In compliance with the Scottish Outdoor Access Code - The use of a land access map

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DECLARATION

This dissertation has been composed by me. It has not been accepted in any previous application for a degree, and the work of which it is a record has been done by me. All quotations have been distinguished by quotation marks and sources of information have been acknowledged in the text and cited in the list of references.

Johan Olofsson
15th of August 2007

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To Silke,
my pathfinder

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ABSTRACT

The aim of the thesis is to produce a land access map according to guidelines presented in the Scottish Outdoor Access Code. The major outcome is a land access map containing restricted zones based on up-to-date land use data and information concerning nature conservation. The purpose of the map is to advise the public how to use the landscape responsibly in compliance with the Scottish Outdoor Access Code.

The project consisted of two main parts. Firstly, the concept of a land access map was modelled and the methodology and the necessary data types outlined in detail. The second part of the project consisted of performing a case study and applying the model on a study area.

The study area was chosen based on a set of criteria regarding land use categories, occurrence of officially protected sites, and accessibility. The 48.5 km^2 large area is situated in the Southwest of Aberdeenshire near Ballater in Scotland and is a part of the Cairngorm national park.

Issues concerning visualization and distribution forms are examined and future developments of the model are discussed.

Keywords: Scottish Outdoor Access Code, Remote sensing, GIS, modelling, land cover classification, visualization.

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1 Introduction

Land managers, ramblers, campers, researchers, etc. are but a few of the many devoted users of the outdoors. A variety of interests (economical, recreational, cultural etc.) has to be weighted against each other and mutual respect and understanding amongst the stakeholders makes the process easier. In some areas, the challenge is to maintain a high level of public access to the outdoors at the same time as protecting it.

The Scottish outdoor access code, approved 1st of July 2004 by the Scottish parliament, regulates the access to the outdoors in Scotland. ‘Outdoors’ is defined as “mountains, moorland, farmland (enclosed and unenclosed), forests, woods, rivers, lochs and reservoirs, beaches and the coastline, and open spaces in towns and cities.” (Scottish outdoor access code, §1.7). The basis for the Code is the Land Reform (Scotland) Act 2003. Every citizen has, according to the Act a right to access areas as defined by the Code. The purpose of the code is to function as a guide for the public regarding their responsibilities and access rights to outdoor areas.

The Code states that the public should access the outdoors based on informed decisions to prevent unnecessary damage. Certain situations where visitors could violate the access rights, such as trampling of crops, blocking entrances to fields, disturbing wildlife etc. are addressed (SOAC, §3.3). The Scottish outdoor access code suggests several measures that can be undertaken in order to facilitate a proper and responsible uses of the land (SOAC, §6.7). Information regarding various aspects of the outdoor access is however not available from one source only but many. Official bodies as well as private land managers are recommended to provide information on-site by the use of signs and brochures. Some information is available in books and on internet (information on e.g. protected wildlife). Consequently, a member of the public who wants to exercise his or her right to access the outdoors and wishes to do so in a responsible way, i.e. as informed as possibly, has to search several sources for information before entering a certain area.

1.1 Problem statement and justification

The potential conflicts of interests amongst land managers, residents, and the public need to be addressed in order to maintain the interest in and respect for the Outdoor Access Code. SNH has published information on the internet (http://www.outdooraccess-scotland.com) and in leaflets regarding acceptable behaviours and recommendations concerning suitable outdoor activities. However, this information is in most cases generic. To become a useful tool in practise, the information should be more specific. It should present information about 'a nesting bird of species A in area B', or 'a rare plant of species C in forest D'. The information could also reflect on temporal aspects, e.g. 'a bird of species A is most sensitive for disturbance in May' or 'a plant of species C is vulnerable of trampling during the seeding season June-July'.

Based on information from land managers regarding farming activities, information about habitat preferences for various species (plants and animals) and with local knowledge about e.g. hunting activities, etc. a spatial risk assessment visualized on a map could function as a compliment to on-site information. The map would contain a valuation of the 'risk of disturbance' to assist the public exercising their right to access the outdoors. A great benefit of using a map to visualize the code is the easiness with which data can be retrieved. An up-to-date land access map could function as a tool of communication between the occasional visitor and the land manager, were current information on agricultural activities, hunting activities etc. can be published. This information would give the user an immediate idea of the suitability of crossing a particular field or forest.

1.2 Aim

The aim of this project is to produce a land access map according to guidelines presented in the Scottish Outdoor Access Code, up-to-date land use data, and information concerning nature conservation. The project consists of two main parts. Firstly, the concept of a land access map is modelled and the methodology and the necessary data types are outlined in detail. The goal is to create a transparent model that can be applied on any area of interest and to make full use of current geospatial technology such as satellite imagery, image processing, digital datasets, and GIS. The second part of the project consists of applying the model on a study area.

1.3 Objectives

- To develop a methodology based on geospatial technology for creating a land access map
- To define necessary datasets for creating a land access map
- To develop a ‘access index’ to facilitate the generation of a land access map
- To develop a suitable map design for presenting and visualising land access information
- To look into feasible distribution forms
- To evaluate the methodology based on a case study
- To produce an up-to-date land access map.

2 Background

The principle idea of the Scottish Outdoor Access Code is to let people walk 'anywhere' and any time; and when exercising this right, people are expected to take responsibility for their own actions and respect other people's privacy. The public is under the obligation to follow a few simple rules when exercising their rights, as summarized in part 3 of the Code:

- "take responsibility for their actions;
- respect the privacy of others;
- help land managers to work safely and effectively;
- care for their environment;
- keep dogs under proper control"

There are areas were access has been restricted. A person cannot access enclosed areas such as farmyards, factories, military bases etc. Access is restricted if there is a risk of disturbing inhabitants in the area. Private gardens, fields were crops (cereals, vegetables, fruits etc.) have been sown or are growing, any sport facility if they are in use and areas were public health could be at risk (airports, railways etc.) are also excluded from these rights. Furthermore, the Act states that a visitor cannot have access rights to "sufficient adjacent land" to a house, a tent, a caravan, or other places were people live (LRSA, §14). In §2.11 of the Code, more examples of such areas are listed.

The Code suggests how to act when passing through pastures or other fields where farm animals are held (SOAC, §3.29-34). Different animals react differently to humans (and dogs). Cattle can be very protective when they have calves, pigs, sheep and deer can react aggressively to humans, especially when they have offspring (SOAC, §3.29). The code encourages people to contact land managers before planning and executing an organized outdoor activity in order to get up-to-date information about the area

(Scottish Outdoor Access Code, §3.58). A 'Land manager' is defined by the Land Reform (Scotland) Act 2003 as the owners and occupiers of land such as farmers, crofters, and foresters.

The Act also gives rights to access a range of other areas, such as recreational sites, golf courses, and sport fields. The public can access croplands as long as they have not been sown. If the crop is growing, the field can be crossed along its margins. Furthermore, grasslands can be accessed until they reach a stage where damage might be done to the hay. Pastures, even if there are grazing farm animals, can be accessed. The only limitation is that a person exercising this right does so in compliance with the Code.

The Code does not only apply to the public, but also to the land managers that have an extensive responsibility to facilitate the access to their land (SOAC, part 4). The land manager cannot stop or otherwise hinder people from exercising their access rights (SOAC, §4.8). The code has summarized the obligations as follows:

- Respect access rights in managing land or water.
- Act reasonably when asking people to avoid land management operations.
- Work with local authority and other bodies to help integrate access and land management.

Land managers are encouraged to build and maintain paths through their land (SOAC, §4.10).

Activities such as ploughing, planting, moving animals, maintenance or other farm related work are visible events that most parties of the public can recognise and avoid interrupting. Other things can be more difficult to recognize for a non-professional, such as to discriminate whether a field has been sown or not or whether grassland is meant for grassing or production of hay and silage.

2.1 Scottish Outdoor Access Code in the media

The idea of a right to access the outdoors is controversial as recent statements in the press imply. A series of articles published by BBC News Online Scotland (http://bbc.co.uk) shows a variety of concerns put forward by landowners, organisations, and members of parliament. Conservative MSP Bill Aitken has claimed that the code is "largely unnecessary". In his view, there have been no conflicts between land managers and ramblers (BBC 22 January 2003). On the other hand, Deputy Rural Development Minister Allan Wilson stated that the legislation before the code was unclear regarding trespassing and that the new legislation would clarify the rights to access. The deputy chairman of Scottish natural heritage Michael Scott highlighted the need for the public as well as the land managers to get involved in the process of develop the concept of free access to the outdoors (BBC 26 March 2003).

Land managers have expressed their concerns about having the public accessing private land. Farmer Mr Macdonald highlights the risks involved when inexperienced people encounter livestock. Based on his own experience, cattle behaviour can be unpredictable and cause severe accidents (BBC 3 November 2003). Other land managers fear that public access will cause damage to crops (BBC 21 January 2004). Landowners have also expressed concerns regarding their own security. Two landowners, one in Perthshire, and one in Stirlingshire have asked for an exemption from the Scottish Outdoor Access Code. The former won her case (BBC 12 June 2007), whereas the latter remains to be settled (BBC 23 May 2007). Dave Morris from the Ramblers Association Scotland is worried that the legislation will be weakened by the court ruling (BBC 12 June 2007).

2.2 Access to the outdoors in an international context

All of the Nordic countries have developed national systems that give extensive rights to the public to access the outdoors. During the last centuries, the access right has been established as a custom, which gave everyone the right to travel across the land and to collect food for sustenance (berries etc.). During the 18th and early 20th century, private interests tried to reduce public access to the outdoors (Peter Scott Planning Services 1998). As a response to these claims, the governments in each country started to formulate ideas on how to keep the outdoors open to everyone.

Norway passed the Outdoor Recreation Act of 1957 in order to meet demands from the public and to ascertain the protection of the rights (Peter Scott Planning Services 1998). In Sweden, the ‘allemansrätt’ is not a law per se, but is safeguarded by general laws concerning e.g. the environment (Naturvårdsverket). The right was added to the Swedish constitution in 1994. Finland has a similar system as Sweden (Zettersten et al. 1997). The legislation in Denmark concerning access rights were gradually introduced during the 20th century, with the introduction of the Conservation of Nature Act in 1917. The framework for these rights is formulated in the Protection of Nature Act (1992). The legislation focuses on the rights of the land manager to protect private land. Iceland has a similar system as Denmark (Zettersten et al. 1997).

The legislation in the Nordic countries presents some differences, where Denmark has the most restrictive laws and Sweden the most unrestrictive (concerning rights to use bicycles, berry picking etc.) (Jusconsult 2001).

In Germany, the Betretungsrecht is regulated in the Federal Law for Nature Protection 1987 as well as the Federal Forest law 1975. These laws give extensive rights to people to roam in the open countryside and are supposed to be interpreted and implemented in the legislation of each Bundesland (Peter Scott Planning Services 1998).

Common to the above-mentioned countries are the willingness to allow people to access most types of land (woodland, rangeland, coasts, etc.) and to use private roads.

Central to all of the varying legislations regarding outdoor access rights is the idea that the land users must not damage, disturb, or cause any form of trouble when exercising their rights.

2.2.1 Public Rights of Way in England and Wales

The Countryside and Rights of Way Act 2000 is the legislation that regulates the access to the outdoors in England and Wales. The Act gives access by foot to mountains, moors, heaths, as well as to registered common land. The use of any vehicle is prohibited. Cultivated land is also exempted from public access.

The Countryside agency has according to this act, a duty to publish maps showing open land and registered common land (Part 1, section 4). The agency should also keep the public informed about rights and responsibilities (Part 1, section 20).

2.3 The impact of outdoor activities on plants and wildlife

According to the Code, no wildlife should be disturbed. This is considered especially important during the breeding season (SOAC, §3.45). A visitor may unintentionally cause disturbance, habitat alterations, or even death when exercising his or her right to access the outdoors (Boyle and Samson 1985). Different species will react differently to outdoor activities.

Occasional trampling by humans has a documented effect on plants in a variety of habitats ranging from rocky shores to alpine environments (Whinam and Chilcott 1999, Eckrich and Holmquist 2000, Littlemore and Barker 2001, Whinam and Chilcott 2003, Lehvävirta et al. 2004, Roovers et al. 2004, Rossi et al. 2006). The sensitivity of plant communities are measured by two parameters; resistance to trampling and ability to recover from trampling (Gallet and Rozé 2002, Monz 2002, Roovers et al. 2004). The variables are e.g. variation in vegetation cover, vegetation height, and species composition. Higher trampling rate (a few hundred passes) causes damage still visible after two years depending on species composition (Littlemore and Barker 2001, Whinam and Chilcott 2003, Roovers et al. 2004). Even as few as 25 passes can cause an effect on the plant community (Littlemore and Barker 2001). Trampling can also have a negative influence on species diversity (Littlemore and Barker 2001, Gallet and Rozé 2002, Waltert et al. 2002, Ros et al. 2004). Herbal plants are more sensitive to trampling than other plant communities e.g. heather. Quercus-Betula forests are more vulnerable than Alnus-Fraxinus forests and needs much longer time to recover (Roovers et al. 2004). Plants dependent on seeds for regeneration such as the bluebell (Hyacinthoides non-scripta) are particularly vulnerable (Littlemore and Barker 2001). Water living species such as sea grass (e.g. Thalassia testudinum) and macro algae (e.g. Dictyota mediterranea) are susceptible to human trampling in a similar way as terrestrial plants (Eckrich and Holmquist 2000). Based on a study on heath land, Gallet and Rozé (2002) have shown that the vulnerability varies during the seasons and that heath land is less affected in wintertime.

Incubating colonial birds are susceptible to disturbance by humans, which may cause them to leave the nest (Burger and Gochfeld 1983). Even short-term abandonment can cause thermal stress to the eggs. Studies carried out on different species of sea gull suggests that the reproductive success is decreasing in areas were the nesting birds are disturbed by humans (Robert and Ralph 1975, Burger and Gochfeld 1983). Others have corroborated these results and shown that various seabirds, waterfowl, and waders react at different distances when humans approach (Erwin 1989, Knapton et al. 2000, Lafferty 2001, Finney et al. 2005). Larger birds such as bald eagles and ospreys are in a similar way disturbed by humans but do not display a related decrease in reproductive success (Mathisen 1968, Stalmaster and Newman 1978, Levenson and Koplin 1984, Fraser at el. 1985). Researchers have suggested protective zones based on detailed studies on individual species. Common terns (Sterna hirundo) leave their nest when intruders are 200-400m away whereas waders stay until 50m away (Erwin 1989). It is suggested by Erwin (1989) that a protective perimeter of 200-300m should be used during the short period before the birds have chosen their nesting place. The perimeter can be reduced to 100-200m (depending on species) when they are nesting. The spotted owl (Strix occidentalis lucida) living in canyon habitats should be protected by a 55m buffer (Swarthout and Steidl 2001).

Mammals such as elks (Cervus elaphus), deer (Dama dama, Odocoileus hemionus)) and reindeer (Rangifer tarandus tarandus) are affected by human intrusion, which may result in a decline in population growth if disturbed during the calving season (Freddy et al. 1986, Recarte et al. 1998, Phillips and Alldredge 2000, Vistnes and Nellemann 2001, Reimers et al. 2003).

Other species, such as the carabid beetle, could benefit from trampling since the under growth is opened up (Lehvävirta et al. 2006).

2.4 Remote sensing, satellite imagery and image processing

Remote sensing is an important tool for investigating phenomena on the earth's surface. The technique can record images at a spatial resolution that can reveal details otherwise invisible to the naked eye (Lillesand and Kiefer 1999). Many definitions of remote sensing include the notion of detecting and analysing the emittance or reflectance of electromagnetic waves from the surface of an object of interest, e.g. the Earth (see for example Short 2006). Campbell (2007) defines remote sensing as "the practice of deriving information about the Earth's land and water surfaces using images acquired from a an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from the Earth's surface".

Remote sensing is dependent on spatial, spectral, radiometric, and temporal resolution (cf. Jensen 2000, Campbell 2007, or Appendix 1).

The use of satellite imagery has a long tradition when mapping land cover and land use. The Landsat program has provided data for the community of the Earth's sciences for 35 years. The 16-day repeat cycle and the production of 30-m spatial resolution of multispectral images have proven valuable in various fields of research (Arvidson et al. 2001, Goward et al. 2001). Landsat data has been used when monitoring land cover change, natural hazards, climate change, and the dynamics of ecosystems, (Goward et al. 2001, Vogelmann et al. 2001, Guerschman et al. 2003). A contributing factor to the widespread use of the Landsat images might be that there are no restrictions on sharing and copying original or derived data sets (Goward et al. 2001). The latest of the Landsat satellites is Landsat 7 and it carries an enhanced thematic mapper sensor (ETM+). This sensor has some advantages compared to the older thematic mapper (TM) sensor (Masek et al. 2001). Tests on radiometric precision performed by Masek et al. (2001) suggests that ETM+ has an improved capability to distinguish different types of land cover compared to TM. The geodetic accuracy has also been improved. The data from TM and ETM+ are, however, compatible and can be used simultaneously (Vogelmann et al. 2001). Utilizing satellite images of medium spatial resolution has inherent problems (Cingolani et al. 2004). Land cover or land use units derived solely from a satellite image cannot be smaller than the spatial resolution of that particular sensor. There is also a risk of so-called mixed pixels, where one pixel covers more than one type of land cover (Smith and Fuller 2001). Consequently, enumeration units have to be larger than the resolution of the dataset.

Using older satellite images when conducting research on land cover and land use can be problematic. Preferably, the imagery should be collected within the same period as the ground-truthing is performed (ground-truthing is the documentation of land cover or any other parameter using sources such as field visits or aerial photos), the reason being that land cover and land use might change over time (Lee et al. 1999). Due to factors like cloudiness and availability, a recently captured image can be difficult to find.

2.5 GIS and modelling

Modelling can be defined as breaking down datasets and data processing techniques into smaller well-defined units (Tomlin 1991). Map layers containing individual and unique data types can be regarded as variables, which can be used for 'calculations' or procedures that will result in the required final data set (or map). A simple modelling technique defines only the map layers required, whereas more complex techniques defines basic datasets and a complete set of procedures (or operations) needed to reach the final stage. The purpose of any model is to clarify what the necessary datasets and procedures are and the proper order the datasets are used and the procedures are applied. A model should also contain procedures for data preparation and data presentation (Tomlin 1991).

During the last 30 years, geographic information systems (GIS) have become an increasingly important tool for gathering, storing, analysing, modelling, and visualising spatial data (Lee et al. 1999, Ceccato and Snickar 2000). It has gradually moved from being a replacement of traditional, manual techniques of mapmaking to a potent tool for manipulation and analysing geographic information. In e.g. nature conservation, GIS can be used as a decision support system to find suitable areas to protect (Lee et al. 1999, Geneletti 2004).

2.6 Land cover and land use

Land cover can be defined as the vegetation and man made constructions, whereas the term land use is more concerned with the management of the land cover (Anderson 1972). However, the two concepts are not always easy to differentiate. A satellite sensor will only record land cover, but the image can be interpreted and divided into land use categories by using texture, shape, location etc. (Anderson et al. 1971). A land cover category 'Grassland' can be interpreted as a land use category 'Cropland' based on its rectangular shape, homogenous texture, and closeness to a farm. Defining land use can be an elaborate process concerning the utilisation of other sources of information (interviewing land managers, analysing recent aerial photos etc.).

The production of a land cover/land use datasets should be founded on well-defined classification systems. The choice of a proper system of classes (forest, cropland, etc.) is important and entails central concepts such as scale and level of detail. Issues concerning representation in GIS have been addressed by Bibby and Shepherd (2000), where the authors stress the importance of using a proper terminology when naming land use classes. They suggest that utilizing a GIS will reduce the amount of diffuse terminology. It is considered vital to have a clear concept of a proper denomination of a particular land use when addressing the public or the land manger, where confusing terminology could result in errors throughout data collection.

2.7 Land access map and visualization

Successful map design is based on a balance between visual aspects and practical aspects (Skupin 2000). When creating maps for professionals, particularly within the same profession, the mapmaker can assume a certain degree of prior knowledge on how to interpret the presented data. A map that is intended for use by people of varying (or unknown) experience should be created with extra care. Symbols, patterns, and colours need to be carefully thought out, which is especially important for static maps. In dynamic digital maps, these problems can (to some degree) be overcome by using GIS-like functionality. Asche and Herrman (1994) identified three levels of interactive maps where spatial data exploration can take place. The first level is the 'view-only type' where only simple tools such as zooming and clicking buttons to change the data are used. The second level is the 'database interaction type' where more flexibility is built in. The user can add different data layers from the database. The third level is called the 'analytical type' and allows the user to perform the same kind of analysis and exploration as the creator of the system. These forms of interactive maps can, if used on internet facilitate the distribution of spatial information to a wider audience (Ceccato and Snickar 2000).

3 Modelling land access

The attempt here is to weigh various (and sometimes conflicting) interests together in a coherent model that will function as a guide for the production of a land access map. There are elements of subjectivity in the process of putting all interests together. The model should not only fit most physical environments it should also cater for the diverse interests amongst land managers and land users.

The project is restricted to model farming activities, hunting activities, plants, and wildlife. Other activities such as forestry, fishery, etc. are not modelled. Furthermore, only restrictions to land are taken into consideration, not water. The aim is to model land access in such a manor, that it can be expanded to any type of activities or any form of access related to the outdoors.

3.1 Model overview

The first part of the model is about creating a land use map, which is the basis for the access map. Existing official land cover maps can be used if they are of recent date and of sufficient spatial resolution. An intricate part of developing the land use map is to define and create land parcels (i.e. polygons representing individual land units such as a crop field or a small forest). The landscape should be divided into parcels based on cadastral units. In Scotland, there are official sources for property information (Scottish land registry, etc.) but some are incomplete or confidential. Ordinance Survey land line data does contain information about field boundaries, which can be used as a basis. Satellite imagery at the resolution of 10m or better can be used when detecting field boundaries, but aerial photos are preferred. Enhanced multispectral visible and near-infrared satellite sensor data should be used as a support when deciding upon boundaries between different forms of land cover. A criterion for the construction of a parcel should be that it must be recognisable in the field by professionals as well as non-professionals and reflect an up-to-date land use. Very large parcels have to be divided into smaller units that are easier to identify in field. These are (preferably) based on shifts in land use or vegetation. Small patches of vegetation can be omitted to create a more generalized map. During the creation process, every parcel is given a unique identification number. The second part is about processing necessary datasets and adding data to the land parcels as attributes. Processing the various data types represents different difficulties. Planned activities such as farming and hunting are spatially restricted by quite definitive boundaries (fields) in contrast to plants and wildlife, which usually are not. A detailed distribution map based on observations of a plant is not likely to change very quickly due to immobility, whereas a map showing the distribution of an animal may change shortly after the map is produced. Plants and wildlife are to high degree dependent on suitable habitats, which can be used when estimating the distribution. The third part is about calculating and applying an access index based on the available datasets. The index is a value reflecting the risk of disturbance and is to some extent subjective. The fourth part of the model is about producing a map output that is consistent with the theory of cartography and geovisualisation to make it understandable and useful to most people. The datasets used to produce the land access map should allow a 1:25,000 scale paper map to be generated.

The datasets and procedures constituting the model are summarized in Figure 1.

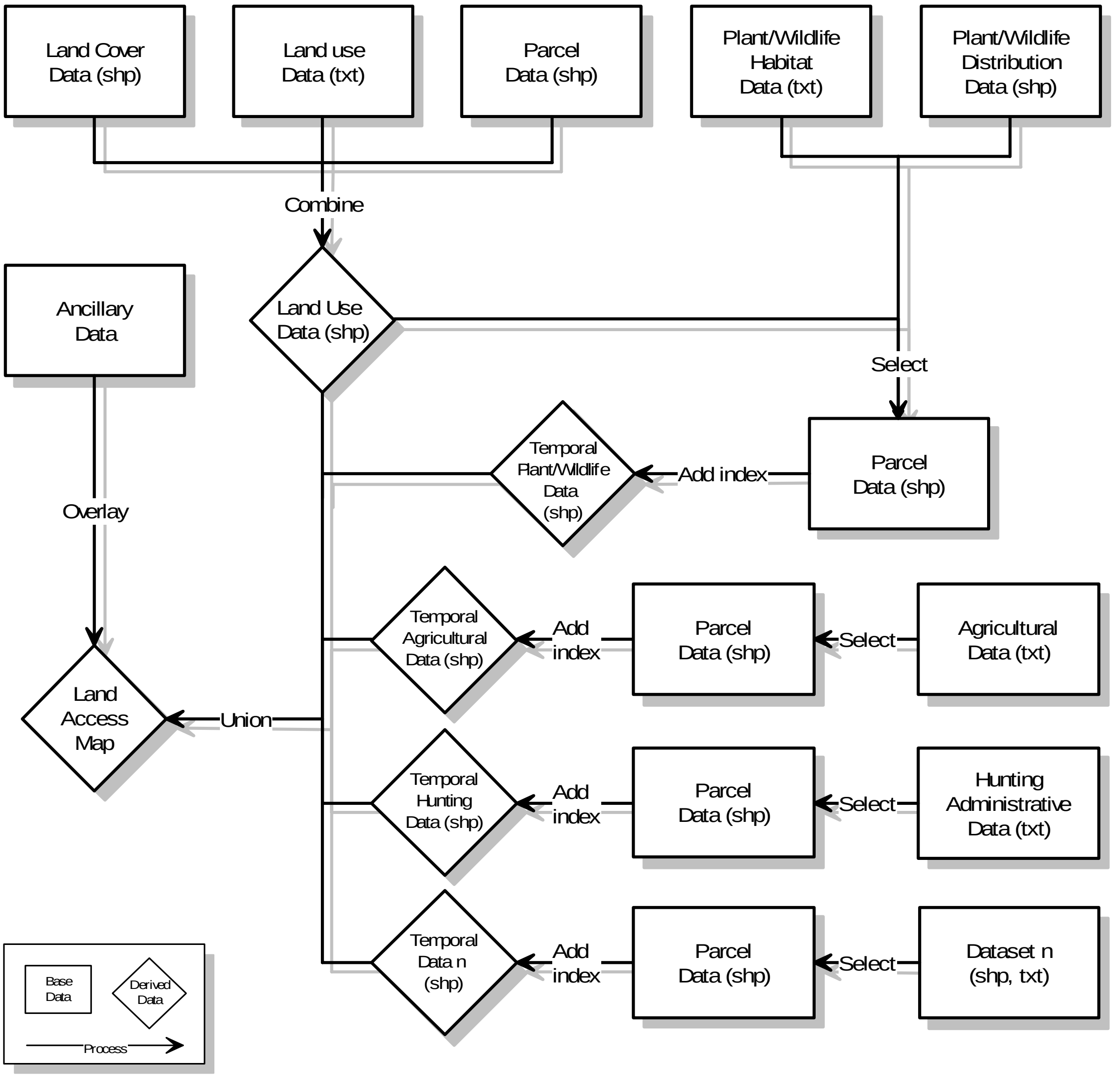

Figure 1. The land access model. The flowchart outlines the datasets and procedures for generating a land access map.

3.2 Determining land cover and land use

The general methodology for creating a land cover/land use map covering an area of interest consists of three phases: data collection, pre-processing of datasets, and processing of datasets. Data collection consists of finding satellite imagery of reasonable spectral and spatial resolution that is needed for the classification process. Ground-truthing based on extensive fieldwork is crucial for a successful classification of the land cover/land use types. Pre-processing consists of geo-correcting images, projecting images to a common reference system (e.g. the British national grid), reduce datasets to fit the extent of the area, and to generate a land parcel dataset. The first two phases are intermingled, since pre-processing of some data (e.g. unsupervised classification of a satellite image), has to be performed before other data can be collected (e.g. ground-truth data). Processing consists of performing the final classification of land cover/land use. Parts of the methodology concerning procedures for image processing in ERDAS Imagine have been outline in Figure 2.

3.2.1 Land parcels

Parcel-based mapping as described by Smith and Fuller (2001) is a methodology suitable for building a vectorized land cover dataset. The landscape is divided into parcels, were each parcel represents a piece of land with a specific land cover type. This method is very efficient in areas dominated by urban, arable, or grassland fields, and less efficient in natural environments were the parcels might be less pure. The benefit of this methodology is that each parcel (or polygon) can be joined to other kinds of information (ancillary datasets) such as size, class or any other value.

3.2.2 Land cover/Land use classes

During the process of creating a land cover/land use dataset, a classification scheme is necessary. Worldwide, there are several options available. In Scotland, the Macaulay Land Use Research Institute used the Land Cover of Scotland 1988 (LCS88) scheme when the first Scottish land cover census was undertaken (The Macaulay land use research institute 1993). Land Cover Map 2000 (LCM2000) (Jackson 2000) has been used by the Centre for Ecology & Hydrology and focuses more on differentiating habitats. Classification schemes are usually created to meet specific demands made by the project owner and seem difficult to standardize for general use.

In the current land access project, the aim is to create a simplified classification scheme consisting of a few classes easily recognisable in the field by a member of the public. US Geological Survey (USGS) has created a scheme that intends to be open and easily adjusted to differing requirements.

A set of seven major land cover/land use classes based on the classes defined by USGS (Anderson et al. 1971) is sufficient to meet the basic needs (see Table 1). The classes are agricultural land, rangeland, moorland, wetland, woodland, urban/built-up land (including roads), and water (lakes, rivers etc). Each class is illustrated by photographs in Appendix 2.

Table 1. Suitable land cover/land use classes.

Class	Class No	Subclass	Subclass no	Description
Agricultural Land	1	Undetermined	10	No discriminating features
Agricultural Land	1	Cropland	11	Crops, potatoes etc.
Agricultural Land	1	Pasture	12	Grassing animals
Agricultural Land	1	Meadow	13	Hay production
Rangeland	2	-	2	Grassland, not agricultural land
Moorland	3	-	31	Heather etc. and trees
Moorland	3	-	32	Heather etc.
Wetland	4	-	4	Bogs and marshes
Woodland	5	Deciduous	51	Birch, oak, aspen etc.
Woodland	5	Coniferous	52	Pine, spruce etc.
Woodland	5	Mixed	53	>33% of either 51 or 52
Urban/Built-up land	6	-	6	Residential areas, roads, etc.
Water	7	-	7	Rivers, lakes etc.

Agricultural land is divided into three subclasses: cropland, pasture, and meadow. Moorland is divided into two subclasses; one with trees (a mix of coniferous and deciduous) and one without. Woodland is be divided into three subclasses deciduous, coniferous, and mixed. The various subclasses can be difficult to separate using only image processing techniques and will have to be separated using other techniques such as ground-truthing and ancillary data from Ordinance survey. Data for Urban/built-up land and water bodies can be retrieved from OS Land line data.

3.2.3 Pre-processing data

A part of the problem of collating datasets into one coherent system is the variety of data formats used. Before any processing of data can occur, conversion of the various datasets into suitable formats is important. Some of the OS data are distributed in the National transport format (NTF), which needs to be converted to ESRI shape files using e.g. ESRI Map Manager. Text based information can be edited and converted into MS Excel for easy manipulation. Furthermore, an unnecessary large data set will slow down the analysis and to solve this, all the acquired data has to be reduced (e.g. cropped) to fit the extent of the area of interest. Image files (satellite images etc.) can be cropped using ERDAS Imagine and vector files can be clipped using ESRI ArcView. Tiles of raster data from Digimap can be converted to ERDAS Imagine format (image) to reduce the number of individual files. In general, vector data should be converted to (or produced in) ESRI ArcView format (shape) to facilitate data manipulation, since this is a well-known and widely used format.

Satellite imagery can be georectified (if necessary) in ERDAS Imagine using at least 10 ground control points from an OS raster map (scale 1:10,000). The image should also be enhanced using a 3x3 low pass filter to facilitate the classification process.

An unsupervised classification should be undertaken to build up an a priori knowledge about possible land cover classes. The aim is to separate circa ten classes based on the ISODATA algorithm. Representative ground-truth points should be distributed across the area of interest. At least three representative ground-truth points should be selected from each class (excluding Urban/built-up land and water, which are retrieved from an OS raster map). An increased number of points will result in a more accurate map, but will also take longer to produce. These points can be mapped using e.g. ESRI ArcView 3.3 and the coordinates and point names can be exported to a text file. The points should be located in the field using a GPS and thoroughly documented in field taking photos of representative views and detailed photos of the ground. These photos can be used as references when comparing ground-truth data and checkpoints for future error assessment. A compass can be used for describing the direction of the view.

Conventional image processing techniques such as NDVI index (Normalized Difference Vegetation Index) could facilitate the separation of subclasses such as cropland, pasture, and meadow. This index should also separate different kinds of crops (even different stages of growth). This technique would need very up-to-date imagery to be useful since shifts in land use can occur at any time.

3.2.4 Processing data

The main part of the processing consists of performing a supervised classification based on a satellite image. Two types of classifiers can be used: parametric and non-parametric (Thomas et al 1987). Parametric signatures depend on statistical methods to assign a pixel to a particular class, whereas nonparametric signatures use feature space, i.e. distance (Gibson and Power 2000). Maximum likelihood is commonly used as a parametric rule to decide to which class a particular pixel should belong. It will assign pixels to classes according to probability i.e. further away from the class the smaller the probability is that the pixel belongs to that particular class. This method assumes that the datasets in each training field are normally distributed (Gibson and Power 2000).

When classifying the Landsat image, band 3, 4, and 5 of the ETM+ sensor may be used because of their suitability to separate different vegetation types (Gemell 1995, Smith and Fuller 2001, Dymons et al. 2002). Furthermore, these bands are less influenced by atmospheric conditions as bands of shorter wavelength.

In Erdas Imagine, spectral signatures from each class based on the ground-truth data are created using the 'Region Grow' tool. This tool selects all pixels in an area that comply with user-defined distance and value parameters. Based on the signatures collected, a supervised classification can be undertaken.

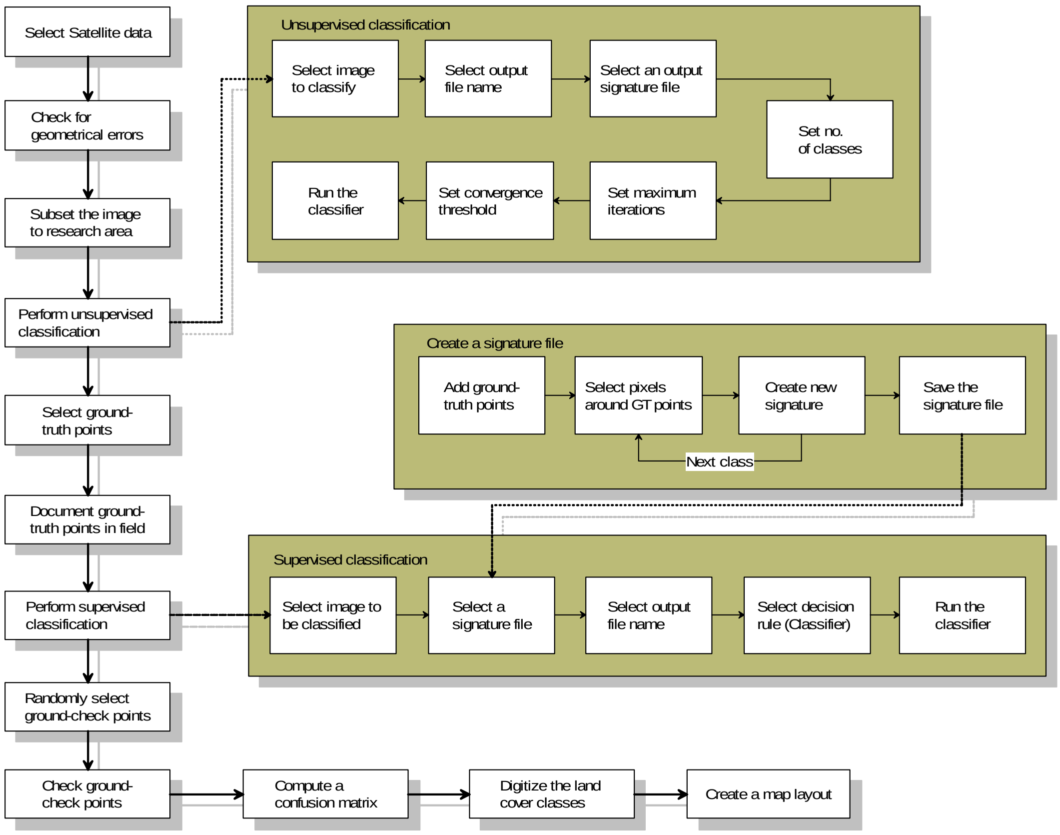

Figure 2. Flowchart outlining the necessary steps to produce a land cover map in ERDAS Imagine.

3.2.5 *Defining land use*

A vital part of the model is the preparation of a land use dataset based on land cover data, information from land managers, and land parcels. Furthermore, since the use of some types of land is likely to shift during a year, temporal information has to be added. Forests and urban areas can be regarded as being quite static compared to agricultural fields, which are assumed changing regularly (ploughed, sown, growing, harvested, and fallow). The temporal resolution of the agricultural dataset could be a few hours since it is dependent only on the intervals between updates.

Up-to-date land use information regarding agriculture and hunting has to be retrieved from land managers. For agricultural activities, a questionnaire can be distributed to land managers either via postal services or at meetings depending on how many individual managers operates in the area of interest. A questionnaire should consist of simple questions about where, when and how a particular field is used (see Figure 3).

Questionnaire												
Name												
Property												
Contact info												
Field name.							Field no.					
Primary use	Crop land		Pasture		Meadow		Other					
Secondary use	Crop land		Pasture		Meadow		Other					
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Unsuitable for passing												
Not preferable to pass												
Suitable for passing												

Figure 3. A suggested questionnaire to be used when retrieving information from farmers within the area of interest.

3.3 Processing agricultural data

Agricultural data such as growth season for crops, breeding season for animals is necessary when suggesting restricted access to particular agricultural fields. Access to official records of land manager data, i.e. name, address, field name and field boundary, facilitates the process of collecting these data.

Establishing a detailed land use using medium resolution satellite imagery can only be done to a certain level of accuracy. Agricultural land is particular difficult to separate into detailed subclasses. The attributes of an area of interest covered by a satellite image is represented by brightness values (spectral signature) and texture and can be used to tell whether it is e.g. agricultural land or woodland. To determine if e.g. the agricultural land is used for crops or hay production is much more difficult. Furthermore, a grassing field might be accurately classified, but not if it is used for cattle or sheep. To make these classifications, sources such as land managers or extensive fieldwork is needed. Temporal information regarding the crop calendar (i.e. when crops are sown, when they are harvested, etc.) must be added as an attribute data to all fields.

The general procedure for processing agricultural data involves gathering detailed information about when and where activities such as growing crops or hay, breeding livestock, etc. occur (according to the procedure given in section 3.2.5). The land parcels used for the various types of agricultural activities are selected and an index value is added to the attribute table of the selected parcels.

3.4 Processing plant and wildlife data

Data on plants and wildlife, particular protected species, must be used when suggesting level access to the outdoors. The use of existing data on protected sites (e.g. SSSI, SPA, SAC, and Ramsar) facilitates the process of assessing sensitive areas.

Areas were wildlife is common can be retrieved from e.g. NBN Gateway (http://gateway.snh.gov.uk). Temporal information concerning nesting/breeding period for animals and growth season for plants as well as habitat preferences can be found in floras and faunas and must be added as attribute data to all species. To locate suitable habitats for plants, a soil map (25m resolution or better) showing variations of soil types is necessary.

There is a clash of interest when making people aware of the existence of protected species in an area. On the one hand, people are expected to know the whereabouts of sensitive species. On the other hand, organisations put to protect these species are reluctant to give away detailed information about the position of these species (cf.

http://gateway.snh.gov.uk). Precautions must be taken to make sure the collated data will not facilitate criminal actions such as the collection of eggs or seedlings from protected species. This means that in order to protect the species, the spatial resolution of plant and wildlife datasets cannot be too high. A reasonable spatial resolution regarding habitats is one square kilometre for species on the IUCN Red List of Threatened Species (http://www.Iucnredlist.org) and 100m for other species. The various habitats for plants and wildlife have to be 'down sampled' (or generalized) in order to fit the general characteristics of the land cover classes used (see section 3.2.2).

The general procedure for processing plants and wildlife is to select sites based on habitat preferences and official distribution maps. The locations are buffered to a distance determined by information retrieved from reference literature and research papers regarding individual species. The buffer is used when selecting land parcels representing land use classes most similar to the habitat of the mapped species. An index value is added to the attribute table of the selected parcels. If no literature references regarding buffer distances are available, a default distance of 300m may be used (based on the perimeter suggested by Erwin (1989) for birds during the mating season).

Species that are used in the Land access map should be named by their common name and scientific name.

3.5 Processing hunting data

Information on other seasonal activities, such as hunting needs to be incorporated in the model. Hunting activities are in a similar way to agricultural activities organised by land managers and to some extent, restricted to particular vegetation types. The timing and location of activities such as stag stalking and grouse shooting can be retrieved from local hunting organisations and land managers.

The general procedure for processing hunting data is to gather information on species that are hunted in the area of interest. Temporal information about when the species are hunted is added to each species. If no organisation or land manager is at hand to give this information, general data on hunting seasons can be retrieved on internet (e.g. http://www.naturenet.net). The land parcels used as hunting grounds are selected and an index value is added to the attribute table of the selected parcels.

3.6 Access index

An index value based on the risk of disturbing a site is used to facilitate the process of modelling land access. The index must cater for spatial and temporal differences in vulnerability between specific land parcels. It will function as a tool for valuating the various activities within the area of interest. The index, which is called *Access index*, has three grades, where level one represents no risk of disturbance and level three represents a high risk of disturbance. A three-graded scale will be sufficient to define the preferred access, whereas more levels might be confusing to the user of the land access map. In Table 2, the three levels are defined and examples are given for each type. The definitions of these levels are based on the interpretation of the Scottish Outdoor Access Code and published research papers (reviewed in section 2.3).

Table 2. Definition of the three levels of the access index.

Access index		**Definition**	**Agricultural data**	**Wildlife data**	**Plant data**	**Hunting data**
Level 1	Free access the area	Low risk of disturbance	Fallow or harvested field	Not breeding	Dormant	No activity
Level 2	Access the area but tread carefully	Medium risk of disturbance	Grassing animals or a growing meadow (<20cm)	Nursing	Growing	Ancillary activities
Level 3	Do not access the area unless necessary	High risk of disturbance	Sowed field, growing crop, meadow (>20cm), animals with young ones	Breeding/ mating	Seeding	On going activities

In the context of the land access model the term ‘disturbance’ is defined as ‘any form of behaviour, such as walking, bicycling, riding, and camping that may disturb farming activities, wild plants, wildlife, hunting activities etc.’.

Every land parcel in the area of interest has to be evaluated against all available data types. To facilitate the process, a hierarchical system of matrices is constructed, where each matrix contains information from each data type. The matrix consists of the time periods (e.g. month or any other suitable temporal resolution) as columns and the individual parcels as rows (see Table 3). A datasheet containing such a matrix is constructed for each data type.

Table 3. Data table showing how the access index values are structured. Each land parcel is assigned an index value calculated from a set of data sheets (one sheet for each activity or species). PID = Parcel identification number.

PID	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
P1	1	1	1	1	1	1	1	1	1	1	1	1
P2	1	1	1	1	1	1	1	1	1	1	1	1
P3	1	1	1	1	1	1	1	1	1	1	1	1
P4	1	1	1	1	1	1	1	1	1	1	1	1
P5	1	1	1	1	1	1	1	1	1	1	1	1

For plant data, wildlife data, and hunting data, an individual datasheet is created for each species. Every individual parcel in one data sheet is compared to the same parcel in all of the other data sheets. A combined maximum index ($Index_{max}$) is calculated from the highest index value for particular parcel in each datasheet (see Figure 4).

The system of using matrices (sheets) for each individual data type allows for an indefinite number of data types to be added. This procedure results in a final dataset that will be used as the land access attribute.

Most parcels may receive a very low number in wintertime when there are few agricultural and wildlife activities, whereas most parcels might receive a high number during the summer season because of a high level of agricultural and wildlife activities. Plants and wildlife that is not protected (e.g. not on the IUCN Red List), will be assigned level 1 most part of the year, whereas for species that are protected, only level 2 or 3 will be used depending on season. Agricultural and hunting activities may be assigned any of the three levels depending on season and land use.

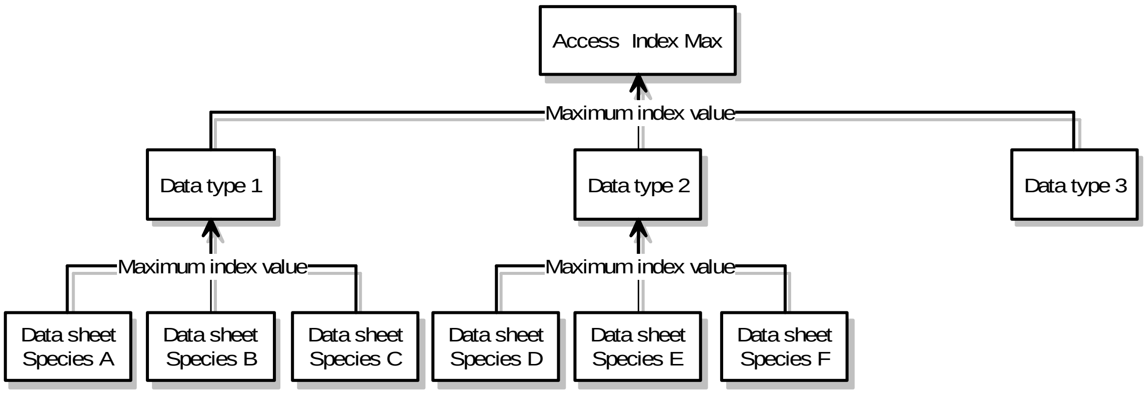

Figure 4. The flowchart shows the hierarchical structure of the matrices. Individual data sheets are compared, and the highest index value for each land parcel in each sheet is transferred on to the next level. Data sheet A to F represents individual species of plant and wildlife data. Data type 1 to 3 represents higher level of collated data (agricultural data, hunting data, or plant and wildlife data, etc.).

The final access index sheet is exported to a dbf file or text file and imported to a GIS software package (see Appendix 3). The index file is joined to the land parcel shape file. Displaying temporal variation is achieved by choosing data from a preferred column (e.g. ‘January’).

3.6.1 Agricultural data

Three different levels of agricultural activities are suggested. When a field is put to fallow or has been harvested, accessing the field can cause very little damage (level 1). Fields that are used e.g. by grassing animals or for growing hay or silage (a meadow) can be accessed (level 2), whereas sowed fields, growing crops, meadows grown more than 20cm (defined by the Scottish Outdoor Access Code, part 3:§37), meadows for animals with young ones, etc. should not and are thereby classified as level 3.

3.6.2 Wildlife data

Different forms of wildlife display different responses to disturbance by humans (see section 2.3). Three general stages in the animal life cycle can be distinguished; ‘Not breeding’ (level 1), ‘Nursing’ (level 2), and ‘Breeding’ (level 3). Nursing amongst e.g. birds is regarded as being a less vulnerable stage than breeding (Erwin 1989).

3.6.3 Plant data

The three levels for plants are defined as ‘Dormant’ (level 1), ‘Growing’ (level 2), and ‘Seeding’ (level 3). During the dormant period, usually during the autumn and winter season, plant sites are presumed to be less sensible to trampling. During the growth season, and later when they are producing seed cases, they are increasingly vulnerably to inattentive ramblers.

3.6.4 Hunting data

When evaluating hunting activities the three levels can be defined as ‘No activity’ (level 1), ‘Ancillary activities’ (level 2), and ‘On going activities’ (level 3). Ancillary activities are defined as actions supporting hunting such as building hideouts and towers, feeding game etc. A visitor may disturb the work that is carried out or the animals that tries to access fodder. ‘Ongoing activities’ refer to the actual hunt. A visitor can be risking his or her life by entering the area. There is also a risk of interrupting the hunting activity.

3.7 Error assessment

In any form of data collection or data processing, errors will accumulate. Developing an understanding of how they are created and how to handle them is important. Sources of error include the number of documented ground-truth points, the spatial resolution of the datasets (e.g. satellite image), the spectral resolution of the satellite image, and the classification method itself etc. A major source of error is the satellite image. It is important that the image is relatively up-to-date or collected about the same time of year the collection of ground-truth is performed (Campbell 2007). Another main source of error is the number of land cover/land use classes chosen. If the number of classes is too low, there will be a high risk of mixed classes and if the number is to high similar land cover/land use types could be separated into different classes. The spectral patterns of the defined classes have a natural variation due to vegetation age and state of growth. Factors like haze, topographical errors and sensor noise affects the spectrum (Campbell 2007).

An accuracy assessment of the land cover/land use classification should be performed based on a comparison between ground-truth data and the classified map using a so-called error matrix or confusion matrix (cf. Jensen 2005, Campbell 2007). The literature does not give a concise number of ground-truth points needed relative to the size of the area or number of classes. There are various sampling methods based on statistical analysis that can be utilized e.g. stratified random sampling (Jensen 2005). The number of points is normally a compromise between time, resources, and the required quality of the final classification. The aim should be to gather good quality ground-truth data to achieve a level of accuracy higher than 80 percent. Furthermore, a producer’s accuracy, i.e. the probability of a pixel being correctly classified and consumer's accuracy, i.e. the probability that a pixel on the classified map will prove to be correct when compared to field data should also be calculated. The producer’s accuracy shows how good the classification can be, whereas the consumer's accuracy shows how well the classification fits to the real world (Campbell 2007). Calculation of omission and commission errors will improve the understanding about how reliable the classification is.

Processing plant and wildlife data contains two different kinds of errors. Distribution maps of a particular species shows were the species was spotted at the time when the data was collected. It does not mean that they actually are present the day the land access map is produced. The other kind or error is the choice of buffer size. Suitable protective perimeters have been determined for relatively few species. Distance values based on one species may have to be used for other species of similar behaviour and habitat, which may be erroneous.

3.8 Visualization

To design a map suitable for presenting and visualising the land access information is not a straightforward task. The land cover/land use classes are nominal categories and lend them selves well to be symbolized by colour (Kraak and Ormeling 2003). A suitable colour scheme should not only focus on the capability of separating classes (and land parcels) but also follow conventional map design (blue for water, green for forest etc.). Preferably, the colour scheme of the map should simulate natural colours to facilitate identification in field. However, defining what the natural colour of e.g. a crop field is complicated since the colour will change from brown (ploughed) to green (growing crop), and finally to yellow as the crop matures. Other problems concerning the use of colour compared to grey-scale are e.g. colour blindness. These issues could be solved if the map would be distributed digitally, where the colour scheme could be changed to better suite the user. For printed maps, for which prizes have dropped dramatically over the last years, great care has to be taken when choosing colours to represent various land uses.

The visualisation of the access index and its variation across the area of interest is vital for the success of the land access map. Kraak and Ormeling (2003) have described the creation of a map as a limiting process, where geospatial data has to be reduced and sometimes generalised in order to fit the available space that will be the final map. The real world is modelled into points, lines, and polygons, which allows for adding a variety of attributes to the map. The map should only contain data directly related to the access index and should rely on complimentary maps for additional information. The land access map would otherwise be cluttered with features that might put the sole purpose of the map at risk i.e. highlighting risk areas. On the other hand, too few guiding features will make the map difficult to use. Persons with little experience in reading maps should be able to retrieve the information.

Symbols, colour schemes, and scale are aspects of the map that have to be carefully considered. Bertin (1981) has defined eight visual variables that can be used when constructing the graphic system of a map. Besides the position of a point (the x and y coordinates), six other visual variables - size, value, texture, colour, orientation, and shape - can be used for symbolizing the variation in the third dimension 'z'. Bertin separates theses variables into two groups; variables of the image (x, y, size, and value) and differential variables (texture, colour, orientation, and shape). The first group can be used to indicate order or proportion, whereas the second group lacks this ability. A smaller to a larger circle or a change in value from 'light grey' to 'dark grey' can be a sign of an order, whereas e.g. the colours 'green' and 'red' and the shapes 'square' and 'circle' can not.

The choice of symbols for the access index is based on three criteria. Firstly, the meaning and interpretation of the symbols should be immediately apparent. Secondly, the symbol layer has to be transparent not to cover the underlying land use information. Thirdly, the symbolisation has to work at different scales. Based on Bertins (1981) research, the preferred symbolisation in this case would be variations in size or in value. However, these do not meet the criteria stated above. The size of the symbol is limited by the size of the parcel. It must be large enough to be easily recognised and it must not exceed the boarder of the parcel. On a small-scale map, using symbols only differing in size might be difficult to visually separate. A variation in value (e.g. two variations of grey) fails the criteria of transparency. Bertin (1981) states that differential variables in theory cannot depict an order between to points, with one exception - ‘texture’. Texture can create a sense of relief if used properly and hence, be utilised when showing an order between parcels. Used in this sense, ‘texture’ bares similarities to ‘value’. A parcel containing many dots will be perceived as darker than a parcel containing fewer dots. Since it can be adapted to any scale and it can be made transparent, the use of texture is the symbolisation that meets the three criteria and solves the problem of representing the two levels of access most efficiently. Optimally, there should be a symbol for each data type or even for each species but this would cause the map to be too overloaded with symbols.

A texture created from two differences in density can be used when symbolising level 2 and level 3. Level 1, which is defined as ‘full access any time’, will have no texture (see Figure 5). If level 1 would have a texture, the result would be a map completely covered in symbols and would make the map unnecessary cluttered.

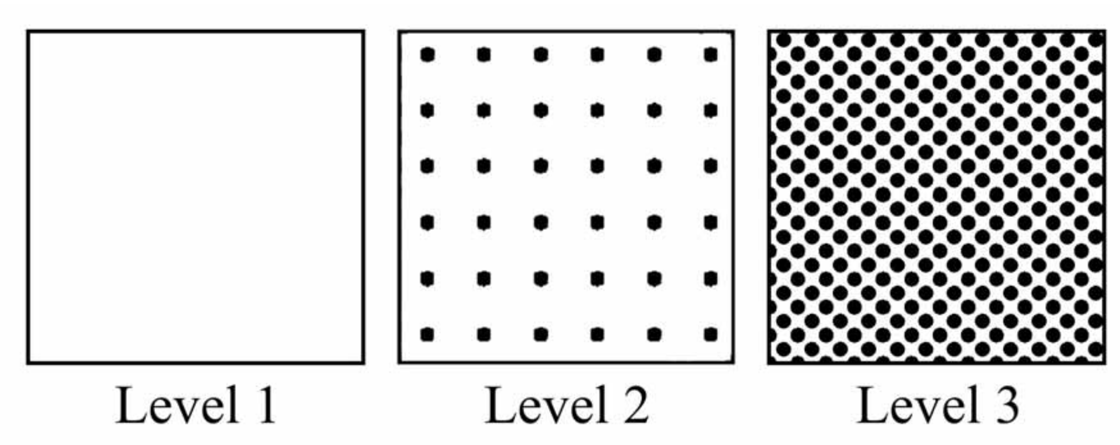

Figure 5. The three levels of access are symbolized using a variation in texture.

According to Bertin (1981) when the visible variables are used for depicting order, the absence of a symbol will carry meaning. Consequently, if there are areas were no data is available, e.g. a crop field were the land manager has not revealed the land use, the parcel should be left blank (i.e. no colour). The parcel would otherwise be regarded as part of a level 1 area.

4 A case study

In order to test the model, a case study was carried out. The selection process for finding a suitable area to perform a case study is based on a set of criteria. A study area must contain a mixture of forests, agricultural fields such as cropland and pastures, and hunting grounds. To ascertain an abundance of plants and wildlife, the area should also contain one or more Site of Special Scientific Interest (SSSI), Special Protection Areas (SPA), Special Areas of Conservation, or RAMSAR. Furthermore, it should contain a sufficient level of roads and paths to facilitate fieldwork. The size of the area should not be too large due to the time constraints of the project and it should not be made too small, which could result in a reduced number of differing land cover/land use types.

The study area chosen is situated in the Southwest of Aberdeenshire in Scotland (see Figure 6), crossing the borders of Upper Deeside, Aboyne, and Donside and Cromar counties. The area is 48.5 km^2 or 4848ha (x339250y802600 - x347150y796500 or NJ 339250802600 - NO 347150796500) and is a part of the Cairngorm national park. It contains the sites Muir of Dinnet (SSSI, SAC, SPA, Ramsar), Dinnet Oakwood (SSSI, SAC), and River Dee (SAC) (see Figure 7). Loch Kinord and Loch Davan are SPA and Ramsar. Furthermore, it contains representatives of all of the land cover/land use classes suggested in the model (see Table 1).

4.1 Datasets and sources

Based on the model outlined in Figure 1, the necessary datasets were collected. Many of the datasets were retrieved through resources on internet, from government agencies, and from university/library resources (journals, books, and maps). The data utilized consisted of a variety of formats such as raster images, vector data, and text-based data and are summarized in Table 4. The British National Grid was used as the reference system throughout the project.

Since the project is unfunded, no satellite imagery, aerial photography, official land cover/land use information, or soil data were purchased. Only free sources or licensed sources paid for by the University of Aberdeen were utilized.

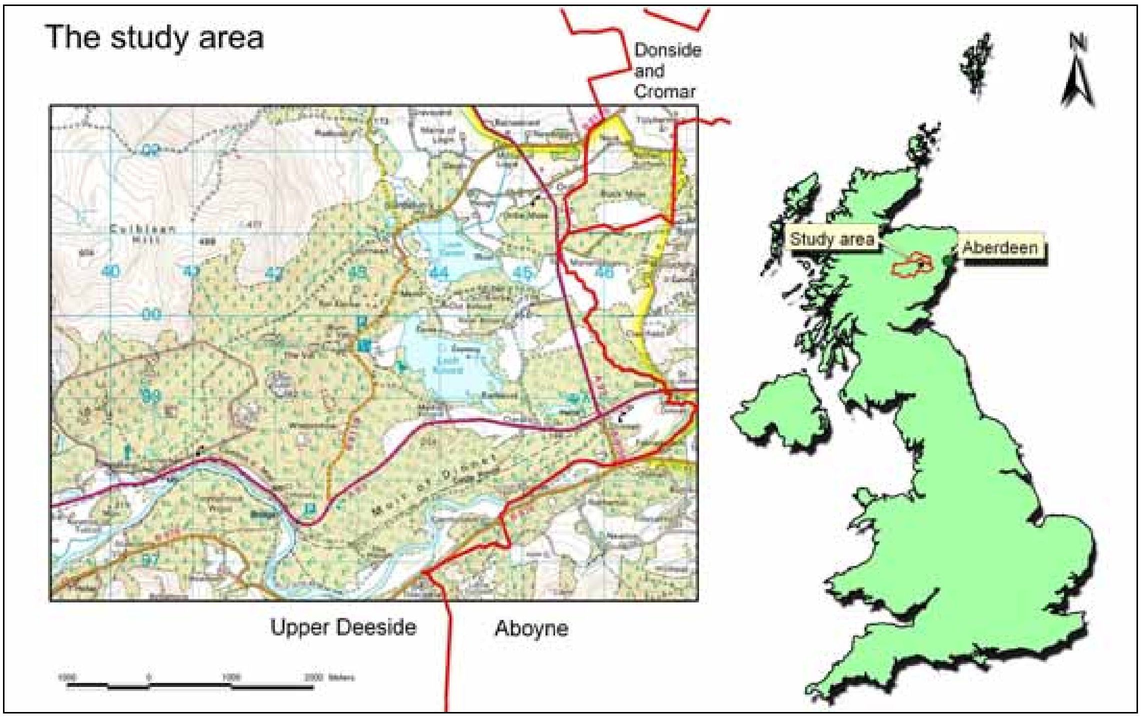

Figure 6. The location of the study area 50 km West of Aberdeen and the study area and county borders in detail. © Crown Copyright/database right 2007. An Ordnance Survey/(Data centre) supplied service.

4.1.1 Satellite imagery

A Landsat 7 ETM+ was retrieved from Landmap (http://www.landmap.ac.uk) (Path 205, Row 020) which was the most current image freely available. It was regarded to be a reasonable compromise between spatial resolution (30m), spectral resolution (seven bands), and collection date (acquired 17th of July 2000) and was utilized when determining the land cover. A SPOT panchromatic image was used as an aid when digitizing field boundaries (Path 21, Row 234, acquired 22nd of February 1991) and was retrieved from Landmap.

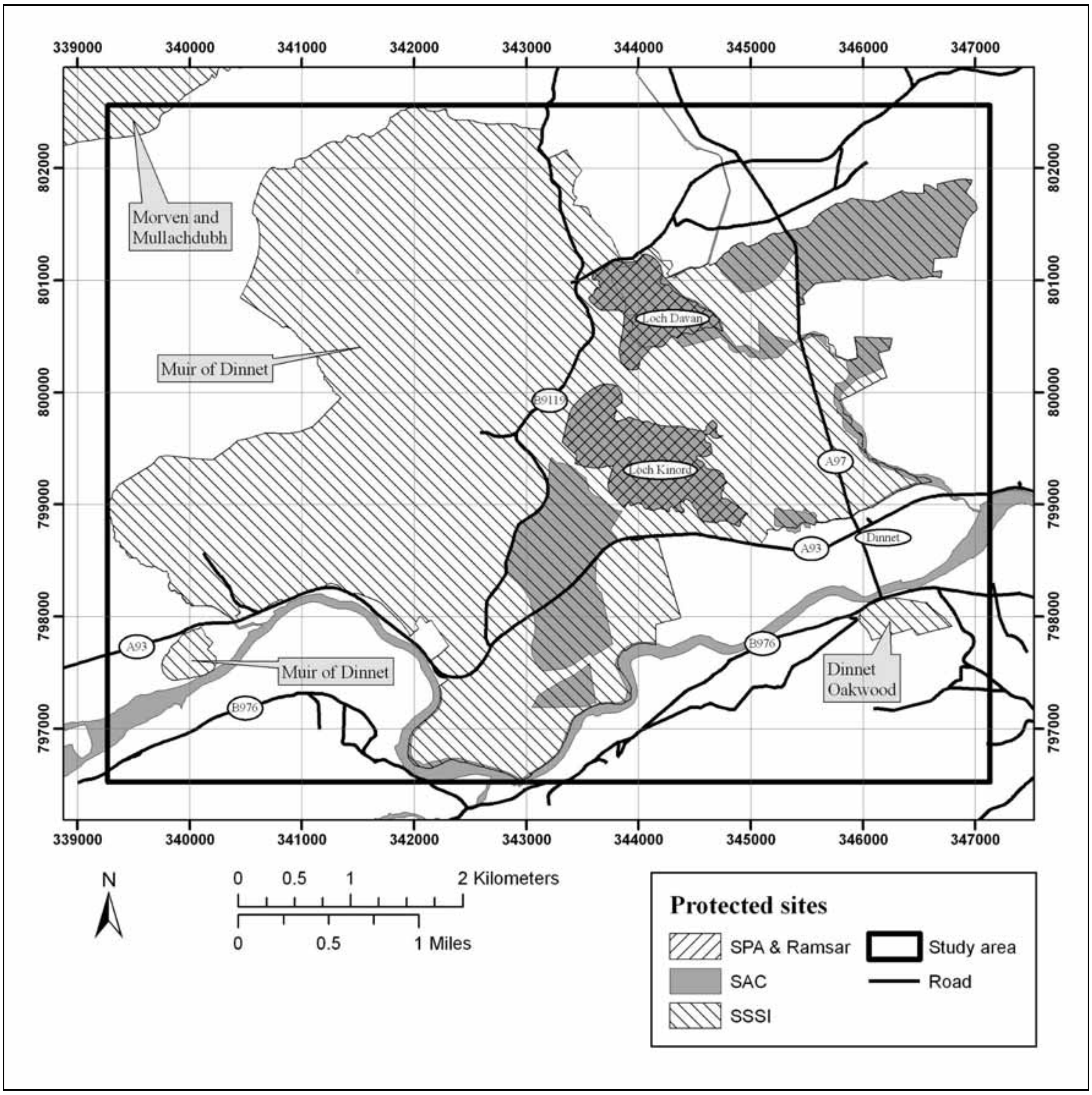

Figure 7. Protected sites within the study area. The boundary shape files are supplied by SNH, © Crown Copyright. All rights reserved [2007].

4.1.2 Fieldwork

Ground-truth data from 27 sites was collected (three points per class) and was used as training data when spectral data (brightness values) in the image was translated to land cover/land use information on the ground. An additional 29 ground-truth data points were randomly distributed across the research area and documented. These points were used in an error assessment where a coefficient of agreement was calculated.

4.1.3 Officially protected sites

Detailed text based information about the SSSI, SPA, SAC, and Ramsar containing site descriptions and species information was downloaded from Scottish Natural Heritage, SNH (http://snh.org.uk), and the Joint Nature Conservation Committee, JNCC (http://jncc.gov.uk). ESRI shape-files containing SPA, SAC, SSSI, and Ramsar boundaries was downloaded from SNH and used as an overlay when selecting the study area.

4.1.4 Agricultural data

Agricultural and Horticultural Census for Scotland (http://edina.ac.uk/agcensus) holds census data for various crops grown on agricultural land in Scotland. However, the spatial resolution is $2km^2$, which is not sufficient for the task of mapping activities within individual fields. Accessing detailed and accurate land use information regarding agricultural land requires information given by landowners. In Scotland, a range of sources of varying quality is available for data on land ownership. The Scottish Land registry has collected information about landowners since 1982 (Scottish executive central research unit 2001). A shortcoming of this database is that only land that has been sold has to be registered with the agency, whereas land that has not been sold (e.g. inherited) is not. Information that is older than 1982 can be retrieved from the Sasines Register, which holds data since 1617. However, these sources were not used. Based on the information given by people working in the study area and via a contact at the Upper Deeside Trust, basic data (name and telephone number) about landowners was possible to collate.

According to Millman (1969), the major part of the land in the study area is owned by Dinnet & Kinord and Glen Tanar estates. Dinnet & Kinord estate, which own most of the land within the study area, were invited to contribute to the project. Based on information given by them, the land use dataset could be corrected. Furthermore, the estate provided general advices concerning admission to grazing fields, which should not be accessed when used for cows with calves at foot, bulls, etc. According to Dinnet & Kinord estate, changes in land use are dependant on factors such as number of livestock and weather conditions, which change on a weekly or even daily basis, and are difficult to foresee. Hence, the temporal land use information needed in order to fulfil the criteria for the land access model could not be added. Consequently, the land access concerning agricultural activities could not be tested fully.

4.1.5 Plant and wild life data

A selected set of wildlife and plant species was used to test the model (one mammal, one bird, and one plant). To use the full extent of the study area and to map all current species was not feasibly given the time available for carrying out the project work (ca. 12 weeks). Spatial distribution of species and other data regarding plant and wildlife species was retrieved from the National Biodiversity Network Gateway (NBN Gateway, http://gateway.snh.gov.uk). The data can be used in research with some restrictions concerning the publication of original datasets. Data from NBNG are text based as well as map based. Information about protected plants and animals are available from the Peoples Trust for Endangered Species (http://www.ptes.org/) and The IUCN Red List of Threatened Species (http://www.Iucnredlist.org).

From the list of species published on NBN Gateway for the area of interest, the European otter (Lutra lutra), the Black-headed gull (Larus ridibundus), and the Early-purple Orchid (Orchis mascula) were selected as test species. These species were chosen because they are associated to specific habitats and thereby are easier to map in contrast to species that can live in a broad range of habitats.

The spatial resolutions of the downloaded datasets were 100 to 1000m for otter, 100m for the seagull, and 10km for the orchid. The distribution maps downloaded from

NBNG were registered to the British national grid in ArcView and the sites for each species were digitized. Habitat data, information about breeding seasons etc. was retrieved from internet sources and reference literature. Temporal information was documented with a resolution of one month.

4.1.5.1 The European otter

The European otter is a protected species according to the Wildlife and Countryside Act 1981 (Wildlife and Countryside Act 1981). It forages in water and build nests on land (Kennedy 2003). Rivers and lakes as well as streams are preferred habitats. The mating season is February to March and July and the cubs are borne ca. two month later. The cubs stay with their mother for as long as fourteen month. A Spanish study has shown that the core area for a group of otters can be 0.5–1.2 km long and covering an area of 6–7 ha (Ruiz-Olmo et al. 2005). Converting the hectares into a rectangle using 0.5-1.2 as one side gives a living space extending 58-140m away from a water body. No information regarding suitable size of a buffer zone could be found. By adding an arbitrary 50% to the estimated living space, gives a buffer of approximately 200m from any water body were the otter has been spotted.

Species	European otter (Lutra lutra)
Habitat	Terrestrial. Near water bodies
Perimeter	200m
Level 1	-
Level 2	April-June, August-January
Level 3	February-March, July

The otter data was processed by digitizing polygons from the distribution map at a 1000 m resolution (see Figure 8A). Water bodies in the study area were clipped using the ‘otter polygons’ as an overlay (see Figure 8B). The new set of water bodies were buffered to 200m and the buffer were used when selecting land parcels (select by theme in ArcView) (see Figure 8C and D). The selected land parcels represent an area of 1761 ha.

4.1.5.2 The Black-headed gull

The Black-headed gull is not a protected species in Britain (IUCN Red List of Threatened Species, http://www.Iucnredlist.org). It nests late April and May on the ground in colonies of 11-100 pairs (Hitztaler 2001). The habitat is terrestrial near the coast, at inland water bodies, or in marshes. Each pair uses approximately a $10m^2$ area, which they defend. The incubation lasts for 3-4 weeks and the chicks are independent after another 4-6 weeks (Tuck 1978). According to Erwin (1989), a 300m protective zone during the mating phase and 200m zone during the nesting phase should be sufficient to protect the gull.

Species	Black-headed Gull (Larus ridibundus)
Habitat	Terrestrial. Near water bodies, marshes
Buffer	200m (level 2), 300m (level 3)
Level 1	June-February
Level 2	April-June
Level 3	March

The seagull data was processed in a similar way as the otter data (see Figure 8). The selected land parcels represent an area of 296 ha.

4.1.5.3 The Early-purple orchid

The Early-purple orchid is, according to the Vascular Plant Red Data List for Great Britain (Cheffings and Farell 2005), not regarded as an endangered species. It grows on dry calcareous soil, preferably on meadows, on the margin of a forest, or in groves (Lang 2004). The orchid is a 10-60 cm high plant with purple flowers, some having dark spots on their leaves. White and pink flowered plants are known variations. It flowers late April to early July and depends entirely on seeds for regeneration. For this reason, the plant should be protected from trampling during spring and summer seasons.

Species	Early-purple Orchid (Orchis mascula)
Habitat	Meadows, on the margin of a forest, or in groves. Dry calcareous soil
Perimeter	
Level 1	September-March
Level 2	-
Level 3	April-August

From a soil map, woodland and meadows on calcareous soil would have been selected and used as potential habitats for the orchid. However, no soil map for the study area was available. Instead, a Land capability for agriculture map (Soil survey of Scotland 1986) was used when estimating suitable sites for the orchid. The map was scanned and registered to the land use data. An assumption was made that areas suitable for arable cropping (i.e. not to low pH) also would suit orchids. The 10km polygon that constitutes the area where the orchid has been found is covering the southern half of the study area. All parcels representing land use classes 'woodland' and 'rangeland', and the subclass 'meadow' intersected by Land capability classes 1 through 4 (see Soil survey of Scotland 1986 for reference) was selected. A buffer was not considered necessary since the selected land parcels represent a considerable area (174 ha).

4.1.6 Hunting activities

Stag stalking, grouse shooting, etc. are important activities that the public expects to know about before entering an area (Scottish Outdoor Access Code). Naturenet (http://www.naturenet.net) has information on hunting seasons for various animals. SNH maintain a system called Hillphones (http://www.snh.org.uk/hillphones) where the public can get information on when and where stag stalking will take place. The Hillphones service provides centre coordinates for the stalking area and suggests alternate ways to pass through the area. The service was however not active in the study area.

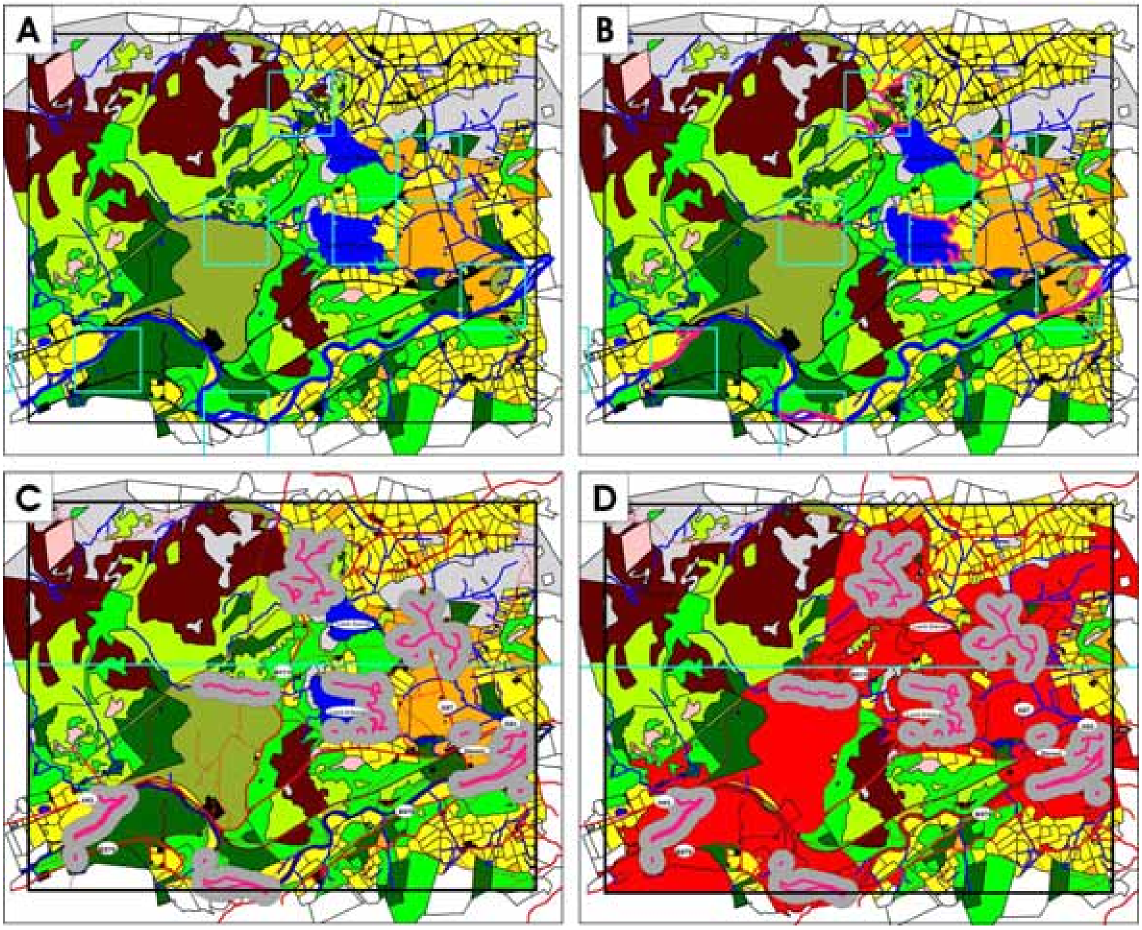

Figure 8. Map A-D exemplifies how land parcels are selected by using species polygons and buffering. In this case, otter data was used (European otter, Lutra lutra). Map A shows the extent of 1km polygons representing sites were otters have been spotted. In map B, the dataset containing water bodies has been clipped using the otter polygons. The new set of water bodies are buffered to 300m (map C) and the buffers are used when selecting land parcels (map D).

According to Dinnet and Kinord estate, hunting activities undertaken in the area concern roe deer stalking, grouse shooting, and pheasant shooting. The preferred habitats of the roe deer (Capreolus capreolus) are meadows and forests mixed with croplands. (Jacques 2000). Roe deer are hunted 1 April to 20 October (buck) and 21 October to 31 March (doe), which effectively means that hunting for this species can be carried out twelve month a year (Naturenet). The preferred habitat for pheasant

(Phasianus colchicus) is open land, edges of woodland, in groves and hedges (RSPB 2007a). Pheasant are hunted 1 October to 1 February (Naturenet). The preferred habitat of grouses is moorland (RSPB 2007b). Red grouse (Lagopus lagopus) are hunted from 12 August to 10 December (Naturenet).

Information about the exact location of the hunting activities could not be obtained from the land manager within the time frame of the project. Consequently, the land access concerning hunting activities could not be tested fully.

4.1.7 Ancillary data

Ordinance Survey map data was downloaded from Digimap (http://digimap.edina.ac.uk). OS Raster, scale 1:10,000, was used as a backdrop to other data sets. Vector data (field boundaries, roads, water bodies etc.) were retrieved from OS Land line plus and was used as overlay. To ascertain that there are possible access routes to the study area, data on existing paths was retrieved from SNH and used as an overlay on maps.

4.2 Software/Hardware

ERDAS Imagine 8.7 was used for image processing of satellite imagery. Other forms of image processing (photo enhancement and creation of original images/drawings) were carried out using CorelDraw and Corel Photo-paint 10. ESRI ArcView 3.3 and ArcGIS 9.1 were used as a GIS. Meesoft’s Diagram designer was used for creating flowcharts.

Field measurements of geographical coordinates and initial documentation of ground-truth data were made using a Garmin GPS 12XL (a handheld GPS). These GPS’s have an accuracy of better than 15 metres (95% of the time) and can be several metres better if the conditions and the satellite constellation are optimal (http://www.garmin.com/support/faqs). The aim was to have an accuracy of these measurements better than +/- 10 m, which was considered appropriate regarding the low spatial resolution (30m) of the satellite images used. Comparing the GPS coordinates and OS map coordinates indicates an overall accuracy better than 20 metres. A digital camera (Olympus µ 300) was used when documenting fieldwork and land cover/land use classes.

Table 4. Datasets and sources that have been utilized when generating the land access map.

Information	Details	Data source	Internet address	Format
Satellite imagery - Landsat ETM+	Path 205, Row 020 30m res.	Landmap	http://www.landmap.ac.uk	Image
Satellite imagery - SPOT	Path 21, Row 234 10m res.	Landmap	http://www.landmap.ac.uk	GeoTiff
Ancillary data - OS Land line plus		Digimap	http://digimap.edina.ac.uk	Shape
Ancillary data - OS Raster	Scale: 1:10,000	Digimap	http://digimap.edina.ac.uk	Tif
Ground-truth		Field data		Text, jpg
Path data		Scottish Nature Heritage, SNH	http://snh.org.uk	Shape
Protected species		Joint Nature Conservation Committee, JNCC	http://jncc.gov.uk	Text
		The IUCN Red List of Threatened Species	http://www. Iucnredlist.org	Text
		Peoples trust for endangered species	http://www.ptes.org	Text
Species - General		National biodiversity network gateway	http://gateway.snh.gov.uk	Text, jpg
Species - Birds		The Royal Society for The Protection of Birds	http://www.rspb.org.uk	Text
		The British Trust for Ornithology	http://www.bto.org	
Species - Plants		Den virtuella floran	http://linnaeus.nrm.se/flora/	Text, jpg
Hunting season		Naturenet	http://www.naturenet.net	Text
Special Protection Areas (SPA)		SNH	http://snh.org.uk	Shape
Special Areas of Conservation (SAC)		SNH	http://snh.org.uk	Shape
Site of Special Scientific Interest (SSSI)		SNH	http://snh.org.uk	Shape
Ramsar		SNH	http://snh.org.uk	Shape

4.3 Creating land parcels

An important part of the project was to create and use land parcels that are easily recognised in the field by an occasional visitor as well as meaningful to a land manager. To simplify the process of determining land parcels, official data on property boundaries, land ownership, etc in digital form would have been preferred. However, official data was effectively unavailable for this project. Parcels had to be constructed based on satellite imagery and Ordinance Survey data (both vector and raster data). Furthermore, the land parcels had to be artificially numbered.

Field boundaries from an OS Land line plus dataset are delivered in polyline format. To function as land parcels, they were converted to polygons. This procedure was facilitated by using the ArcView script *Polylines to polygons 2.3* (Ciavarella 2006).

4.4 Land cover/Land use map

The production of the land cover/land use map was carried out according to the methodology outlined in sections 3.2 and 3.2.5.

The unsupervised classification map was created from ten undefined classes. Three ground-truth points from each class (in all 27 points) were documented in field (see Appendix 4). Based on the ground-truth data, a supervised classification was undertaken (see Appendix 5). The two classes 'Urban/built-up land' and 'Water' were retrieved from OS map data and were not sampled from the satellite images. All of the classes defined in the model (see section 3.2.2) could be detected within the study area.

Using the land parcel shape file as a basis, the supervised classification raster map was manually converted into a vector dataset using ESRI ArcView (see Figure 9). Larger parcels covering heterogeneous areas (i.e. contains pixels from more than one class) were divided into smaller parcels and assigned to the class to which the majority of pixels belonged. By adding information based on the datasets in section 4.1, the land cover map was gradually developed into a land use map.

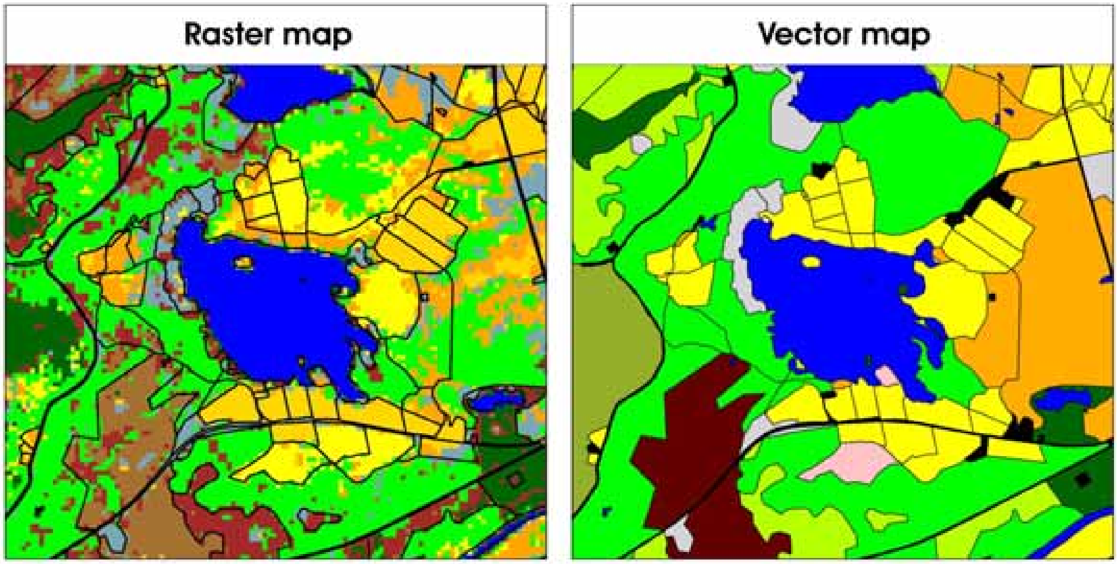

Figure 9. The left map shows a subset of the raster map using the land parcel shape file as an overlay. The right map is the classified vector map.

4.4.1 Accuracy assessment

The spatial resolution of Landsat ETM+ is 30 metres and this meant that any land cover class smaller than this will not be accurately detected. It also meant that borders between classes will be less distinct and could result in mixed pixels (Campbell 2007). This problem was to some extent overcome by using a well-defined land parcel dataset, which helped 'forcing' pixels into defined land use classes.

Most of the parcels were considered large enough to be detected by a Garmin 12XL GPS and the error of documenting wrong parcels was estimated to be minimal.

The final vector based land use map was checked for errors by performing an accuracy assessment. Based on a stratified random sampling technique (Jensen 2005), five percent of the land parcels from each class were randomly selected using the ArcView script *DNR Sampling Generator* (Minnesota Department of Natural Resources). The number of parcels selected was considered a reasonable compromise between time, resources, and the quality of the satellite image (the seven-year-old image was expected to contain errors when compared to recent land use). The classes 'Urban/built-up land' and 'Water' were excluded since they were retrieved from OS map data and considered accurate. The selection process resulted in 29 parcels out of the total set of 717 (see Appendix 5 and Appendix 6), which were documented in the field.

Normally, the calculation of the overall accuracy is based on a selection of pixels in a raster image. According to Jensen (2005) polygons can be used instead in cases where the image is vector based.

The reference data from the 29 selected parcels was added to an error matrix (see Table 5). The overall accuracy of the classification map was determined by dividing the total correct polygons (sum of the major diagonal = 24) by the total number of reference data (= 29) in the error matrix (Campbell 2007). In addition, a producer's accuracy and user's accuracy were calculated.

Table 5. The error matrix shows a high overall accuracy when comparing the reference data and the classified data. N = number of points, AgriL = Agricultural land, RangeL = Rangeland, MoorL = Moorland, WetL = Wetland, WoodL= Woodland. PA = Producer's accuracy, CA = Consumer's accuracy, EC = Errors of commission, EO = Errors of omission

N = 29	**Classified data**							
Reference data	**AgriL**	**RangeL**	**MoorL**	**WetL**	**WoodL**	**Total**	**PA%**	**EO%**
AgriL	**14**	0	0	0	1	15	93.3	6.7
RangeL	0	**3**	0	0	0	3	100.0	0.0
MoorL	0	0	**2**	0	1	3	66.7	33.3
WetL	0	0	1	**1**	1	3	33.3	66.7
WoodL	1	0	0	0	**4**	5	80.0	20.0
Total	15	3	3	1	7	24		
CA%	93.3	100.0	66.7	100.0	57.1			
EC%	6.7	0.0	33.3	0.0	42.9			
Overall accuracy		**83%**						

The overall accuracy of 83 % is acceptable given the quality of the satellite image. The producer's accuracy and the consumer's accuracy show variability between the classes. Most difficult to classify is the category 'Wetland', which can be hard to separate from wet 'Moorland' or 'Woodland –Deciduous'. Furthermore, 'Moorland' overgrown by birches can be mistaken for 'Woodland'.

4.5 The Land access map

Two land access maps were generated based on the methodology outlined in chapter 3 and available datasets outlined in section 4.1. Variations in land access index for January and June are presented in Figure 10 and Figure 11 respectively.

Many of the land parcels display a rather high index level (2 or 3). This is expected, since a majority of the parcels are in close vicinity to protected sites. The major differences between January and June can be located to Loch Kinord and River Dee, where the orchid and the otter influence the extent of protected zones.

The use of 'natural' shaped parcels instead of the actual perimeter of buffer zones causes the protected zone to be unnecessary large. E.g., the seagull would need a protective zone of seven hectares, but because of the shape and size of the local parcels, the area becomes approximately seven times bigger. On the other hand, the actual location of a particular species (in this case the black-headed gull) is likely to vary depending on where exactly suitable habitats are available. Since the selected parcels coincide with the habitat criteria for a species the extended zone is acceptable.

5 Discussion and future directions

In the present thesis, a new way of addressing issues regarding access to the outdoors is discussed. By using the Scottish Outdoor access code as a starting point and by adding information from nature conservation agencies and from land managers, important aspects regarding the protection of a variety of values in the landscape are visualized in a so called 'land access map'. The focus of the thesis is to suggest a set of data types and procedures in order to model the concept of a land access map.

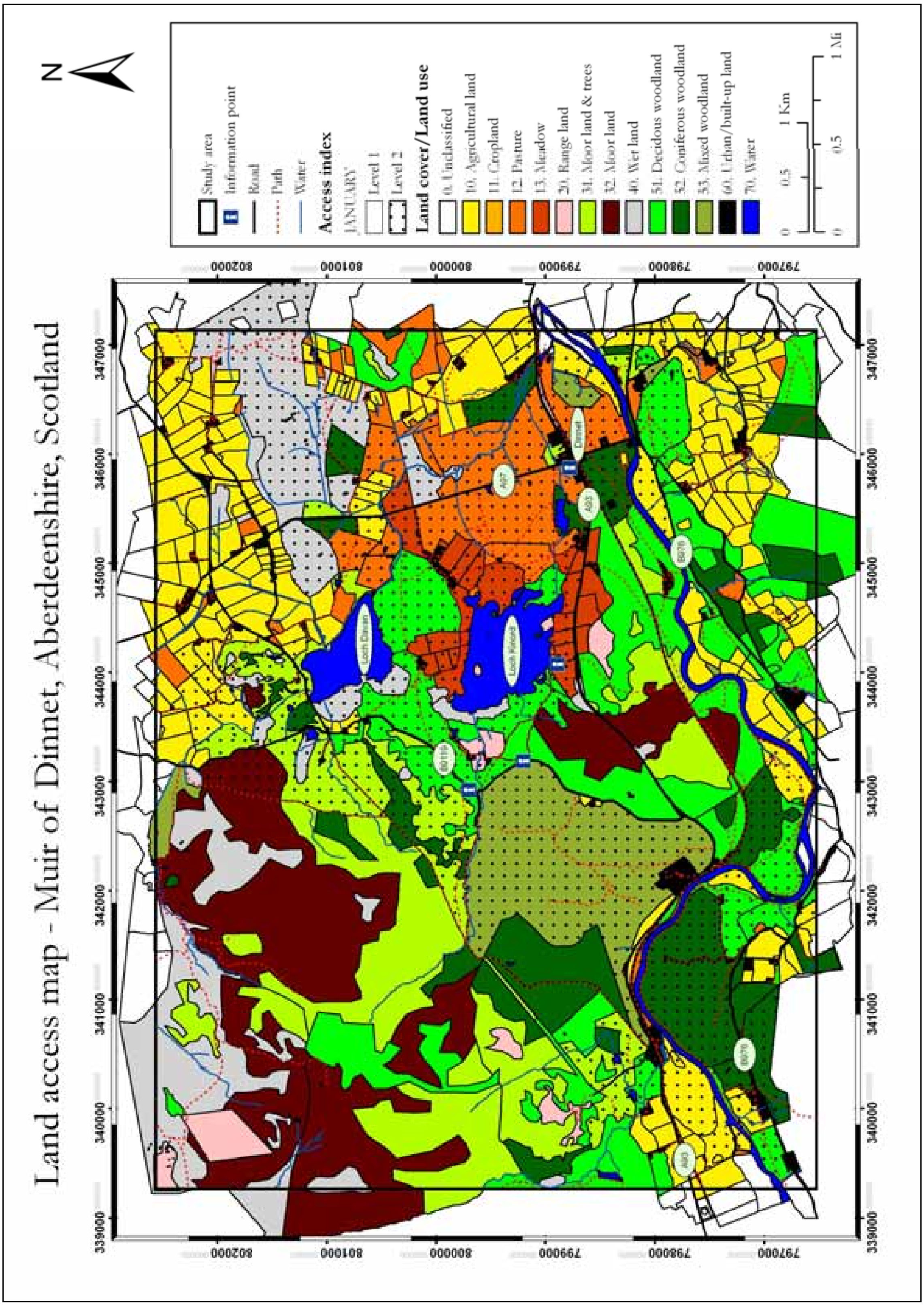

Figure 10. A land access map covering the study area shows restricted zones for the month of January. The access index is based on plant and wildlife data. Data regarding agriculture and hunting activities are not included.

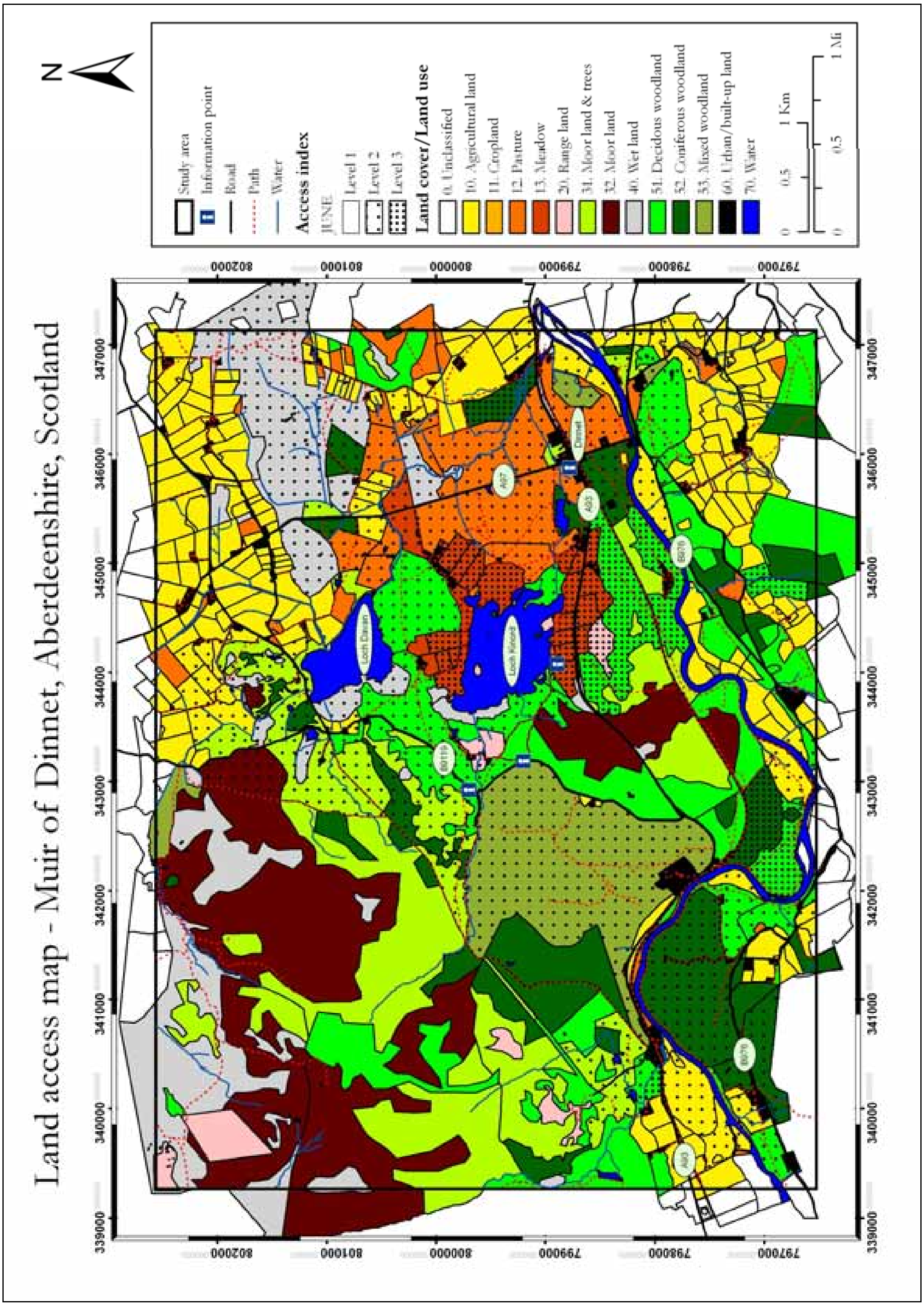

Figure 11. A land access map covering the study area shows restricted zones for the month of June. The access index is based on plant and wildlife data. Data regarding agriculture and hunting activities are not included.

The quality of the land access map is partly determined by the quality of the land use data, which on its part is dependent on good satellite data. The final land use dataset used here would be improved by using an up-to-date satellite image of a high spatial and spectral resolution, preferable from June 2007 i.e. when the fieldwork was undertaken.

The way the access index is applied, i.e. selecting the full parcel instead of buffering e.g. the actual habitat of an animal or plant is not optimal. However, in order to identify parcels in the field correctly, visible borders such as woodland/agricultural land or meadow/crop field have to be utilized. This will by necessity cause large parcels in some cases. The use of 'invisible' habitat buffers would demand for a technical solution comprising a digital version of the map and a hand-held GPS based device.

The choice of a rather simple classification system consisting of seven major classes and six subclasses was motivated by the necessity of the final map to be easily interpreted by inexperienced as well as experience users of land use information. A separation of land use into more classes would not necessarily add value to the final product, but might instead confuse the user.

The methodology for producing a land cover/land use dataset met the accuracy requirements stated by the model of an overall accuracy of >80 %. The producer's accuracy and the consumer's accuracy show variability between the classes. Most difficult to classify is the category 'Wetland', which can be hard to separate from wet 'Moorland' or 'Woodland –Deciduous'. Furthermore, 'Moorland' overgrown by birches is in some cases mistaken for 'Woodland'.

The variations in scale between the various datasets presented problems. The data about species distribution retrieved from NBNG varies between 100m to 10km, which made the information difficult to use. Data for the otter and the gull were resampled to

1km, which was the lowest resolution for any of the records. (The orchid data had a resolution of 10km and was not resampled). The use of low-resolution data resulted in unnecessary large protection zones. Furthermore, the medium-resolution Landsat image was not adequate when identifying detailed landscape objects. However, since the purpose was to retrieve general land cover/land use information by combining satellite data and ancillary data from sources such as Ordnance survey and land owners, the problem was to some extent overcome.

A set of three different levels of restriction was defined: '(1) Free access the area', '(2) Access the area, but tread carefully', '(3) Do not access the area unless necessary'. To divide the level of access into more than three categories might make the map less distinct. Using only two levels (e.g. 1 and 2) would make the map very easy to interpret but would not give the opportunity to protect e.g. bird during its most sensitive season or an agricultural field close to harvest. However, a fourth level could be used for immediate danger such as tree felling and shooting. This information could be added as point on the map contrary to level 1-3, which is symbolized by a texture.

The process of producing a land cover/land use map would be improved by using a combination of official cadastral information (property boundaries) and an object-based classification technique. Object-based techniques depend on software that can segment the satellite image into finite areas, which have shape, texture, and topology and corresponds to real world objects (cf. Benz et al. 2004, Oruc et al. 2004, Bock et al. 2005). This technique allows ancillary data to influence the classification process. Spring (Spring 2007) and eCognition (Definiens Imaging 2007) are examples of software packages capable of segmenting a satellite image and performing an object-based classification.

5.1 Maintenance

The main source of accurate and up-to-date land use information is the local land manager. Other sources are Scottish natural heritage, Joint Nature Conservation Committee, and various trusts and societies. Involving land managers and other operators in an area of interest is crucial for the success of producing and maintaining a Land access map. Without the supply of information from the land managers in the area of interest, the quality of the land access map will suffer.

To solve the problem of organizing, storing, updating, and retrieving data a database system will be needed. A conceptual model for a land access database has been tentatively outlined in Appendix 7 using an enhanced entity-relationship diagram. A spatial database suitable for holding all the data necessary to produce a land access map should meet the following criteria:

- Web-based interface for easy input and update of information
- Connection tools and protocols to download data from external sources (e.g. NBNG)
- References to ancillary data such as an OS base map
- Automated map production (adding north arrow, scale bar, legend, title etc.)
- Web based interface for retrieving the map.

A centrally organized system for maintaining and updating land access information would be preferable. Based on land managers' reports, the land access dataset can be updated by a 'Land access service'. The updates could also be entered directly via a web-based interface. Such a system would allow the restrictions for a particular field to be changed on a daily (or even hourly) basis. A suggested maintenance system is outlined in Figure 12.

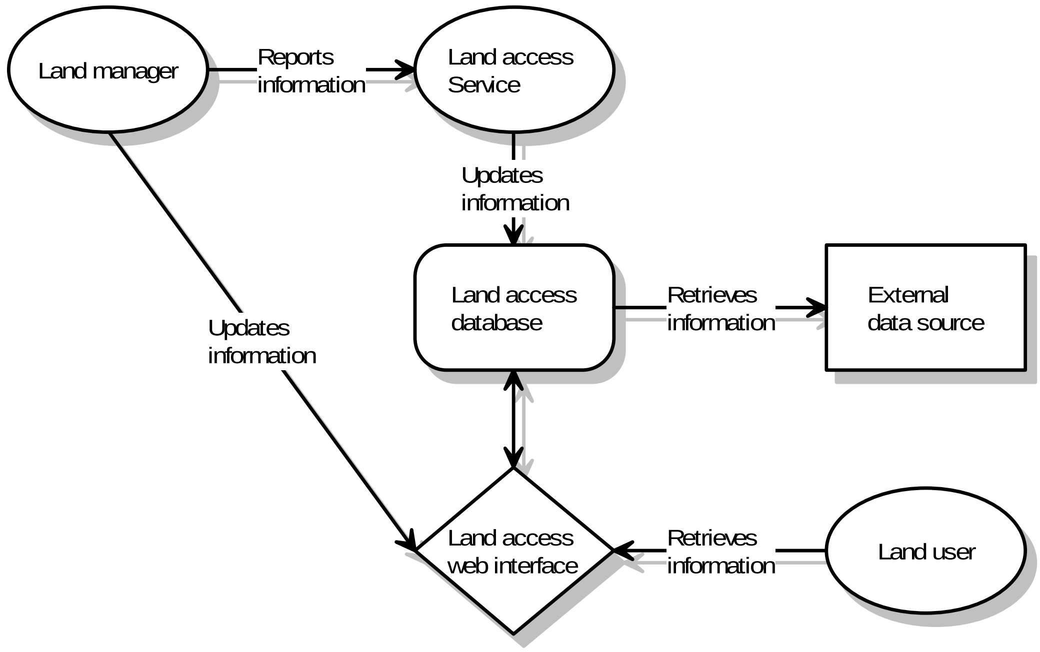

Figure 12. An outline of a maintenance system for a land access database.

Concerns related to keeping the information up-to-date has been addressed by representatives from Dinnet and Kinord estate. They fear that the system will consume considerable resources to maintain. In their case, updates concerning land use and land access may be needed on a weekly to even a daily basis. Unless the procedures for updating the database can be co-ordinated with updating local information structures, there may be difficulties to implement the system.

5.2 Potential users and distribution forms

Tourist offices, organizers of outdoor activities, and the public are potential users of land access information. A 'Land access service' could maintain an internet based system for distributing the map in digital or paper form. The map could be either static, i.e. displaying information using one layer and a fixed layout, or dynamic, i.e. using several layers and a variable layout.

Wireless technical solutions such as personal digital assistants (PDAs) and mobile phones with GPS functionality are becoming affordable and more abundant. This technology, in combination with a downloaded digital (and dynamic) dataset along with a custom-made GIS-like software package (or commercial software packages such as ESRI ArcPad), allows for a much wider set of possibilities to be catered for, such as user-interaction. Slocum et al (2005) have suggested a set of methods to interact with a dataset such as data manipulation, varying the symbolization, modifying colour schemes, changing scale and perspective, highlighting portions of a data set by selecting a variable, showing more than one map by using multiple views, accessing external resources, etc. These methods would all add value to the land access map.

5.3 Expanding the model

The model is structured in such a way it allows other data types to be added. Data types such as forestry, fishery, and archaeology would be suitable additions. Expanding the model by adding a terrain model (DTM) would facilitate orientation in the landscape. Land manager contact information could be added as an attribute to the land parcels to facilitate the communication between the service who updates the information and the land manager. This information would also be valuable to the land user, who might want to contact the land manager. He or she could discover things that should be communicated to the land manager. Issues concerning e.g. an animal in distress (e.g. trapped in a fence or run over by a car) or damaged infrastructure (broken water pipe, hole in a fence, etc.) can be communicated immediately to the land manager. Adding sound functionality to a GPS equipped device would allow a warning sound to be triggered when a visitor is about to enter the perimeter of a protected species or approaching a restricted agricultural field etc.

The land access model can be used in other countries with similar outdoor access rights. The basic data types should largely be the same. However, a land access dataset based on Scottish conditions might not be immediately transferable to other countries.

There might be variations in the national laws regulating access rights or the number of protected species might differ.

6 Conclusion

The methodology proposed in the presented thesis is based on a variety of geospatial technologies such as remote sensing, image processing, and geographical information systems. These techniques are suitable when collating and analysing the spatial data that a land access map is based upon.

The use of medium resolution satellite imagery and with support of ancillary data is sufficient when creating a land use map suitable for the land access map. The basic classification system consisting of seven major classes and six subclasses were adequate for creating easily recognizable land cover/land use categories. A higher degree of separation would probably not add value to the final product.

The important step of creating land parcels would be improved by using professional computer software for object oriented classification. The combination of digitized land parcels and a pixel-based method used here is time-consuming and might not be feasible for larger areas.

Based on the results from the case study, some improvements have been suggested. The implementation of a database rather than using Excel sheets for storing and updating the datasets, would improve data entry and data retrieval. Furthermore, the necessary datasets defined by the model is not sufficient to address the variation of features in the countryside. Forestry, fishery, and archaeology are examples of data types that should be added to the model.

7 Summary

The aim of the presented project was to produce a land access map according to guidelines presented in the Scottish Outdoor Access Code. The major outcome is land access map containing restricted zones based on up-to-date land use data and information concerning nature conservation. The purpose of the map is to advise the public how to use the landscape responsibly in compliance with the Scottish Outdoor Access Code.

The project consisted of two main parts. Firstly, the concept of a land access map was modelled and the methodology, procedures, and the necessary data types were outlined in detail. The goal was to create a transparent model that can be applied on any area of interest and to make full use of current geospatial technology such as satellite imagery, image processing, digital datasets, and GIS. The second part of the project consisted of performing a detailed case study to test the model. The study area was chosen based on a set of criteria regarding land use categories, occurrence of officially protected sites, and accessibility. The 48.5 km^2 large area is situated near Ballater in the Southwest of Aberdeenshire in Scotland and is a part of the Cairngorm national park.

Future developments are suggested such as adding a terrain model (DTM) to facilitate orientation in the landscape, adding land manager contact information as attributes to the land parcels, develop a database for storage and updates instead of using individual data sheets. Distribution of the land access map to various users such as tourist offices can be done in paper form as well as digital form. A digital format of the map instead of a printed paper map would add interesting functionality such as possibility to create user specific layouts, where colour etc. can be adjusted, and the use of sound as a warning when entering restricted zones.

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Appendix 1. Discussion on Spatial, spectral, radiometric, and temporal resolution.

Spectral resolution is the minimum width of a band a sensor can separate from another band (band is a range of wavelengths). Higher capacity to detect and separate the spectrum the higher is the resolution. Common bands are 0.4-0.5 μm (the blue band), 0.5-0.6 μm (the green band) or 0.6-0.7 μm (the red band) (Jensen 2000). A sensors spatial resolution defines the smallest feature that can be spatially separated from another feature (Jensen 2000). A term used is "spatially resolved", which means that two objects are visually separated (Campbell 2007). However, this is not necessarily accurate in all situations. Campbell (2007) and Joseph (2000) suggest that if an object has a high contrast compared to the background smaller objects than the actual sensor resolution can be seen (e.g. roads). The sensor has a recording media (digital or film) with a minimum pixel size. If the pixel size is too large, the image is blurred which makes the detection of small objects difficult. A smaller pixel size will represent areas, lines, and points in greater detail. Radiometric resolution defines the minimum change in reflection that the sensor can detect (Jensen 2000, Joseph 2000, Campbell 2007). The brightness of an object is divided into levels, typically 64, 256 or even as many as 4096 levels (Jensen 2000) usually referred to as 6 bits, 8 bits, and 12 bits respectively. The larger the contrast between the object and its surroundings the more likely it will be detected. Temporal resolution is the shortest time-period between two images collected from the same area (Jensen 2000), typically defined in days.

The different kinds of resolutions affect each other, in the sense that if one is changed at least one of the other are likely to change too (Campbell 2007). If the spatial resolution is increased, smaller objects can be seen. Small objects reflect less light than bigger ones (if made of the same material and directed the same way) and hence, the radiometric resolution deteriorates. If a lower spectral resolution is considered acceptable (letting more light in to the detector), the radiometric resolution can be improved. Even when the spatial resolution is very high, the separation of objects can still be difficult if the spectral resolution and radiometric resolution are too low, e.g. if two features reflecting similar wavelengths they will not be separated (Jensen 2000).

Appendix 2. Photo documentation of vegetation classes.

Class 11: Agricultural land - Cropland	Class 12: Agricultural land - Pasture
	

Class 13: Agricultural land - Meadow	Class 2: Rangeland
	

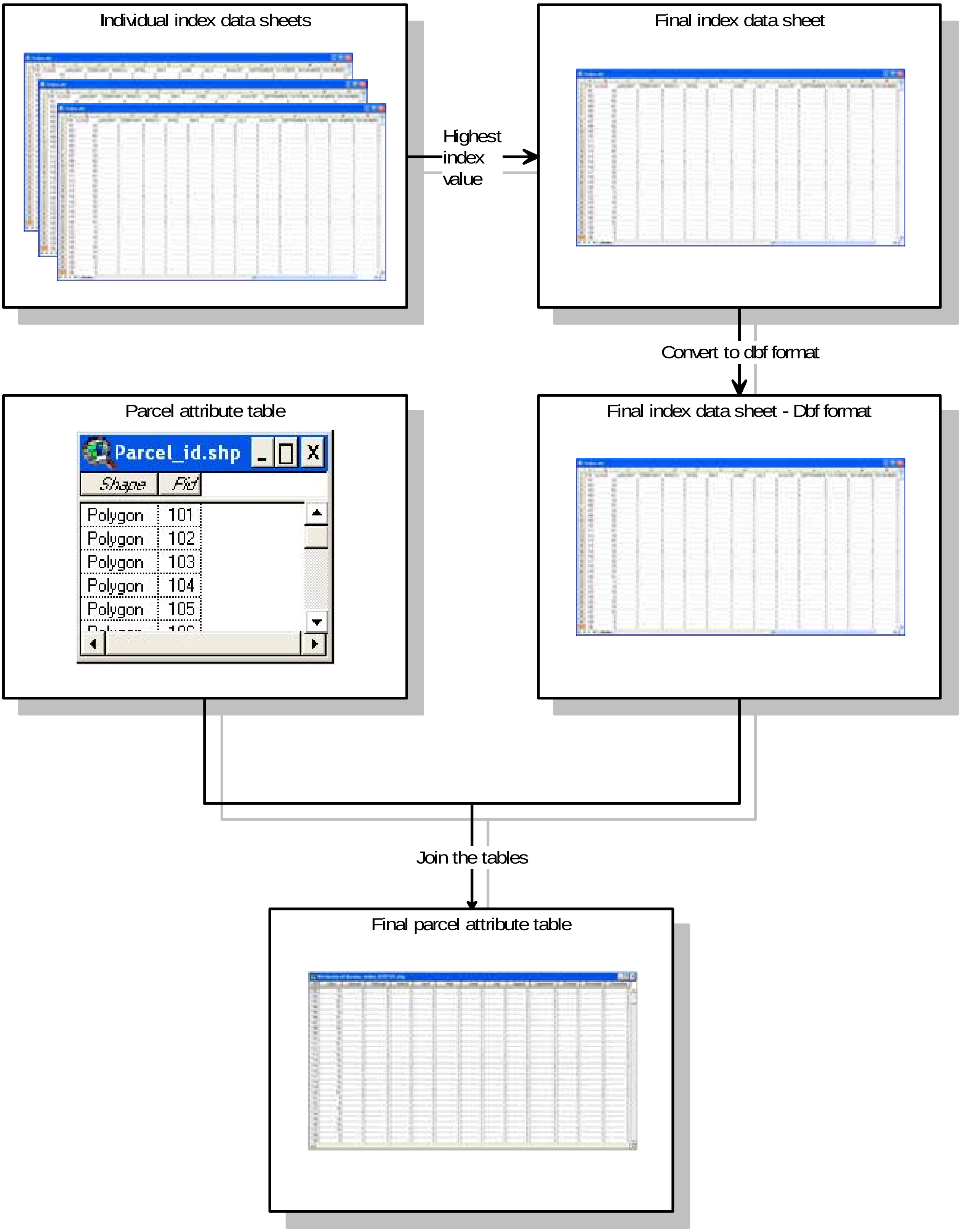
Class 31: Moorland with trees	Class 32: Moorland
	

Class 4: Wetland	Class 51: Woodland - Decidous
	

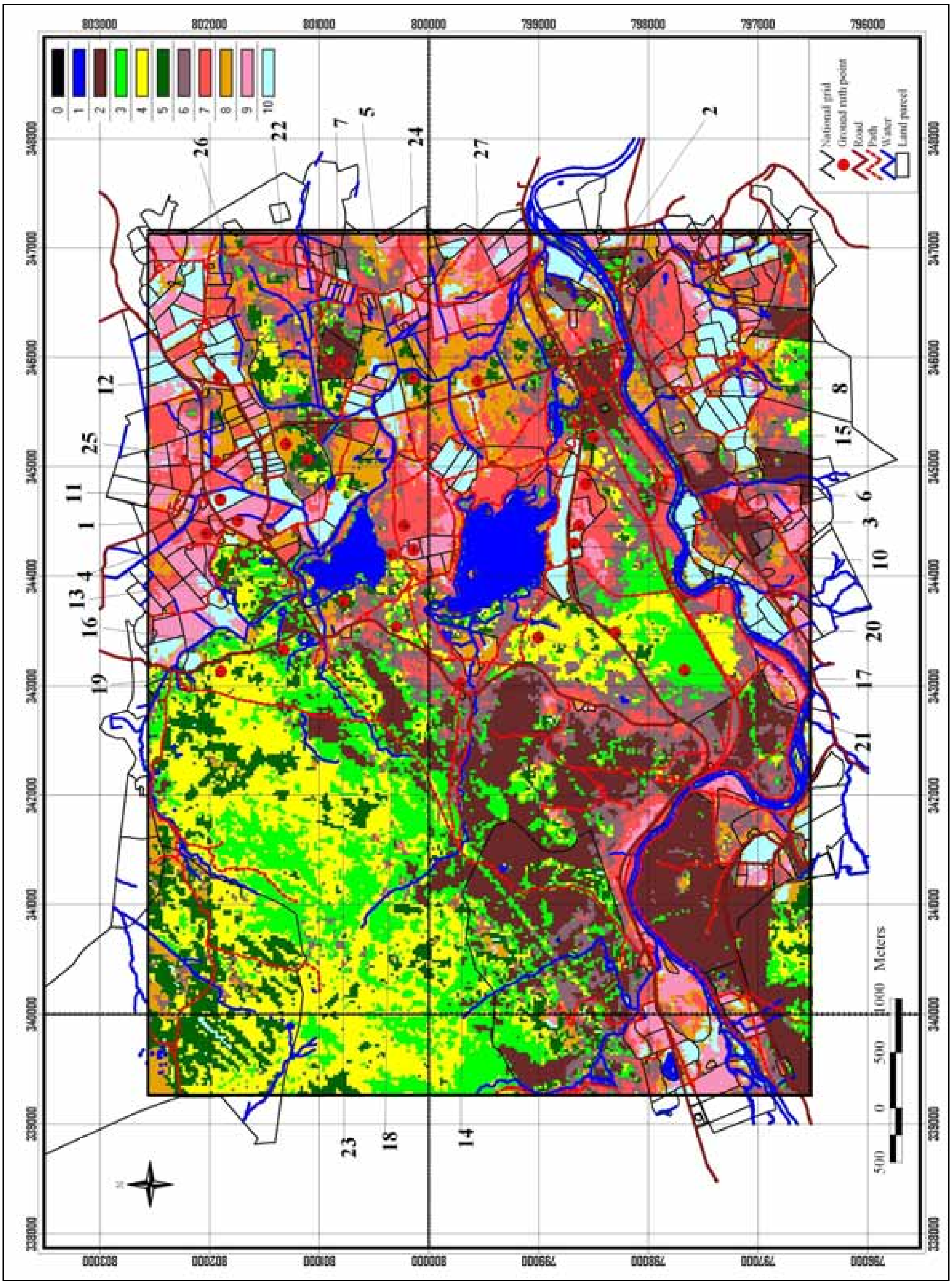
Class 52: Woodland - Coniferous	Class 53: Woodland - Mixed
	

Class 6: Urban/built-up land	Class 7: Water
	

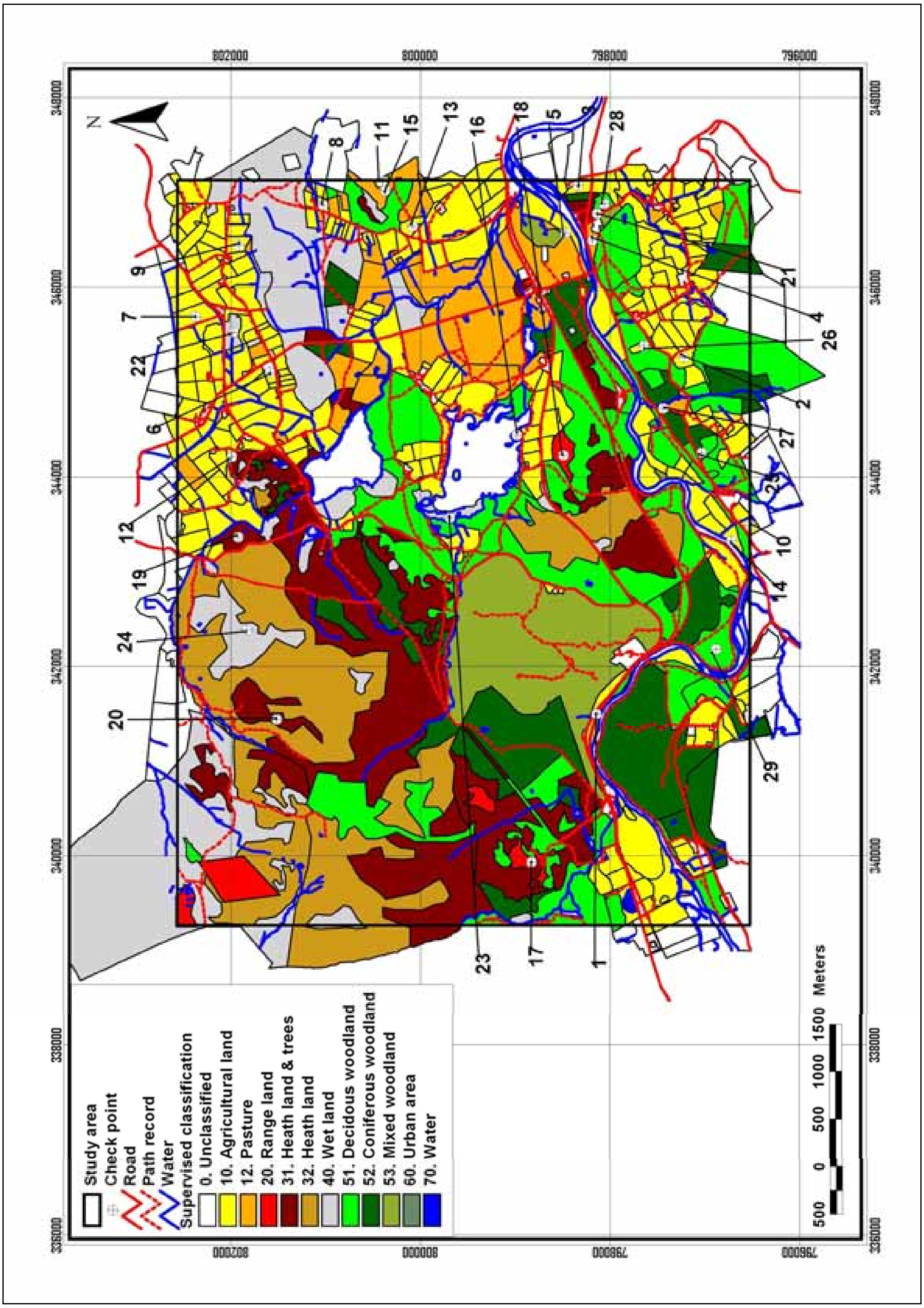
Appendix 3. The procedure for transforming individual index data sheets (e.g. MS Excel format) to an attribute table that can be added to e.g. ESRI ArcView involves a few basic data manipulations.



Appendix 4. Unsupervised classification map. The colour scheme for the unsupervised classification map was based on the default colours suggested by the software package. The map shows the location of the ground-truth points used when undertaking the supervised classification.



Appendix 5. Supervised classification map. The map shows the location of the randomly selected ground-truth points used when undertaking the error assessment. The colour scheme was selected to facilitate visual separation of the different classes and had no intention to resemble real world land cover colours.



Appendix 6. Ground-truthing data. Checkpoints for accuracy assessments. 'Classified' = land cover/land use on the map, 'Reference' = land cover/land use in the real world.

Ground-truth no	ParcelID	Easting	Northing	NG	Classified	Reference	Photo no	Note
1	105	341499	798146	NO	1	1	98N	
2	170	345262	797222	NO	1	1	127S	
3	209	347077	798339	NO	1	1	-	
4	212	346494	798188	NO	1	1	-	
5	214	346576	798473	NO	1	1	133S	
6	293	345107	801591	NJ	1	1	-	
7	303	345691	802371	NJ	1	1	-	
8	320	346871	801028	NJ	1	1	147N	
9	323	346447	801915	NJ	1	1	147N	
10	362	343484	796527	NO	1	1	130S	
11	378	347115	800401	NJ	1	5	149N	
12	407	344215	801988	NJ	1	1	-	
13	492	346643	800082	NJ	1	1	138N	
14	645	343331	796721	NO	1	1	131N	
15	653	347024	800371	NJ	1	1	139N	
16	538	344446	798984	NO	2	2	117E	
17	605	339934	798826	NO	2	2	95N	
18	627	344229	798493	NO	2	2	113S	
19	664	343367	801920	NJ	3	3	-	
20	698	341441	801516	NJ	3	3	171	
21	718	346780	798136	NO	3	5	121	Wet
22	297	345525	801970	NJ	4	5	-	
23	593	343569	799687	NO	4	4	-	
24	707	342386	801831	NJ	4	3	-	
25	145	344258	797035	NO	5	5	132N	
26	570	345381	797644	NO	5	1	125N	
27	713	344726	797442	NO	5	5	-	
28	717	346884	798062	NO	5	5	118N	
29	667	342185	796884	NO	5	5	100N	

Appendix 7. An enhanced entity-relationship diagram describing the entities of the land access model. The entity 'OtherData' represents any data type that would fit within the model (e.g. forestry data, archaeological data, etc.).