). Sections of three motorways: the M8, the M74, and the M77. And trainlines that run east, south, and west from Glasgow Central Station. In short, Glasgow's Southside is a truly suburban landscape (as can be seen in figure 4).

There is, however, land in Glasgow's Southside that possesses attributes of wildness. There is land that is natural, land that is untouched, and land that is rugged. Glasgow's Southside has parks, Country Parks, woodlands, forests, and wetlands. It has numerous Sites of Importance for Nature Conservation (SINCs), numerous Sites of Special Landscape Importance (SSLIs), and over 12 000 hectares of green belt that prevent urban sprawl by protecting land against development (Department for Levelling Up, Housing and Communities, 2023). Its centre is dominated by Pollok Country Park: 146 hectares of mostly undulating grassland, forest, and woodland (the area labelled A1 in figure 3). To the west, west of Roughmussel, is the partly wooded Hurlet Hill, the mainly coniferous Hurtlehill Plantation, and the mainly deciduous Bull Wood (the area labelled A2). To the southwest is part of Dams to Darnley Country Park and Local Nature Reserve (LNR) and the Waulkmill Glen Site of Special Scientific Interest (SSSI;

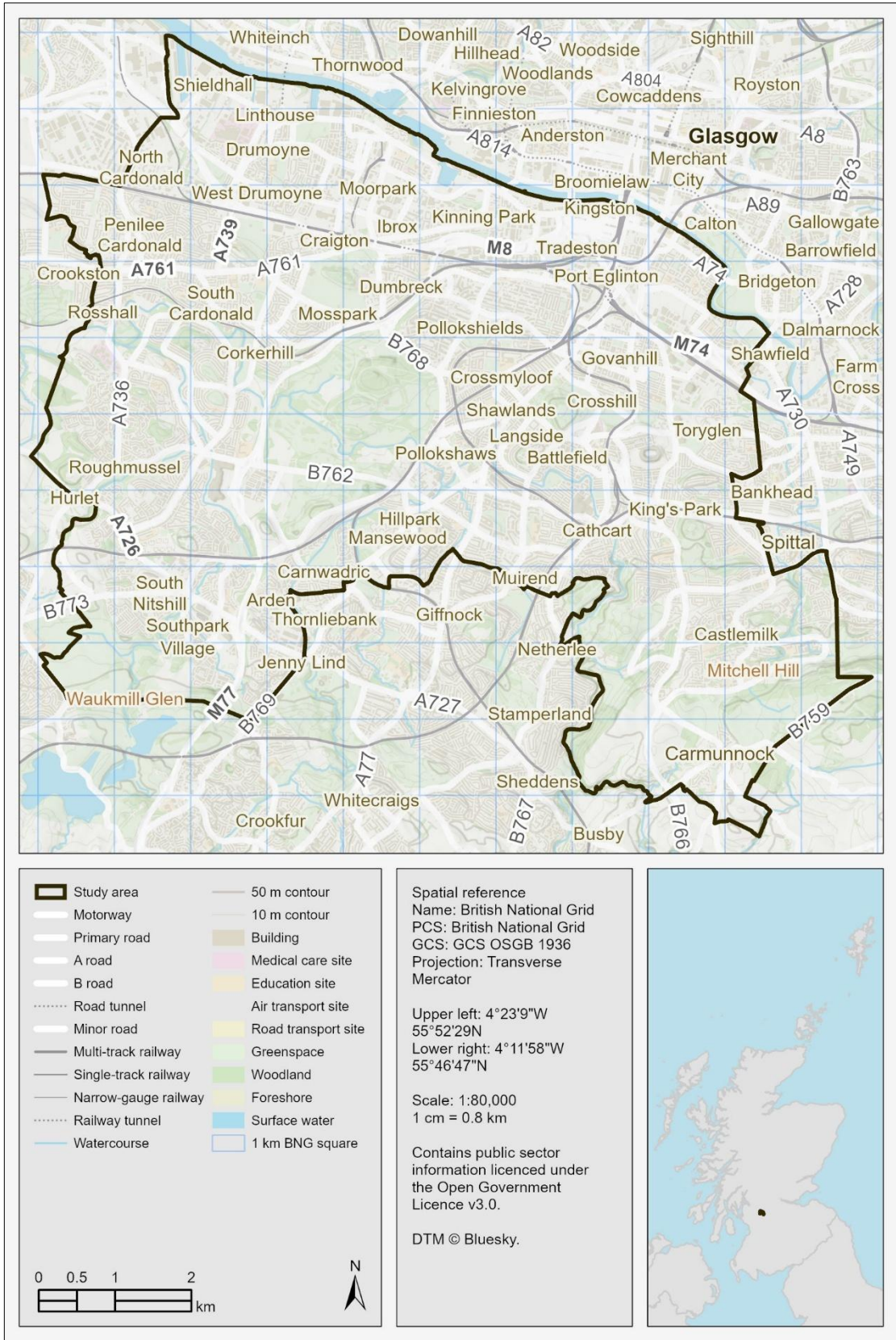


Figure 2: The topography of Glasgow's Southside

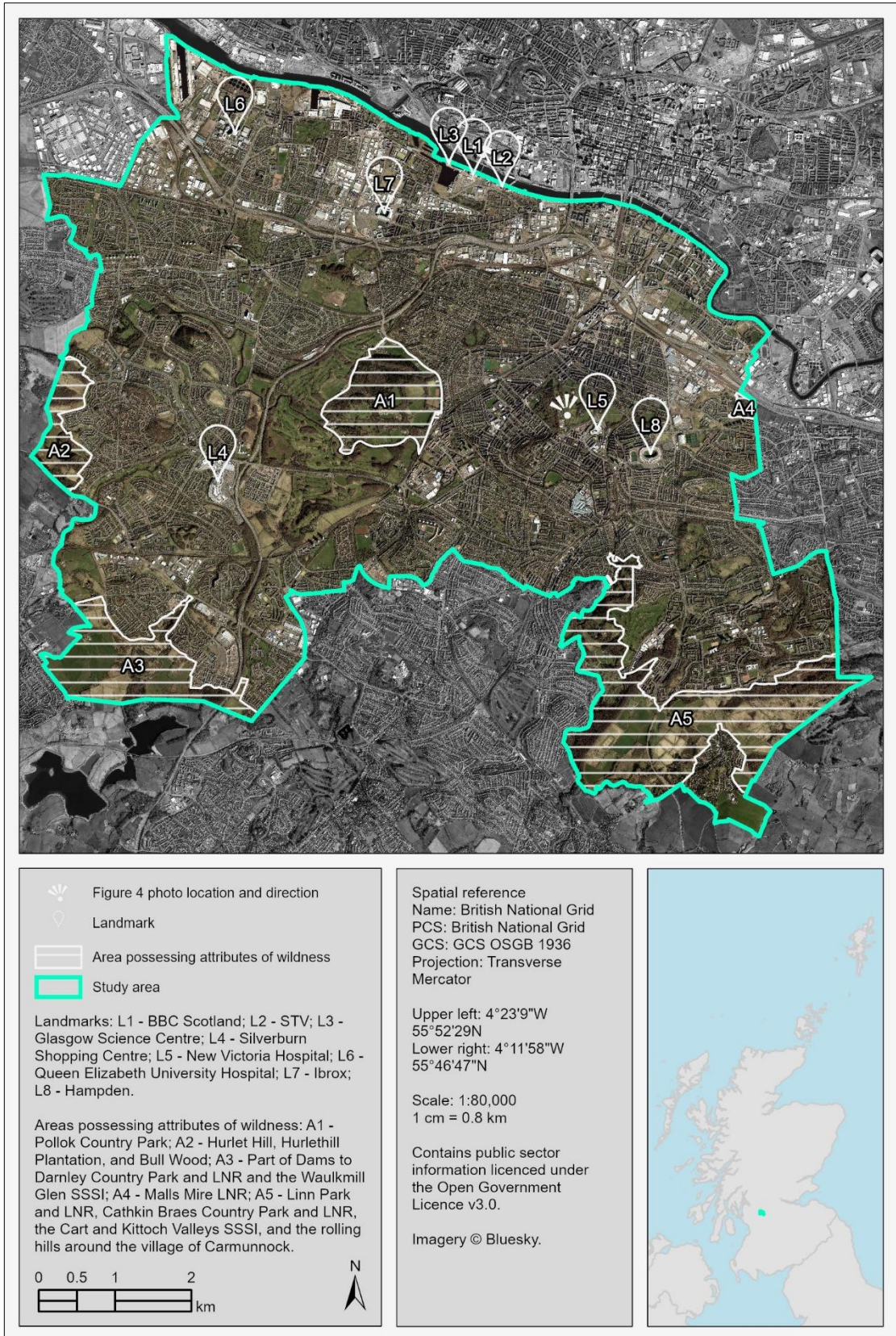


Figure 3: Imagery of Glasgow's southside plus landmarks, areas possessing attributes of wildness, and figure 4 photograph location and direction



Figure 4: Part of Glasgow's Southside from Queen's Park (People Make Glasgow 2023; photograph location and direction shown in figure 3)

the area labelled A3). Dams to Darnley Country Park and LNR is a mosaic of grassland, woodland, wetland, and open water. The Waulkmill Glen SSSI is a site protected for its sequence of 320-million-year-old sedimentary rocks. It is also covered in an extensive natural woodland. To the east, in Toryglen, is Malls Mire LNR: 7 hectares of mixed woodland and wetland habitat (the area labelled A4). And finally, to the southeast there is the green expanse of Linn Park and LNR, Cathkin Braes Country Park and LNR, the Cart and Kittoch Valleys SSSI (also known as Netherton Braes), and the rolling hills around the village of Carmunnock (the area labelled A5). Linn Park and LNR is 82 hectares of mostly undulating grassland, forest, and woodland. Cathkin Braes Country Park and LNR, reaching 200 metres above sea level, is the highest point in Glasgow, and is covered in grassland, heathland, and ancient woodland. And the Cart and Kittoch Valleys SSSI is a dense ancient woodland.

4. Method

A GIS-based MCE model was developed to map relative wildness (see section 4.1). Then, locations containing areas of high relative wildness were surveyed to determine whether they are potential urban wildness areas (see section 4.2). To validate the results, the urban habitat type composition of the wildest and least wild areas was derived from an urban habitat map (see section 4.3). And to establish whether the wildest areas are protected, their distribution was compared to the distribution of protected areas (see section 4.4). Figure 5 provides an overview of the method.

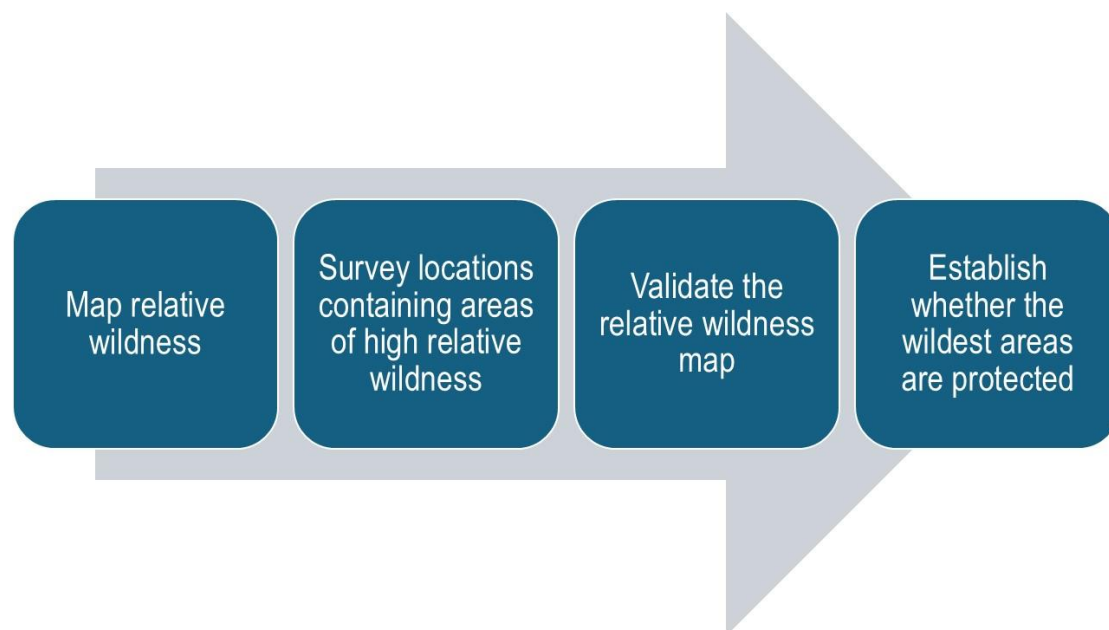


Figure 5: Overview of the method

4.1. Mapping relative wildness

Influenced by previous RWM studies (primarily Carver et al. (2012), Müller et al. (2015), Müller et al. (2018), and Radford et al. (2019)), this study used the following variables to measure the extent and intensity of the four basic attributes of wildness identified by Scottish Natural Heritage (2002): (1) perceived naturalness of land cover, (2) absence of noise and modern human artefacts, (3) remoteness from mechanised access, and (4) ruggedness and physical challenge of the terrain. Perceived naturalness

Table 1: Datasets used for mapping relative wildness

Dataset	Source	Year	Format	Resolution/accuracy
Building Part	Ordnance Survey	2023	GeoPackage (polygons)	Within ± 1 m
GB Railways	University of Edinburgh	2017	Shapefile (lines)	Within ± 1 m
Land Cover Map	UKCEH	2021	GeoTIFF	10 m
National Forest Inventory	Forestry and Land Scotland	2019	Shapefile (polygons)	Unstated
Native Woodland Survey of Scotland	Forestry and Land Scotland	2019	Shapefile (polygons)	Unstated
Noise	SEPA	2018	Shapefile (polygons)	Unstated
Path Link	Ordnance Survey	2023	GeoPackage (lines)	Within ± 1 m
Photogrammetric DSM	Bluesky	2022	Arc ASCII Grid	2 m
Photogrammetric DTM	Bluesky	2022	Arc ASCII Grid	5 m
Rail (infrastructure)	Ordnance Survey	2023	GeoPackage (polygons)	Within ± 1 m
Road Link	Ordnance Survey	2023	GeoPackage (lines)	Within ± 1 m
Road Track or Path	Ordnance Survey	2023	GeoPackage (polygons)	Within ± 1 m
Site	Ordnance Survey	2023	GeoPackage (polygons)	Within ± 1 m
Street	Ordnance Survey	2023	GeoPackage (lines)	Within ± 1 m

Structure	Ordnance Survey	2023	GeoPackage (polygons)	Within ± 1 m
Structure Line	Ordnance Survey	2023	GeoPackage (lines)	Within ± 1 m
Structure Point	Ordnance Survey	2023	GeoPackage (points)	Within ± 1 m
Water	Ordnance Survey	2023	GeoPackage (polygons)	Within ± 1 m
Water Link	Ordnance Survey	2023	GeoPackage (lines)	Within ± 1 m

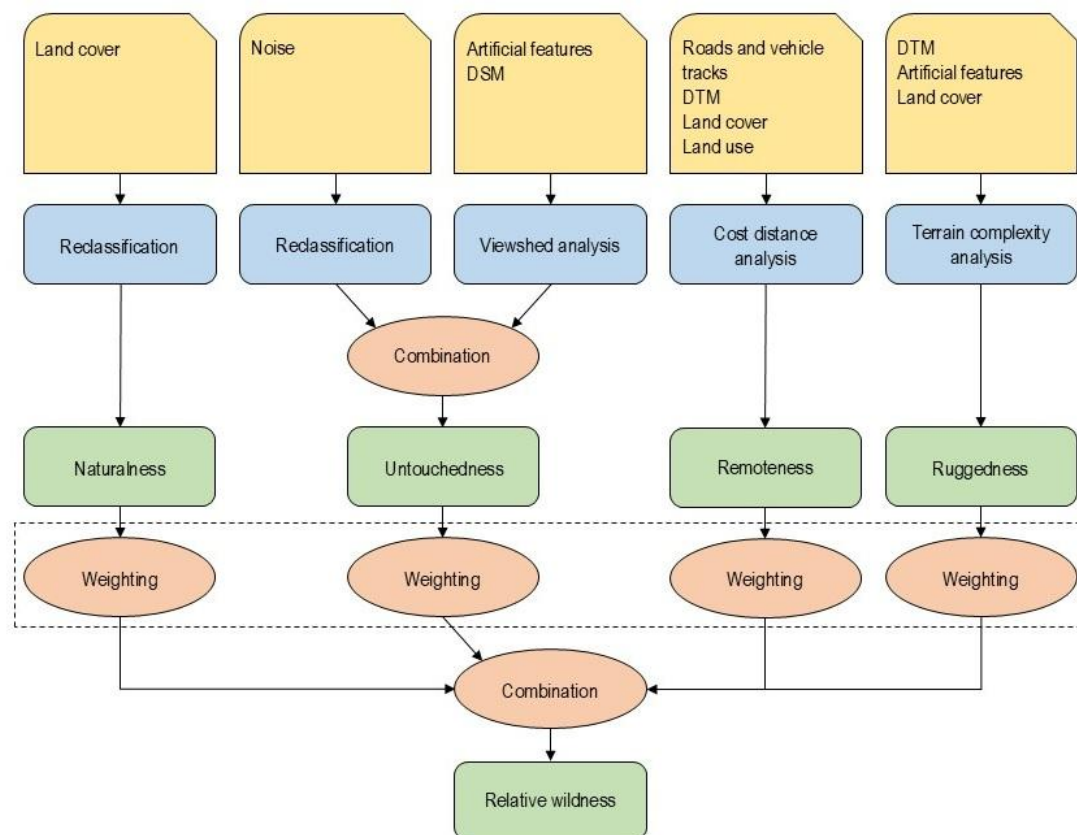


Figure 6: Overview of the MCE model and dataflow

of land cover is the degree to which land management, or lack of it, creates a pattern of vegetation that appears natural to the casual observer. Absence of noise and modern human artefacts is the absence of road, rail, and industrial noise from the sonic

landscape and artificial features from the visible landscape (i.e., roads and vehicle tracks, railway, buildings, and structures). Remoteness from mechanised access is the time it takes to walk to somewhere from the nearest public road or track that provides vehicular access. And ruggedness and physical challenge of the terrain relates to the physical characteristics of the landscape with respect to the effects of steep, rough, and challenging terrain (Scottish Natural Heritage, 2002; Carver et al., 2012).

Spatial data layers were created for each indicator and those four layers were weighted and combined to create a map of relative perceived wildness describing the continuum of the human modification of Glasgow's Southside and the physical nature of its terrain. Table 1 lists the datasets used and figure 6 provides an overview of the MCE model and dataflow. Analysis was performed in ArcGIS Pro 2.7, using the EPSG:27700 (British National Grid (OSGB36)) projected coordinate system, at the highest possible spatial resolution (mainly 10 m, the coarsest spatial resolution of the input datasets), and to an extent that avoided edge effects.

4.1.1. Mapping perceived naturalness of land cover

Land cover data from UKCEH's 2021 Land Cover Map, Forestry and Land Scotland's 2019 Native Woodland Survey of Scotland, Forestry and Land Scotland's 2019 National Forest Inventory, and a June 2023 download of Ordnance Survey's Water dataset was (1) reclassified into five broad naturalness classes from class 1, no perceived naturalness, to class 5, very high perceived naturalness, and (2) combined to create a composite map of naturalness. Then, the mean perceived naturalness score of all cells within a 250 m radius of each target cell was calculated to account for the influence of the land cover adjacent to the observer. A radius of 250 m was decided upon by the project steering group Carver et al. (2012) worked alongside and is taken to represent the extent of the surrounds an individual would be expected to experience. The reclassification (table 2) is taken from Scottish Natural Heritage (2014). It has been reviewed by Scottish Natural Heritage officials and is informed by the results of the 2008 Scottish wildness perception survey (Market Research Partners, 2008).

Table 2: Reclassification of land cover classes into the five naturalness classes

Dataset	Land cover class	Naturalness class
UKCEH's 2021 Land Cover Map	Acid grassland	4
	Arable and horticulture	2
	Bog	5
	Broadleaved woodland	4
	Calcareous grassland	3
	Coniferous woodland	3
	Fen, marsh, and swamp	4
	Freshwater	5
	Heather	4
	Heather grassland	4
	Improved grassland	2
	Inland rock	5
	Littoral rock	5
	Littoral sediment	5
	Neutral grassland	3
	Saltmarsh	4
	Saltwater	5
	Suburban	1
	Supralittoral rock	5
	Supralittoral sediment	5
Urban	1	
Forestry and Land Scotland's 2019 Native Woodland Survey of Scotland	0-50% semi-naturalness	4
	51-100% semi-naturalness	5

Forestry and Land Scotland's 2019 National Forest Inventory	Broadleaved woodland	4
	Coniferous forest	3
	Felled woodland/forest	2
	Ground prepared for planting	2
	Mixed but mainly broadleaved woodland	4
	Mixed but mainly coniferous forest	3
	Shrub	4
	Young trees	3
Ordnance Survey's Water dataset	Open reservoirs	3
	Open tank reservoirs	3
	Still water	5

The source data needed preparing for reclassification and combination. First, the data was clipped to the extent of analysis: a 5 km buffer envelope of the study area. Then, specific features were extracted from the vector datasets and converted to raster. Native woodlands, nearly-native woodlands, and Plantations on Ancient Woodland Sites (PAWS) with greater than or equal to 20% canopy coverage were extracted from the Native Woodland Survey of Scotland as a minimum of 20% canopy coverage is required to define woodland (Forestry and Land Scotland, 2022). Forests, woodlands, shrubs, and areas of ground prepared for planting were extracted from the National Forest Inventory as the dataset also includes artificial features such as roads, quarries, and wind farms. And still water, open reservoirs, and open tank reservoirs were extracted from Water as this dataset also includes some forest data.

The Native Woodland Survey of Scotland, the National Forest Inventory, and Water was used as a supplement to the Land Cover Map for a more accurate and refined representation of the area's woodlands, forests, and waterbodies. It therefore took precedence over the Land Cover Map. Overlaps of the Forestry and Land Scotland and

Ordnance Survey data were resolved through calculation of the maximum naturalness value of the three layers.

4.1.2. Mapping absence of noise and modern human artefacts

Absence of noise and absence of modern human artefacts were mapped separately then combined. Absence of noise was mapped using noise exposure data from SEPA's Noise dataset. First, consolidated road, rail, and industrial noise levels (L_{den}) from SEPA's Glasgow noise study were extracted from the Noise dataset as the dataset contains overlapping sources, metrics, and studies. Then, the extracted data was clipped to the extent of analysis (that 5 km buffer envelope of the study area) and converted from vector to raster. After that, the data was reclassified so higher values would represent lower levels of noise and vice versa (so the variable would be positively correlated with relative wildness).

Absence of modern human artefacts was determined by viewshed analysis. Viewshed analysis identifies the geographical area that is visible from a location. It is a far more effective method of establishing the impact of modern human artefacts than the simple distance measurements utilised by a number of RWM studies (e.g., Lesslie (1993), Carver (1996), Sanderson et al. (2002), and Müller et al. (2015)) and this is simply because a remote place from which one can see an extensive urban area offers a reduced wilderness experience, while a location within an urban area may seem wild if there are no observable signs of human presence (Orsi et al., 2013).

To start with, artificial features from numerous datasets were combined in a binary raster dataset locating artificial features spanning a 15 km buffer envelope of the study area (see Appendix A). The features were sourced from the University of Edinburgh's 2017 GB Railways dataset and June 2023 downloads of Ordnance Survey's Building Part, Rail, Road Link, Road Track or Path, Street, Structure, Structure Line, and Structure Point datasets. The selection of artificial features was based upon Scottish Natural Heritage wild land policy (Scottish Natural Heritage, 2002) and the results of the aforementioned Scottish wildness perception surveys (Market Research Partners, 2008; MVA Consultancy and Research Now, 2012). And the raster dataset spanned a

15 km buffer envelope of the study area because the viewshed analysis would adopt a maximum view distance of 15 km for artificial features as recommended by Bishop (2002). Ruined buildings were removed from Building Part under the assumption they are not modern. Paths were removed from Road Track or Path as both Scottish wildness perception surveys suggest they do not detract from wilderness experience. And, for obvious reasons, anything historic (e.g., burial chambers, cairns, and inscribed rock), buried (e.g., buried storage tanks), or perceivable as natural (e.g., leats and dry reservoirs) were removed from Structure, Structure Line, and Structure Point. The different types of artificial features were considered equally influential as it was not possible to confidently derive weights from the results of the Scottish wildness perception surveys for every artificial feature type.

The next step was to prepare the digital surface model (DSM; Bluesky's 2022 Photogrammetric DSM). The DSM is the standard terrain descriptor for viewshed analysis (Müller et al., 2018). First, unsupported by the software, the ASCII files were converted to Esri Grid. Then, the nearly 5 000 DSM tiles were merged. Next, the cells were aggregated to 10 m using the aggregate mean. And after that, the DSM was clipped to and aligned with the 15 km buffer envelope of the study area.

Once the DSM was prepared, 10 995 observer points were created by aggregating the DSM to 100 m, clipping it to a 1 km buffer of the study area, converting the cells to points, and splitting the resulting point layer into 10 995 separate feature classes. Following Müller et al. (2018), this one element of the analysis was performed at a spatial resolution of 100 m owing to the massive computational demand of performing so many individual viewshed analyses. First, a viewshed was created for each observer point. The outer radius was set to 15 km and the observer offset was set to 168.15 cm, the average height of a person in Scotland. Then, each binary viewshed was multiplied by the binary artificial features raster, creating binary rasters identifying visible artificial features. Next, the number of visible cells occupied by an artificial feature were tallied through calculation of the zonal statistics of a zone covering the full extent of the rasters. And after that, that figure was attached to the observer points by a short Python script (see Appendix B). When the script had finished, the observer points were

merged then converted to raster. The raster was then resampled to 10 m using the nearest neighbour method.

Next, following Orsi et al. (2013), taking into account the likely summertime screen effect provided by woodlands and forests, and based upon in the field experimentation, the number of visible cells occupied by an artificial feature value was reduced wherever the National Forest Inventory, the Native Woodland Survey of Scotland, or the Land Cover Map showed there to be broadleaved woodland or coniferous forest (reduced by 60% for broadleaved woodland, 90% for coniferous forest, 70% for a mixture of the two but mainly broadleaved woodland, and 80% for a mixture of the two but mainly coniferous forest). The National Forest Inventory identifies each of these four feature types. They were extracted from the dataset, clipped to the extent of analysis (that 1 km buffer of the study area), and converted from vector to raster. Then, the raster was reclassified so broadleaved woodland = 40, coniferous forest = 10, mixed but mainly broadleaved woodland = 30, and mixed but mainly coniferous forest = 20. The Native Woodland Survey of Scotland only identifies broadleaved woodland (at least in and around the study area). It was extracted from the dataset and processed the same as the National Forest Inventory data. The Land Cover Map was reclassified so broadleaved woodland = 40, coniferous woodland (i.e., coniferous forest) = 10, and everything else = 100. To apply the screen effect, the number of visible human artefacts raster was simply divided by 100 and multiplied by the reclassified land cover data. Finally, following Müller et al. (2018) and recognising the probable greater significance of variation in lower numbers of visible artificial features, the number of visible modern human artefacts raster was converted to integer and reclassified into five classes: 0 visible cells occupied by an artificial feature = 5; 1 = 4; 2-5 = 3; 6-10 = 2; > 10 = 1. The absence of modern human artefacts analysis is illustrated in figure 7.

To allow meaningful combination of the absence of noise and absence of modern human artefacts rasters, the values of each raster were normalised onto a common relative scale ranging from 0 to 255 (equation 1).

$$NX_{ij} = \frac{(X_{ij} - m_i) \times (NM - Nm)}{M_i - m_i} + Nm$$

Equation 1: The normalisation formula used to normalise the values of rasters onto a common relative scale

where NX_{ij} is the normalised value of cell j in raster i , X_{ij} is the current value of cell j in raster i , m_i is the minimum value in raster i , NM is the new maximum value (255), Nm is the new minimum value (0), and M_i is the maximum value in raster i . The rasters

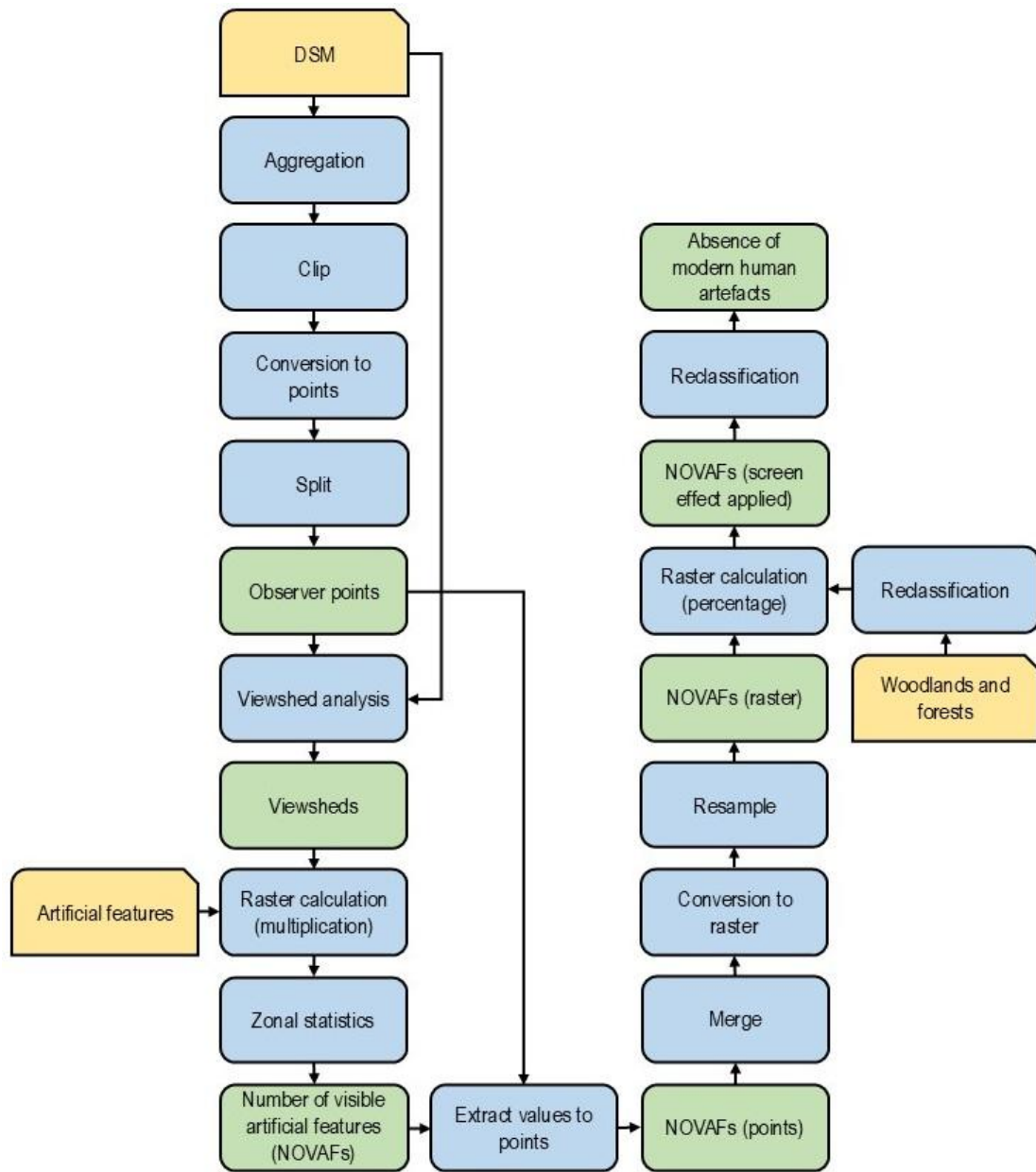


Figure 7: Illustration of the absence of modern human artefacts analysis

were combined through calculation of the mean. They were weighted equally as the results of an expert survey carried out by Radford et al. (2019) suggest them to be of equal importance as measures of untouchedness.

4.1.3. Mapping remoteness from mechanised access

Remoteness from mechanised access was determined by cost distance analysis. Simply put, cost distance analysis calculates the least cost path from one location to another. The analysis considered gradient through an implementation of Tobler's (1993) hiking pace function and land cover and land use through the definition of barriers to movement and the application of time penalties to cells covered by land cover types that are relatively difficult to traverse. The analysis was performed by ArcGIS Pro's Distance Accumulation tool. The tool utilised an ASCII file containing Tobler's hiking pace function expressed in degrees and s/m (reproduced in Appendix C) and four rasters: a roads and vehicle tracks raster, a digital terrain model (DTM), a cost surface raster, and a barriers to movement raster.

The roads and vehicle tracks raster represented mechanised access and defined the source locations of the least cost paths. The roads and vehicle tracks were sourced from Road Link. First, motorways, slip roads, dual carriageways, roundabouts, and guided busways were removed from the dataset as they generally do not afford access. Then, the dataset was clipped to the extent of analysis (that 5 km buffer envelope of the study area) and converted from vector to raster.

The DTM (Bluesky's 2022 Photogrammetric DTM) was used to calculate (1) the actual surface distance covered when passing through each cell and (2) the slope used to determine the vertical factor incurred when moving from one cell to another, as defined by Tobler's hiking pace function. It was prepared in much the same way as the DSM (see section 4.1.2).

The cost surface raster was used to modify walking pace through cells covered by land cover types that are relatively difficult to traverse. Following Carver et al. (2012) and Müller et al. (2018), normal walking pace was considered 5 km/h, walking pace through broadleaved woodland 4 km/h, through coniferous forest and heather 3 km/h, and

through bog, fen, marsh, and swamp 2 km/h. Cost here is a multiplier of pace, so in the cost surface dataset, a regular cell = 1 (multiply pace (s/m) by 1, pace is unaltered), a cell covered by broadleaved woodland = 1.25 (simply 5 over 4; multiply pace by 1.25, pace is reduced), a cell covered by coniferous forest or heather = 1.66 (5 over 3; multiply pace by 1.66, pace is reduced to a greater extent), and a cell covered by bog, fen, marsh, or swamp = 2.5 (5 over 2; multiply pace by 2.5, pace is reduced to an even greater extent). The different land cover types were sourced from the Land Cover Map, the National Forest Inventory, and the Native Woodland Survey of Scotland. The Land Cover Map was reclassified so broadleaved woodland = 1.25, coniferous woodland (i.e., coniferous forest), heather, and heather grassland = 1.66, bog, saltmarsh, and fen, marsh, and swamp = 2.5, and everything else = 1. The National Forest Inventory identifies broadleaved woodland and coniferous forest. These two land cover types were extracted from the dataset, clipped to the extent of the analysis, and converted from vector to raster. Then, the raster was reclassified so broadleaved woodland (and mixed but mainly broadleaved woodland) = 1.25 and coniferous forest (and mixed but mainly coniferous forest) = 1.66. The Native Woodland Survey of Scotland only identifies broadleaved woodland (at least in and around the study area). It was extracted from the dataset and processed the same as the National Forest Inventory data.

The barriers to movement raster defined cells that cannot be traversed. They cannot be traversed because they are occupied or covered by at least one of the following barriers to movement: a building, a structure, a restricted site, a motorway, a dual carriageway, a roundabout, a railway, a watercourse, a waterbody, a slope greater than 45°. With the exception of slopes greater than 45°, the barriers to movement were sourced from Building Part, GB Railways, Rail, Road Link, Structure, Structure Line, Water, and June 2023 downloads of Ordnance Survey's Site and Water Link datasets (Ordnance Survey's point structures, representing structures too small to be represented by polygons, were assumed too small to form an obstruction). First, certain features were either extracted or removed from certain datasets. Motorways, slip roads, dual carriageways, and roundabouts were extracted from Road Link, restricted sites such as allotments, private gardens, schools, sports grounds, construction sites, and quarries were extracted from Site, and dams, retaining walls, flood controlling walls, and built

obstructions were extracted from Structure Line as the dataset also includes countless unobstructive features. Archways, lych gates, roofed bandstands, and multistorey car parks were removed from Building Part, features including pylons and dry reservoirs were removed from Structure, and buried features and coniferous trees were removed from Water because they can be passed through/over. Then, each vector dataset was clipped to the extent of analysis and converted from vector to raster. Next, the numerous rasters were reclassified to be binary and combined through calculation of the maximum. Afterwards, features such as paths, footbridges, subways, and level crossings were extracted from a June 2023 download of Ordnance Survey's Path Link dataset, clipped to the extent of analysis, and converted from vector to raster. The raster was reclassified to be binary and used to modify the barriers to movement raster so that cells occupied by such features could be rightfully traversed. This was a critical step as without the modification, one could not, for example, cross the River Clyde. Slopes greater than 45° were derived from the DTM. Slopes were calculated and reclassified so slopes greater than $45^\circ = 1$ and all others = NoData. The reclassified raster was then combined with the other barriers to movement through calculation of the maximum.

4.1.4. Mapping ruggedness and physical challenge of the terrain

Ruggedness and physical challenge of the terrain was determined by terrain complexity analysis. Following Carver et al. (2012), Müller et al. (2015), and Radford et al. (2019), it was determined by calculating the standard deviation of terrain curvature of all cells within a 250 m radius of each target cell. The higher the standard deviation, the steeper and rougher the terrain. Again, the figure of 250 m is taken to represent the extent of the surrounds an individual would be expected to experience.

The first step was to calculate the curvature of the DTM. Of course, high spatial resolution DTMs not only capture terrain, but also artificial features such as raised roads (Müller et al., 2018). Such features tend to score highly in such analyses and the potentially higher standard deviation of such locations would, rather than an attribute of wildness, indicate something quite the opposite (Aznarez et al., 2022). For this reason, the artificial features of the artificial features raster created for the viewshed analysis were removed from the terrain curvature raster prior to the calculation of the

standard deviation. First, the artificial features raster was clipped to the extent of analysis (that 5 km buffer envelope of the study area) and reclassified so artificial features = 0 and everything else = 1. Then, the terrain curvature raster was multiplied by the reclassified artificial features raster. The values of the reclassified artificial features raster meant cells occupied by an artificial feature acquired a value of 0, while all other cells retained their terrain curvature value. After that, the 0s were changed to NoData.

The standard deviation of terrain curvature of all cells within a 250 m radius of each target cell was then calculated. NoData values were ignored, meaning the target cell would still obtain a standard deviation value if one or more NoData values existed within its 250 m neighbourhood. The calculation would simply be based on the cells with data values. There were just two examples of neighbourhoods with not one data value within them. In this scenario, the target cell obtains a NoData value. The two NoData values were changed to 0s.

Certainly, not all physically challenging terrain is rugged (Scottish Natural Heritage, 2014; Aznarez et al., 2022). As noted above, bog, fen, marsh, and swamp is particularly difficult to traverse, and it is generally found on flatter ground. This being so, and following Müller et al. (2018) and Aznarez et al. (2022), the mean standard deviation of terrain curvature (0.3) was added to cells covered by bog, fen, marsh, or swamp using a reclassification of the Land Cover Map (bog, fen, marsh, and swamp = 0.3 and everything else = 0).

4.1.5. Checking for correlation of indicator layers

Strong correlations between single indicators can seriously bias results (Carver et al., 2011; Müller et al., 2015). Accordingly, the correlation coefficients between each combination of two indicator layers (table 3) were calculated. Values of 0-0.19 represent very weak correlations, 0.2-0.39 weak, 0.4-0.59 moderate, 0.6-0.79 strong, and 0.8-1 very strong (Evans, 1996). There is a moderate positive relationship between perceived naturalness of land cover and remoteness from mechanised access. This suggests a noticeable trend, but also significant variability.

Table 3: Pearson correlation matrix of the four indicator layers (1 = perceived naturalness of land cover, 2 = absence of noise and modern human artefacts, 3 = remoteness from mechanised access, 4 = ruggedness and physical challenge of the terrain)

	1	2	3	4
1	1.00000	0.13075	0.50155	0.29601
2	0.13075	1.00000	0.05031	-0.08412
3	0.50155	0.05031	1.00000	0.10064
4	0.29601	-0.08412	0.10064	1.00000

4.1.6. Weighting and combining the indicator layers

GIS-based MCE methods were used to weight and combine the four indicator layers. The results of such methods tend to be highly sensitive to the weightings applied, so great care must be taken when defining the weightings (Carver et al., 2012; Carver et al., 2013). The output index must be defensible despite its relative nature (Carver et al., 2011). Fortunately, there have been Scottish wildness perception surveys. Following Carver et al. (2012) and Müller et al. (2015), the weighting scheme (table 4) was derived from the results of the 2008 survey commissioned by Scottish Natural Heritage (Market Research Partners, 2008) and guidance provided by the project steering group Carver et al. (2012) worked alongside (with equal weights used as a benchmark). The survey asked a sample of 1 004 Scottish residents representative of the population of Scotland about their perceptions of wild places and landscapes in Scotland. The derived weighting scheme is based on the responses to a question asking what features or

Table 4: The weighting scheme used to weight the indicator layers

Attribute of wildness	Weight
Naturalness	0.48
Untouchedness	0.16
Remoteness	0.32
Ruggedness	0.04

characteristics make an area wild. Each mentioned feature or characteristic was scored as the percentage of respondents that mentioned it, then all mentioned features and characteristics were classified in accordance with the four basic attributes of wildness (naturalness, untouchedness, remoteness, and ruggedness).

To allow weighting, the values of the indicator layers were normalised onto the 0-255 common relative scale introduced above. The weightings were applied and the indicators were combined within a weighted linear combination MCE model (equation 2).

$$RW_j = \sum_{i=1}^n W_{ij}NX_{ij}$$

Equation 2: The weighted linear combination MCE model used to weight and combine the indicator layers

where RW_j is the overall relative wildness value of cell j in the resulting relative wildness map, n is the number of indicators, i is the current indicator's number, W_{ij} is the weighting applied to cell j in indicator map i , and NX_{ij} is the normalised value of cell j in indicator map i .

4.2. Surveying locations containing areas of high relative wildness

Locations containing areas of high relative wildness were surveyed to determine whether they are potential urban wildness areas. First, aerial imagery (Bluesky's 2022 12.5 cm Aerial Photo), a large-scale Ordnance Survey map (VectorMap Local – Colour Raster), and all land use and cover data used for mapping relative wildness was examined to determine the urban habitat type and, as far as possible, the land management intensity of each location. Then, during January and February 2024, a visit was made to each location with a natural urban habitat type subject to an apparently low land management intensity to (1) determine the degree of accessibility, (2) estimate ecological wildness and greenness, (3) record which of the three elements of

Fredrickson and Anderson’s (1999) psychologically oriented definition of wilderness it appears to provide (direct contact with nature, periods of solitude, and inherent physical challenges), and (4) take photographs as evidence (with the information collected using QField 3.1.9, QFieldCloud, and QGIS 3.28.8).

For a structured, objective appraisal, ecological wildness and greenness was estimated using the wildness and greenness components of Hand et al.’s (2016) bioscore method. The method’s wildness component is an assessment of naturalness and management. The naturalness metric (table 5) reflects how altered a habitat is from a hypothetical natural state and the management metric (table 6) represents the spectrum from a completely controlled environment to one under very little human influence. The standalone greenness metric is the percentage coverage of vegetation of the ground and canopy rescaled to a 0-4 range. Greenness is a commonly applied metric in both social

Table 5: The five naturalness classes of the wildness component of Hand et al.’s (2016) bioscore method

Class	Description
0	Completely artificial (e.g., concrete surface).
1	Predominantly artificial with some natural features present.
2	Mix of natural and artificial features.
3	Natural with some alteration.
4	Natural with minimal alteration.

Table 6: The five management classes of the wildness component of Hand et al.’s (2016) bioscore method

Class	Description
0	Completely controlled environment.
1	Mostly human-influenced environment, but some natural features.
2	Half-controlled, half-natural features.
3	Slightly visible human influence.
4	No visible human influence.

and ecological studies. It is linked to positive perceptions of sites (Wells, 2000; Lee et al., 2008). Finally, regarding urban habitat types, Hand et al. (2016) identify 13. These 13 were reclassified into six broader, more comprehensible urban habitat types: woodland, natural, vacant lot/fringe vegetation, agricultural, artificial vegetation, and paved (table 8).

4.3. Determining the urban habitat type composition of the wildest and least wild areas

First, land use and cover data from the Land Cover Map, the Native Woodland Survey of Scotland, the National Forest Inventory, Improvement Service's 2024 Vacant and Derelict Land dataset, and April 2024 downloads of Scottish Government's Agricultural Land Parcels dataset and Ordnance Survey's MasterMap Greenspace, Rail, Road Track or Path, and Site datasets was (1) reclassified into the six broad urban habitat types defined in table 7 (see Appendix D) and (2) combined to create a composite urban habitat map (see Appendix E). The data was combined so vacant lot/fringe vegetation data (Vacant and Derelict Land, Rail, and Road Track or Path) > woodland data (the Native Woodland Survey of Scotland and the National Forest Inventory) > agricultural data (Agricultural Land Parcels) > artificial vegetation data (Greenspace and Site) > the underlying Land Cover Map (data for the woodland, natural, agricultural, and paved urban habitat types): an order of precedence that reflects the relative granularity of the input datasets. Then, the 1%, 5%, and 10% of all cells with the highest and lowest relative wildness scores were extracted from the output of the MCE (three thresholds easily understood by most people (Fisher et al., 2010)). The extracted data was converted from raster to vector and made single multipart polygons. The urban habitat type composition of these areas was determined by clipping the urban habitat map to them and calculating percentages from the counts.

4.4. Establishing whether the wildest areas are protected

The distribution of the 1%, 5%, and 10% of all cells with the highest relative wildness scores were compared to the distribution of areas of green belt, Country Parks, LNRs,

Table 7: The urban habitat type typology used for recording dominant urban habitat type(s)

Reclassified urban habitat type	Hand et al. (2016) urban habitat type	Description
Woodland	Woodland	Area dominated by continuous tree cover.
Natural	Natural	Non-woodland area largely maintained in a native state (e.g., grassland).
Vacant lot/fringe vegetation	Vacant lot/fringe vegetation	Dominantly vegetated area with unmanaged or un-landscaped vegetation (e.g., abandoned lot or road verge).
Agricultural	Agricultural	Arable or pastoral land use area.
Artificial vegetation	Parkland	Area dominated by lawns with flowerbeds and planted trees.
	Recreational green	Managed grassland maintained for sports activities (e.g., football pitch).
	Garden 1	Garden rich area (> 1/3 of lot size is garden) dominated by tree and scrub vegetation.
	Garden 2	Garden rich area (> 1/3 of lot size is garden) low in tree and scrub vegetation.
Paved	Open public area	Largely paved area open for public use.
	Recreational paved	Paved area designed for sports or play (e.g., tennis court or playground).
	Street	Street or road in a non-residential area and associated landscaped vegetation.
	Residential street	Street in a residential area and associated landscaped vegetation.
	Garden 3	Garden poor area (< 1/3 of lot size is garden) low in tree and scrub vegetation.

SINCs, SSLIs, SSSIs, and Tree Preservation Orders (TPOs; Appendix F) through calculation of overlap percentages. The protected areas datasets were sourced from Glasgow City Council and NatureScot. Glasgow City Council designates areas of green

belt, SINCs, SSLIs, and TPOs. Areas of green belt prevent urban sprawl by protecting land against development (Department for Levelling Up, Housing and Communities, 2023), SINCs protect locally important natural heritage (NatureScot, 2024a), SSLIs protect features that are important components of the wider landscape character (Glasgow City Council, 2017), and TPOs protect individual trees, groups of trees, or woodlands that have amenity value or make a significant contribution to the landscape (Glasgow City Council, 2024). NatureScot designates Country Parks, LNRs, and SSSIs. Country Parks are managed by local authorities and protected as convenient opportunities for people to enjoy the countryside and open-air recreation in or close to urban areas (NatureScot, 2020), LNRs protect locally important natural heritage (NatureScot, 2024b), and SSSIs protect land that best represents Scotland's natural heritage, in terms of its flora, fauna, geology, or geomorphology (NatureScot, 2024c).

5. Results

5.1. Where in Glasgow's Southside are areas of high relative wildness located?

Maps of each of the four basic attributes of wildness and relative wildness (figures 7-14) are presented across the following five subsections. They are presented on the abovementioned common relative scale from low wildness (0; dark blue) to high wildness (255; bright yellow).

5.1.1. Perceived naturalness of land cover

The perceived naturalness of land cover map (figure 7) shows a strong spatial pattern that distinguishes between built-up areas as relatively low perceived naturalness of land cover and greenspace as relatively high and moderate perceived naturalness of land cover. The areas of high perceived naturalness of land cover are (1) dominated by native broadleaved woodland and (2) situated within areas of greenspace large enough to provide at least mostly natural 250 m vicinities (a 250 m vicinity being the extent of the surrounds an individual would be expected to experience). The areas of greenspace bordering (i.e., less than 250 m from) built-up areas are unable to provide mostly natural 250 m vicinities. This creates the buffer of relatively moderate perceived naturalness of land cover that separates the areas of relatively high and low perceived naturalness of land cover.

There is relatively high perceived naturalness of land cover within each of the locations noted in section 3 as locations that possess attributes of wildness. The attribute is most intense within Pollok Country Park. This extensive area of relatively high perceived naturalness of land cover is North Wood. The wood is a largely native broadleaved woodland, and approximately 500 m north to south and 1 km east to west, comfortably large enough to provide entirely natural vicinities. The attribute is also comparatively intense ($P_{99} (\geq 198.5)$) and extensive in and around Bull Wood and Hurtlehill Plantation

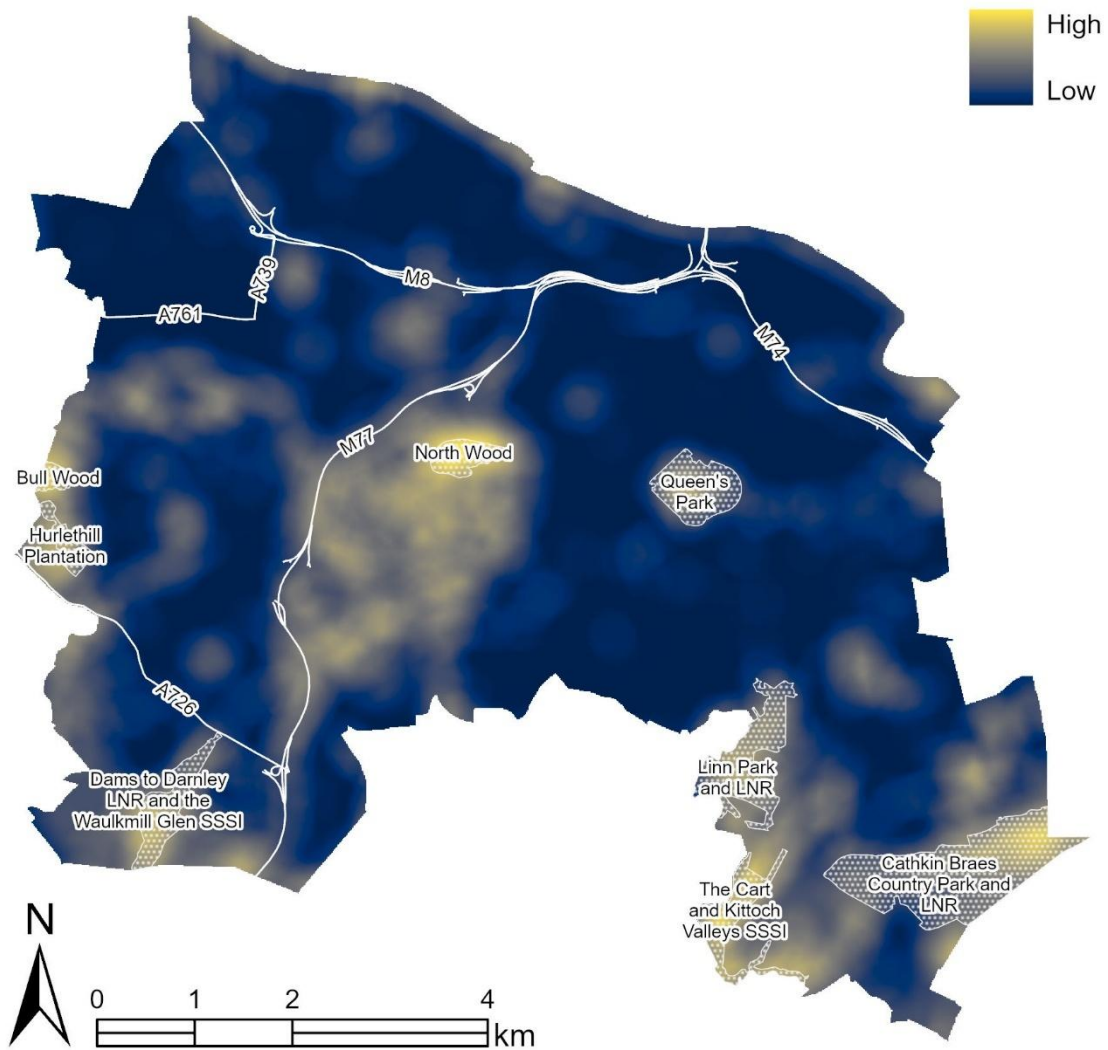


Figure 8: Perceived naturalness of land cover across Glasgow's Southside

to the west, within Dams to Darnley Country Park and LNR and the Waulkmill Glen SSSI to the southwest, and in and around the Cart and Kittoch Valleys SSSI and within Linn Park and LNR and Cathkin Braes Country Park and LNR to the southeast. Bull Wood is a mainly native broadleaved woodland and Hurliehill Plantation is mainly coniferous forest. Both are surrounded by grassland. The area within Dams to Darnley Country Park and LNR and the Waulkmill Glen SSSI is a sizeable native broadleaved woodland a little short of 1 km north to south and approximately 250 m east to west. The Cart and Kittoch Valleys SSSI is a dense ancient woodland. The area within Linn Park and LNR is mainly grassland and two broadleaved woodlands. And the area within Cathkin Braes Country Park and LNR is Big Wood, a native broadleaved woodland approximately 200-300 m north to south and 2 km east to west. The attribute is also

comparatively intense in the centre of Queen’s Park, a 60-hectare park nestled between the residential areas of Battlefield, Crosshill, Mount Florida, Shawlands, and Strathbungo. This area, located on Camp Hill, is a native broadleaved woodland approximately 500 m north to south and approximately 200 m east to west.

5.1.2. Absence of noise and modern human artefacts

The absence of noise map (figure 8) reveals there is a relative absence of noise (< 65 dB) across much of the study area. The noisiest features (generally > 80 dB) are the motorways. Then there are the trainlines, the busiest roads, and certain sites of industry (65-80 dB). In general, the noise of these features is confined to narrow corridors and immediate areas and thus does not impact much or at all on greenspace. The noise of

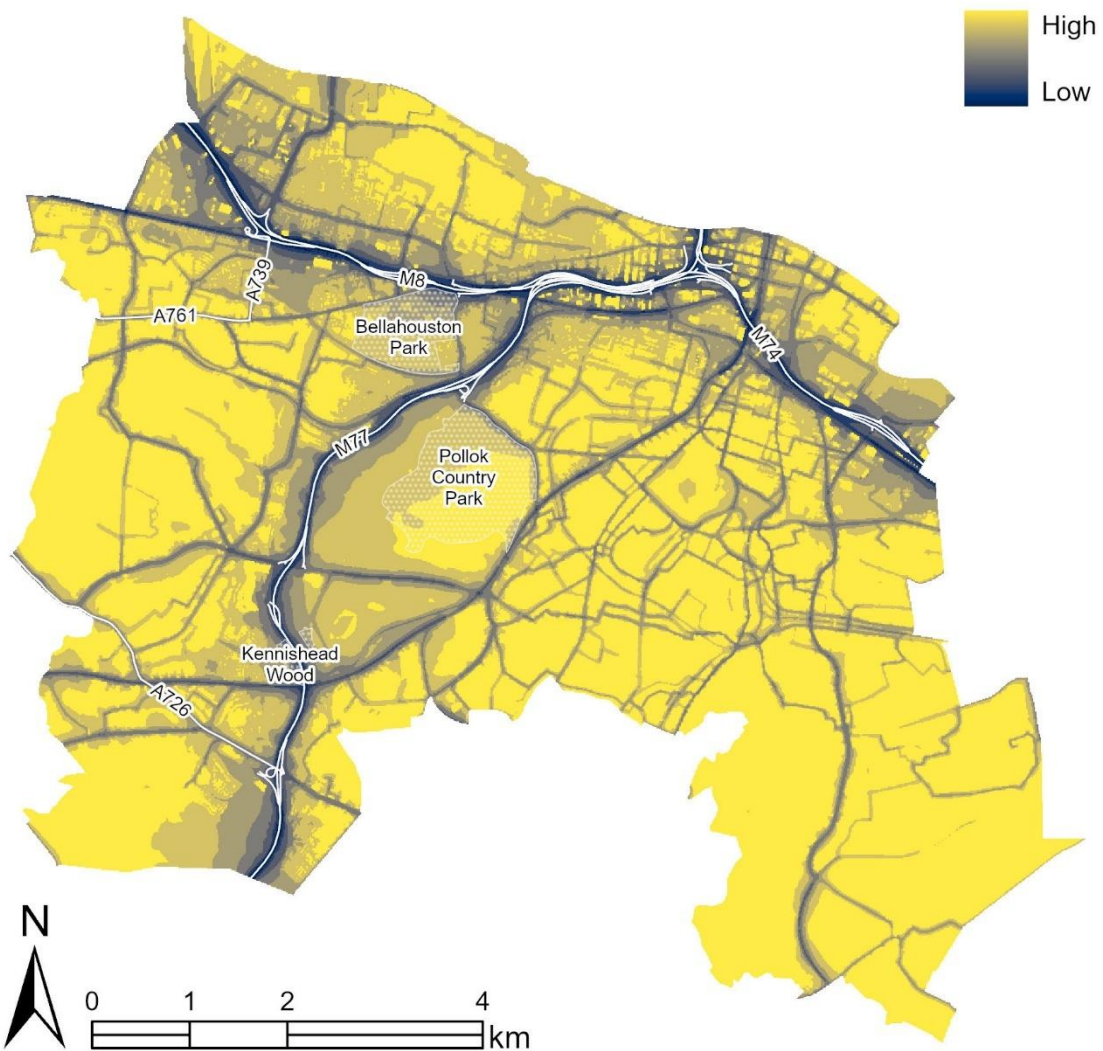


Figure 9: Absence of noise across Glasgow's Southside

of the motorways, however, can be heard across much wider corridors and certain areas of greenspace are impacted. The noise of the M8 and the M77 can be heard across Bellahouston Park and the noise of the M77 can be heard within Kennishead Wood and across the northwest of Pollok Country Park. These areas therefore score lower than other areas of greenspace.

The absence of modern human artefacts map (figure 9) shows there are only a limited number of places from which ≤ 10 modern human artefacts can be seen. Unsurprisingly, they are each situated within greenspace, with most situated within woodlands or the wooded areas of parks where vegetative screening clearly has some effect, and many situated in within hollows where views are clearly obscured by the surrounding

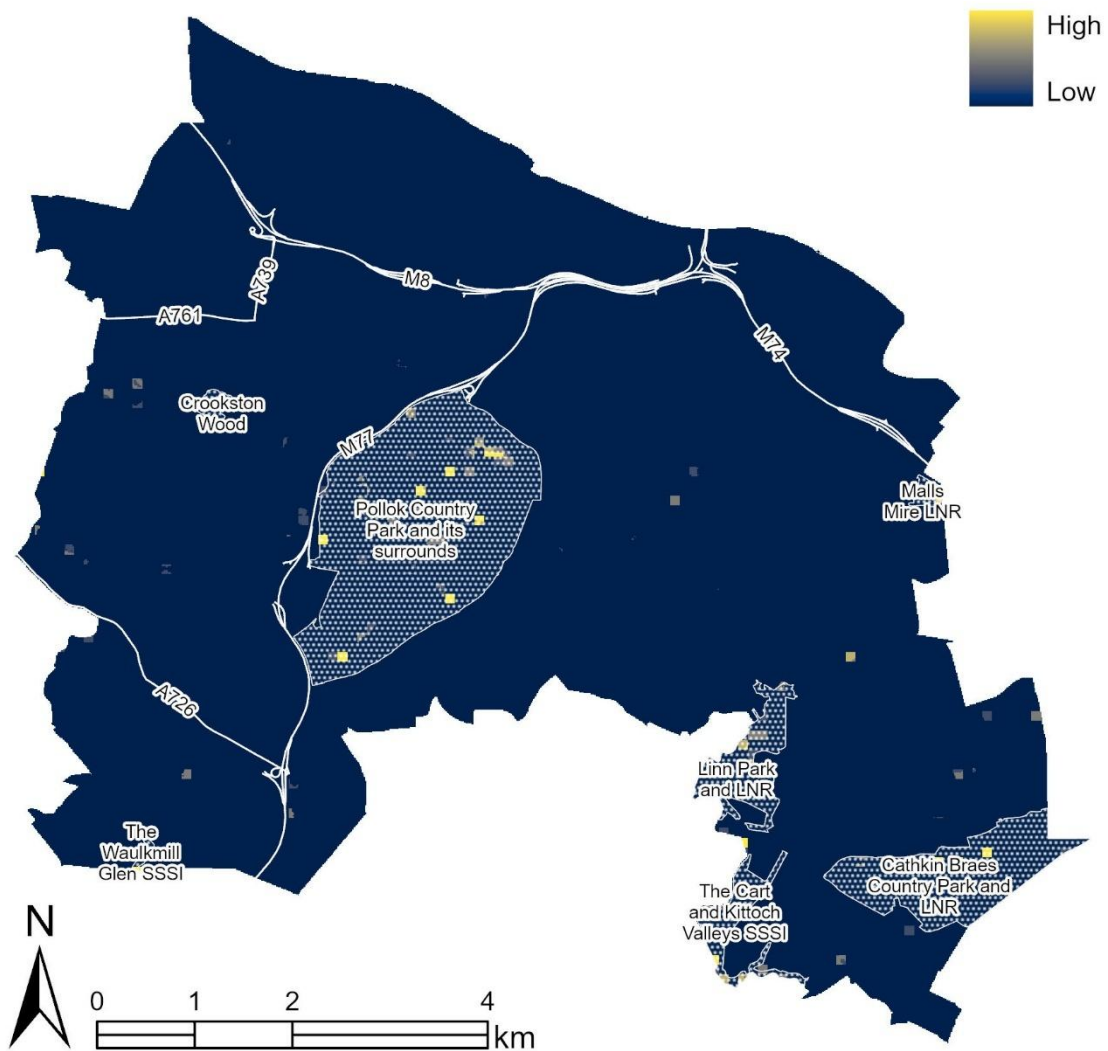


Figure 10: Absence of modern human artefacts across Glasgow's Southside

landforms. A large proportion of them are scattered across Pollok Country Park and its surrounds. There is also a cluster inside Linn Park and LNR. The rest are scattered across the study area. Areas from which no modern human artefacts can be seen cover just 0.2% of the study area. They are located within Crookston Wood, Malls Mire LNR, Linn Park and LNR, Cathkin Braes Country Park and LNR, the Waulkmill Glen SSSI, the Cart and Kittoch Valleys SSSI, and across Pollok Country Park and its surrounds.

The absence of noise and modern human artefacts map (Figure 10) shows there are very few places within the study area where an individual can experience a virtual absence of both road, rail, and industrial noise from the sonic landscape and artificial features from the visible landscape. To relate them to the preceding results, they are simply the

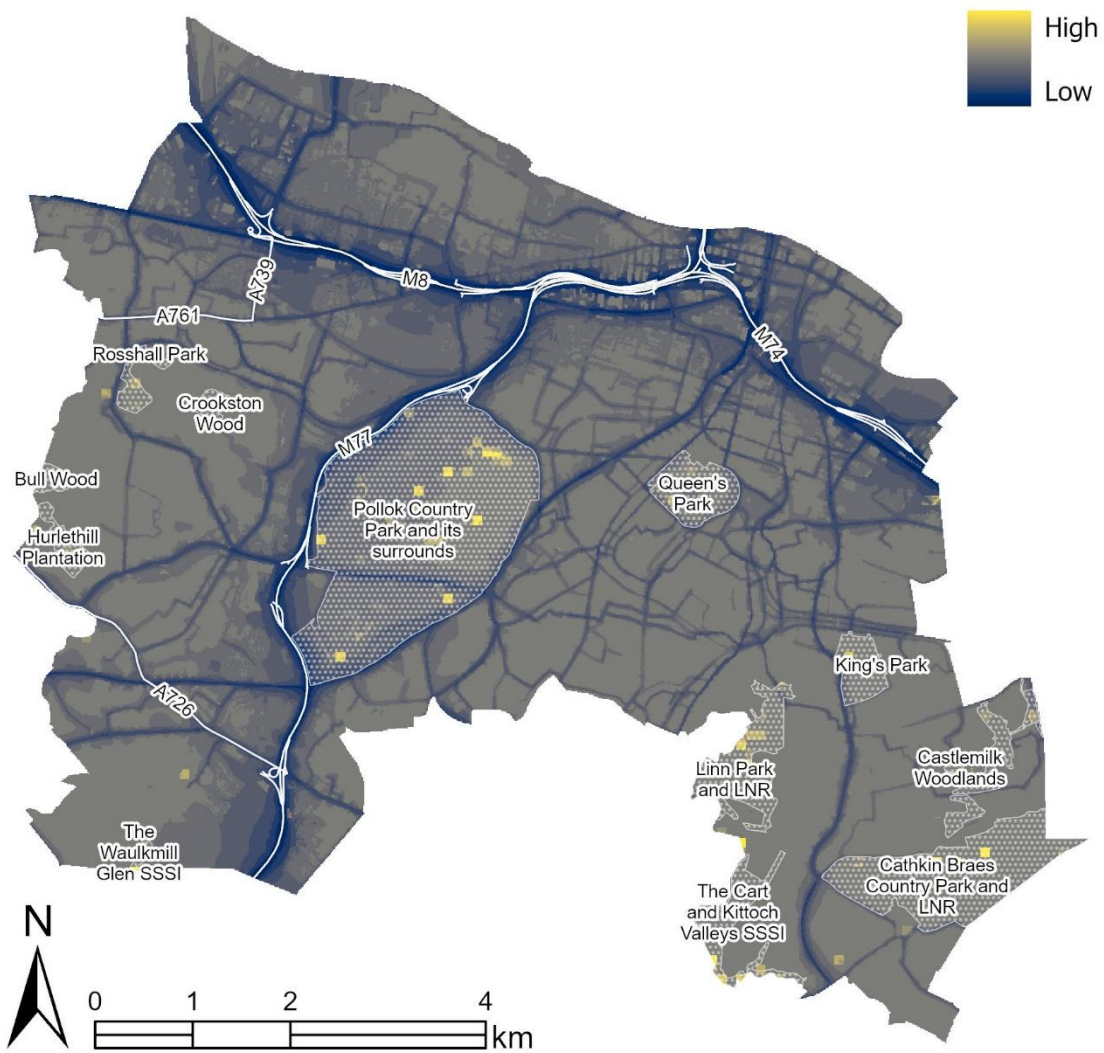


Figure 11: Absence of noise and modern human artefacts across Glasgow's Southside

places within the study area from which ≤ 10 modern human artefacts can be seen that do not fall or do not fall far within the corridors of noise created by the three motorways. The highest number are within Pollok Country Park. There are also clusters within Linn Park and LNR and the Cart and Kittoch Valleys SSSI. And there are some within Bull Wood, Crookston Wood, Castlemilk Woodlands, and Hurllehill Plantation, King's Park, Queen's Park, and Rosshall Park, and Cathkin Braes Country Park and LNR, the Waulkmill Glen SSSI, and the surrounds of Pollok Country Park.

5.1.3. Remoteness from mechanised access

Predictably, the remoteness from mechanised access map (figure 11) shows relatively remote areas are situated exclusively within greenspace. Remoteness was calculated from roads and vehicle tracks and comparatively few roads and vehicle tracks pass through greenspace. Additionally, the study area's greenspace tends to be at least partly wooded. Within the model, walking pace through broadleaved woodland is 4 km/h, 1 km/h down on normal walking pace.

Taking around 15 minutes to walk to from vehicular access, the areas of high relative remoteness ($P_{99} (\geq 149.5)$) appear to be in this group because they are almost completely surrounded by long, unbroken barriers to movement, meaning, in each case, the nearest vehicular access is not nearly the nearest road or vehicle track in terms of straight-line distance. The most extensive of these areas is the northwest corner of Pollok Golf Course. To the north is a river, to the east is a network of drains, to the south are more drains plus fences, and to the west is a fence then the M77 motorway. This means the nearest vehicular access is a vehicle track approximately 850 m south. The second most extensive area is the southwest corner of Househill Park, a 25-hectare park nestled between the residential areas of Nitshill, Roughmussel, and Househillwood. To the southeast is a river and to the southwest and northwest are dual carriageways, meaning the nearest vehicular access is a minor road approximately 1 km northeast. The third and final area is a thin strip of land sandwiched between the M77 and the trainline that runs between Glasgow Central and Paisley. To the southeast is the M77 and to the northwest is the trainline, meaning the nearest vehicular access is a minor road over 1 km southwest.

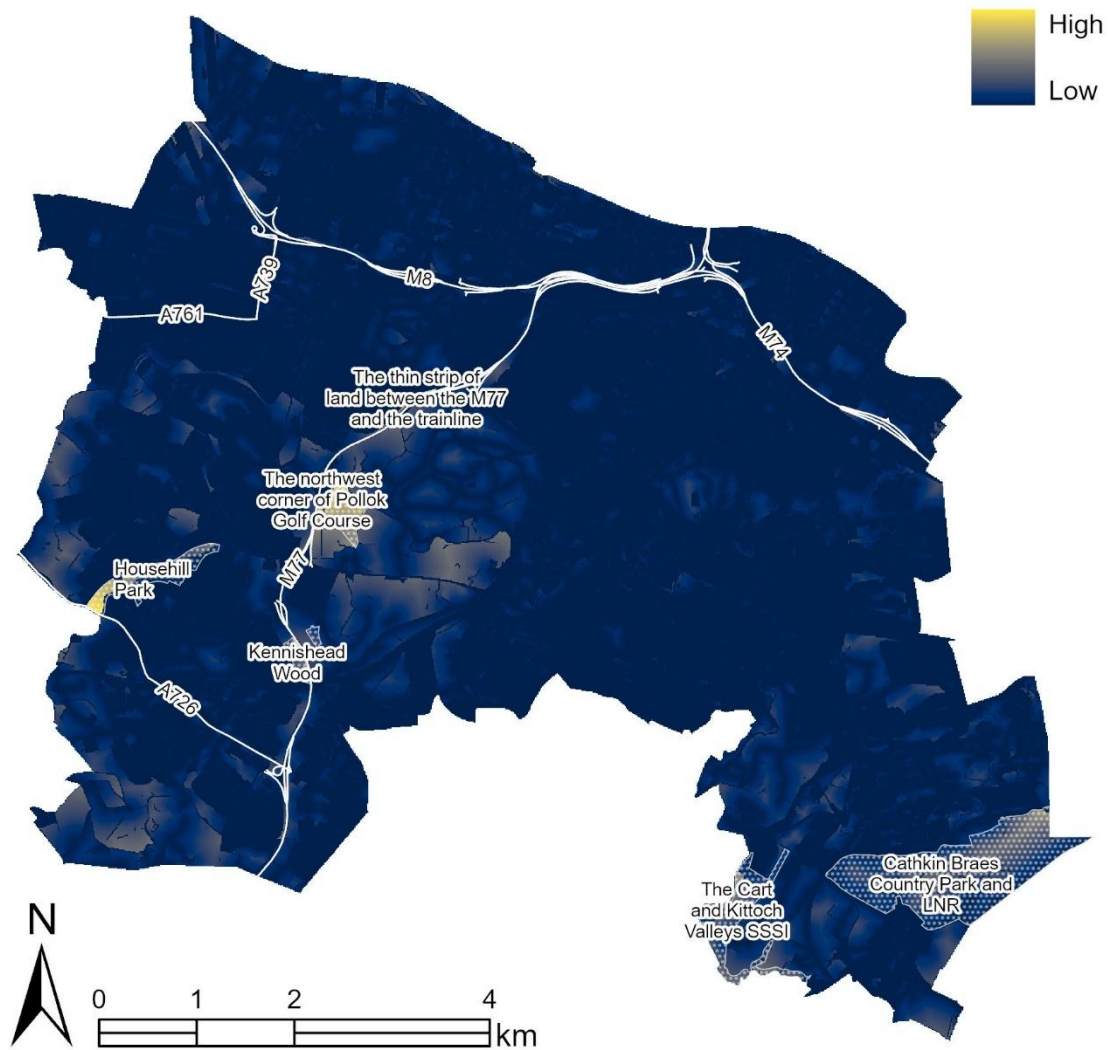


Figure 12: Remoteness from mechanised access across Glasgow's Southside

Next along the spectrum are numerous areas that take around 10 minutes to walk to from mechanised access. The most extensive of these are an area in the east of Cathkin Braes Country Park and LNR, an area in the north of the Cart and Kittoch Valleys SSSI, and an area within Kennishead Wood, along Brock Burn. These three areas highlight the influence of gradient if significant. The shortest paths between these areas and vehicular access are between half to quarter the length of those between the areas of high relative remoteness and vehicular access, but, despite this, they still take as much as two-thirds the time to reach. The clearest difference between these two groups in relation to model inputs is the absence/presence of appreciable vertical distances.

5.1.4. Ruggedness and physical challenge of the terrain

The ruggedness and physical challenge of the terrain map (figure 12) shows relatively rugged and physically challenging terrain is found across the study area, inside and outside of greenspace. Ruggedness and physical challenge of the terrain is controlled primarily by variability of terrain. It is therefore apparent such variability can be found across a suburban landscape. Steep-sided hills and steep wooded slopes are variability, but so too are the heavily developed River Clyde and the many motorway and rail embankments that support the local and national transport infrastructure.

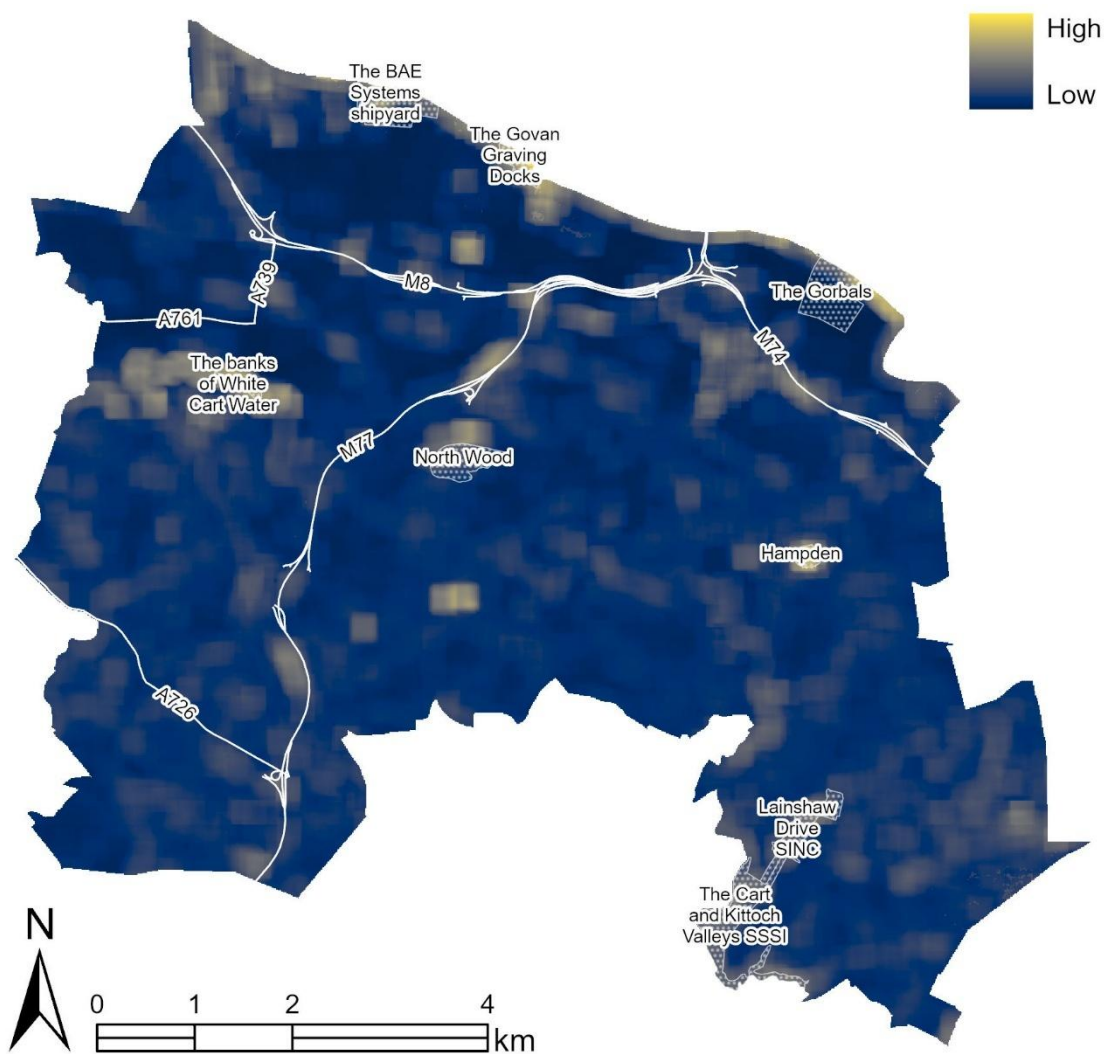


Figure 13: Ruggedness and physical challenge of the terrain across Glasgow's Southside

There are five sizeable areas of high relative ruggedness and physical challenge of the terrain ($P_{99} (\geq 144.5)$). Three of them are situated along the south bank of the River Clyde. The BAE Systems shipyard in Govan has a steep-sided dock. Additionally, the River Clyde is steep-sided at that point. The north bank opposite, a brownfield site, approximately 125 m away and therefore just within the shipyard's 250 m vicinity, rises quickly to a full 15 m higher than the river. The Govan Graving Docks are also steep-sided and there are three of them. In addition, the wider area is mostly covered by saltmarsh, one of the physically challenging terrains generally found on flatter ground. The heavily developed area of the Gorbals at first appears anomalous as the area is more or less flat. However, there is the River Clyde, and on the north bank opposite is Glasgow Green, a park that undulates and, within this area's 250 m vicinity, rises to more than 10 m higher than the river. The fourth area is the banks of White Cart Water, north of Crookston Wood. The banks are steep and at the top of the north bank are rail embankments. The fifth area is certainly anomalous. It is the perfectly flat playing surface of Hampden, Scotland's national stadium of football. The structure of the stadium, as recorded by Ordnance Survey, was, of course, ignored by the model. However, on close inspection, there is the slightest misalignment between the rasterized Ordnance Survey data and the DTM, meaning slithers of the steep-sided structure have entered into the model's calculations that have thus, in this instance, outputted false high relative ruggedness.

Next along the spectrum are countless areas of still comparably rugged and challenging terrain ($P_{95} (\geq 96.5)$). These include three steep-sided hills within North Wood, a steeply sloped area within the woodland of Lainshaw Drive SINC, and an area of rough terrain within the Cart and Killoch Valleys SSSI, close to the banks of White Cart Water. The rest are mainly stretches of motorway and rail embankments and other areas along the south bank of the river Clyde.

5.1.5. Relative wildness

The relative wildness maps (figures 13 and 14) distinguish built-up areas as low relative wildness and greenspace as high and moderate relative wildness. They also reveal intricate patterns in the variation of wildness that are difficult to discern through

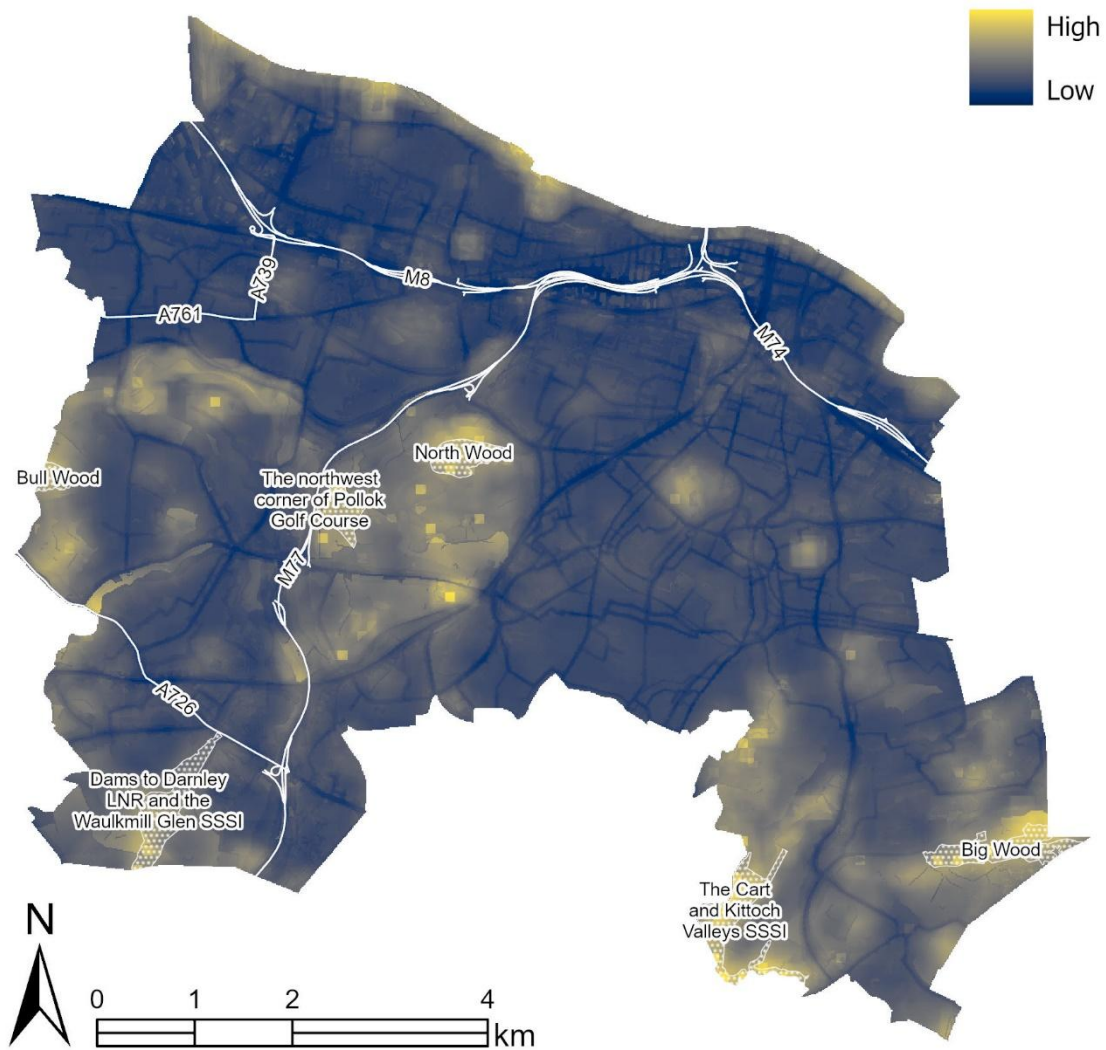


Figure 14: Relative wildness across Glasgow's Southside (equal weights)

scrutiny of the attribute maps alone. The relative wildness map generated using the survey weights (figure 14) identifies no less than six locations containing a sizeable area of high relative wildness ($P_{99} (\geq 203.5)$): Bull Wood, Pollok Country Park's North Wood, Cathkin Braes Country Park and LNR's Big Wood, Dams to Darnley LNR and the Waulkmill Glen SSSI (DTD LNR + WG SSSI), the Cart and Kittoch Valleys SSSI (CAKV SSSI), and the northwest corner of Pollok Golf Course (NW corner of PGC). The six locations are shown more clearly in figure 15. For context, they are shown alongside the wildest 1%, 5%, and 10% plus greenspace. Five of these locations or the wider location within which they are situated were noted in section 3 as locations that possess attributes of wildness. Their identification therefore comes as little surprise. The location not noted in section 3 is NW corner of PGC. It is also important to mention

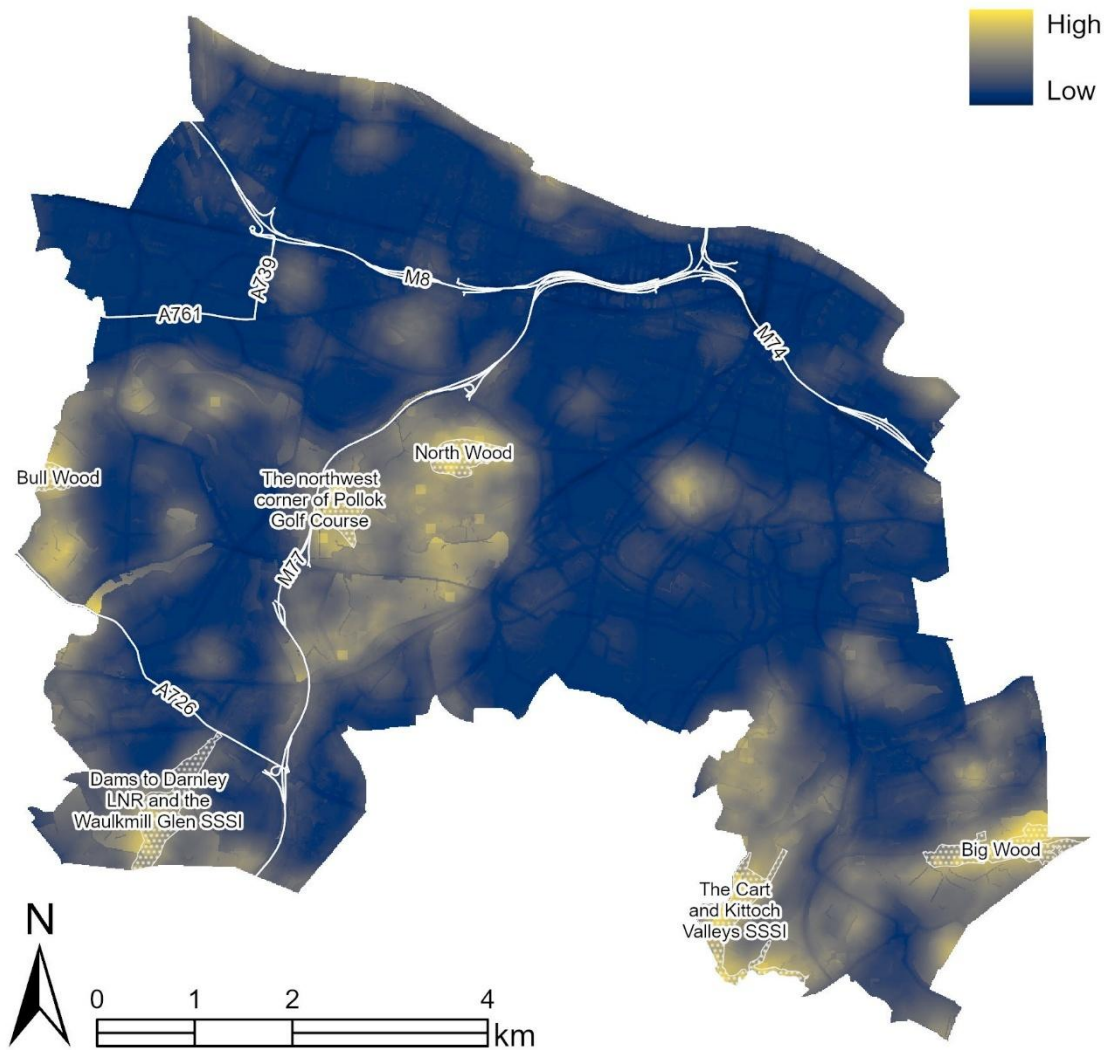


Figure 15: Relative wildness across Glasgow's Southside (survey weights)

not all locations noted in section 3 were identified. The omissions from this top tier of relative wildness are Hurlet Hill, Hurtlehill Plantation, Malls Mire LNR, and Linn Park and LNR.

Table 8 presents the locations' perceived naturalness of land cover statistics. Each location boasts areas of high perceived naturalness of land cover ($P_{99} (\geq 198.5)$), except for NW corner of PGC, which has a maximum value of 151, a value lower than the P_{95} threshold of 159.5. North Wood's maximum value is 255, the highest possible value on the adopted common relative scale. The high maximum values are unsurprising considering the attribute's weight of 0.48. Within the model, high perceived naturalness of land cover is almost a requirement of high relative wildness. Apart from North

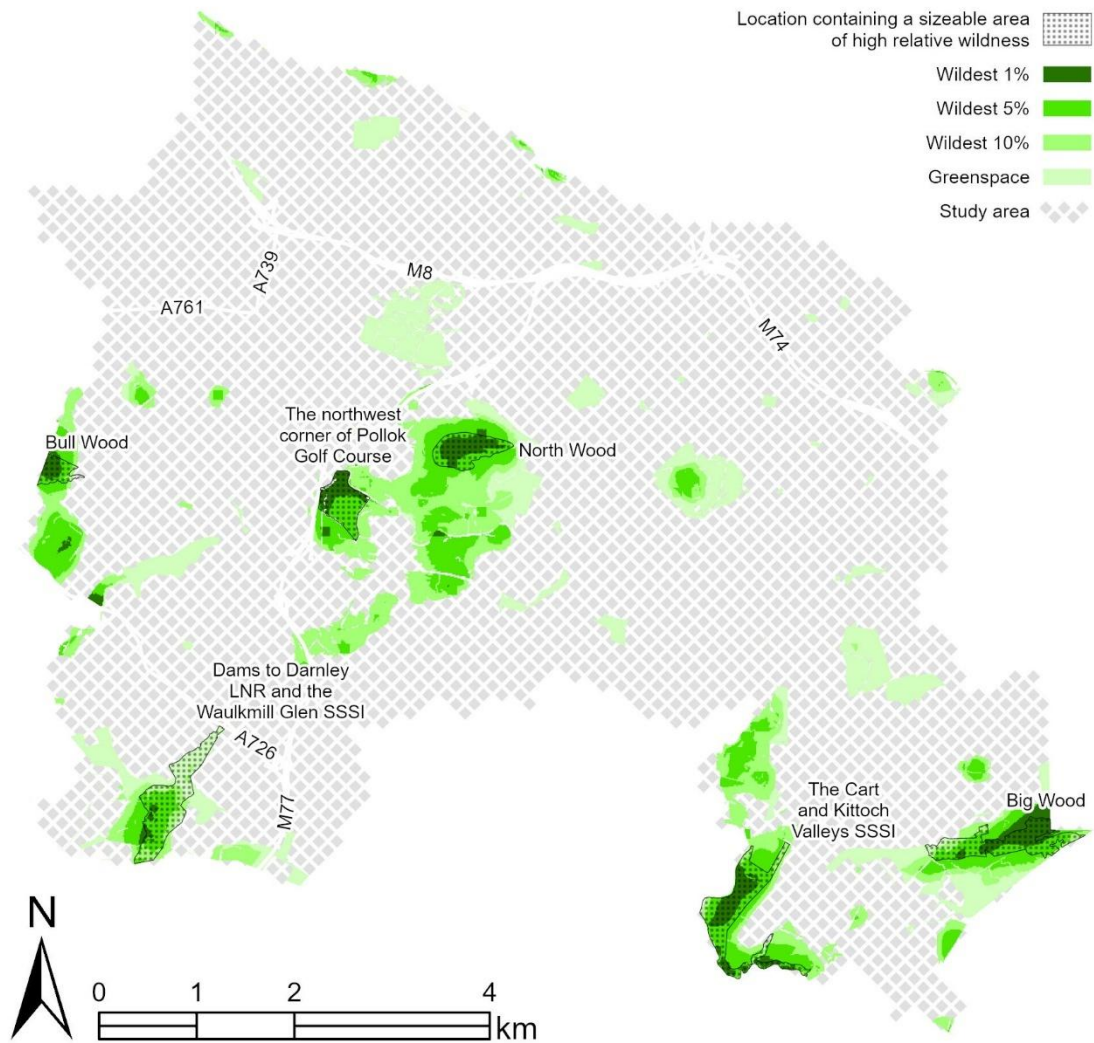


Figure 16: The six locations containing a sizeable area of high relative wildness ($P_{99} \geq 203.5$)

Wood, with a minimum value of 161, which is within P_{95} and so still comparatively intense, each of the six locations have low minimum values, far lower than the P_{95} threshold. These values most likely represent greenspace bordering built-up areas and, in most cases, result in a substantial range of values. Reflecting its high maximum and minimum values, North Wood has the highest mean and median values. NW corner of PGC and DTD LNR + WG SSSI have the lowest, reflecting NW corner of PGC's low maximum value and DTD LNR + WG SSSI's low minimum value.

Table 9 presents the location's absence of noise and modern human artefacts statistics. Five of the six locations have a maximum value of 255, meaning there are places within those five locations from which an individual can hear only limited noise and cannot

see any modern human artefacts. The exception once more is NW corner of PGC, which has a maximum value of 138. The obvious contributor towards this lesser value is the M77, which is situated alongside the location. Places from which ≤ 10 modern human artefacts can be seen that do not fall or do not fall far within the corridors of noise created by the three motorways cover just 0.8% of the study area. It is therefore unsurprising that each of the six locations have minimum, mean, and median values either lower than or around the midrange.

Table 8: *The perceived naturalness of land cover statistics of the six locations containing a sizeable area of high relative wildness ($P_{99} (\geq 203.5)$)*

Location	Min.	Max.	Range	Mean	Mdn.	SD
Bull Wood	82	232	150	195	203	31
North Wood	161	255	94	228	232	20
Big Wood	95	231	136	177	179	29
DTD LNR + WG SSSI	56	202	146	148	155	35
CAKV SSSI	106	233	127	184	185	23
NW corner of PGC	110	151	41	131	131	11

Table 9: *The absence of noise and modern human artefacts statistics of the six locations containing a sizeable area of high relative wildness ($P_{99} (\geq 203.5)$)*

Location	Min.	Max.	Range	Mean	Mdn.	SD
Bull Wood	127	255	128	130	127	19
North Wood	106	255	149	137	106	46
Big Wood	106	255	149	139	127	37
DTD LNR + WG SSSI	63	255	192	131	127	30
CAKV SSSI	127	255	128	133	127	23
NW corner of PGC	21	138	117	92	85	17

Table 10 presents the locations' remoteness from mechanised access statistics. With a maximum value of 240, a mean value of 173, and a median value of 181, NW corner of PGC is considerably more remote than the other five locations. Clearly, the location's inclusion within this top tier of relative wildness is an almost direct consequence of its high relative remoteness plus the attribute's weight of 0.32. While the other five locations' values are much lower, only North Wood's maximum value is lower than the P₉₅ threshold of 79.5. Each of the six locations have a minimum value of 0. This simply means all six locations include at least one road, vehicle track, or barrier to movement.

Table 10: *The remoteness from mechanised access statistics of the six locations containing a sizeable area of high relative wildness (P₉₉ (≥ 203.5))*

Location	Min.	Max.	Range	Mean	Mdn.	SD
Bull Wood	0	84	84	48	50	21
North Wood	0	55	55	16	12	14
Big Wood	0	125	125	58	63	30
DTD LNR + WG SSSI	0	118	118	23	16	23
CAKV SSSI	0	150	150	52	50	34
NW corner of PGC	0	240	240	173	181	47

Table 11 presents the locations' ruggedness and physical challenge of the terrain statistics. North Wood, Big Wood, and CAKV SSSI have a maximum value higher than the P₉₅ threshold of 96.5, meaning there is land within these three locations that is comparably rugged and physically challenging. Evidently, the other three locations are relatively flat and unchallenging. However, each of the six locations have low minimum values, which indicates there is also flat and unchallenging land within North Wood, Big Wood, and CAKV SSSI. CAKV SSSI has by some margin the highest mean and median values, with both values close to the P₉₅ threshold. This suggests a significant proportion of CAKV SSSI is comparably rugged and physically challenging.

Table 11: The ruggedness and physical challenge of the terrain statistics of the six locations containing a sizeable area of high relative wildness ($P_{99} (\geq 203.5)$)

Location	Min.	Max.	Range	Mean	Mdn.	SD
Bull Wood	25	50	25	43	46	7
North Wood	13	136	123	56	50	25
Big Wood	29	113	84	52	47	8
DTD LNR + WG SSSI	20	60	40	38	39	8
CAKV SSSI	30	140	110	90	91	17
NW corner of PGC	8	58	50	22	19	12

And table 12 presents the locations' relative wildness statistics. Of course, each of the six locations boast areas of high relative wildness ($P_{99} (\geq 203.5)$). However, each of the six locations have a minimum value lower than the P_{95} threshold of 156.5. For the most part, these values represent greenspace bordering built-up areas: greenspace in sight of buildings, close to mechanised access, and with a not entirely natural 250 m vicinity. The mean and median values of the six locations are around the P_{99} threshold, except for DTD LNR + WG SSSI, which has mean and median values around the P_{95} threshold, reflecting its noticeably low minimum value of 57 and the fact its boundary extends a distance north beyond the extents of the study area's wildest 1% and 5%.

Table 12: The relative wildness statistics of the six locations containing a sizeable area of high relative wildness ($P_{99} (\geq 203.5)$)

Location	Min.	Max.	Range	Mean	Mdn.	SD
Bull Wood	93	255	162	195	202	29
North Wood	148	247	99	206	207	18
Big Wood	102	244	142	191	195	31
DTD LNR + WG SSSI	57	246	189	150	153	33
CAKV SSSI	109	235	126	193	196	27
NW corner of PGC	103	249	146	200	201	24

5.2. Are these locations potential urban wildness areas?

Examination of the aerial imagery and spatial information revealed all but one of the six locations containing a sizeable area of high relative wildness ($P_{99} (\geq 203.5)$) have a natural urban habitat type subject to an apparently low land management intensity (see table 13). Unsurprisingly, the exception is NW corner of PGC. The imagery in figure 16 shows NW corner of PGC is simply a corner of a golf course, a mosaic of fairways, bunkers, and greens. Apart from some woodland, the location is heavily managed, and, as noted above, it is situated alongside the M77. It may be relatively remote from mechanised access, but relative remoteness from mechanised access alone does not make a potential urban wildness area. While respecting Nash's (1993, p. 1) notion that "one man's wilderness is another's roadside picnic ground," NW corner of PGC is simply not somewhere one would likely experience wilderness. Furthermore, it is unlikely the members of Pollok Golf Club would appreciate an influx of people seeking wilderness experience. Consequently, the decision was made to visit Bull Wood, North Wood, Big Wood, DTD LNR + WG SSSI, and CAKV SSSI, but not NW corner of PGC.

Table 13: Urban habitat type and apparent land management intensity of the six locations containing a sizeable area of high relative wildness ($P_{99} (\geq 203.5)$)

Location	Urban habitat type	Land management intensity
Bull Wood	Woodland	No apparent human influence.
North Wood	Woodland	Apparent minor human influence.
Big Wood	Woodland	Apparent minor human influence.
DTD LNR + WG SSSI	Woodland/natural	Apparent minor human influence.
CAKV SSSI	Woodland	No apparent human influence.
NW corner of PGC	Artificial vegetation/woodland	Mostly human-influenced environment, but some natural features.



Figure 17: Imagery of the northwest corner of Pollok Golf Course (a location containing a sizeable area of high relative wildness ($P_{99} \geq 203.5$))

Bull Wood is a small but dense woodland that straddles the boundary between the Glasgow City and Renfrewshire council areas. It is a mainly native broadleaved woodland. Its dominant species is birchwood. There are a couple of paths that assist entry into the wood. Within the wood, there is little other than the source of Blacksey Burn (figure 17, photograph 1), which runs into the nearby White Cart Water. There is no apparent land management, but there is a human impression. Unfortunately, the wood is heavily littered in places (e.g., photographs 2 and 3). With respect to Fredrickson and Anderson's (1999) psychologically oriented definition of wilderness, Bull Wood provides direct contact with nature (e.g., photographs 4 and 5) and, if one can disregard the faint sound of the M77, periods of solitude. However, being more or less completely flat (photograph 6), it surely fails to provide inherent physical challenges.

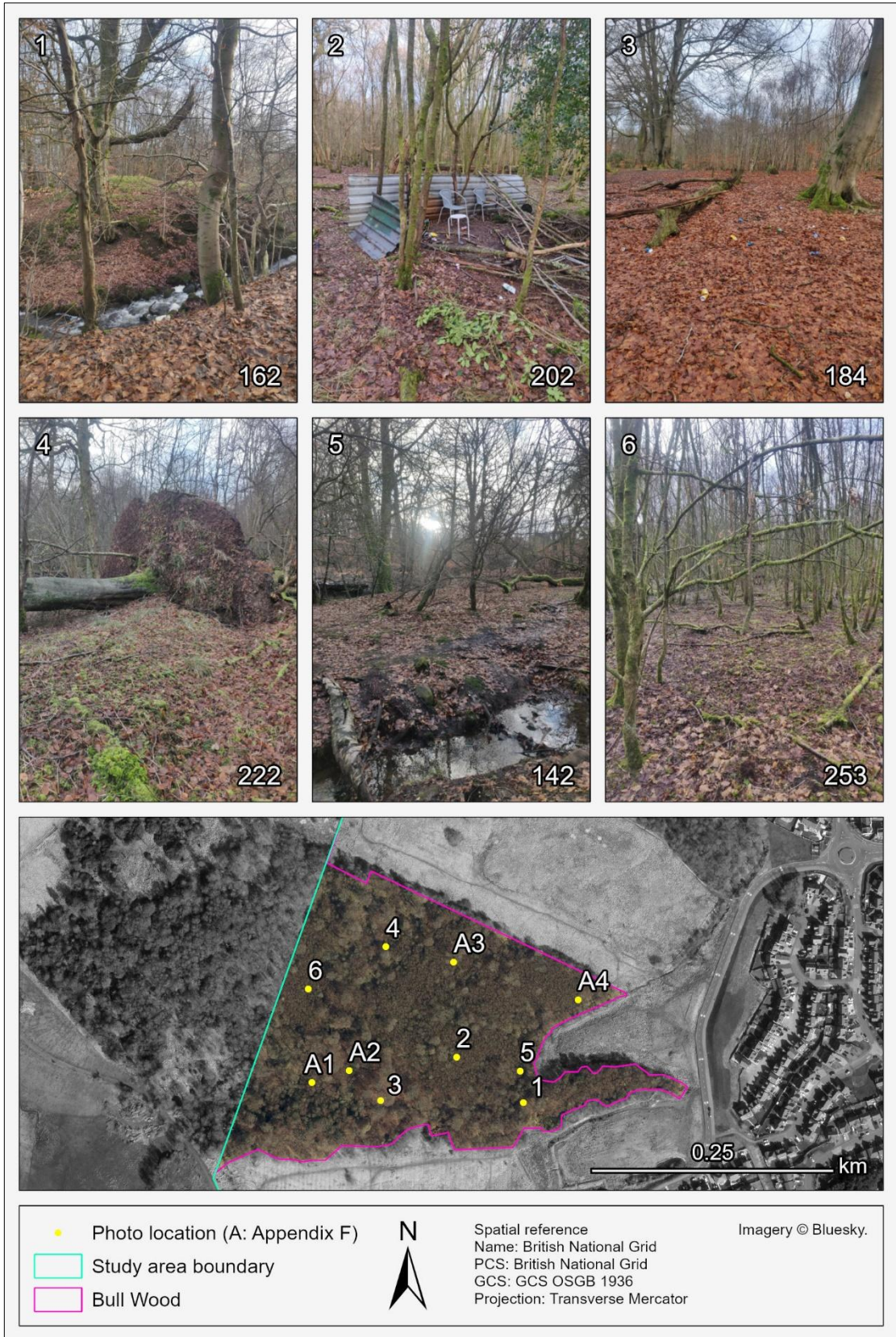


Figure 18: Imagery of Bull Wood with relative wildness scores of photograph locations (bottom right corner of photographs; photographs taken at locations with a label prefixed with A are presented in Appendix G)

North Wood is a dense and expansive woodland. It is a largely native broadleaved woodland made up of a mixture of different lowland deciduous trees. Regarding accessibility, there is a track that circles the wood and several tracks and paths that enter into it. There are signs of land management. There are drains (e.g., figure 18, photograph 1), evidence of felling (e.g., photograph 2), at least one information board (photograph 3), and some of the paths are surfaced. However, this is minimal land management and there is no visible human influence across its majority. North Wood provides direct contact with nature (e.g., photograph 4), some very challenging terrain (e.g., photograph 5) and flora (e.g., photograph 6) and so inherent physical challenges, and, if one can disregard the hum of the M77, periods of solitude.

Big Wood is a dense but narrow woodland. It is a native broadleaved woodland made up of a mixture of birchwood and different lowland deciduous trees. There are numerous paths that offer easy access into the wood. There are signs of land management. There are drains and there are mountain bike trails. However, again, this is minimal land management and there is no visible human influence across its majority. Big Wood provides direct contact with nature (e.g., figure 19, photograph 1) and some very challenging terrain (e.g., photograph 2) and flora (e.g., photograph 3) and so inherent physical challenges. However, it surely fails to provide periods of solitude. One can clearly hear the B759 (Cathkin Road) when near the study area boundary. And, from certain spots, one can see a police communications radio mast (photograph 4), the solitary wind turbine of Cathkin Braes Wind Farm (right of photograph 5), and indeed most of Glasgow (beyond the trees in photograph 6). That said, the wood was visited in the middle of winter when its trees were bare and their screen effect was least.

DTD LNR + WG SSSI is a mosaic of woodland and grassland. The woodland is native broadleaved woodland, a mixture of different lowland deciduous trees. Regarding accessibility, there are several paths that cross the location. There is a human footprint. There is a road, a small car park, drains, sluices, and surfaced paths (e.g., figure 20, photograph 1). Nevertheless, there are still areas with no visible human influence. DTD LNR + WG SSSI provides direct contact with nature (e.g., photographs 2 and 3), periods of solitude, and some challenging terrain (e.g., photographs 4 and 5) and flora (e.g., photograph 6) and so inherent physical challenges.



Figure 19: Imagery of North Wood with relative wildness scores of photograph locations (bottom right corner of photographs; photographs taken at locations with a label prefixed with A are presented in Appendix G)

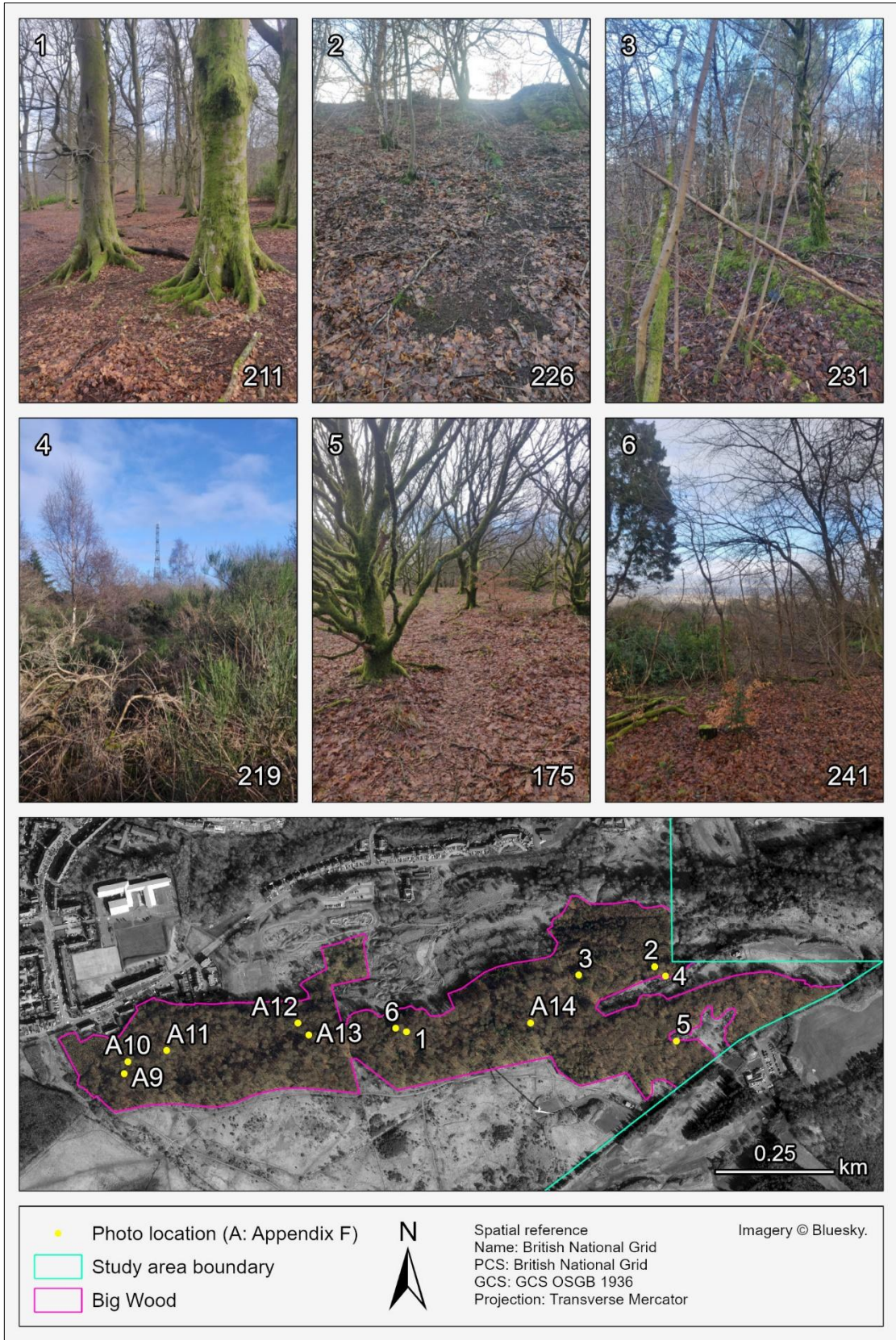


Figure 20: Imagery of Big Wood with relative wildness scores of photograph locations (bottom right corner of photographs; photographs taken at locations with a label prefixed with A are presented in Appendix G)



Figure 21: Imagery of Dams to Darnley LNR and the Waulkmill Glen SSSI with relative wildness scores of photograph locations (bottom right corner of photographs; photographs taken at locations with a label prefixed with A are presented in Appendix G)

CAKV SSSI is a dense and expansive woodland. It is an ancient native broadleaved woodland made up of a mixture of different lowland deciduous trees. There are just a couple of entry points on the northern edge of the wood and a few paths that lead south to its centre. There is no proper access to the wood's southern section, Kittoch Valley. There is no apparent land management within CAKV SSSI, but there is a slight human impression. There is an instance of heavy littering (figure 21, photograph 1) and there is a riverside hangout (photograph 2). CAKV SSSI provides direct contact with nature (e.g., photograph 3), including roe deer, with 10+ spotted during a two-hour visit. It also provides periods of solitude. Zero people were spotted and all one can hear is the fast flowing White Cart Water. The only reminder one is still in Glasgow is the occasional glimpse of the residential area of Stamperland through the trees (photograph 4). CAKV SSSI also provides some seriously challenging terrain (e.g., photographs 5 and 6) and so inherent physical challenges. That said, no responsible authority or initiative would encourage the general public to navigate the terrain of Kittoch Valley. Some of it is dangerously steep.

The results of the fieldwork are summarised in table 14. Each of the five locations score full marks for naturalness, meaning they are natural with minimal alteration, except for DTD LNR + WG SSSI, which scores 3, meaning it is natural with some alteration. This reflects its numerous manmade features. Bull Wood and CAKV SSSI also score full marks for management, meaning there is no visible human influence across these locations. The rest score 3, meaning there is a slight visible human influence (e.g., drains and evidence of felling). Each of the locations score full marks for greenness, meaning they have an 80-100% coverage of vegetation of the ground and canopy, except for DTD LNR + WG SSSI, which scores 3, meaning it has a 60-80% coverage. This reflects it being approximately half open grassland and thus having only a 40-60% crown cover. Finally, North Wood, DTD LNR + WG SSSI, and CAKV SSSI provide each of the three elements of Fredrickson and Anderson's (1999) psychologically oriented definition of wilderness. Big Wood fails to provide periods of solitude and Bull Wood fails to provide inherent physical challenges.

Despite scoring highly for ecological wildness and greenness, as Big Wood and Bull Wood fail to provide each of the three elements of the psychologically oriented



Figure 22: Imagery of the Cart and Kittoch Valleys SSSI with relative wildness scores of photograph locations (bottom right corner of photographs; photographs taken at locations with a label prefixed with A are presented in Appendix G)

Table 14: *The on the ground wildness scores and attributes of the five visited locations (Nat. = naturalness, Man. = management, Green. = greenness, CWN = (direct) contact with nature, POS = periods of solitude, and IPC = inherent physical challenges)*

Location	Nat.	Man.	Green.	CWN	POS	IPC
Bull Wood	4	4	4	Yes	Yes	No
North Wood	4	3	4	Yes	Yes	Yes
Big Wood	4	3	4	Yes	No	Yes
DTD LNR + WG SSSI	3	3	3	Yes	Yes	Yes
CAKV SSSI	4	4	4	Yes	Yes	Yes

definition of wilderness, one may reasonably conclude they are not potential urban wilderness areas. While Bull Wood could be considered as such because of the limited emphasis the wilderness perception survey respondents placed upon ruggedness as a characteristic of wilderness, the focus is on discovering locations that provide all three, of which Glasgow’s Southside apparently has three. On this basis, and on the basis they are each accessible, North Wood, DTD LNR + WG SSSI, and CAKV SSSI are potential urban wilderness areas. A study of DTD LNR + WG SSSI may want to focus on WG SSSI. If assessed independently, WG SSSI would have scored full marks for ecological wilderness and greenness. It also has a mean relative wilderness score of 182 (versus DTD LNR + WG SSSI’ 150) and a minimum relative wilderness score of 135 (versus DTD LNR’s 57). A study of CAKV SSSI should focus on its northern section, Cart Valley. Kitch Valley is perhaps too wild for the general public.

5.3. Which urban habitat types make up the wildest and least wild areas of Glasgow’s Southside?

The urban habitat type composition of the wildest and least wild areas of Glasgow’s Southside is presented in table 15. For context, the entire study area is 13.8% woodland, 6.1% natural, 5.7% vacant lot/fringe vegetation, 5.8% agricultural, 24.2% artificial vegetation, and 44.4% paved. The results show the MCE model has had a great deal of success distinguishing what is greenspace and what is built-up. The wildest areas are dominated by woodland (58.3%-84.4%), almost entirely unpaved (0.4%-2.7%), and

made up of a relatively small amount of artificial vegetation (9.7%-12.7%; wildest 1%: only NW corner of PGC). The least wild areas are more or less exclusively a combination of paved land (73.4%-82.3%), vacant lots/fringe vegetation (9.8%-15.2%), and artificial vegetation (1.6%-15.7%).

Table 15: Urban habitat type composition of the wildest and least wild areas of Glasgow's Southside (Wood. = woodland, VL/FV = vacant lot/fringe vegetation, Agri. = agricultural, AV = artificial vegetation, W = wildest, and LW = least wild)

Bracket	Wood.	Natural	VL/FV	Agri.	AV	Paved
W 1%	84.4%	3.1%	0.3%	2.1%	9.7%	0.4%
W 5%	67.3%	11.5%	1.1%	11.1%	8.0%	1.0%
W 10%	58.3%	13.7%	1.5%	11.1%	12.7%	2.7%
LW 1%	0.5%	0.0%	15.2%	0.4%	1.6%	82.3%
LW 5%	0.5%	0.1%	11.7%	0.5%	10.3%	76.9%
LW 10%	0.5%	0.1%	9.8%	0.5%	15.7%	73.4%

Table 16: Overlap percentages of the wildest areas and protected areas

Designation	Wildest 1%	Wildest 5%	Wildest 10%
Areas of green belt	97.6%	94.1%	90.0%
Country Parks	50.6%	42.0%	36.0%
LNRs	30.1%	25.6%	20.5%
SINCs	98.0%	86.6%	82.3%
SSLIs	69.7%	70.2%	69.8%
SSSIs	24.1%	10.8%	6.3%
TPOs	6.5%	5.4%	5.2%
Combined	99.9%	98.2%	96.6%

5.4. Are the wildest areas protected?

The wildest areas are well protected. 99.9% of the wildest 1%, 98.2% of the wildest 5%, and 96.6% of the wildest 10% is covered by at least one of the seven designations and therefore under some form of special protection (table 16). The unprotected wildest areas (or wildest areas not under some form of special protection) include a 500 m strip of land taking in parts of Hurllehill Plantation and the smaller Rocks Plantation (the area labelled 1 in figure 22), a 500 m strip of Kennishead Wood, along Brock Burn (the area labelled 2), and a 250 m² portion of Glen Wood, Castlemilk (the area labelled 3).

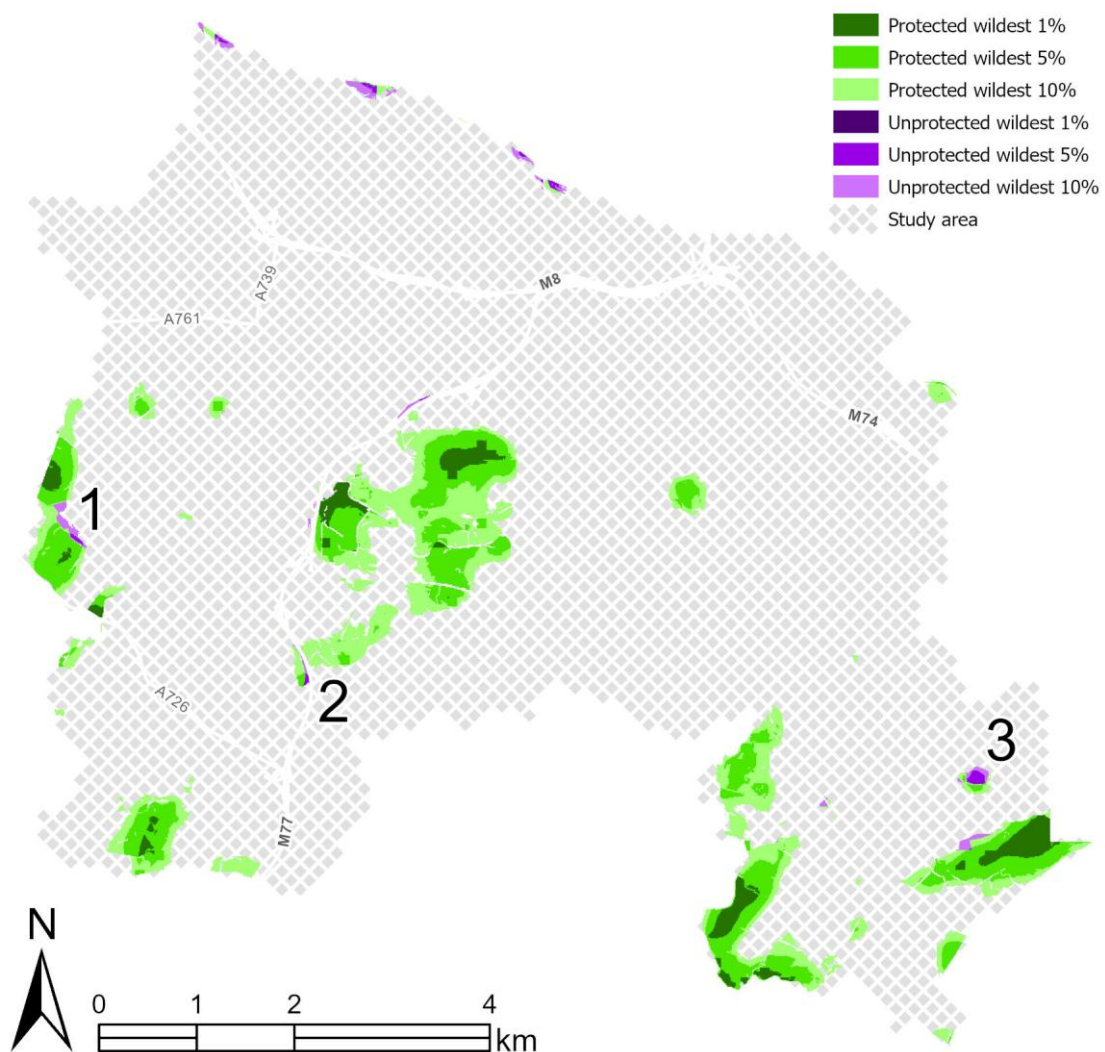


Figure 23: Protected and unprotected wildest areas (1, 2, and 3 = unprotected wildest areas; 1 = a 500 m strip of land taking in parts of Hurllehill Plantation and Rocks Plantation, 2 = a 500 m strip of Kennishead Wood, and 3 = a 250 m² portion of Glen Wood)

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6. Discussion

6.1. The results and their implications

6.1.1. Where in Glasgow's Southside are areas of high relative wildness located?

The RWM analysis distinguished six locations containing a sizeable area of high relative wildness: Bull Wood, North Wood, Big Wood, DTD LNR + WG SSSI, CAKV SSSI, and NW corner of PGC. While it has been argued an area must be of a certain size before it can be considered wilderness (McCloskey and Spalding, 1989; Ólafsdóttir and Runnström, 2011), no minimum size was applied here. Small, fragmented pockets of high relative wildness are important within urban environments. Despite being small and fragmented, they can still provide places for active recreation (Konijnendijk, 2005; Dvorak and Borrie, 2013), aesthetic enjoyment (Van den Berg and Koole, 2006), and interactions with nature (Zefferman et al., 2018). They should not be overlooked. They should at least be surveyed. The smallest of the six locations is Bull Wood. It covers an area of 0.08 km². The largest are DTD LNR + WG SSSI and CAKV SSSI. They both cover an area of 0.37 km², which is still some way short of the 400 000 ha minimum applied by McCloskey and Spalding (1989)! Theirs, though, was a global study.

Five of the six locations are or are dominated by native broadleaved woodland and are or are within locations noted in section 3 as locations that possess attributes of wildness. These five locations boast areas of high perceived naturalness of land cover, areas from which an individual can hear only limited noise and cannot see any modern human artefacts, and areas that are relatively remote. Three of them – North Wood, Big Wood, and CAKV SSSI – also boast areas of comparably rugged and challenging terrain. The unexpected result is NW corner of PGC. As established in section 5.2, NW corner of PGC is simply a corner of a golf course: mostly heavily managed artificial vegetation and not somewhere one would likely experience wilderness. However, the MCE model's identification of NW corner of PGC does not reveal a flaw within the model. This unexpected result is simply explained by the location's high relative remoteness and the significance of the attribute's weight. Lastly, each of the six locations have

minimum relative wildness values lower than the 95th percentile. This is simply successful identification of greenspace bordering built-up areas: greenspace in sight of buildings, close to mechanised access, and with a not entirely natural 250 m vicinity.

These results plus the general pattern of relative wildness (built-up areas mapped as low relative wildness and greenspace mapped as high and moderate relative wildness) demonstrate RWM is capable of mapping variations of wildness across a suburban landscape. While this is the first recorded application of RWM to a suburban landscape, this supports the findings of the three previous applications to anthropogenic landscapes (Müller et al., 2015; Müller et al., 2018; Aznarez et al., 2022). The results of this study are additional evidence RWM is capable of distinguishing different management intensities across different anthropogenic contexts. And in being so, they add weight to Carver et al.'s (2012) claim the general approach presented in their paper and followed by this study is both transferable and scalable.

Finally, it is worth highlighting the marked spatial variability among the different attributes of wildness across Glasgow's Southside. The perceived naturalness of land cover map clearly distinguishes between built-up areas and greenspace. The absence of noise and modern human artefacts map reveals there are very few areas where an individual can experience a virtual absence of both road, rail, and industrial noise from the sonic landscape and artificial features from the visible landscape. The remoteness from mechanised access map shows the remotest areas are situated exclusively within greenspace. However, it also shows remoteness is variable within greenspace. And the ruggedness and physical challenge of the terrain map shows areas of high ruggedness and physical challenge of the terrain are spread widely across the study area, inside and outside of greenspace. Spatial variability among attributes has been reported across a variety of landscapes. It is shown by Carver et al. (2012), who apply RWM to Scotland's two national parks, Müller et al. (2015), who apply it to heavily farmed and densely populated Denmark, and Radford et al. (2019), who apply it to Switzerland, the country home to the central Alps. As these studies are the only studies found that present their attribute maps and as each study reveals variability, it is entirely possible such variability is characteristic of any landscape. MCE and the combination of

attributes is clearly essential as intricate patterns in the variation of wildness are at least frequently indiscernible through scrutiny of attribute maps alone.

6.1.2. Are these locations potential urban wildness areas?

The survey of the six locations containing sizeable areas of high relative wildness determined three of them provide each of the three elements of Fredrickson and Anderson's (1999) psychologically oriented definition of wilderness (direct contact with nature, periods of solitude, and inherent physical challenges). They are North Wood, DTD LNR + WG SSSI, and CAKV SSSI. These three locations are advanced as potential urban wildness areas and thus considered worthy of further exploration within a future study to properly evaluate how impactful each potential urban wildness area is.

The survey results demonstrate the importance of surveying where RWM indicates areas of high relative wildness when RWM is applied to a suburban landscape and when a potential outcome is the designation of urban wildness areas. The examination of aerial imagery and spatial information confirmed NW corner of PGC is simply a corner of a golf course. In doing so, it also confirmed RWM can produce unexpected results when applied to a suburban landscape. The subsequent field visits revealed (1) Big Wood fails to provide periods of solitude (mainly due to road noise and the visibility of most of Glasgow), (2) Bull Wood fails to provide inherent physical challenges (due to being more or less completely flat), (3) there are numerous manmade features within DTD LNR, (4) CAKV SSSI's southern section, Kittoch Valley, is more or less inaccessible, and (5) there is some dangerously steep terrain within Kittoch Valley. Regarding DTD LNR's numerous manmade features and Big Wood and Bull Wood's failure to provide each of the three elements of the psychologically oriented definition of wilderness, it is important to remember RWM produces results that represent wildness on a relative scale. Although the six locations containing a sizeable area of high relative wildness are at least theoretically those most likely to be perceived as wild, situated within a suburban landscape, their inclusion within this top tier of relative wildness does not necessarily eliminate possibility of perceivable human influence or guarantee terrain that poses challenge. Regarding Kittoch Valley's inaccessibility, areas

of high relative wildness are areas most likely to be relatively remote. Because relative remoteness may in part be the consequence of an absence of entrances, footpaths, and other green infrastructure, and because access is one of the key pathways to wildness contact in urban settings (Kowarik, 2018), increasing the attractiveness of urban wildness areas to the general public (Unt and Bell, 2014), it is important to establish whether there is access into and across areas of high relative wildness. And regarding Kittoch Valley's dangerous terrain, although in this instance, ruggedness and physical challenge of the terrain only carried a weight of 0.04, areas of high relative wildness are areas most likely to be areas of steep and rough terrain. When a potential outcome is the designation of urban wildness areas, it is critical areas of high relative wildness are surveyed to ensure they are not too steep and rough for the general public. In light of the survey, it was concluded (1) NW corner of PGC, Big Wood, and Bull Wood are not potential urban wildness areas, (2) future study of DTD LNR + WG SSSI may want to focus on WG SSSI, and (3) future study of CAKV SSSI should focus on CAKV SSSI's northern section, Cart Valley.

Finally, despite leading to the conclusion only three of the six locations containing a sizeable area of high relative wildness are potential urban wildness areas, the survey provides plenty of evidence RWM is capable of pinpointing wildness within a suburban landscape and thus further supports the findings of the three previous applications of RWM to anthropogenic landscapes (Müller et al., 2015; Müller et al., 2018; Aznarez et al., 2022). The five visited locations are mainly dense native woodland, are generally subject to minimal land management, score highly for ecological wildness and greenness, and, between them, provide direct contact with nature, periods of solitude, and inherent physical challenges.

6.1.3. Which urban habitat types make up the wildest and least wild areas of Glasgow's Southside?

The urban habitat type composition of the wildest and least wild areas shows the MCE model has had a great deal of success distinguishing between what is greenspace and what is built-up. It is reasonable proof RWM is capable of mapping variations of wildness across a suburban landscape. To reiterate, the wildest areas are dominated by

woodland, almost entirely unpaved, and made up of a relatively small amount of artificial vegetation, while the least wild areas are more or less exclusively a combination of paved land, vacant lots/fringe vegetation, and artificial vegetation. Of course, these results need to be validated.

6.1.4. Are the wildest areas protected?

The wild sides of towns and cities can provide enormous social benefits and contribute to more liveable towns and cities (McKinney et al., 2018). Unfortunately, they are under constant threat from urban growth and densification (McDonald et al., 2013; Soga et al., 2014). Protecting them should thus be high on the landscape planning agenda (Kowarik, 2018). An assessment such as this can be used to inform landscape planners where additional protections may be needed (Carver et al., 2002; Müller et al., 2015). The results reveal there is no pressing need to establish additional protections in Glasgow's Southside. Its wildest areas are well protected. 99.9% of the wildest 1%, 98.2% of the wildest 5%, and 96.6% of the wildest 10% is covered by at least one of the seven designations and therefore under some form of special protection. However, certain Glasgow City Council designations may be extended to include unprotected wildest areas (or wildest areas not under some form of special protection). Either the area of green belt, the Hurllethill SINC, or the Bullwood at Hurllethill SSLI may be extended to include the 500 m strip of land taking in parts of Hurllethill Plantation and the smaller Rocks Plantation. Either the Brock Burn (including Aurs Burn) SINC or Brock Burn SSLI may be extended to include the 500 m strip of Kennishead Wood. And the Castlemilk Glen/King's Burn SINC may be extended to include the 250 m² portion of Glen Wood, Castlemilk.

6.2. Reflections on the method

The analysis was performed at the highest possible spatial resolution, to detect those small, fragmented pockets of high relative wildness. However, results are always sensitive to the methods and data used (Carver et al., 2012) and there is always possibility of error and uncertainty (Feizizadeh and Blaschke, 2014; Müller et al., 2018). It is therefore important to reflect upon each aspect of the method.

6.2.1. The four indicators of wildness

This study used four indicators of wildness: (1) perceived naturalness of land cover, (2) absence of noise and modern human artefacts, (3) remoteness from mechanised access, and (4) ruggedness and physical challenge of the terrain. They are considered both scientifically justifiable and reliably quantified. They represent the four basic attributes of wildness identified by Scottish Natural Heritage (2002): naturalness, untouchedness, remoteness, and ruggedness. And they have been used with success within previous studies (e.g., Carver et al. (2012), Müller et al. (2015), Müller et al. (2018), and Radford et al. (2019)). Additionally, their quantification is based upon existing datasets, meaning their implementation is both time- and cost-efficient. And, the availability of comparable datasets means the method could be applied in other European countries (Kuiters et al., 2013).

6.2.2. Mapping perceived naturalness of land cover

The method of mapping perceived naturalness of land cover is largely based upon expert opinion. The definition of the five naturalness classes and the reclassification of land cover classes into these five classes was informed by the expert opinion of Scottish Natural Heritage officials (Scottish Natural Heritage, 2014). The 250 m figure taken to represent the extent of the surrounds an individual would be expected to experience was decided upon by the project steering group Carver et al. (2012) worked alongside. The incorporation of expert opinion contributes towards a method that is more objective and transparent (Radford et al., 2019). Of course, expert opinion is prone to subjectivity. For instance, Scottish Natural Heritage's (2014) reclassification of UKCEH land cover classes is based upon a subjective reading of UKCEH's land cover class descriptions. Nevertheless, expert opinion is usually credible and a method's incorporation of it means less reliance upon the individual perceptions and assumptions of the researcher.

The source of greatest potential error is UKCEH's Land Cover Map. The dataset is considered here the best available for forming the basis of an indicator of naturalness for a landscape scale study. However, (1) there will be varying levels of naturalness within UKCEH land cover classes due to varying levels of management and (2) the

Land Cover Map is known to include misclassification errors at the local scale, on a cell-by-cell basis (Fuller et al., 2002; Carver et al., 2011; Carver and Müller, 2014). Across the study area, the confidence of the classification ranges from 100% to just 12%. The lowest confidence values are generally found in a few specific locations where there is a mosaic of a combination of the broadleaved woodland, arable, improved grassland, and heather grassland land cover classes. Misclassification among these four land cover classes could be consequential as the broadleaved woodland and heather grassland land cover classes were reclassified into naturalness class 4, while the arable and improved grassland land cover classes were reclassified into naturalness class 2. The Land Cover Map was supplemented by Forestry and Land Scotland's Native Woodland Survey of Scotland, Forestry and Land Scotland's National Forest Inventory, and Ordnance Survey's Water dataset. This was in essence an attempt to lessen potential misclassification errors and at least account for differing levels of management across the study area's woodlands, forests, and waterbodies. While it resulted in a more accurate and refined representation of these three land cover types, the perceived naturalness of land cover map should still be regarded as somewhat generalised. That said, it is felt to adequately represent naturalness at the landscape scale.

Finally, published in 2021, 2019, and 2019 respectively, the Land Cover Map, the Native Woodland Survey of Scotland, and the National Forest Inventory are now 4-6 years old. Suburban landscapes are dynamic landscapes and can change considerably in 4-6 years. However, these three datasets are regarded here the best available for the purpose, and these particular versions of the datasets were the most recent releases at the time of analysis.

6.2.3. Mapping absence of noise and modern human artefacts

Noise exposure data from SEPA's Noise dataset was used as the absence of noise map more or less as provided. The dataset was produced for regional-level planning and decision-making and does not necessarily represent every situation at the local level (Scottish Government, 2016). Furthermore, it was published in 2018 and is therefore 7

years old. Nonetheless, it is the only noise dataset available and is felt to adequately represent noise at the landscape level.

It is regrettable the viewshed analysis was performed at 100 m spatial resolution. This was unavoidable due to the computational costliness of viewshed analysis plus computational restraints. Off-the-shelf GIS viewshed tools such as ArcGIS Pro's Viewshed 2 tool are generally slow, making more detailed analysis of whole landscapes with high spatial resolution DSMs impractical (Wildland Research Institute, 2017). Performed at 100 m spatial resolution, the processing time was still over a week. It is also clear the method is less sophisticated than Carver et al.'s (2011) and Carver et al.'s (2012). They built Viewshed Explorer: a custom software that uses a voxel-based landscape model and a highly optimised ray-casting algorithm similar to those once used in computer games and real-time rendering applications (Franklin and Ray, 1994; Carver et al., 2011; Wildland Research Institute, 2017). The software allowed them to calculate a viewshed for every single modern human artefact and a cumulative visibility surface based on the vertical area of each visible modern human artefact taking into account the effect of distance decay on relative size using an inverse square distance function (Carver et al., 2011; Carver et al., 2012). The binary outputs of off-the-shelf GIS viewshed tools are based upon simple interpolation of line-of-sight across an elevation surface. They simply indicate whether or not cells are visible. A method that utilises an off-the-shelf GIS viewshed tool can only provide counts of the number of visible cells occupied by an object. Clearly, this is a less exact calculation of visual impact than one based upon detailed analysis of how much of objects are visible and how much of the observer's 360° field of vision is occupied by objects (Wildland Research Institute, 2017). Nevertheless, any method utilising any form of viewshed analysis is a far more effective method of establishing the impact of modern human artefacts than the simple distance measurements adopted by several RWM studies (e.g., Lesslie (1993), Carver (1996), Sanderson et al. (2002) and Müller et al. (2015)). Again, this is simply because a remote place from which one can see an extensive urban area offers a reduced wilderness experience, while a location within an urban area may seem wild if there are no observable signs of human presence (Orsi et al., 2013). Finally, it is probable the method has generally overestimated the visibility of modern human

artefacts from within woodlands and forests, despite taking into account the likely summertime screen effect provided by these two land cover types. Using a DSM places observers on top of tree canopies, high above the ground, in a position to see much further afield. The measure should therefore be considered conservative wherever there is woodland or forest. This could at least partly be addressed by setting the observer offset to 0 cm wherever there is woodland or forest. However, this needs testing and will be tested if RWM is applied to more of Scotland's suburbs.

6.2.4. Mapping remoteness from mechanised access

It is now apparent the remoteness from mechanised access map overestimates the relative remoteness of at least two areas. One of those areas is NW corner of PGC. The overestimation of its relative remoteness is a consequence of the incompleteness of Ordnance Survey's Path Link dataset. Although the most comprehensive path dataset available, there are paths and footbridges visible in the aerial imagery that are unrecorded. Crucially, there is an unrecorded footbridge that crosses a network of drains on the eastern edge of NW corner of PGC. The model regards watercourses as barriers to movement. If the footbridge was recorded, the cell it occupies would be traversable, the network of drains would be crossable, and the model would calculate it takes less than 15+ minutes to walk to the furthest reaches of the area from vehicular access. If the footbridge was recorded, it is entirely possible NW corner of PGC would not have been mapped as an area of high relative wildness. The solution of course is to digitise any unrecorded footbridges. This is likely feasible at the suburban landscape-scale. The other area is the southwest corner of Househill Park. The overestimation of its relative remoteness is a consequence of the model regarding dual carriageways as barriers to movement when the aerial imagery shows the dual carriageways that border the park have pavements that could be used to reach a southwest corner entrance. If dual carriageways were omitted from the barriers to movement dataset, the model would calculate it takes far less than around 15 minutes to walk to the area from vehicular access. However, while a number of the study area's dual carriageways have pavements, a number do not. Thus, the solution is to check each dual carriageway and add only those without pavements to the barriers to movement dataset. This too is likely feasible at the suburban landscape-scale.

While it overestimates the remoteness of these two areas, the model generally underestimates remoteness. In reality, it is highly unlikely individuals will follow the optimum routes taken by the model, at least not in their entirety (Carver et al., 2011). Error may have resulted from differing degrees of divergence between the instinctive and optimum routes between locations. However, the extent of such error cannot be determined. Another potential source of error is UKCEH's Land Cover Map. Again, the lowest classification confidence values are generally found in a few specific locations where there is a mosaic of a combination of the broadleaved woodland, arable, improved grassland, and heather grassland land cover classes. Misclassification among these four land cover classes could be consequential as the model considers walking pace over arable land and improved grassland 5 km/h (normal walking pace), through broadleaved woodland 4 km/h, and over heather grassland 3 km/h.

Finally, the calculation of remoteness considered gradient, land cover, and land use. The consideration of gradient allowed calculation of (1) slope for the vertical factor and (2) actual surface distance covered. The consideration of land cover and land use allowed the definition of barriers to movement and the application of time penalties to cells covered by land cover types that are relatively difficult to traverse. Despite the error and uncertainty, the method of mapping remoteness produces a measure of remoteness far more accurate than the measures used by many previous studies. One example is population density. Müller et al. (2015) used population density, and reflecting on their method, conceded while it is capable of revealing patterns of remoteness at the regional- and national-scale, population density is most likely not an accurate enough measure of remoteness for local-scale RWM. Applied correctly, cost distance analysis produces a measure that is.

6.2.5. Mapping ruggedness and physical challenge of the terrain

Ruggedness and physical challenge of the terrain was determined by terrain complexity analysis and terrain complexity was determined by calculating the standard deviation of terrain curvature of all cells within a 250 m radius of each target cell. As Carver et al. (2011) acknowledge, there are numerous way of determining ruggedness and physical challenge of the terrain. Those considered include fractal complexity analysis

and methods considering both slope and aspect. Terrain complexity analysis was chosen because it has been used with success within a number of previous studies (e.g., Carver et al. (2012), Müller et al. (2015), and Radford et al. (2019)).

The application of terrain complexity analysis to a suburban landscape appears to have been largely successful. However, despite the removal of artificial features from the terrain curvature raster prior to the calculation of standard deviation, the results are to some extent distorted by Hampden football stadium and certain other artificial features. They have created distortion because of slight misalignment between the rasterized Ordnance Survey data and the DTM, meaning slithers of them have entered into the model's calculations that have thus outputted false relative and high relative ruggedness. The number of anomalous results are, however, limited.

Finally, it has been suggested ruggedness as an indicator of wildness could require a richer topography than that of a typical anthropogenic landscape and therefore might be excluded when RWM is applied to an anthropogenic landscape (Radford et al., 2019). It was right to include it within this analysis. It is now apparent the study area contains numerous areas of rough terrain plus steep hills, slopes, and riverbanks. And a sensitivity test investigating the effect of excluding each indicator from the mapping of relative wildness (see Appendix H) revealed the relative wildness map excluding ruggedness and physical challenge of the terrain has a correlation coefficient (R) of 0.94 when compared to the original relative wildness map (generated using equal weights). This is greater than that of the map excluding perceived natural of land cover (0.85), but the same as the map excluding absence of noise and modern human artefacts and less than the map excluding remoteness from mechanised access (0.97). With all coefficients greater than 0.7, the general trend of pixel values stays much the same whichever indicator is excluded.

6.2.6. Weighting and combining the indicator layers

Differences in the detailed patterns of the two relative wildness maps show the survey weights distinguish the landscape's different management intensities more clearly. This highlights the influence of weighting schemes and consequent importance of using

schemes that are appropriate and grounded in research. It is therefore fortunate there have been Scottish wildness perception surveys. There have not been wildness perception surveys in most countries. It is also fortunate the results of the 2008 Scottish wildness perception survey have been translated into a weighting scheme by experts (the project steering group Carver et al. (2012) worked alongside). Of course, this perception survey is now 17 years old. Additionally, its sample is representative of the population of Scotland, not the population of suburban Scotland or the population of Glasgow's Southside. However, while a survey with a more focused sample might have produced a more justifiable weighting scheme, and while the consideration of the opinions of local people can be invaluable when eventually promoting acceptance of an initiative (Blondet et al., 2017), conducting a wildness perception survey was never feasible within the scope of an MSc GIS thesis project. It would have been feasible to survey experts. A short survey sent to a limited number of experts and focused on the suburban context would have been easy enough to administer. However, as noted above, expert opinion is prone to subjectivity and the perception of wildness is completely subjective. An expert survey can help to define a weighting scheme but should only be used if there is no applicable wildness perception survey.

The weightings were applied and the indicators were combined within a weighted linear combination MCE model. Weighted linear combination is the most commonly used GIS-based MCE method (Malczewski, 2006; Malczewski and Rinner, 2015) and is almost always used for RWM (e.g., Carver et al. (2012), Müller et al. (2015), Müller et al. (2018), and Aznarez et al. (2022)). It is often used without a full understanding of its underlying assumptions of linearity and additivity. Linearity is constancy of desirability of an additional unit of an attribute across all levels of the attribute. Additivity is mutual preference independence of all attributes under consideration (Malczewski and Rinner, 2015). In truth, it is difficult to meet these assumptions when MCE is spatial (Malczewski, 2000). However, weighted linear combination produces close approximations of the outputs of more complex non-linear combination methods, while being much easier to use and understand (Hwang and Yoon, 1981; Massam, 1993; Stewart, 1996). It is easy to implement within GIS (Tomlin, 1990) and it is intuitive (Malczewski and Rinner, 2015).

6.2.7. Mapping robustness

The similarity of the general patterns of the two relative wildness maps indicates a high degree of mapping robustness and leads to confidence in the data, method, and maps (Carver et al., 2011; Radford et al., 2019). It also suggests the map derived from survey weights is unlikely to be overly distorted by the sample being representative of the population of Scotland and not suburban Scotland or Glasgow's Southside. The method is therefore considered applicable to other suburban landscapes in Scotland and beyond using alternative weighting schemes if perceptions of wildness vary.

6.3. Applications of the results

People living in towns and cities, particularly young people, are opting to spend less time experiencing nature (Ward Thompson, 2012; Soga and Gaston, 2016). Meanwhile, opportunities for wilderness experience are decreasing in built-up areas as they become increasingly built up (Lin and Fuller, 2013). The relative wildness maps visualise areas of high relative wildness. They can be used to increase awareness and valuation of these areas. The results can be used to inform planning policy, ensure protections, and orientate locals towards nature by highlighting the area's remaining opportunities for wilderness experience. However, the results are not a basis for the designation of urban wildness areas. Glasgow City Council would need to conduct proper surveys to fully establish the accessibility of each potential urban wildness area. It may decide access needs formalising as this increases the attractiveness of urban wildness areas (Unt and Bell, 2014). It must also consider the mitigation of risks resulting from natural processes such as flooding (Kangler et al., 2014) and human misbehaviours such as littering (Rupprecht et al., 2015). Issues of safety are important, just as they are in other types of urban greenspace (Sreetheran and Konijnendijk van den Bosch, 2014).

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7. Conclusion

The aim of this study was to test the applicability of RWM to suburban Scotland. The results lead to the conclusion RWM is capable of pinpointing wildness within a suburban landscape and mapping variations of wildness across a suburban landscape. Answering the first research question (where in Glasgow's Southside are areas of high relative wildness located?), the analysis distinguished six locations containing a sizeable area of high relative wildness within Glasgow's Southside: Bull Wood, North Wood, Big Wood, DTD LNR + WG SSSI, CAKV SSSI, and NW corner of PGC. A survey was conducted to answer the second research question (are these locations potential urban wildness areas?). The survey revealed the locations are mainly dense native woodland, are generally subject to minimal land management, score highly for ecological wildness and greenness, and, between them, provide the three elements of Fredrickson and Anderson's (1999) psychologically oriented definition of wilderness (direct contact with nature, periods of solitude, and inherent physical challenges). Providing each of the three elements themselves, North Wood, DTD LNR + WG SSSI, and CAKV SSSI are advanced as potential urban wildness areas. Further exploration of DTD LNR + WG SSSI may want to focus on WG SSSI as DTD LNR contains a number of manmade features. And a study of CAKV SSSI should focus on the Cart Valley as the Kittoch Valley contains dangerously steep terrain and is practically inaccessible. A comparative analysis was performed to answer the third research question (which urban habitat types make up the wildest and least wild areas of Glasgow's Southside?). The wildest areas are dominated by woodland, almost entirely unpaved, and made up of a relatively small amount of artificial vegetation, while the least wild areas are more or less exclusively a combination of paved land, vacant lots/fringe vegetation, and artificial vegetation. And a comparative analysis was performed to answer the fourth research question (are the wildest areas protected?). The wildest areas are well protected. 99.9% of the wildest 1%, 98.2% of the wildest 5%, and 96.6% of the wildest 10% is covered by at least one designation and therefore under some form of special protection.

There is a need for further research. Firstly, qualitative research is required to properly evaluate how impactful each potential urban wildness area is. Cheesbrough et al. (2019) used photovoice interviews to explore the perceived health and wellbeing effects of visits to the city of Edmonton's Natural Area Parks. Something similar could be employed here. Secondly, the results need to be validated. The method needs to be applied to more of Scotland's suburbs.

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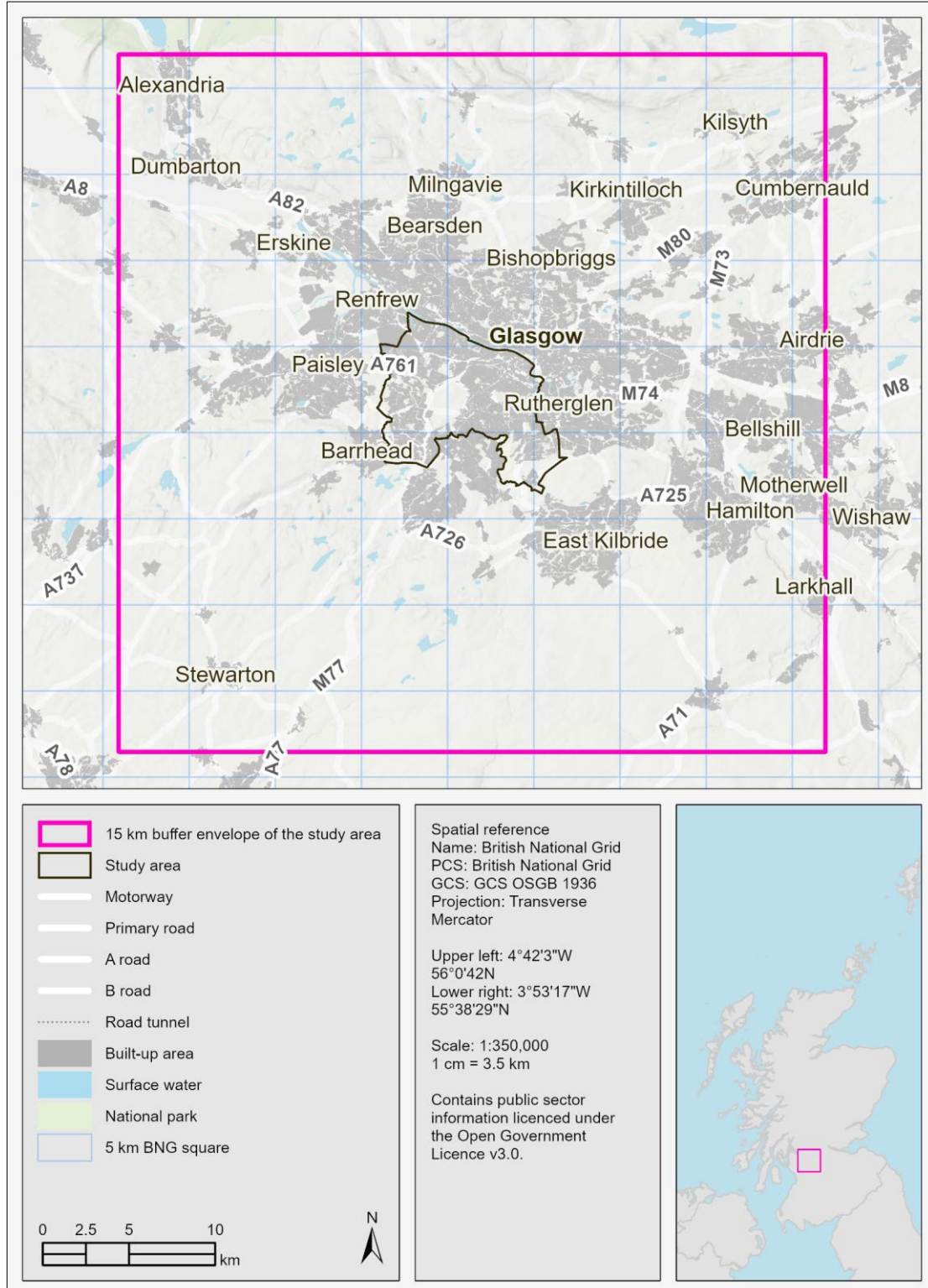
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Appendix A: Map of the 15 km buffer envelope of the study area



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Appendix B: The Python script that extracted values from multiple rasters to multiple points for the viewshed analysis

```
# Name: Extract_values_from_multiple_rasters_to_multiple_points.py
# Description: Extracts the sums of visible cells occupied by an
# artificial feature to output point datasets representing each
# individual observer point.
# Requirements: The Spatial Analyst extension.

# Imports ArcPy
import arcpy

# Imports the environment settings from ArcPy
from arcpy import env

# Imports the spatial analyst tools from ArcPy
from arcpy.sa import *

# Stops the outputs from being added to the map
env.addOutputsToMap = False

# Sets the workspace
env.workspace = r"D:\workspace"

# Lists the observer point datasets in the workspace
observerPoints = arcpy.ListFeatureClasses()

# Lists the raster datasets in the workspace (the datasets
# containing the sums of visible cells occupied by an artificial
# feature)
sumRasters = arcpy.ListRasters()

# Loops through the corresponding observer point and raster datasets
# as tuples
for observerPoint, sumRaster in zip(observerPoints, sumRasters):
    # Sets the point dataset base name as the output name
    outputName = arcpy.Describe(observerPoint).baseName;
    # Extracts the sum of visible cells occupied by an artificial
    # feature to an output point dataset
    ExtractValuesToPoints(observerPoint,
                           sumRaster,
                           r"D:\output_points\{}".format(outputName))
```

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Appendix C: Tobler's hiking pace function expressed in degrees and s/m

Degrees	s/m
-90	-1
-80	-1
-70	7557.874996
-60	216.232063
-50	32.632607
-40	9.497448
-30	3.799616
-20	1.800511
-10	0.933624
0	0.714748
10	1.324876
20	2.555046
30	5.391914
40	13.477518
50	46.307873
60	306.847904
70	10725.135142
80	-1
90	-1

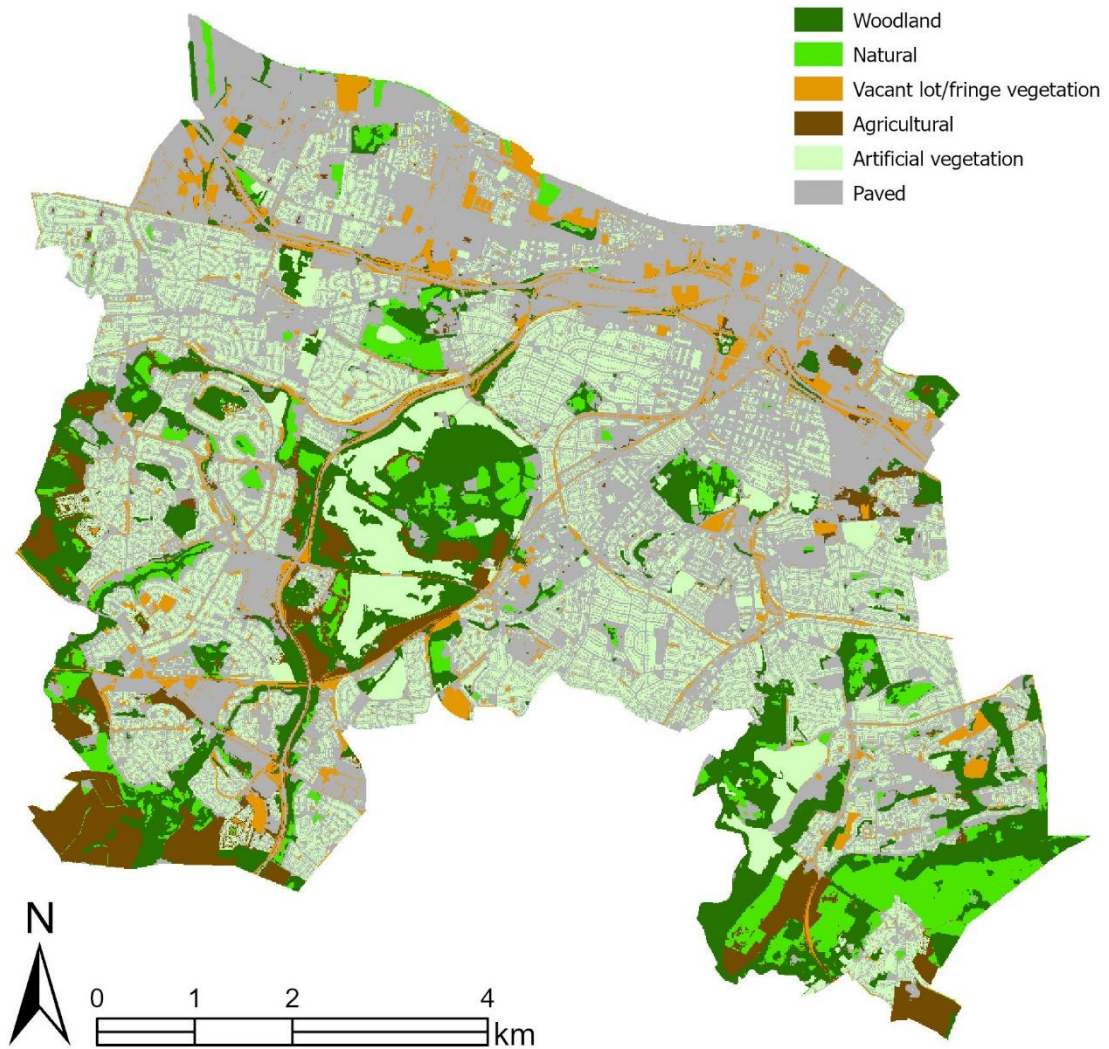
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Appendix D: Reclassification of land cover/land use classes into the six broad urban habitat types

Urban habitat type	Dataset	Land cover/land use class(es)
Woodland	UKCEH's 2021 Land Cover Map	Broadleaved woodland and coniferous woodland.
	Forestry and Land Scotland's 2019 Native Woodland Survey of Scotland	Native woodland, nearly-native woodland, and PAWS.
	Forestry and Land Scotland's 2019 National Forest Inventory	Broadleaved woodland, coniferous forest, felled woodland/forest, ground prepared for planting, mixed but mainly broadleaved woodland, mixed but mainly coniferous forest, shrub, and young trees.
Natural	UKCEH's 2021 Land Cover Map	Acid grassland, bog, calcareous grassland, fen, marsh, and swamp, freshwater, heather, heather grassland, improved grassland, inland rock, littoral rock, littoral sediment, neutral grassland, saltmarsh, saltwater, supralittoral rock, and supralittoral sediment.
Vacant lot/fringe vegetation	Improvement Service's Vacant and Derelict Land dataset	Derelict land, vacant land, and vacant land with building(s).
	Ordnance Survey's Road Track or Path dataset	Transport curtilage.
	Ordnance Survey's Rail dataset	Open vegetation and trees.
Agricultural	UKCEH's 2021 Land Cover Map	Arable.

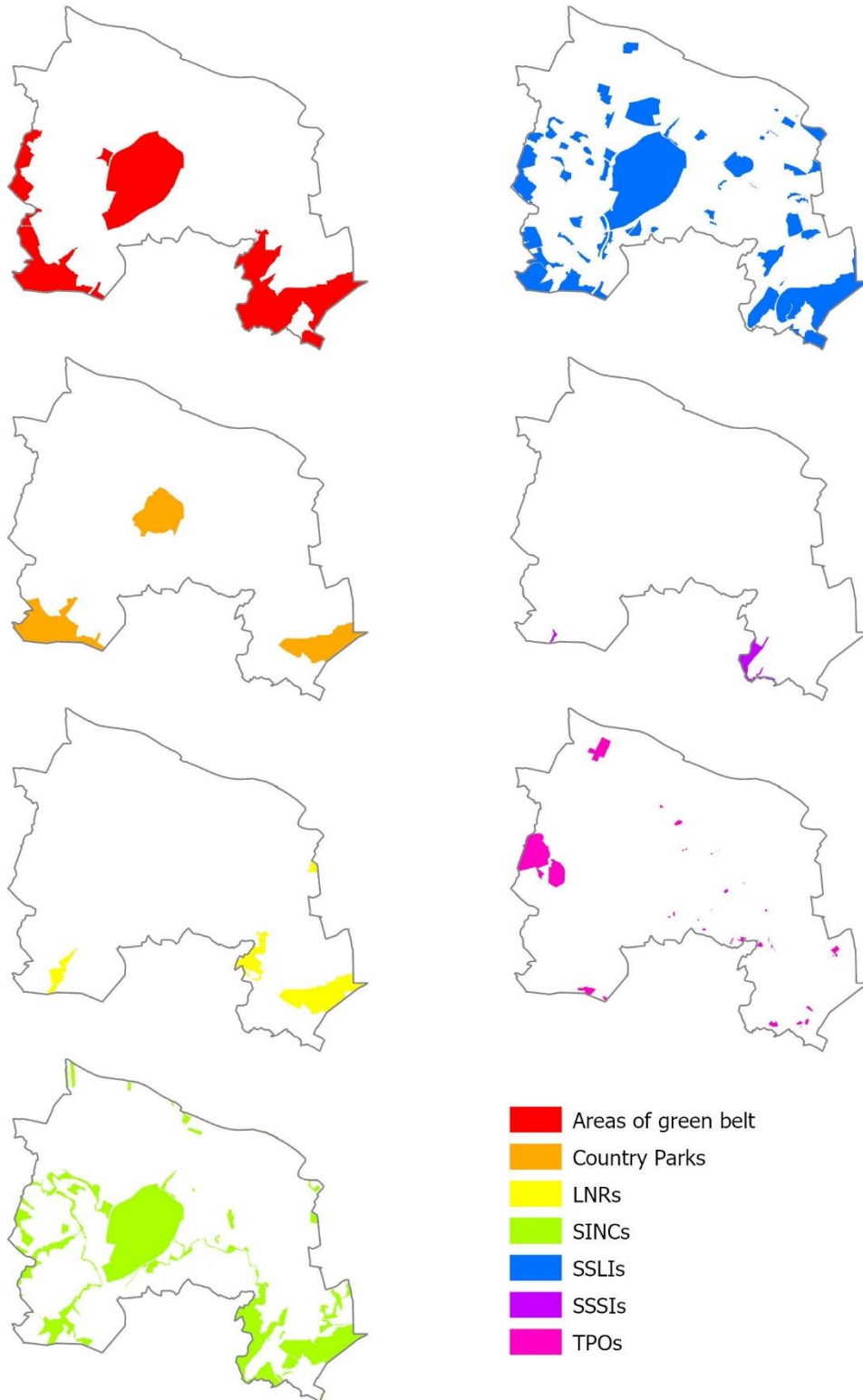
	Scottish Government's Agricultural Land Parcels dataset	Agricultural land parcel.
Artificial vegetation	Ordnance Survey's MasterMap Greenspace dataset	Private garden.
	Ordnance Survey's Site dataset	Allotments, botanical garden, bowling green, camping and caravanning site, cemetery, cricket pitch, equestrian sports facility, football pitch, garden of rest, golf course, golf driving range, maze, memorial garden, pitch and putt course, playing field, professional sports training ground, putting green, recreation ground, and rugby pitch.
Paved	UKCEH's 2021 Land Cover Map	Suburban and urban.

Appendix E: Urban habitat map of Glasgow's Southside



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Appendix F: The distribution of protected areas within Glasgow's Southside



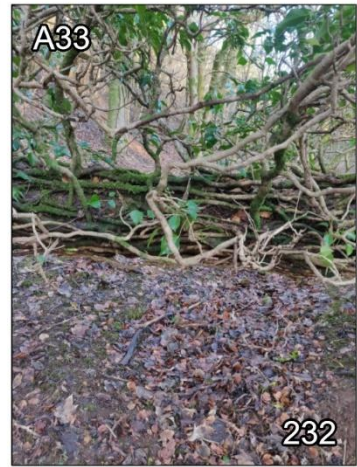
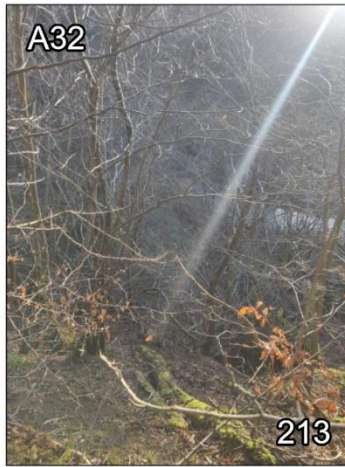
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Appendix G: Additional photographs of the five visited locations with relative wildness scores of photograph locations









Appendix H: The results of a sensitivity test investigating the effect of excluding each indicator from the mapping of relative wildness

Comparison of the wildness scores of the original relative wildness map (generated using equal weights) and relative wildness maps excluding one indicator

Indicator excluded	Mean difference	Maximum difference	Correlation coefficient (R)
Perceived naturalness of wildness	16.7	85.0	0.8
Absence of noise and modern human artefacts	31.8	89.6	0.94
Remoteness from mechanised access	4.4	108.0	0.97
Ruggedness and physical challenge of the terrain	8.7	98.2	0.94

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