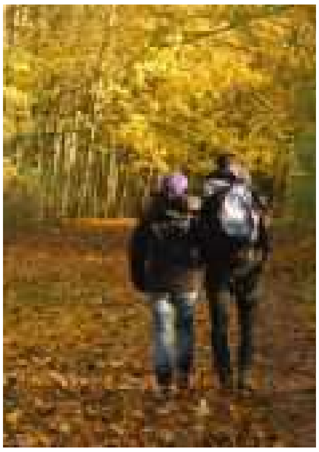
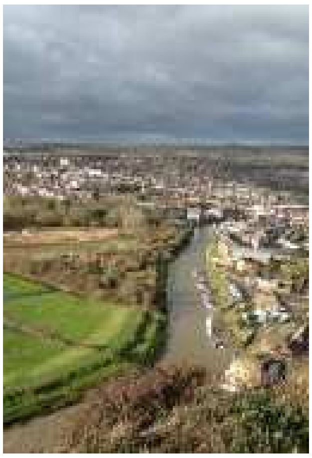
On behalf of Sussex and Hampshire & Isle of Wight Local Nature Partnerships

Ecoserv-GIS- A Wildlife Trust toolkit for mapping multiple Ecosystem Services

Created by Durham Wildlife Trust, June 2014

Handbook to accompany
Ecosystem Service Evidence Workshop
January 2015
Linklater Pavilion, Lewes

All references in this report can be found in full in the original document; Bellamy, C. C., Winn, J.P., and Fisher, T. (2014), "EcoServ-GIS Version 2 (England only): A Wildlife Trust toolkit for mapping multiple ecosystem services. User Guide (Document Version 2.1, April 2014)", Durham Wildlife Trust. The original document and this summary can be found on the Sussex Local Nature Partnership Website.

THE wildlife TRUSTS

South Downs National Park

Sussex Biodiversity Record Centre

NATURAL ENGLAND

Contents

Summary

EcoServ-GIS is a Geographical Information Systems (GIS) toolkit for mapping ecosystem services at the county scale, which has been developed for the Wildlife Trusts.

The toolkit generates fine scale (Default 10m grid cell resolution) maps illustrating the requirement (human need or demand) for each service as well as the capacity of the natural environment to provide the service, using scientifically-based, standardised methods and widely available datasets.

It provides users with the facility to overlay these maps to show how well demand and capacity coincide in space, highlighting those natural areas providing high levels of service delivery that should be conserved, as well as those that are most in need of measures aimed at improving single or multiple service delivery.

The toolkit was piloted in the Durham Biodiversity Action Plan (dBAP) area, northeast England. This large region (~3,000 km2) covers multiple local authorities and a wide range of habitats, providing an ideal landscape for testing the analysis methods. The Toolkit was further tested in the South Downs National Park and NIA, the Nene Valley NIA (Northamptonshire) and within Somerset.

About this guide

This guide was created specifically for the Ecosytem Service Evidence Workshop held in Lewes in January 2015. It aims to provide enough background information on ecosystem service mapping and the services mapped to help participants make optimum contribution to the event and its outputs. All the text in this guide comes directly from Bellamy, C. C., Winn, J.P., and Fisher, T. (2014) which is cited in full below:

Please cite this user guide in any material relating to the use of the toolkit.

The full report (which can be downloaded from the Sussex Local Nature Partnership website) was written by Chloe Bellamy in 2013, and updated and edited by Jonathan Winn in 2014. Tom Fisher contributed to selected service sections.

Recommended citation Bellamy, C. C., Winn, J.P., and Fisher, T. (2014), "EcoServ-GIS Version 2 (England only): A Wildlife Trust toolkit for mapping multiple ecosystem services. User Guide (Document Version 2.1, April 2014)", Durham Wildlife Trust**.**

Glossary

Terms used to describe general ecosystem service topics:

Ecosystem The individuals, species and populations in a spatially defined area, the interactions among them, and those between the organisms and the abiotic environment (Likens 1992).

Ecosystem service The conditions, processes, and components of the natural environment that provide both tangible and intangible benefits for sustaining and fulfilling human life (Daily *et al.* 1997).

Ecosystem service goods or benefits

The socio-cultural or economical welfare gain provided through the ecosystem service, such as health, employment and income (Van Oudenhoven *et al.* 2012).

Geospatial ecosystem service indicators

Geographically linked data describing features of the environmental, biophysical and socio-economic landscape, which indicate levels of societal demand and regulatory need for a service, and ecosystem service capacity over space.

Green infrastructure

Planned networks of linked multifunctional green spaces that contribute to protecting natural habitats and biodiversity, enable response to climate change and other biosphere changes, enable more sustainable and healthy lifestyles, enhance urban liveability and wellbeing, improve the accessibility of key recreational and green assets, support the urban and rural economy and assist in the better longterm planning and management of green spaces and corridors (CUDEM 2006).

Greenspace

Any natural or semi-natural habitats (including water-related habitats and amenity grassland).

Human well-being

A human experience that includes the basic materials for a good life, freedom of choice and action, health, good social relationships, a sense of cultural identity, and a sense of security (Díaz *et al.* 2006).

Terms used to describe EcoServ-GIS mapped output:

Ecosystem service demand

The demand for an ecosystem service. Calculated from the societal demand (for cultural and provisioning services) or from a combination of the societal and ecosystem demand (for regulatory services). The term is used to reflect the relative need or potential benefit that peoples would receive from the particular services, if it were present.

Ecosystem Service regulatory demand

The regulatory services help to minimise or prevent environmental processes or anthropogenic hazards that can cause direct or indirect harm to people (e.g. the mitigation of anthropogenic noise or the prevention of erosion). Therefore, a regulatory service will only be provided by a functioning ecosystem if it falls within those areas that are affected by these processes or hazards. The toolbox extracts these areas and grades them by the likelihood or magnitude of conditions that may cause or contribute to the direct or indirect harm to people, which could otherwise be regulated or suppressed by ecosystem processes.

Ecosystem service societal demand

The likelihood or magnitude of people's requirements for a particular ecosystem service across space, according to the distribution of people that are most likely to benefit from the service (in terms of any goods provided, improvements to their physical and mental health, or prosperity). For regulatory services, levels of societal demand are only calculated within zones of ecosystem service regulatory demand.

Ecosystem service capacity (all)

The performance and capability of an ecosystem or a landscape to deliver services (Bastian, Haase, & Grunewald 2011) regardless of the societal or regulatory need for the service or human actions or restrictions which may limit flow (ecosystem service restrictions). This is based on current habitat type, land use or management regimes.

Ecosystem service capacity (unrestricted)

The performance and capability of an ecosystem or a landscape to deliver services (Bastian, Haase, & Grunewald 2011), modified by the presence of ecosystem service restrictions. This data maps areas where there is capacity, but no restrictions to flow occur, the service is "unrestricted". For example with public access related services, this data shows only areas of capacity with public access. For any services where such restrictions are not relevant, then this data is not produced.

Ecosystem Service Benefitting Areas

These are the areas where there is both ecosystem service capacity and ecosystem service demand and it is therefore assumed that there is a flow of services to society. The areas may be graded, in which case the flow is considered more likely to occur in areas of spatial overlap between high demand and high capacity compared to areas of low demand and low capacity.

Ecosystem service flow

The transfer of ecosystem service benefits and goods across space from the ecosystem / natural environment to the beneficiaries.

Ecosystem service gaps

Areas where there is demand for a service, but there is currently no capacity in the natural environment to provide it.

Ecosystem service flow restrictions

The locations where human activities or restrictions are preventing service flow. These maps allows us to identify those areas that would be valuable providers of a service if the restriction was removed (e.g. lack of public access is a "restriction").

Restricted ecosystem service flow

Areas where there is capacity to deliver a service and some demand for the service, but human flow restrictions prevent society from receiving the benefits. (e.g. where there is no public access to an area that could otherwise provide a particular service).

Multi-functionality

The number or diversity of services provided by an ecosystem.

What does ECOSERV-GIS do?

EcoServ-GIS is a Geographical Information Systems (GIS) toolkit for mapping ecosystem services at the county scale, which has been developed for the Wildlife Trusts.

EcoServ-GIS overlays spatial datasets describing various aspects of the landscape, such as the habitat type, grey infrastructure distribution, and socioeconomic factors, in order to estimate the likelihood of ecosystem service provision at each point, mapped pixel or GIS grid cell. The toolkit has been developed to work from the OS MasterMap topography layer.

The first stages of the Toolkit create the "**BaseMap**" (based on OS MasterMap), a fine scale map of habitat types, land use, population density and socioeconomic variables, such as health deprivation. These outputs are used by the subsequent tools, which each focus on mapping the delivery of an individual ecosystem service in three stages.

The emphasis of the mapped outputs is on locating where ecosystem services occur and indicating where there is relatively high demand for a service or capacity to deliver a service. The Toolkit concentrates on spatial locations and relative measures and does not attempt to quantify the actual impact of each service. For example, the air pollution service does not measure the actual amount of pollutant trapped per unit area of habitat, instead it grades the predicted ability of habitats in the study area to trap pollutants from high to low and compares this to measures of predicted air pollution demand (need) among human populations.

Which ecosystem services does EcoServ-GIS map?

The Millennium Ecosystem Assessment (2005) is a widely recognised standard reference for ecosystem service language and classification (Blogg *et al.* 2007). It groups ecosystem services into four broad themes:

1) **Provisioning:** services providing natural materials and products directly used or harvested by humans e.g. food

2) **Regulating:** services obtained directly from ecosystem processes which impact directly on human well-being e.g. local climate regulation

3) **Cultural:** the mental, physical and other intangible benefits provided to people through access to Greenspace e.g. opportunities for leisure and recreation

4) **Supporting:** those services that underpin the production of all other services e.g. nutrient cycling

To prepare for the Toolkit production a review of previous ecosystem service mapping projects revealed a long list of services for consideration. These were narrowed down to twenty one services that are applicable to a local scale and for which spatial indicators could be developed with the data and scientific knowledge currently available.

The supporting services were omitted because the delivery of many ecosystem services is reliant upon these and incorporating measures of both of these services could lead to "double counting", compromising the usefulness of the Multi-functionality maps for making logical decisions regarding resource and land management (Hein *et al.* 2006; Wallace 2007; Fisher & Turner 2008; UK National Ecosystem Assessment 2011). Additionally, supporting services typically cannot be linked spatially to beneficiaries and so do not fit well within an ecosystem service spatial planning framework.

The services were classified using the hierarchal structure suggested by the Common International Classification for Ecosystem Services (CICES; version 4.1; Haines-Young & Potschin 2010, 2011). This was designed to help standardise classifications, providing an approach that avoids the double counting of benefits and improves the accuracy and efficiency of their economic valuation. EcoServ-GIS includes tools for mapping several of these ecosystem services, including provisioning, regulating and cultural services .

The services mapped in EcoServ-GIS were selected according to the following criteria, in order of priority:

1) **Wildlife-related services were given high priority because these are often neglected in similar ecosystem assessments**, but information on where the benefits of wildlife and accessible nature are delivered to people is a priority for the Wildlife Trusts.

2) **Services were ranked on the availability of current and widely accepted scientific knowledge and information on what drives ecosystem service demand and capacity, and the spatial scales over which these operate**. To map service delivery over an area, we first need to understand how the biophysical and biotic properties of ecosystems determine what services they are capable of providing, and how these services are valued and used by society.

3) **To ensure that the tools were geographically transferrable and delivered useful maps, services were only mapped if geospatial indicators were available which were accurate, up-to-date, and relevant at the county scale.** Geospatial indicators are geographically-linked datasets that inform us about the functioning of an ecosystem and help us map the ecological and socioeconomic factors driving the requirement and demand for a service. However, the availability and reliability of such data varies across the ecosystem services. Data which were not freely available were avoided.

4) **Services were selected where there was a logical link between the capacity of the natural environment and the benefits to people such that these benefits occurred at a neighbourhood to county scale**. Several services occur across regional or national scales and such services cannot meaningfully be mapped at a county scale using the EcoServ-GIS method. Examples include long distance water supply transport for drinking water and, long distance flood impact.

5) **Services were chosen which were least likely to be highly correlated with the services already mapped to avoid bias towards a particular ecosystem or area.**

Service Definitions

1. Accessible Nature (cultural)

Areas where people benefit from opportunities to experience and enjoy natural places and landscapes within their living, working, and commuting space. The capacity of the natural environment is mapped by identifying public accessibility status and scoring areas by their level of perceived naturalness. The demand (need) for accessible nature is mapped by estimating the number of people likely to travel to an area and their relative need for the related health benefits, based on current Index of Multiple Deprivation health scores.

2. Carbon (Regulating)

The storage of carbon in above and below ground biomass. The capacity of the natural environment is mapped by assigning potential carbon storage values per mapped habitat type based on peer-reviewed literature. Values map typical habitat storage levels and levels within the upper 30cm of soils. The demand (need) for carbon storage is considered to be constant across the entire study area as there are global benefits in the storage of carbon.

3. Local Climate Regulation (Regulating)

Areas where the natural environment may help to mitigate the urban heat island effect due to the cooling impact of the types and configurations of habitat that are present. The capacity of the natural environment is mapped based on presence of water bodies and various types of green space within the local environment. The regulatory demand (need) for local climate regulation is mapped by

calculating the proportion of urban landcover within the local environment. Societal demand (need) for local climate regulation is mapped based on population density, and population vulnerability to raised temperatures and heat waves, based on age.

4. Water Purification (Regulating)

Areas where habitats and vegetation help trap sediment in water runoff in locations where pollutants are likely to be mobilised. The capacity of the natural environment for water purification is mapped by calculating surface resistance based on vegetation type and slope gradient. The regulatory demand (need) is calculated based on fine scale erosion risk (likelihood to contribute pollutants) and the proportion of the watershed covered by agricultural or urban landuse (sources of pollution).

5. Pollination (Regulating)

Allotments, orchards and areas of agricultural land where natural pollinators may contribute to crop yield and stability. The capacity of the natural environment to provide pollination is mapped based on the likelihood of pollinator visitation, calculated using likely travel distance from pollinator habitat. The demand (need) for pollination is mapped by identifying allotments, orchards and areas of agricultural land where crops may occur which may benefit from insect pollinators.

Linking capacity & demand: mapping the flow of services to beneficiaries

The ecosystems approach puts people at the heart of the picture: what services do we receive from our natural environment and how do these vary over space? This can be illustrated by mapping the final benefits received by people e.g. the amount of pollutants stored by a stream buffer. However, some benefits, particularly those arising from cultural services, can be very difficult to measure. Therefore an alternative option is to model this environment-to-people relationship by estimating both the ability of an ecosystem to deliver a service to an area, as well as the likelihood of that service being realised and having a positive impact on the health and well-being or livelihoods of people. For example, a belt of trees may be capable of buffering noise, but is it within an area that is likely to be affected by high noise pollution? Furthermore, is this noise pollution considered to be causing a problem – do people use the area and how likely are they to benefit from a reduction in noise? This example is illustrated in Figure 2. EcoServ-GIS explicitly models the "**flow**" of ecosystem services, from the natural environment to people, in several discrete stages.

The following stages are conducted for each mapped ecosystem service:

1) Ecosystem Service Capacity
Areas containing ecosystems that are considered to be capable of providing a particular service are identified. These areas of **capacity** are graded from High to Low according to the predicted level or quality of the service they may be able to provide, according to specified service-specific geospatial indicators. Data for **capacity (no restrictions)** are also mapped where restrictions apply for a particular service and it is useful to show areas of capacity that are no impacted by such restrictions. For example areas of capacity where there are no restrictions on public access.

2) Ecosystem Service Demand
The level of **societal demand** for a particular service is estimated by measuring the relative number of potential beneficiaries, and the possible level of improvements to health and well-being that a service could provide to them (e.g. the Index of Multiple Deprivation Health scores are used to estimate the demand for the health benefits of the accessible nature service). For those ecosystem services that relate to the regulation of hazards the hazard areas are identified first and then only these areas are graded according to demand by combining the likelihood of the hazard occurring (**regulatory need**) and levels of **societal demand**.

3) Ecosystem Service Flow: Service Benefitting Areas and Service Gaps
The separate **demand** and **capacity** maps are overlaid to illustrate how well they coincide in space,highlighting regions in the study area where there is both demand and capacity and therefore a likely or possible flow of the ecosystem service to society. These are termed "**Ecosystem Service Benefitting Areas**" (Palomo *et al.* 2012). The Ecosystem Service Benefitting Areas are then classified and graded according to the relative levels of service capacity and demand, helping to target decision making. The method assumes that where areas of High Demand and High Capacity overlap there is a higher probability of ecosystem service "flow" occurring compared to areas where Low Demand and Low Capacity coincide (Section 1.2.5). In those services where both **capacity (all)** and **capacity unrestricted** are mapped then the Ecosystem Service Benefiting Areas are mapped using the **capacity unrestricted** in order to represent realized areas of service rather than potential service delivery areas (see section below for further explanation).

In some areas of the landscape there may be predicted demand for a particular ecosystem service but no current capacity in the natural environment to deliver the service. These areas are termed "**Ecosystem Service Gaps**" and are potential areas for habitat creation or restoration. Not all services have service gaps mapped as they may not be relevant to some services.

The capacity and demand maps are split by area into 5 Quintiles to allow an investigation of the grading of the Service Benefitting Areas. In order to identify potential priority zones the Quintiles areas are combined to produce areas of "**High Demand, High Capacity"** where there is a high likelihood that the ecosystem service is being delivered and also areas of "**High Demand, Low Capacity"**, where management intervention, habitat creation or restoration could occur to help the environment deliver the service better.

With some services there may be human-related barriers or restrictions that prevent the flow of a service from ecosystems to people, within an area of demand. For example, wildlife watching areas that are privately owned cannot be accessed by the majority of potential service beneficiaries. In such cases, the "**Ecosystem Service Flow Restrictions"** are mapped and the Ecosystem Services Benefitting Areas falling nside these restricted zones are mapped as **"Restricted Ecosystem Service Flow"** (e.g. wildlife watching reas within privately owned land).

1. CARBON STORAGE

The estimated amount of carbon stored in the vegetation and the top 30 cm of soil within each raster cell.

©Andrew Mason Toolkit Development *Chloe Bellamy Jonathan Winn Tom Fisher* 60%/40%/ -

Background

The UK government has pledged to reduce greenhouse gas emissions by 80% in 2050, compared to 1990 levels, as part of the "Low Carbon Transition Plan" (HM Government 2009; 2011). The importance of managing land as a carbon store was recognised in the Plan, which encourages woodland creation and sensitive land management to protect and increase this carbon store. Levels of carbon sequestration can be difficult to estimate, therefore, many studies have estimated and mapped the amount of carbon stored instead (e.g. Chan *et al.* 2006; Collingwood Environmental Planning 2008; Countryside Council for Wales 2010; Davies *et al.* 2011).

Carbon Capacity - Estimates the relative amount of carbon stored in vegetation and top 30 cm of soil within each raster cell.

Analysis steps & rationale

The amount of carbon stored within the vegetation and top 30 cm of soil of each raster cell is mapped according to the land use and habitat type present (See Technical Report). All manmade structures or surfaces, water courses, water bodies, the sea, sand dunes, intertidal areas, rock and unclassified habitats are considered to store zero carbon (Milne & Brown 1997; Cantarello, Newton, & Hill 2011).

- Carbon storage values are based on a UK-based systematic literature review which compared measurements of carbon storage within different land use classes recorded in the scientific literature (Cantarello *et al.*, 2011). Cantarello *et al.* grouped land use types into 11 classes and calculated the mean amount of carbon storage (t ha-1) for each of these using the measurements reported by the studies reviewed. Five measurements per land use class were used to do this, with a priority towards those records made within 2000 – 2005 (to match Corine Land Cover 2000 they used for mapping) in South West England, followed by the rest of England, the UK, and worldwide.

Notes & limitations (capacity)

- This is only an estimate of carbon storage capacity. In reality carbon storage by each habitat will vary locally according to factors that this model does not take into account.
- The link between land use / habitat and carbon values is simplistic and assumes a particular habitat state. It can be considered a potential maximum capacity value. Local factors such as habitat age (e.g. time since planting of woodlands) or management (e.g. draining on moorland) will greatly impact and reduce the real world carbon storage levels. Topography will also influence both vegetation and soils carbon content.

- The carbon storage values assume a particular contribution from "typical" soils likely to be found under each habitat type. Several situations occur where these measures will be inaccurate. For example improved grassland present over deep moorland soils will underestimate the carbon storage. Similarly different plantation woodland values over deep peatland soils, e.g. planted on blanket bog will give inaccurate carbon storage values.
- Uncertainty will be introduced into the model by the BaseMap, which is not a completely accurate representation of habitat presence and land use, but is EcoServ-GIS’s best approximation based on the data available.
- Many of the factors that would aid more accurate mapping of the carbon values are simply not readily available as spatial data (e.g. management type, soils data, habitat age).
- It is debateable the improvements that would be gained by attempting to include further datasets.
- For example soils data is often coarsely mapped and the boundary for example of deep peat soils may in many cases be better represented by various BAP habitat mapping than by using soils maps (with the exception of the woodland habitats noted above).

Modifications and actions to improve the Model (capacity)

- Further literature sources on carbon content could be included to allow measures to be matched against a finder resolution of habitat categories.
- Values or estimates for a further range of modified habitat types could also be included , such as woodland plantation over various habitats such as blanket bog or

Carbon Demand - Illustrates the (homogeneous) demand for carbon storage across the study area

Analysis steps & rationale

A map showing equal, high demand for carbon storage across the study area is produced.

- The effects of carbon release on the climate and the resulting mal-effects on the environment and people occur over spatio-temporal scales too large to map at a county scale.

Notes & limitations (demand)

- The effects of carbon release on the climate and the resulting mal-effects on the environment and people occur over spatio-temporal scales too large to map at a county scale.
- The method is not able to identify areas of Low vs. High Demand, all areas are therefore considered to be High Demand for Carbon storage.

Carbon Service Flow Maps

Analysis steps & rationale

This model overlays the Demand and Capacity maps to illustrate how well they align across the study area. The map outputs illustrate the areas where it is predicted people benefit from this ecosystem service. The areas of Demand and Capacity are split into quintiles by area and these are used to identify areas of High and Low Capacity and Demand. Priority areas are identified where there is a combination of High Demand and High Capacity (priority for conservation or protection) and areas of High Demand and Low Capacity (priority for habitat creation or enhancement). Where appropriate, areas where there is no Capacity to deliver a service are identified as Ecosystem Service “Gaps”. Please see Box 1 for a more detailed explanation of methods.

Notes & limitations (flows)

- Gaps are not mapped for this service. All areas have a mapped level of capacity and demand, except for the built environment and infrastructure and land use change is unlikely to occur in such areas.
- **©Paul Hobson**

2. LOCAL CLIMATE

Chloe Bellamy Jonathan Winn Tom Fisher 70%/30%/-

Background

Land use has a large impact on local climate because surface types differ in their rates of net radiation absorption and their influence on the amount of water that is absorbed or enters into surface runoff or evapotranspiration (Kalnay & Cai 2003; Foley *et al.* 2005; Gill *et al.* 2007). A large proportion of people living in the UK reside in urban areas (90% of the population in 1991) and urban areas continue to expand at a faster rate than other types of land use (Antrop 2004). As opposed to the USA, where cities have tended to grow "outward", creating vast regions of urban sprawl, in the UK urbanisation has tended to involve increasing the density of buildings and people per unit area, often resulting in the loss of urban Greenspace (Dallimer *et al.* 2011). These built-up areas experience different local climates compared to rural areas because of the relative amount of impervious, manmade surfaces compared to unsealed areas with vegetation (Gill *et al.* 2007). Temperatures within these urban areas are often one or two degrees warmer than surrounding countryside. Global climate change is likely to amplify these differences (Gill *et al.* 2007; Bowler *et al.* 2010).

Local Climate Capacity- Estimates the capacity of an ecosystem to cool the local environment and cause a reduction in urban heat maxima.

Analysis steps & rationale

This model uses two indicators to assess local capacity for Climate Regulation. The analysis calculates the proportion of the landscape that is covered by Greenspace within a 200 x 200 m window around each focal cell. The same calculation is used to estimate the proportion of this 200 m window that is covered by trees and water:

- Natural and semi-natural habitats can reduce urban temperature maxima over small scales (Shashua-bar & Hoffman 2000).
- The effectiveness of natural cooling by Greenspace is improved by increased tree and water cover, and this is likely to be strongest at small scales (Merbitz *et al.* 2012).

The two indicators are combined, and form the capacity measure. This results in high scores where areas have high covers or Greenspace and low covers of infrastructure or buildings. The highest scores are where there is a high cover of water, woodland or trees within the focal search distance. This measure then represent the cooling ability of the immediate local environment.

Notes & limitations (capacity)

- Please note that this ecosystem service provides benefits to the local area around each functioning ecosystem. Therefore, "LocClim_Capacity" illustrates this capacity for cooling to be delivered at each cell, even if the ecosystem providing the service is not present at that particular cell.

- More evidence is needed to establish the degree to which Greenspace cools the surrounding area and how this is affected by habitat composition, structure and configuration at different scales (Bowler *et al.* 2010; Kleerekoper, van Esch, & Salcedo 2011).
- Landform, topography and building form may all impact temperature maxima, but are not measured by the model.
- Uncertainty will be introduced into the model by the BaseMap, which is not a completely accurate representation of habitat presence and land use, but is EcoServ-GIS's best approximation based on the data available.

Modifications and actions to improve the Model (capacity)

- The model would benefit from further literature justification of the focal search distances over which the natural environment has cooling effects
- The model would benefit from further literature justification of the relevant benefits particular habitat types on the level of potential cooling achieved. However such attempts at "improvements "to this model must acknowledge that for such a strategic tool as this that full information on habitat structure, management or composition will never be fully available at a fine resolution and there is a limited scope to fully include fine scale habitat information on potential cooling.

Local Climate Demand- Estimates societal demand and regulatory need across space for ecosystems that can reduce temperature maxima

Analysis steps & rationale

Regulatory need

Within those areas classified as urban in the 2001 census plus a 200m buffer the proportion of land covered by manmade surfaces is calculated and re-scaled from high to low, at the 200 m scale:

- Building and manmade surface densities are positively correlated with temperature maxima (Tratalos *et al.* 2007; Merbitz *et al.* 2012).
- Merbitz et al (2012) found that surface sealing was most strongly related to temperatures at the 200m scale.
- Tratalos *et al.* (2009) reported a positive relationship between urban density and increasing temperatures in UK cities, with roughly a 4 degree rise different between areas with <10 addresses per hectare, compared to areas with ~20 addresses per hectare.

Societal need

Population densities and the proportion of residents ≤12 or ≥65 years of age are calculated at the 200m scale within the urban area buffers (using 2001 Census data):

- Higher temperatures can cause thermal discomfort and heat waves pose a risk to human health (Forest Research 2008; Kleerekoper *et al.* 2011).
- Areas with high population densities are more at risk and older people are more vulnerable to health problems associated with heat waves (Department of Health 2010; Tomlinson *et al.* 2011).

Total demand

Urban area buffers are extracted and the standardised scores for regulatory and societal demand are summed with an equal weighting to illustrate total demand for this service.

Notes & Limitations (demand)

- Population and age risk data are upscaled from Lower Super Output Areas to those buildings predicted to be domestic housing.
- Urban areas of different sizes are considered to require this service equally. In reality demand may be higher in larger cities.
- The use of proportion of man-made surfaces as a proxy for high temperature risk is simplistic.
- The indicators are currently combined with equal weighting.

Modifications and actions to improve the Model (demand)

- Future work could research the effects of manmade surface cover, city size or population density and may investigate incorporating thresholds under which temperature regulation are considered to be relevant. These may vary with latitude. For example the service is considered more relevant in the southern UK.
- Further research on the relative impact of different methods to combine the separate demand indicators and the weight given to each could be examined.
- The age risk calculations should be updated to include the more recent 2011 Census results.

Local Climate Service Flow Maps

Analysis steps & rationale

This model overlays the Demand and Capacity maps to illustrate how well they align across the study area. The map outputs illustrate the areas where it is predicted people benefit from this ecosystem service. The areas of Demand and Capacity are split into quintiles by area and these are used to identify areas of High and Low Capacity and Demand. Priority areas are identified where there is a combination of High Demand and High Capacity (priority for conservation or protection) and areas of High Demand and Low Capacity (priority for habitat creation or enhancement). Where appropriate, areas where there is no Capacity to deliver a service are identified as Ecosystem Service "Gaps". Please see Box 1 for a more detailed explanation of methods.

Notes & limitations (flows)

- It is important to remember that service provisioning areas are the result of functioning ecosystems within the local landscape (areas within 200 m) – not just the ecosystem present within a particular cell. Therefore, any changes made to land use and habitat type will have affects to service provision at this scale.
- Due to the methods used there is unlikely to be areas where High Capacity and High Demand overlap, this is due to the inclusion of manmade cover as a demand indicator, and the Greenspace cover as a capacity indicator, with these two being inversely correlated.
- Typically for many study areas there will not be any mapped Gaps as most areas have some level of
- Greenspace present within a 200m radius.

3. POLLINATION

Toolkit Development: *Chloe Bellamy Jonathan Winn Tom Fisher* 60%/10%/30%

Background

It is estimated that around three quarters of globally important crops rely on animal pollination to some degree and the resulting increase and stability in production is valued at between billions and tens of billions of dollars per annum (Kareiva *et al.* 2011).

Pollination Capacity - This model makes predictions on an area's capacity to provide pollination services by likelihood that pollinators will travel from habitat to an arable land.

Analysis steps & rationale

The maximum foraging distance pollinators are willing to travel from habitats is disputed although there is a general consensus that this distance is greater than 1km. Although pollinators may forage over very large distances, 50% of the population may travel no further than a relatively short distance. Ricketts et al (2013) provide evidence which suggests that as distance from pollinator habitat increases, the likelihood of a pollinator visiting a site decreases non-linearly. This finding was used by Schlup et al. (2013) to map the pollination ecosystem service across Europe. EcoServ-GIS adapts this method to map pollination service capacity:

- Edge and Full pollinator habitats are identified within the BaseMap. Edge habitats are woodlands where pollinators are unlikely to utilise the full area of habitat, preferring to nest along the edges of each patch. Full habitats are those such as grasslands where pollinators are likely to use the whole patch to nest.
- Inverse logarithmic distance to full and edge habitats is calculated using a max search distance of 668m. Beyond 668m there is a less than 50% chance that a pollinator will visit a site (Ricketts et al. 2013). This was chosen as an arbitrary cut-off to highlight the best areas for pollination.
- Likelihood to visit a site is calculated based on the equation used by Schlup et al. (2013) : *e(beta×Distance to habitat)* where beta = -0.00104.

Notes & limitations (capacity)

- Likelihood of visitation is only one correlate of pollen production and crop yield. Evidence suggests that pollinator abundance and pollinator species richness may also be important factors in pollen production and crop yield (Kareiva *et al.* 2011, Steffan-Dewenter *et al.* 2001).
- This method does not consider very fine scale habitat attributes (e.g. presence of hedgerows and floral composition).
- Uncertainty will be introduced into the model by the BaseMap, particularly when identifying pollinator habitats. The BaseMap is a combination of all best available habitat and land use data.

Modifications and actions to improve the Model (capacity)

- The linear features habitat data within the BaseMap should be included (e.g. by priority conversion at a fine raster cells size).
- Edge habitats and distances should be further clarified via the literature

Pollination Demand - This model illustrates the distribution of parcels of land where food may be grown which relies on animal pollination to some degree.

Analysis steps & rationale

This model identifies allotments, orchards and areas of arable agriculture. These areas may contain food crops which rely (at least partly) on animals for pollination.

Notes & Limitations (demand)

- No method was found to grade demand areas, therefore all agricultural areas are classified as high (100).
- The main limitation of this model is that the location of arable areas is only approximately mapped, as there is no information freely available on the location of arable land and particular crop types.
- Many areas that are mapped as "Arable" are predicted to hold arable land use due to field size and slope information. However large flat fields that are not arable may be misclassified, leading to errors in the mapping of areas of pollination demand.
- The yield of different types of crops and agricultural regimes will vary in their dependence on wild pollination (some do not require animal pollination at all; Kareiva *et al.* 2011).
- Uncertainty will be introduced into the model by the BaseMap, particularly when identifying agricultural areas. The BaseMap is a combination of all best available data and is not perfect.
- The model does not account for the pollinating service provided to plants providing “wild food” or that are grown in domestic gardens, nor does it illustrate the cultural benefits provided by plants that are pollinated by animals.

Modifications and actions to improve the Model (demand)

- Use of data to more accurately locate arable land, ideally to crop type would greatly improve the models.
- Literature and methods to support the grading of areas by relative demand would be useful, but would be a secondary model improvement, after the locational accuracy of mapped demand areas was improved.

Pollination Service Flow Maps

Analysis steps & rationale

This model overlays the Demand and Capacity maps to illustrate how well they align across the study area. The map outputs illustrate the areas where it is predicted people benefit from this ecosystem service. The areas of Demand and Capacity are split into quintiles by area and these are used to identify areas of High and Low Capacity and Demand. Priority areas are identified where there is a combination of High Demand and High Capacity (priority for conservation or protection) and areas of High Demand and Low Capacity (priority for habitat creation or enhancement). Where appropriate, areas where there is no Capacity to deliver a service are identified as Ecosystem Service “Gaps”. Please see Box 1 for a more detailed explanation of methods. Because the Pollination model was not able to differentiate between how heavily the food crop areas rely on animal pollinators these areas are not graded. “Gaps” are not mapped. It is unlikely that any agricultural site will be more than 668 metres from pollinator habitat, particularly considering that pollinators have a very large range of habitats. As such, Gaps have not been mapped.

4. WATER PURIFICATION

Models the regulation of surface runoff pollutant and sediment loads ©Zsuzsanna Bird

Toolkit Development *Chloe Bellamy Jonathan Winn Tom Fisher* 50%/50%/ -

Background

A reduction in water quality can be caused by excess fine sediment and soluble pollutants (such as pesticides, nitrogen and phosphorus). This can result in increased turbidity, reduced visibility, smothering of the channel bed, the death of fish and other water life and an increase in cyanobacteria blooms. Nitrate levels remain high in UK surface water bodies, often exceeding the EC limit of 50 mg/l, and it is has been suggested that there may be a link with this pollutant and human health problems such as stomach cancer (Koo & O'Connell 2006). Low water quality can impact humans by additional cost for water treatment or through effects on recreation use in or along watercourses (walking, swimming, fishing).

Water Purification Capacity - Illustrates the capacity for an area of land to slow water runoff, trapping pollutants and sediments before they enter water courses

Analysis steps & rationale

The Water Purification Capacity maps grade the landscape by its capacity / potential to slow water and trap or ameliorate pollution. Higher scoring areas are those where structurally complex habitats such as broadleaved woodland, marsh or wetlands occur on flat or gently sloping land. Lower scoring areas are those with structurally more simple habitats or areas of steeper slopes. Manning's roughness coefficient is calculated to describe the surface resistance of the habitat to water flow (Table 12). These values are multiplied by the steepness of the slope on which the habitat lies (Table 13). Flat areas with high roughness values are assigned the highest scores:

- Slope and roughness are good indicators of an area's capacity to purify surface runoff (He, Tayfur, & Ran 2010)

Notes & Limitations (capacity)

- Uncertainty will be introduced by the BaseMap, which is not a completely accurate representation of habitat presence and land use, but is EcoServ-GIS's compilation of best available habitat mapping
- The level of habitat mapping accuracy within the BaseMap will influence the models outputs and accuracy
- The Manning's roughness scores are attributed to broad classes of habitat, in reality there will be variation between different sub habitats types.
- Water flows along its pathway from one cell to another and is not partitioned between multiple downstream cells (Liu & Smedt 2004).
- The water purification services carried out by habitat features that are too fine sale to be captured by MasterMap, such as hedgerows and treelines, are not captured by this model.
- The slope class categories used to indicate habitat potential to deposit or trap pollutant are currently broad and simplistic

Modifications and actions to improve the Model (capacity)

- Literature and methods to support the grading of slope steepness, and the application of roughness values to finer resolution / habitat sub classifications would be useful
- Use of size thresholds for habitat areas would improve the clarity of model results
- Using a majority filter to alter the map outputs to map broader zones (rather than mixed classification cells) could aid the clarity and use of the service maps.

Water Purification Demand - Models the risk of surface runoff water becoming contaminated with high pollutant and sediment loads before entering a watercourse (diffuse pollution only).

Analysis steps & rationale

The Water Purification Demand maps grade the landscape by the predicted relative levels of pollution that could be washed into watercourses. Areas of higher demand are where agriculture occurs on steep slopes close to streams, where there is a risk of erosion events washing the soil and potential pollutants into stream and also where catchments as a whole have higher percentage cover of urban or agricultural land use. Areas of lower demand are those parts of the landscape where there is less agricultural or urban land use and where there is less risk of pollution events or erosion reaching a watercourse.

Regulatory need

This model first estimates the risk of water contamination at the watershed scale by focusing on land use characteristics. At a much finer scale, the "Universal Soil Loss Equation" (USLE) is then used to estimate rates of soil loss at each particular cell. These two factors are then multiplied together.

1) Watershed scale land use: Each watershed is graded according to the proportion of its area that is covered by farmland or manmade surfaces (1 – 100). These scores are combined to give a final land use risk score between 1 - 100, giving the urban cover raster a higher weighting (Table 14). Those areas with higher covers are assumed to have a higher risk of water contamination:

- Fertilisers from agricultural land which have been leached from soils or have been absorbed in water runoff cause a decrease in water quality. Intensive agriculture also increases erosion and sediment load and urbanisation can decrease the quality of water runoff (Foley *et al.* 2005). However, agriculture has been reported to have less of a damaging effect on water quality compared to urban cover (Brabec 2002). Wang *et al.* (1997) found that 10 – 20% of urban cover was enough to cause water quality scores to be classified as "poor", compared to 40% for agricultural areas. Impervious cover models have been used to show the negative impact of urban areas on watershed water quality (Schueler 1994; Wang *et al.* 1997). Hydrology tools are used to create flow accumulation grids, stream networks and watersheds. A threshold of flow accumulation of 20,000 is used to identify the main stream in order to carry out stream delineation and watershed boundary generation. A default is set, but this can be varied by the user. Selection of a higher threshold would result in larger watersheds. Due to the methods used there may be areas at the periphery of the study area, or along lowland coastlines that are not accurately mapped by the watershed analysis. These areas will not receive a demand score and will be mapped as 0. This will not significantly impact on the models as this one of the reason for using a buffer zone around the study area and also any small coastal watersheds will output to the sea, and within the context of the current mapping methods these areas would not impact on any land areas, and there would be no beneficiaries of water purification in these areas. (Beneficiaries would be related to the marine ecosystem, but these are not covered by this toolkit).
- **Fine scale erodibility risk:** Each cell is graded by its estimated risk of erosion using an adaptation of the USLE equation (Sivertun & Prange 2003), resulting in the release of sediment and pollutants. Four factors are created:

A) Land use (Table 15)
B) Soil type (Table 15)
C) Distance to water course $f(x) = (0.6/(\exp 0.002x - 0.4))$
D) Slope length Power(flow accumulation * cell resolution / 22.1, 0.4) * Power(Sin(slope in degrees * 0.01745) /0.09, 1.4) * 1.4
These factors are multiplied together. The resulting value are standardised (1 – 100 scale) to illustrate overall risk at each *cell*:

- Areas that are prone to erosion will contribute highly to the sediment and pollutant load of surface runoff water. Therefore, these areas and those down slope have a high need for ecosystems that can slow this run off, helping to reduce water pollutant load before it enters a watercourse. The "Universal Soil Loss Equation" (USLE) and various modifications of this model have been used to estimate rates of soil loss based on rainfall patterns, soil properties, land cover and topography (Wischmeier & Smith. 1978; Sivertun, Reinelta, & Castenssona 1988; Sivertun & Prange 2003; Wu & Wang 2011; Prasuhn *et al.* 2013). Sivertun & Prange (2003) specially adapted this model for GIS, simplifying the original model by reducing the data required to four factors which can be mapped using GIS (soil, slope length, land use and distance to watercourse); this modified method cannot estimate actual sediment load at any point, but they found it useful for mapping relative erosion risk quickly across large areas in Sweden (Sivertun *et al.* 1988; Sivertun & Prange 2003). The aim of this method is to identify those areas that have a combination of characteristics that may result in erosion, and the transfer of the erosion, sediment, or dissolved pollutants to a water course. Certain land uses (A) and soil types (B) have a higher susceptibility to erosion. The model concentrates on potential overland flow and storm wash events. The inclusion of a factor to represent distance to water courses (C) acts as measure of the likelihood of erosion or pollution reaching a watercourse. This factor emphasis areas closer to streams and rivers, acknowledging that erosion events are unlikely to travel long distances. Erosion events and the transfer of pollutants can occur in any locations, but the assumption is that if they are a long way from water courses that the material will be deposited or intercepted by vegetation or will drain into soils. Subsurface flow or transfer in groundwater is not considered by this model. This factor has been adapted for use in EcoServ-GIS compared to the formula present within the cited research. Euclidean distance to watercourse is not an accurate representation of potential flow distance or connectivity to watercourses because the distance may stretch to a separate watershed or the distance may span steep topography or ridges. Therefore Euclidean distance to the nearest stream has been constrained by applying a mask to the analysis using least cost distance, where areas of ridges or locally high elevation were given a high cost score to ensure ridges are not included in these calculations. This was calculated using a local Topographic Position Index, search distance set at 150m, topographic ridges extracted as all areas > 5 (cost value 50) and areas >2 <5 (cost value 20), compared to other landscape areas. All areas of least cost <=1000 were then used as a mask to the Euclidean distance from streams.

The slope length factor (D) is taken from studies using the USLE equation. There are several important limitations in the use of USLE derived indices. The USLE was developed from measured field values, concentrating on erosion within agricultural areas on moderate slopes within the USA. The LS factor illustrates expected erosion levels, based on a combination of slope steepness and slope length. Steeper slopes and longer slope lengths result in higher erosion level due to their influence on the velocity and power of resulting overland flow events. Different studies have substituted flow accumulation for slope length when calculated within a GIS. There can be issues with this modification of the original calculation. The USLE formula gives a value relative to plot slopes and slope length from the original field trails. The original use of slope length in the formula was from relatively short distance slope lengths (10m to 100m), across which short distance flows of erosion / overland flow may occur. These measures of slope length refer to the distance from the origin point at which overland flow begins, up to an area of deposition (e.g. from low slopes or sudden increase or decrease in gradient) or where the flow enters a watercourse. Recent use of flow accumulation in place of slope length acknowledges the importance of the convergence power of water flow and gives a better reflection of the upslope contributing area over which water accumulation can influence erosion, compared to linear measures of slope length. However use of flow accumulation requires consideration of a suitable threshold. Flow accumulation is calculated throughout a landscape, resulting in the largest values at the lower elevations of a watershed or study area. However the focus of this model is erosion within land, and areas within a stream channel are not considered important. A threshold is commonly applied to flow accumulation values in order to identify where areas of high flow accumulation are considered to be watercourses. In this analysis a maximum flow accumulation threshold value of 500 cells was used, with all values above this being reclassified to 500. Another alteration was made to the use of the slope values. As the focus is identifying need for erosion and pollution reduction in agricultural and urban areas extremes slope values associated with cliffs or non farmland areas were excluded (>40 degrees). Similarly areas of 0 slope, but with modelled flow accumulation valleys were considered to be relevant to this service. These areas may not actively involve erosion of sediment but they can contribute to landscape level transport of sediment, overland flow or storm wash events. Therefore all areas of 0 degrees slope were re-classified to 0.1 to ensure such areas appear in the ecosystem service maps, for areas where flow accumulation is predicted. A final modification relates to the calculation of the flow accumulation grid. In order to highlight areas of higher potential pollution a weight grid was applied to the flow accumulation analysis with values of 1 applied to urban (HabClass = “Infrastructure” OR HabClass = “Urban”) and agricultural (HabNmPLUS = “Cultivated/disturbed land/arable” OR HabNmPLUS = “Grassland, Improved” OR HabNmPLUS = “Grassland, Improved / arable (probable)”) a value of 0 to all other land uses. This is the default setting and can be modified by the use if desired.

This model does not include precipitation or climate data and any variation in these across a study area will influence the predictions of the model. However within most counties this is not considered to be a significant issue, but would be more relevant where there was a very large range in elevation or topography within a study county.

Societal demand

This model does not map the societal demand for water purification because drinking water is typically transported long distances., e.g. via pipelines and this could not meaningfully be mapped in order to indicate the human benefit of water purification.

Notes & limitations (demand)

- The soil data are at a very coarse resolution (1:1,000,000) and therefore do not reflect the local changes in soil properties at the county scale. However, this is currently the only soil dataset that covers the UK and is available for use at no cost.
- Soil and land use characteristics are assumed to be homogeneous for each single raster cell.
- Water flows along its pathway from one cell to another and is not partitioned between multiple downstream cells (Liu & Smedt 2004).
- The water purification services carried out by habitat features that are too fine sale to be captured by MasterMap, such as hedgerows and treelines, are not captured by this model.
- Uncertainty will be introduced by the BaseMap, which is not a completely accurate representation of habitat presence and land use, but is EcoServ-GIS’s compilation of best available information.
- Due to the use of slope steepness, flow length / flow accumulation in the modelling the service will not be mapped well in larger areas of flat, lowland agricultural land. In such area aquatic habitats or large expanses of e.g. reedbed may deliver this service, but there are not highlighted well by this current mapping method.

Modifications and actions to improve the Model (demand)

- Use of size thresholds for habitat areas that influence water quality would improve the clarity of model results Societal demand indicators could be developed

Water Purification Service Flow Maps

Analysis steps & rationale

This model overlays the Demand and Capacity maps to illustrate how well they align across the study area. The map outputs illustrate the areas where it is predicted people benefit from this ecosystem service. The areas of Demand and Capacity are split into quintiles by area and these are used to identify areas of High and Low Capacity and Demand. Priority areas are identified where there is a combination of High Demand and High Capacity (priority for conservation or protection) and areas of High Demand and Low Capacity (priority for habitat creation or enhancement). Where appropriate, areas where there is no Capacity to deliver a service are identified as Ecosystem Service “Gaps”. Please see Box 1 for a more detailed explanation of methods.

5. ACCESSIBLE NATURE

Accessible Nature Toolkit - Opportunities to experience and enjoy natural landscapes ©Zsuzsanna Bird

Toolkit Development *Chloe Bellamy Jonathan Winn Tom Fisher* 80% 20% -

Background
Opportunities to access natural areas has been found to improve people's mental and physical well being (MA 2005; Sustainable Development Commission 2007; Aked *et al.* 2008; Haines-Young & Potschin 2010b; Jorgensen & Gobster 2010; Dallimer *et al.* 2012a).

Access Restrictions & Accessible Nature Capacity - Models the availability of natural areas and scores them by their perceived level of naturalness.

Analysis steps & rationale
Relative measures of perceived land cover naturalness are mapped at two scales (10 or 50 m, and 1 km) and these indices are combined with equal weight. All manmade structures or surfaces and unclassified habitats are assigned a naturalness score of zero. The remaining natural habitats are scored based on results from two tranquillity/wilderness mapping studies which collected survey data on the public's perceived naturalness of different land cover types in England (Jackson *et al.*, 2008) and Scotland (Carver et al 2008), and applied these to Land Cover 2007 data habitat categories for mapping. We averaged the habitat scores from the two studies and assigned scores to the closest matching habitat categories identified in the BaseMap (See Technical Report). Areas classified as a mixture of habitat types were assigned the lowest naturalness score of any habitat present, unless stated.

- People do not perceive all habitats to be equally "natural" (Jackson *et al.* 2008; Carver *et al.* 2011), and prefer to visit those areas they feel have a higher level of naturalness, suggesting that they receive higher health and well-being benefits from these areas (Joyce & Sutton 2009).
- Two scales are used so that the effects of both the immediate surroundings and the wider landscape on the perceived naturalness of an area are incorporated (Jackson *et al.*, 2008).

Flow restrictions
The restriction to the flow of the service from areas with both accessible nature capacity and demand mapped by EcoServ-GIS is accessibility. Private land is considered to block the flow of this service because general members of the public are not able to lawfully access the site to benefit from the service. Accessible areas mapped are:

- 20 m either side of a Public Right of Way, Sustrans route, or pavement
- Areas with Countryside Rights of Way access
- Beaches, and a 100 m swim distance from these
- Local Nature Reserves, National Nature Reserves
- Playgrounds, general amenity Greenspace, cemeteries, parks and public gardens, accessible woods
- Accessible woodlands ("Woodlands for People") mapped by the Woodland Trust

Access Constraints & Accessible Nature Capacity model indicators

Notes & Limitations (capacity)

- No UK dataset exists which shows levels of access to each land use parcel. We therefore had to make assumptions on what land use types are generally accessible, but this method will not correctly identify all publically accessible Greenspace.
- The identification of accessible area is reliant on how accurate and comprehensive the input data are for; GI / Open Space, LNR, NNR, Crow Act land, PRoW, Sustrans. In rare cases these designation may not actually be publicly accessible.
- In particular where GI / Open Space survey data has been poorly mapped or contains multiple categories it may be unclear which areas are publicly accessible.
- The model assumes that areas identified as Manmade and Roadside within OS MasterMap data are pavements and that these areas are generally publicly accessible. In the vast majority of cases this is true, however in a minority of areas, such as private business parks or industrial estates there may not be public access and this data from pavements will be inaccurate.
- PRoW data vary in accuracy and will not reflect all public footpaths.

Modifications and actions to improve the Model (capacity)

- The use of further literature to enable naturalness scores to be linked to a finer resolution or sub categories of habitat would be useful (although such scores would ideally be also related to different source human population characteristics).
- The use of the 1km scale for landscape scale naturalness requires further justification via the literature. Use of an additional intermediate scale to represent naturalness within local walking distance (300m) would be useful.

Accessible Nature Demand - This model estimates the societal demand (need) for opportunities to access and enjoy natural landscapes across the study area by estimating the number of people likely to travel to an area for this activity and their need for the related health benefits.

Analysis steps & rationale

To illustrate the level of societal demand for accessible nature across space five indicators are constructed and then summed with an equal weighting. The first estimates the ease of accessing an area on foot, bicycle or by public transport by measuring the minimum distance to either a public right of way or public transport stop. Secondly, the number of people living within both a 300 m and a 3.2 km radius of any point are estimated and mapped to indicate levels of population based demand. To represent the need for the health benefits provided across space, the mean Index for Multiple Deprivation "Health deprivation and disability" domain indicator is mapped at the same scales, highlighting those areas with high levels of premature deaths and impairment of quality of life by poor health (Mclennan *et al.* 2011).

- The distance to Greenspace from people's houses determines how often it is used for recreation (reviewed by Caspersen & Olafsson, 2010). 300 m is estimated to take roughly 5 minutes to walk and this distance is often used to identify sites that are "easily accessible on foot" (Harrison, Burgess, & Milward 1995; Handley *et al.* 2003; CCW 2006).
- A distance of 3.2 km was selected because in 2010/11 the "National survey on people and the natural environment" found that 66% of outdoor recreation trips were less than 3.2 km from home (Natural England 2011).
- Poor access to Greenspace and nature is linked to health problems (reviewed by Newton 2007). In order to account for limitations in both the mapping rules that identify domestic buildings and the reliability of the population size and Multiple Index of Deprivation statistics at low population density, two thresholds are applied to the Local and Landscape population measures. Areas with less than 50 people at local scale (300m) and 500 people at a landscape scale (3.2km) are not considered in the analysis.

Notes & Limitations (demand)

- The identification of Demand is limited by the way the model estimates both population size and typical health scores. These estimates will be more reliable in highly and densely populated areas compared to very sparse rural areas. The model currently addresses this issue by applying two thresholds, below which population characteristics are not used. At present, these thresholds have been selected following visual examination of the data range within a variety of LSOA areas (50 people at 300m scale, and 500 people at 3.2km scale). They remain essentially arbitrary and would benefit from further investigation and evidence to choose the appropriate threshold level.
- The identification of accessible areas is reliant on how accurate and comprehensive the input data are for; GI / Open Space, LNR, NNR, Crow Act land, PRoW, Sustrans.
- Distance is used to assess likely travel distance and likely use of sites by people. These can only be estimates of the probability of people accessing a site.

Modifications and actions to improve the Model (demand)

- Euclidean distance is used to estimate likelihood of access and use of a site. Ideally future model enhancements would use actual; travel routes to calculate distance, via least cost distance analysis.

Accessible Nature Service Flow Maps

This model overlays the Demand and Capacity maps to illustrate how well they align across the study area. The map outputs illustrate the areas where it is predicted people benefit from this ecosystem service. The areas of Demand and Capacity are split into quintiles by area and these are used to identify areas of High and Low Capacity and Demand. Priority areas are identified where there is a combination of High Demand and High Capacity (priority for conservation or protection) and areas of High Demand and Low Capacity (priority for habitat creation or enhancement). Where appropriate, areas where there is no Capacity to deliver a service are identified as Ecosystem Service “Gaps”. Maps C and C1 show areas where there is accessible nature capacity, but it is private land and therefore cannot be enjoyed by all members of the public (“restricted service delivery”. Please see Box 1 for a more detailed explanation of methods.

Using the maps for targeted decision making

The output maps from the EcoServ-GIS Toolkit can be used to help inform county and local scale decision making. The maps form another evidence base upon which to base decisions and can be used in conjunction with many additional data and evidence sources. The notes on each particular service highlight where additional evidence exists that can be used alongside each service map. **As the maps are derived from OS MasterMap data users should ensure they have the necessary license in place to cover use of the maps in reports, publications or when copying data within the project partnership.**

Ultimately the maps give an indication of where particular services are likely to occur and the predicted extent to which service flow is likely to occur from the environment to people. Ultimately the way this information is used will be project and landscape specific. A number of detailed examples and case studies are provided in the accompanying “Using EcoServ-GIS Map Guide”. An overview and brief summary of the potential uses is provided below.

The key issues relevant to the use of the mapped EcoServ-GIS outputs are:

- available local knowledge
- additional mapped evidence and data
- opportunities to verify, assess , scale or grade the mapped prioritisations
- the difference between identifying large broad areas of potential ecosystem service occurrence versus focussing in detail on mapped priority or target zones

The Toolkit allows ecosystem services to be mapped and quantified and provides one method to identify potential priority areas where ecosystem service flow is likely to be highest. Frequently the mapped outputs will be used in conjunction with other sources of information and particular maps may be more suitable for particular projects.

Ecosystem Service Demand Maps
The **demand** maps illustrate how the mapped indicator of demand varies across the study area. These maps can be used to identify areas where there is high or low demand for a particular service. This information can be used within funding bids, and site or spatial plans to highlight areas where habitat conservation, restoration or creation projects would benefit this ecosystem service. Due to the methods used in the Toolkit and the lack of available information to accurately quantify each service the grading levels are relative to the study area and simply indicate a range from High to Low. Often extensive information on the local importance of a particular ecosystem service will already be known to the local partnership and this information combined with local expertise or additional data may be used to identify locally meaningful cut offs or values that represent local examples of High or low demand.

Ecosystem Service Capacity Maps
The **capacity** maps illustrate how the mapped indicator of capacity varies across the study area. These maps can be used to identify areas where there is high or low capacity for a particular service. This information can be used within funding bids, and site or spatial plans to highlight areas where habitat conservation, restoration or creation projects would benefit this ecosystem service. Due to the methods used in the Toolkit and the lack of available information to accurately quantify each service the grading levels are relative to the study area and simply indicate a range from High to Low. Often extensive information on the local importance of a particular ecosystem service will already be known to the local partnership and this information combined with local expertise or additional data may be used to identify locally meaningful cut offs or values that represent local examples of High or Low capacity.

Ecosystem Service Flow: Service Benefitting Areas and Service Gaps
The output from the “flow” model is considered the most instructive of the output maps because it

highlights areas most in need of protection, management or restoration in order to maximise single or multiple ecosystem service delivery. For each service, up to four outputs are generated (Table 5; the methods used for generating these are outlined in Box 1). There are two versions of the output maps, simple and priority versions. The initial flow map output **"Ecosystem Service Benefitting Areas"** (A, Table 5), shows areas where there is predicted to be both some demand for a service and some capacity of the ecosystem to deliver it. This map shows where there may be a flow of the service from the environment to people, however within this area there will be considerable variation in levels of both capacity and demand and therefore often this is a very broad mapped zone. For simple mapping, to illustrate the wider occurrence of ecosystem services or where the logic for further grading of a service by priority levels is poor then this map may be the most useful. However in most cases the following graded and prioritised versions of the ESBA will be more suitable.

"Ecosystem Service Benefitting Areas, High Demand, High Capacity (A1, Table 5) shows the areas where there is predicted to be a High Demand for a service and High Capacity to deliver it. These areas are where there is a higher confidence that flow of the ecosystem service is occurring, i.e. where people are benefitting from the natural environment. These maps are useful in that they focus on the more important areas for current delivery of the mapped service. In order to produce a standardised system that produces these priority maps the Demand and Capacity maps are split by area into 5 quintiles, with the top quintile by area being "High" and the lower two being"Low". This simple system allows these areas to be quantified and for these priority maps to be produced however the cut off is arbitrary and simply serves to identify spatially one way of mapping the more important areas. These maps will ideally be used in combination with local knowledge and together with other data sources. As a rapid assessment and across wider geographic areas this method will successfully identify priority areas for each service. Ultimately however the cut-off values must be considered against local information to identify locally relevant cut-off for high levels of capacity and demand for each service. The full quintiles data is supplied in the Toolkit and users may wish to examine alternative combinations. This method of using quintiles by area is one reason why the Toolkit is less suitable for smaller or more uniform geographic areas.

These maps can be used to highlight those areas where people are most likely to benefit from the particular ecosystem services. For example it can be used to identify those Greenspace areas where local residents are most likely to receive health benefits from access and recreation, or those woodlands where local residents are most likely to receive health benefits of reduced air pollution from the woodlands being present.

"Ecosystem Service Benefitting Areas, High Demand, Low Capacity" (A2, Table 5) shows the areas where there is predicted to be a High Demand for a service and Low Capacity to deliver it. These maps are useful in that they focus on the areas where people could benefit a lot from the service but delivery of the service is likely to be currently poor. In order to produce a standardised system that produces these priority maps the Demand and Capacity maps are split by area into 5 quintiles, with the top quintile by area being "High" and the lower two being "Low". This simple system allows these areas to be quantified and for these priority maps to be produced however the cut off is arbitrary and simply serves to identify spatially one way of mapping the more important areas. These maps will ideally be used in combination with local knowledge and together with other data sources. As a rapid assessment and across wider geographic areas this method will successfully identify priority areas for improvement of each service. Ultimately however the cut off values must be considered against local information to identify locally relevant cut off for high levels of capacity and demand for each service. The full quintiles data is supplied in the Toolkit and users may wish to examine alternative combinations. This method of using quintiles by area one reason why the Toolkit is less suitable for smaller or more uniform geographic areas.

The maps can be used to highlight areas where if management was altered or if habitats were created or restored then more people would benefit from the ecosystem service. For example it can be used to identify those Greenspace areas where local residents would most likely receive additional health benefits if additional Greenspace was created or the existing Greenspace was made more natural. Additionally the maps could be used to identify where planting additional woodlands would benefit local residents health by reducing air pollution.

Ecosystem Service Gaps (B) are identified as the areas where there is a predicted demand (need) for a service but there is no capacity to supply it. Additionally areas of High Demand but Zero Capacity are classed as **Ecosystem Service Gaps, High Demand** (B1). These maps can be used to influence strategic planning at the neighbourhood or site scale. For example gaps in the Air Pollution Regulation Service can suggest areas where creating woodland habitats would help to improve local air quality.

Restricted Ecosystem Service Flow (C) are the areas where there is a predicted demand (need) for a service and a predicted level of capacity for a service but where there are also restrictions in place that limit the potential flow of the service to people. Examples include areas where public access is restricted and people cannot benefit from certain ecosystem services. Additionally areas of where there is a both High Demand and High Capacity within these restricted flow areas are mapped **Restricted Ecosystem Service Flow, High Demand, High Capacity** (C1). These maps can suggest areas where, if the restrictions were removed, that people would begin to benefit from the ecosystem service.

The ecosystem service maps are useful for gaining insight into the delivery of each service across space, but the "**Multifunctionality**" maps provide a more holistic insight into the benefits we receive from our environment. They allow decision makers to take an "ecosystems approach", by considering the multiple benefits of ecosystems rather than focusing on a particular service or ecosystem. These maps can be used to asses which areas of Greenspace deliver several different ecosystem services. These maps can help to indicate areas that are particularly valuable for several different services and functions. These maps are more useful when they are based on a high number of services as ideally with the ecosystem approach all the different properties and benefits of habitats will be considered in decision making. Although a variety of services are included in the Toolkit this is not comprehensive, and this must be recognised when interpreting these Multifunctionality maps.