An analysis of Ecoserv-GIS Ecosystem Service mapping outputs for the ARC Project Area, using Horsham as a case study.

An Arun and Rother Connections report
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For further details contact the administrator of the Ecoserv-GIS toolkit at ecoserv-gis@outlook.com

Disclaimer

The information interpreted in this report is complex and the results show many features and issues of interest. This report is a short summary of the data, and we recommend that readers investigate the data more fully and compare it to 'real time' issues on the ground before applying the mapping outputs to real landscape planning issues. Ecoserv-GIS is compiled from 40 specific Geospatial datasets. Sussex Biodiversity Record Centre have used the best data available but there are strengths and weaknesses to many digital spatial datasets. Sometimes these data weaknesses will need to be taken into account in interpreting maps.

Introduction

To effectively manage the positive and negative contributions that differing land management practices have on the environment, economy and people in the wider landscape, it has been widely acknowledged that better landscape scale mapping and spatial analyses of land use values and functions are needed. The shift from the evaluation of a piece of land's 'worth' from purely an economic one, to a more detailed assessment of the risks versus benefits to society and wildlife in altering overall land use (i.e. from a park, to a housing development), is a welcome if complex shift. This landscape approach also starts to acknowledge the spatial impacts of different land uses. For example, the change of land use in one place (i.e. urbanisation) may have its geographic impact elsewhere (i.e. flooding downstream of house building).

In conservation, steps have been taken to move away from 'valuing' isolated and disconnected land parcels, to assessing the overall societal value of a connected network of healthy land within the wider landscape. This has been achieved, for example through the identification of Landscape scale focus areas (such as the ARC project area), Habitat Potential Networks and Biodiversity Opportunity Areas. In order for landscape analyses to be effective however, organisations, landowners and partnerships need to be involved in mapping and interpreting the 'value' attributed to one, or a series of land parcels within the broader landscape, and the decision making processes which affect these land parcels.

Historic approaches to conservation have proved insufficient to maintain ecosystem integrity because they tended to be based on the rarity of individual species / habitat rather than their functional significance in the food web / landscape as a whole. New approaches, which focus on the protection of ecological networks and the ecosystem services that they provide should lead to more appropriate conservation targets to maintain the overall integrity of a landscape such as the South Downs (which naturally helps to clean and resource the water that hundreds of thousands of people drink).

For the ARC project we have used good quality, repeatable, geographic data to highlight the roles that different parts of our landscape play in supporting society and the environment. Our ARC Habitat Potential Models show the potential to expand ecological networks at a landscape scale across 8 different habitats in the face of flooding and climate change. To compliment this, Sussex Biodiversity Record Centre (SxBRC) have used Ecoserv-GIS to model the Ecosystem Services that the ARC project area provides.

This ARC Ecoserv-GIS models provide new information to help inform landscape scale planning and conservation. The models help to identify key areas of the ARC project area which provide important multi-functional services. The explanation of the output models involves the use of terms that merit definition.

- **Service demand** – The likelihood / magnitude of people's requirements for an ecosystem service across space, according to the distribution of people that are most likely to benefit from the service
- **Service capacity** - The performance and capability of an ecosystem or a landscape to deliver services
- **Benefiting areas** – areas of land which provide benefits to people and wildlife
- **Beneficiaries** – those who benefit from or who use the ecosystem services
- **Management areas** - identifying where changes in land management can enhance the range of ecosystem services provided, and the amount of people / wildlife that they benefit.

The report is also available at www.arunwesternstreams.org.uk/resources.

Executive Summary of the Ecosystem Services in the ARC project area

One of the most important aims of the ARC project was to involve people in their local environment and in articulating the value that it has for their wellbeing. In order to support human wellbeing, we need a healthy, functioning landscapes which can support essentials such as clean water, good health, good education and an ability to adapt to climate and other change. We call the benefits that nature provides us with (clean air, water, food, fuel) 'natural services' or 'ecosystem services'. A local example are the natural freshwater reservoirs under the Chalk Downs & Greensand. The natural, permeable rocks filter, clean and store water which is harvested to provide over a million people in Sussex with drinking water.

To help show people how their local landscape supports them, an Ecoserv-GIS model was produced for the ARC project area (Arun & Western Rother catchments) to document how/whether the following natural services are being provided to local populations :-

- Accessible nature
- Education
- Green travel
- Carbon storage
- Local climate regulation
- Air purification
- Noise regulation
- Water purification
- Pollination

The model can be used to support landscape and town planning, and to illustrate this, Horsham town was used as a case study. The model showed that nature reserves around Horsham town are providing multiple natural services including regulation of air and noise pollution, and that more can be done to articulate and protect the true multiple benefits value of these local sites. The model can also help to target the creation of green infrastructure around Horsham, to buffer and enhance existing natural services. In addition changes in land management (and management schemes such as Countryside Stewardship and Forestry schemes) can clearly be targeted to enhance and support local ecosystem services.

In some urban fringe areas, some natural services appear to be becoming compromised or overwhelmed, where too much human pressure is being put on the natural resource. There is an opportunity and a need in these areas to carefully consider the future location of housing which could further compromise these natural services. In the case of carbon storage, human demand has already far exceeded the capacity of the environment to provide the service, particularly at a local level, and more therefore needs to be done to lobby nationally for policy changes which help to reduce carbon use and increase carbon storage at larger landscape scales.

In other parts of the ARC project area, particularly in the urban conurbations of Littlehampton and Horsham there is a lack of capacity to provide a range of key natural services such as air purification, access to nature and pollination services for local people. This is likely to result in detrimental health effects on local people, and a corresponding societal/economic burden in terms of health and mental health care.

Over the course of a 4 year Heritage Lottery Funded project, ARC was able to invest significant time, funding and energy into supporting environmental enhancements across the project area. This included a range of project which we believe have contributed directly or indirectly to the provision of ecosystem services. Some of these projects include. In the Horsham area :-

- **Chesworth Farm** – Which provides improved carbon capacity, pollination, air and water purification capacity through environmental enhancements and improved access to nature and education via a new boardwalk, pond dipping platform and educational events (otter and water vole outreach)
- **St Leonards forest** – Gaining national notification via the UK Priority river habitat map of its value as a watershed and habitat – an important means of helping to protect, maintain and enhance this area into the future given its importance for providing multiple ecosystem service benefits.
- **Christ's Hospital** – Providing educational access and access to nature, pollination and carbon capacity benefits via pond and meadow enhancement, black poplar planting and more.

In the wider landscape :-

- Planting trees and hedgerows, restoring rivers, meadows, heaths and wetlands for carbon storage and water purification.
- Creating better access to nature and education at a range of sites and for a range of audiences
- Assisting access to nature, air purification, better water purification and carbon storage via the Littlehampton, Pulborough and Horsham park Sustainable Urban Drainage Schemes
- Our ponds project which helped to create and restore ponds is helping to store carbon. Ponds have been shown to store more carbon than the oceans relative to their size.

We have shown that the ARC project has helped to contribute to better connecting people to their local environment and its value, as well as enhancing the natural services that the landscape can support. We have also supported work in many of the areas shown to be valuable providers of ecosystem services, in ways which will help to provide more of these services in the future (such as water purification) as well as natural services which are not included in the Ecoserv-GIS model (such as natural flood storage).

With the new information available via the Ecoserv-GIS model on how to target the local enhancement of ecosystem services, we hope that the tool will enable planners and other stakeholders in the ARC project area to take environmental services fully into account in their short and long term landscape and urban planning. The model can be used to identify where changes in land management could help to provide more of the required natural services, and to predict where they may be needed in the future.

PLEASE NOTE

- This model focuses on the services provided ***to people***. Large areas of the countryside are providing natural services but these do not score highly in the Ecoserv-GIS model because people do not directly benefit from them. Localised increases in populations could therefore alter model outputs
- The map above shows a basic overlay map of multiple ecosystem service provision. Full multiple service benefits models are currently in production and will be available at a later date.

Local grasslands and green spaces can provide a valuable range of natural services to local people, from access to nature, to air and water purification and pollination services.

What is an Ecosystem or Natural Service?

There is an ongoing dichotomy between the environment and the economy. Both heralded as important to the function of society, one often seen as needing to be sacrificed on behalf of the other. Fundamental to the debate is the assumption that human wellbeing can only be upheld if the current economic status quo is maintained. However, the current system only places value on tangible products which can be measured in monetary terms, and in doing so it allows the irreversible damage of some of the key systems which support the whole of society and the economy.

New methods of evaluating the essential functions that our landscapes play in providing us with 'natural' services have emerged – such as the role that peat bogs play in the stabilisation of our climate (as opposed to the value of the peat sold for potting our plants or for burning), the role that permeable rock landscapes such as chalk play in filtering and storing clean drinking water (e.g. for over 1.1 million people in Sussex), and the role that our entire natural landscape plays in filtering, storing and slowing down floodwater in a way which can benefit the economy, society and biodiversity.

Ecosystem services tend to be grouped into four categories of provisioning, regulating, cultural and supporting services (see Table 1 below). Examples of the types of different services provided under each of these headings are listed below. Supporting services are fundamental to the function of all other services :-

			
Provisioning Services	**Regulating Services**	**Cultural Services**	**Supporting Services**
The products obtained from ecosystems	**The benefits obtained from the regulation of ecosystem processes.**	**The non-material benefits people obtain from ecosystems**	**Ecosystem services that are necessary for the production of all other ecosystem services.**
Food, fibre and fuel, Genetic resources, Biochemicals, Fresh-water.	Invasion resistance, Herbivory, Pollination, Seed dispersal, Pest regulation, Disease regulation, Natural hazard protection, Erosion regulation, Water purification, Climate regulation.	Sense of place and history, Knowledge, Education and inspiration, Recreation and aesthetic values, Spiritual and religious values.	Primary production, Provision of habitat, Nutrient cycling, Soil formation and retention Production of atmospheric oxygen, Water cycling.

Table 1 : Ecosystem service categories. Natural England (2006)

What is Ecoserv-GIS and how can it be applied to the ARC area?

Ecoserv-GIS is a model developed by the Royal Society of Wildlife Trusts for mapping ecosystem services. It is based on national datasets (although many are locally derived) and uses a series of rationales rooted in the National Ecosystem Assessment.

Ecosystem services are the benefits that people gain from nature and the natural environment. Explicitly considering these benefits can inform land use planning and conservation projects. The Ecoserv-GIS toolkit generates fine scale maps illustrating the human requirement (need or demand) for ecosystem services as well as the capacity of the natural environment to provide each service, using scientifically informed, standardised methods and widely available datasets. It provides users with the facility to overlay maps to show how well demand and capacity coincide in space. This highlights natural areas providing high levels of service delivery that should be conserved, as well as those in need of actions to improve single or multiple service delivery. These are illustrated by maps of service benefiting areas and identified management zones.

The maps can be used over a range of scales, from assisting decisions on the management of sites or nature reserves, informing policies, and responding to local planning applications, to aiding the development of landscape scale conservation projects. Ecoserv-GIS 3.3 maps nine provisioning, regulating and cultural services, including ones that grade greenspace according to the opportunities they provide for enjoying nature. This toolkit is free to use or modify. In assisting Local Authorities to implement the ecosystem approach, partnerships can access these data under the specifications of a subcontractor's license agreement.

One outputs of the mapping is a digital habitat map. This is a valuable outcome for organisations that do not have available landscape scale (habitat) mapping. The habitat map can be used to produce automated ecological network maps and to map biodiversity opportunity areas. The toolkit has been produced using ArcGIS ModelBuilder and requires ArcGIS Desktop (version 10.2.2). It is designed to work at the county or region scale and requires between one and four months of GIS staff time to create map outputs. Individual ecosystem service tools are independent of one another and can be run alone or as part of a multiple service assessment. However, the toolkit is more appropriate for a multi service assessment than for use with single service projects.

Ecosystem service	Urban	Urban-fringe	Rural	Uplands
Air purification	✓	✓	✗	✗
Carbon storage	✓	✓	✓	✓
Local climate	✓	✓	✗	✗
Noise regulation	✓	✓	✗	✗
Pollination	✓	✓	✓	✗
Water purification	⚠	✓	✓	⚠
Accessible nature	✓	✓	⚠	✗
Education	✓	✓	⚠	✗
Green travel	✓	✓	⚠	✗

✓ : applicable use, ⚠: use with caution, ✗: not suitable for use

Most of the services relate to urban or peri-urban areas, and outputs are less applicable for rural areas. Maps can easily be produced for a number of Sub Areas within the wider Study Area (e.g. cities, neighbourhoods or catchments). A number of suggested uses and projects are listed for each ecosystem service map.

The range of ecosystem service output maps which have been created for the ARC ECOSERV-GIS maps include Air purification, Accessible nature capacity, Carbon capacity, Education capacity, Green travel capacity, Local climate capacity, Noise regulation capacity, Pollination capacity and Water purification capacity.

Description of the Ecosystem Services which have been mapped for the ARC project area

The following table (taken from the Ecoserv-GIS User Guide) gives detail around the 9 Ecosystem Services and how they have been mapped for the ARC area.

Service Name	Eco-Serv GIS Service Definition
Accessible Nature	Areas where people benefit from opportunities to experience / enjoy natural places and landscapes within their living, working, and commuting space. The capacity of the natural environment is mapped by identifying public accessibility 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 Index of Multiple Deprivation health scores.
Education	Opportunities for students to develop skills and learn within the natural environment. The capacity of the natural environment to provide education / knowledge is mapped by identifying accessible areas and assuming that natural sites with a greater variety of broad habitats have greater capacity, and opportunities for education. Demand (need) is mapped based on local and landscape population density, the distance to local and regional schools and the number of schools within driving distance.
Green Travel	Green travel routes and corridors occur within urban areas where people benefit from a range of positive features of habitats and vegetation cover. Benefits may include: encouraging more frequent active travel behaviour, safer traffic-free routes, calm, relaxing and inspiring locations, and buffer zones away from traffic related pollution. The capacity of the natural environment to provide green travel routes is mapped by assigning perceived naturalness scores to habitats along different types of travel corridors. Societal demand (need) for these routes is identified by mapping the location of key travel destinations or starting points. These include schools, towns centres and train stations. Least cost modelling is used to determine those corridors most connected to the key travel destinations.
Carbon	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 30 cm 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.
Local Climate Regulation	Areas where the natural environment may help mitigate the urban heat island effect due to the cooling impact of 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 local green space. 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.
Air Purification	Urban areas where people benefit from vegetation cover that helps to remove vehicle emissions from the air. The capacity of the natural environment to provide air purification is mapped by assigning air purification scores to broad habitat types based on their ability to trap pollutants, and then identifying areas around the vegetation where air pollution may be reduced. Societal demand (need) for air purification is mapped by calculating population density in urban areas. The regulatory demand (need) for air purification is mapped by estimating traffic based air pollution levels. These are calculated using reverse distance from roads, by road type, assuming higher traffic use on higher category roads.
Noise Regulation	Urban areas where people benefit from vegetation that helps to diffuse and absorb traffic noise. The capacity of the natural environment is mapped by assigning a noise regulation score to vegetation types based on height, density, permeability and year round cover. The demand (need) for noise regulation is mapped by estimating noise volume levels and the potential societal impacts of noise. Potential noise volumes are calculated based on Euclidean distance from roads, railways and airports. Volume is estimated based on distance from noise source, weighted according to source type. The societal need is mapped based on population density and health IMD scores.
Water Purification	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).
Pollination	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

How does Ecoserv-GIS quantify the beneficiaries of Ecosystem Services?

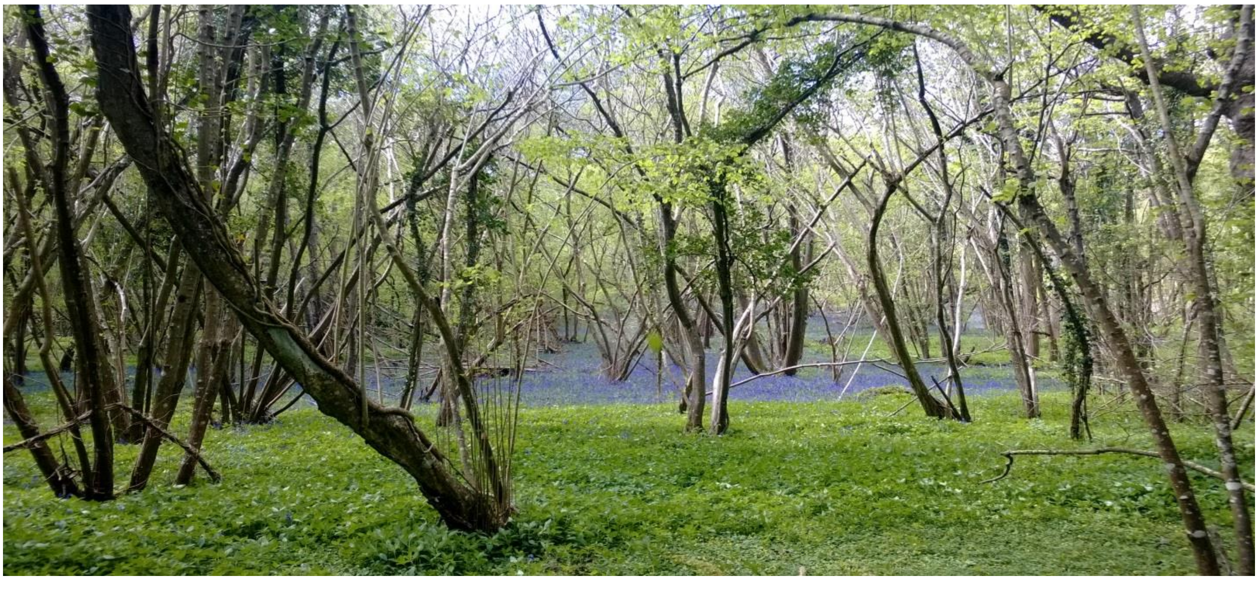
The ecosystem approach puts people at the heart of the picture: what services do we receive from our natural environment and how do these vary over space? One option is to model this environment-to-people relationship by estimating both the ability of an ecosystem to deliver a service to an area, as 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 air pollution, but is it within an area that is likely to be affected by high air pollution? Furthermore, is this air pollution considered to be causing a problem – do people live nearby and how likely are they to benefit from a reduction in pollution? ***Ecoserv-GIS explicitly models the "flow" of ecosystem services, from the natural environment to people.***

The following stages of mapping are conducted for each mapped ecosystem service:

- **Ecosystem Service Capacity**
  Areas capable of providing a particular ecosystem service are identified. These areas of **capacity** are graded according to the predicted level or quality of the service they may be able to provide. For certain services there may be features that restrict the capacity of an ecosystem to deliver a service, for example if an area is publicly or easily accessible or not. In such cases maps of both **restricted capacity** (e.g. only within accessible areas), and **unrestricted capacity** (all areas, even if not accessible) are produced.

- **GI (Green Infrastructure) assets**
  A version of the capacity score is created for each ecosystem service which only maps the areas of capacity that occur within areas of demand. This is termed the **GI asset** for each ecosystem service, as areas of capacity without areas of demand do not, in theory directly contribute significantly to the well-being of people. This output is partially subjective, as people tend to move through land.

- **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**.



How to understand the output maps

Ecosystem Service Flow: Service Benefiting Areas

Demand and capacity maps can be overlaid to illustrate how well they coincide in space, highlighting areas where there is a likely flow of the ecosystem service to society. These are termed "**Ecosystem Service Benefiting Areas**" (ESBA) (Palomo et al. 2012). Ecosystem Service Benefiting Areas are classified according to levels of service capacity and demand, helping to target decision making. Whilst the data on capacity and demand are produced across the whole Study Area, the capacity quintiles are only mapped within areas of demand, as any areas which have ecosystem service capacity but no ecosystem service demand are deemed not specifically relevant to service delivery. At the two extremes of this classification areas of "Highest Demand, Highest Capacity" indicate where it is highly likely that the ecosystem service benefits are being delivered to the people who need them. In contrast, areas of "Lowest Demand, Lowest Capacity" have the lowest likelihood that ES benefits are being delivered to the areas/people where they are needed.

Ecosystem Service Flow: Management Zones

To help inform land management the demand and capacity maps are overlaid to identify "Management Zones". These zones consider the levels of capacity and demand for each service in relation to a set of possible management options. Although many areas of a particular ecosystem, such as woodland may be considered to deliver an ecosystem service, it is unlikely that all will be managed with a particular ecosystem service in mind. By prioritising areas that may be most or least important, different management priorities can be recognised and implemented.

The three categories of "Protect key sites", "Protect / Maintain" and "Maintain" help to rapidly map areas with intermediate or higher levels of capacity and demand, where management will help to continue the delivery of a particular ecosystem service. The category "Improve condition" identifies those areas where there is the highest level of demand but low or lowest capacity**. In these areas management intervention such as habitat area expansion or restoration could improve service delivery**. Areas with no existing greenspace are mapped as "create habitat" zones. Areas with no capacity but where some type of greenspace already occur the "change habitat" management zone is mapped to indicate that converting the habitat into a different type (e.g. from grassland to woodland) would help deliver service benefits.

For several services there may be human-related barriers preventing the flow of a service from ecosystems to people. For example, accessible nature areas that are privately owned cannot actually be accessed by potential beneficiaries. In these areas, providing new permissive footpaths may increase service benefits. In other categories such as "assess resource" areas, management to enhance the particular ecosystem service is not a priority. However these categories provide insight into additional management options.

Key landscapes such as the South Downs provide water purification services to the ARC project area

The Table below summarises the datasets and information which were used to map each ecosystem service in this report. (Taken from Eco-Serv GIS 3.3 – a toolkit for mapping ecosystem services).

TABLE 6 SUMMARY OF INDICATORS USED TO MAP EACH SERVICE

Service	Environmental capacity indicators	Regulatory Demand and Societal Need indicators
Accessible nature	Site accessibility, Perceived naturalness score	Societal: Health IMD, Population, Likelihood of use (travel distance). At 3 spatial scales.
Education	Site accessibility, Habitat diversity	Societal: Number of young people, Education IMD, Distance from Schools. At 3 spatial scales.
Green travel	Perceived naturalness score, Access routes	Societal: Cost distance from origin and destination travel locations. Urban areas. Access routes only.
Carbon storage	Carbon content per habitat	Regulatory: None (all assumed to have demand) Societal: None.
Local climate	Cover of woodland	Regulatory: Urban areas and domestic houses. Societal: Population at risk from heat events.
Air purification	Purification score per habitat	Regulatory: Predicted air pollution (road type, distance), sealed surfaces. Societal: Population, health IMD.
Noise regulation	Regulation score per habitat	Regulatory: Predicted noise levels (Cumulative). Societal: Population, health IMD.
Water purification	Roughness score, slope angle	Regulatory: Soil erosion risk (USLE), Pollution risk (urban and agricultural cover). Distance to watercourses. Societal: None.
Pollination	Pollinator visitation likelihood	Regulatory: Distance to arable, orchards and allotments. Societal: None.

IMD: index of multiple deprivation (England, Scotland and Wales versions). USLE: universal soil loss equation.

Multi-functionality

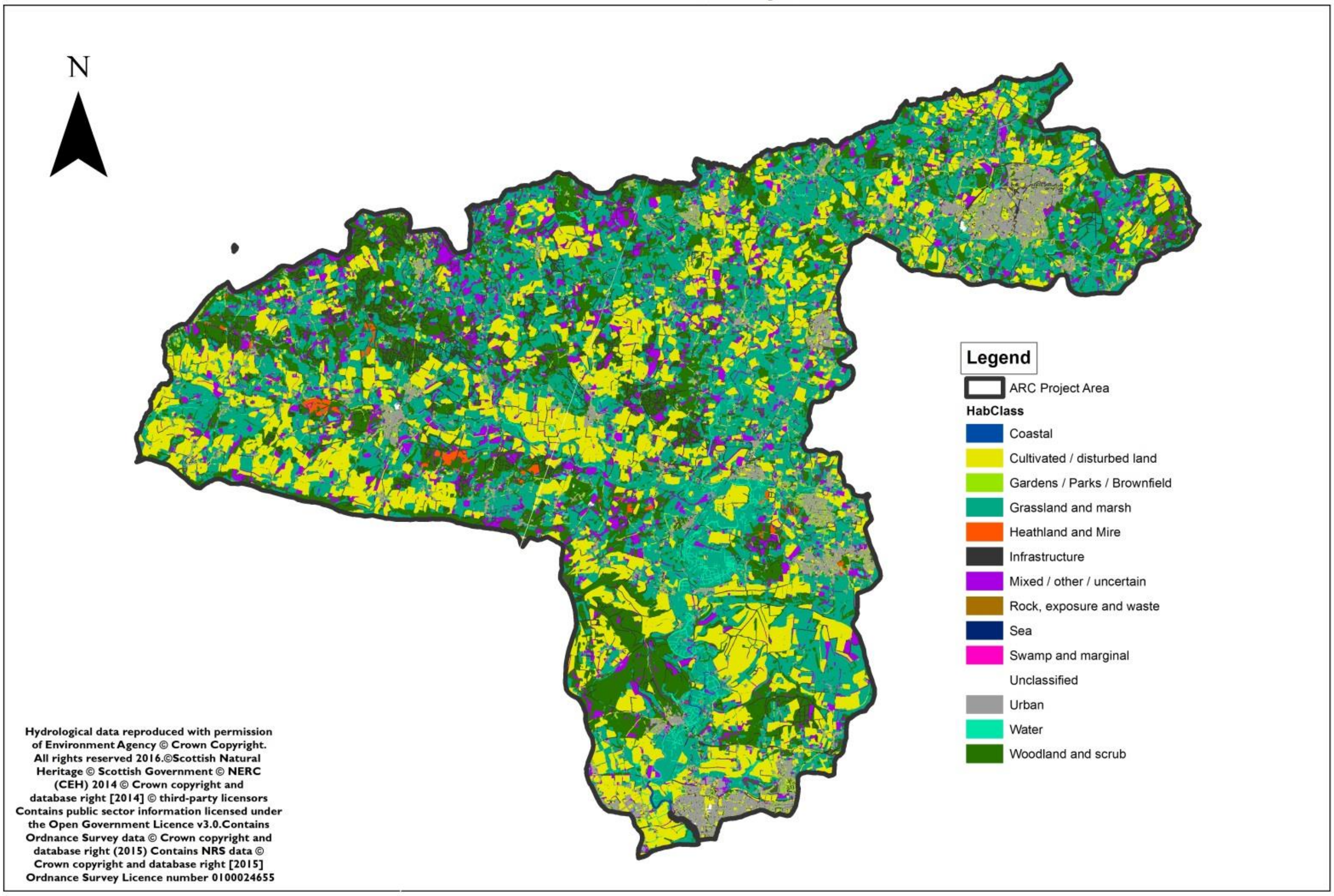
Once all ecosystem services of interest have been mapped, there is a "Multi-functionality" tool which assesses multiple service delivery. The "multi-functionality" score sums the number of services where there is demand in each cell and then calculates the proportion of these that are met with some level of ecosystem service capacity. A range of information is produced to highlight the range of multiple benefits being delivered across the Study Area. Models calculate the following for the services :-

- mean capacity,
- mean demand,
- mean GI assets capacity,
- multi-functionality score,
- priority multi-functionality score,
- number of ESBA types,
- number of Management Zones.

At the time of publication (of this report), the multi functionality elements of the EcoServ GIS models had not been produced. A fairly crude method of overlay was therefore used to show the areas of the ARC project area which are providing, and those which are drawing on, a wide range of ecosystem services. Because this map does not include the full range of capacity and demand in this calculation it may be considered too simplistic***. We therefore recommend that policy makers request final multi-functionality maps from Sussex Biodiversity Records Centre prior to using these maps to inform local policy***. Even within the formally derived multi-functionality maps, the delivery of a service in areas of low demand or capacity may not be considered important (for example in terms of influencing land management or policy). To allow landscape managers further data to compare, a "**Priority multi-functionality**" score can therefore also be produced using only those capacity and demand quintiles of intermediate and above in the calculation. Therefore a service is considered to be delivered at a cell if both demand and capacity are at least of intermediate quintile level. This focuses the mapping on those areas with a higher certainty in the benefits being delivered to people, or of the need for such benefits to be present.

Capacity of the ARC project area to provide multiple services

ARC Catchment - Primary Land Use

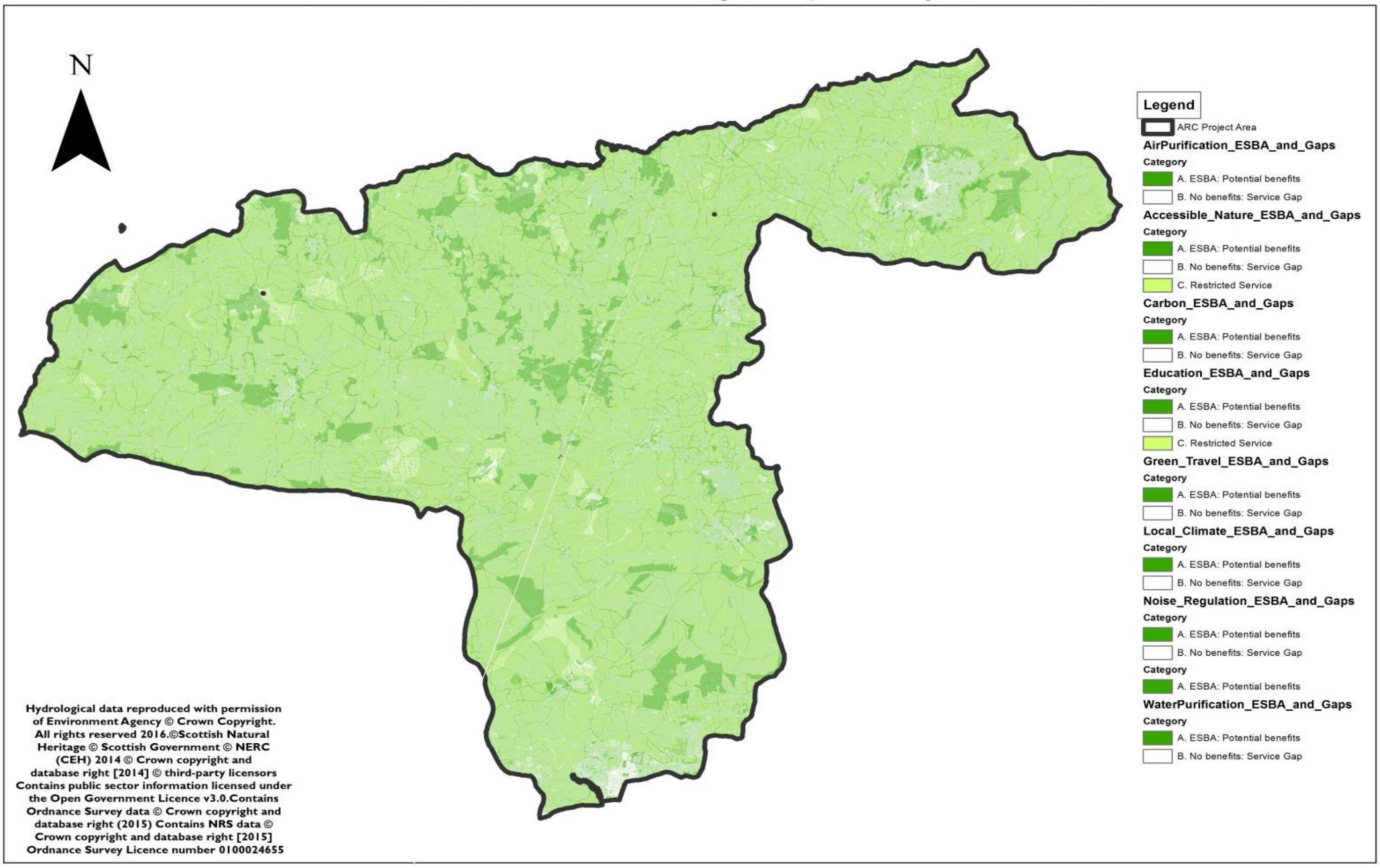


It is a fair assumption that certain types of land use will provide a more diverse and accessible range of ecosystem services to the populations who need them than others. Areas of habitat such as woodland, heathland and wetland are likely to be the main providers of Ecosystem Services, and urban areas are likely to be the main users or sinks.

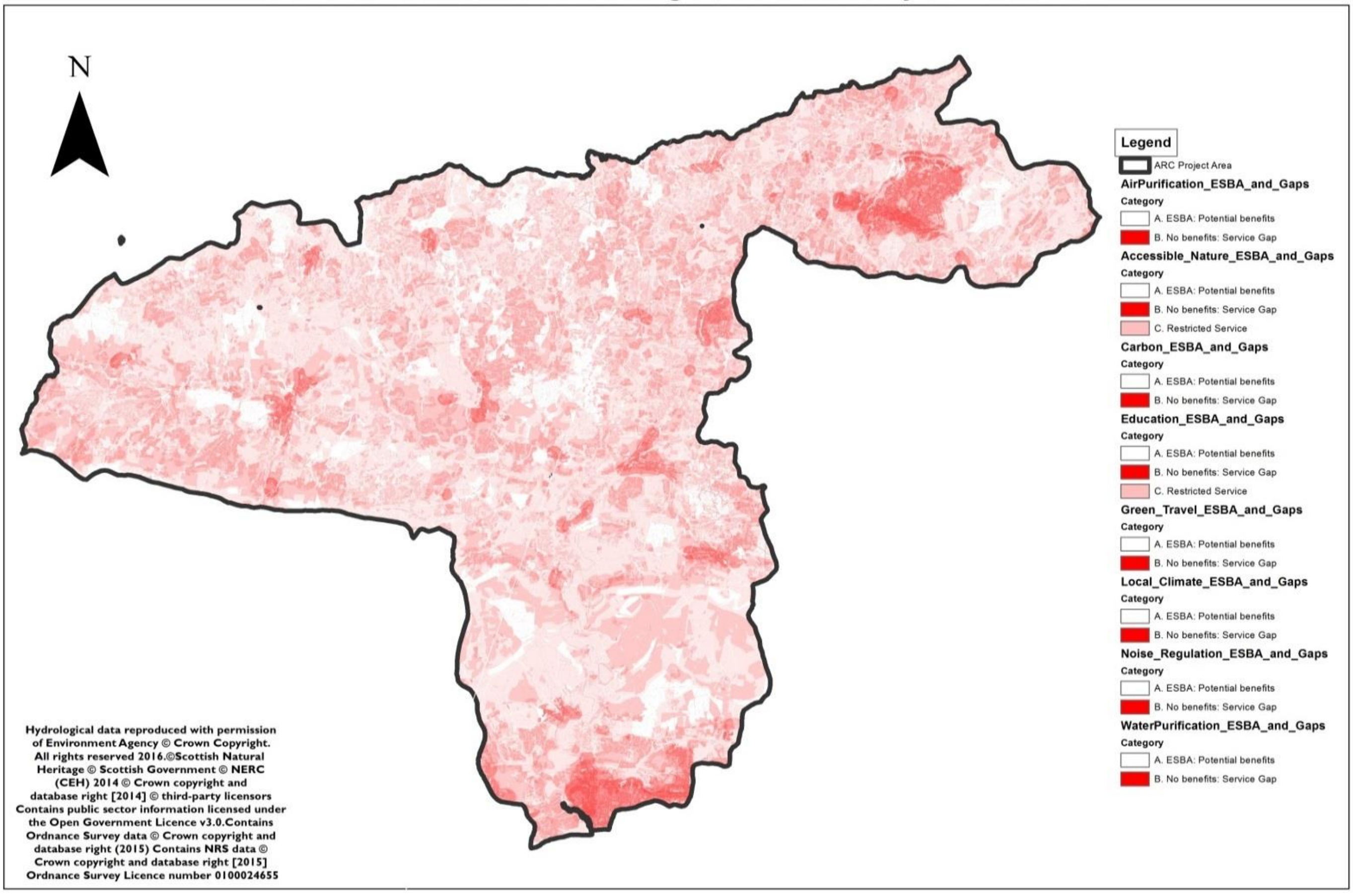
An obvious example is that the demand for the regulation of noise pollution is predominantly required by urban populations, but predominantly provided by rural/green space. Where excess noise is being produced in urban areas without sufficient 'environmental' regulation of noise, options could be investigated for improving Green Infrastructure in the urban areas themselves (i.e. through the provision of green corridors and green roofs), to enhance this ecosystem service more locally.

When maps of all of the 9 modelled ecosystem services are overlaid, there are distinct areas of the ARC project area (darkest green areas, map below) which are very obviously providing multiple ecosystem services. ***This is not a true multiple service benefits map, but rather a primary overlay to show key provisioning areas***. Multi-functional areas appear to coincide broadly with the location of permanent woodlands and other semi-natural habitats. It is interesting to note that other than core zones of major urban conurbations, almost all areas of the landscape are providing some ecosystem service function. There are also defined areas of the landscape which are failing to provide multi-functional ecosystem services (dark red areas). Most of these are urban settlements. The Horsham and Littlehampton conurbations are the most noticeable areas failing to provide the majority of ecosystem services.

ARC Catchment - Areas Providing Multiple Ecosystem Services



ARC Catchment - Areas Failing to Provide Ecosystem Services



Interpreting the Maps

The maps in the **APPENDICES**, show the capacity of the ARC landscape to provide each of the 9 modelled Ecosystem Services. For each of the 9 modelled services, maps have been produced to show the following:-

- Capacity of the ARC project area to provide services, compared to local demand for services (gaps) (APPENDIX 2)
- The areas of the ARC project area with Green Infrastructure which is providing natural services (APPENDIX 3)
- The recommended land management (change, assess, modify, maintain) to ensure that the ecosystem service benefits are maximised (APPENDIX 4)

At first glance, there appear to be some anomalies in the maps. For example the carbon demand map shows as solid red, to illustrate the fact that all British people use far more carbon than each resident can replace in carbon capture, and that the effects of carbon release on people and the environment occur over scales too large to map. Effectively this signifies that 1) we all need to use far less resources and 2) the more carbon capture and storage that we can enable our landscape to provide, the better.

An example of how to interpret the capacity/demand maps is Air Purification. Air Purification Demand indicates areas where high densities of people, with lower population level health scores, live close to busy roads. Populations that are already of lower health and who live in high density areas close to busy roads are most at risk of air pollution impacts to their health. Air Purification Capacity indicates where woodland occurs with sufficient size to be effective in removing air pollutants. Large and wide woodlands are most effective. Capacity is only mapped within areas where demand occurs. Woodlands which are beyond the influence distance from roads are not shown.

The Green Infrastructure maps show existing green infrastructure assets in the ARC project area which are providing benefits to local residents for the mapped ecosystem service. (APPENDIX 3). These maps can be used to assist local authorities and other land managers / planners to avoid the destruction of areas of the landscape which are providing key services for their local populations.

Image left: Some local landscapes in the ARC project area are multi-functional, providing a range of services such as carbon storage, education and access to greenspace for people living nearby. A number of heathlands in the ARC area appear to be providing multiple ecosystem services.

Demand and capacity maps are overlaid using Ecoserv-GIS, to define a range of management zones. The focus is to inform landscape or greenspace managers of how areas could be prioritised in relation to management to maximise the benefits of each ecosystem service. Due to the uncertainties involved the categories should be considered as a broad guide, to which local knowledge can be added. Consequently in many of the recommended management maps, the recommendation is to further assess the ability of these areas of land to provide the service under its current management, or to assess if land management change could further enhance the benefits that the land is providing. For instance in the "improve" areas, woodlands may be able to deliver greater benefits if coppicing is introduced, or access and educational benefits are improved for local people.

A distinction is made between areas with zero capacity to provide natural services but no greenspace, from greenspace areas with zero capacity but where the current habitat cover has no capacity for the service in question. For example with air purification the "create habitat" areas indicate where street trees, hedges, living walls etc. could be created in areas of sealed surface. In contrast the "change habitat" areas indicate where areas such as amenity grasslands could be converted to alternative habitats in order to aid air purification. These categories are mapped separately because the likelihood of management change in each area will differ.

There are some areas of the ARC project area which are obviously providing multiple ecosystem services with multiple benefits to people. These areas are key areas to protect and enhance for the future. Other areas are obvious sinks for ecosystem services and better land management strategies need to be put into place to enable the long term provision of these services.

Applications

The information in this report is useful and interesting, but for the ARC project we wished to ensure that the outputs can be applied directly to local planning, land / landscape management and habitat enhancement programmes. There are a range of ways in which the maps can be used to target landscape planning. These include :-

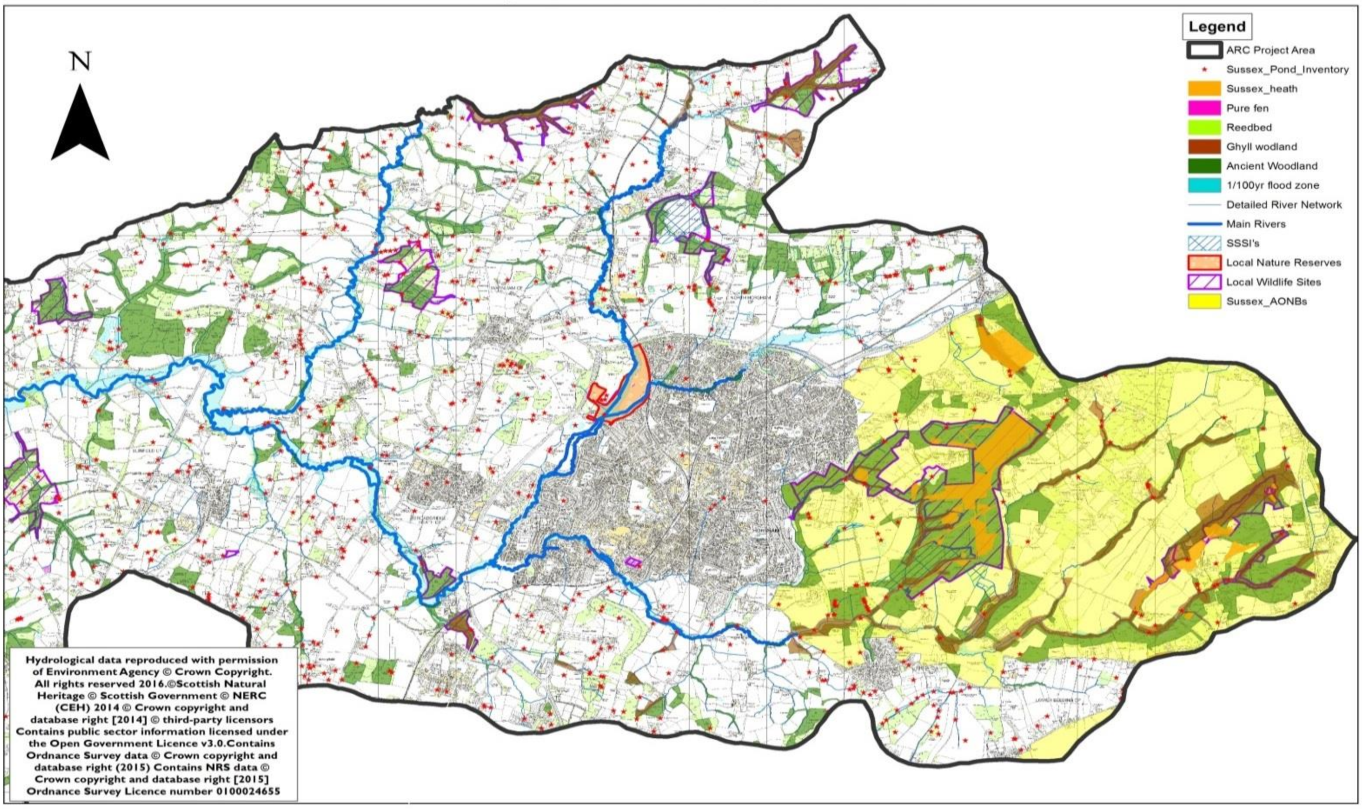
- Pollination capacity / need areas could be used to target future meadow restoration, and may be useful for organisations such as the South Downs National Park Authority and the Buglife B-Lines project for targeting landowner liaison and future spend on habitat work.
- Pollination and accessible nature maps could be used to target Countryside Stewardship payments and to review whether CS schemes are delivering multiple benefits at the landscape scale.
- Accessible nature demand could be used to target the creation and enhancement of urban greenspace to fill this demand.
- Water purification demand / capacity maps could be used by the Arun & Western Streams Catchment partnership to help influence land management and (wetland) habitat restoration to help achieve the targets of key pieces of legislation such as the Water Framework Directive.

There are many other applications, but the maps are best used to generate local case studies for discreet landscapes and land parcels. With this in mind we have generated the Horsham case study below to explain the local applications of Ecoserv-GIS in more detail.

Case Study – Horsham

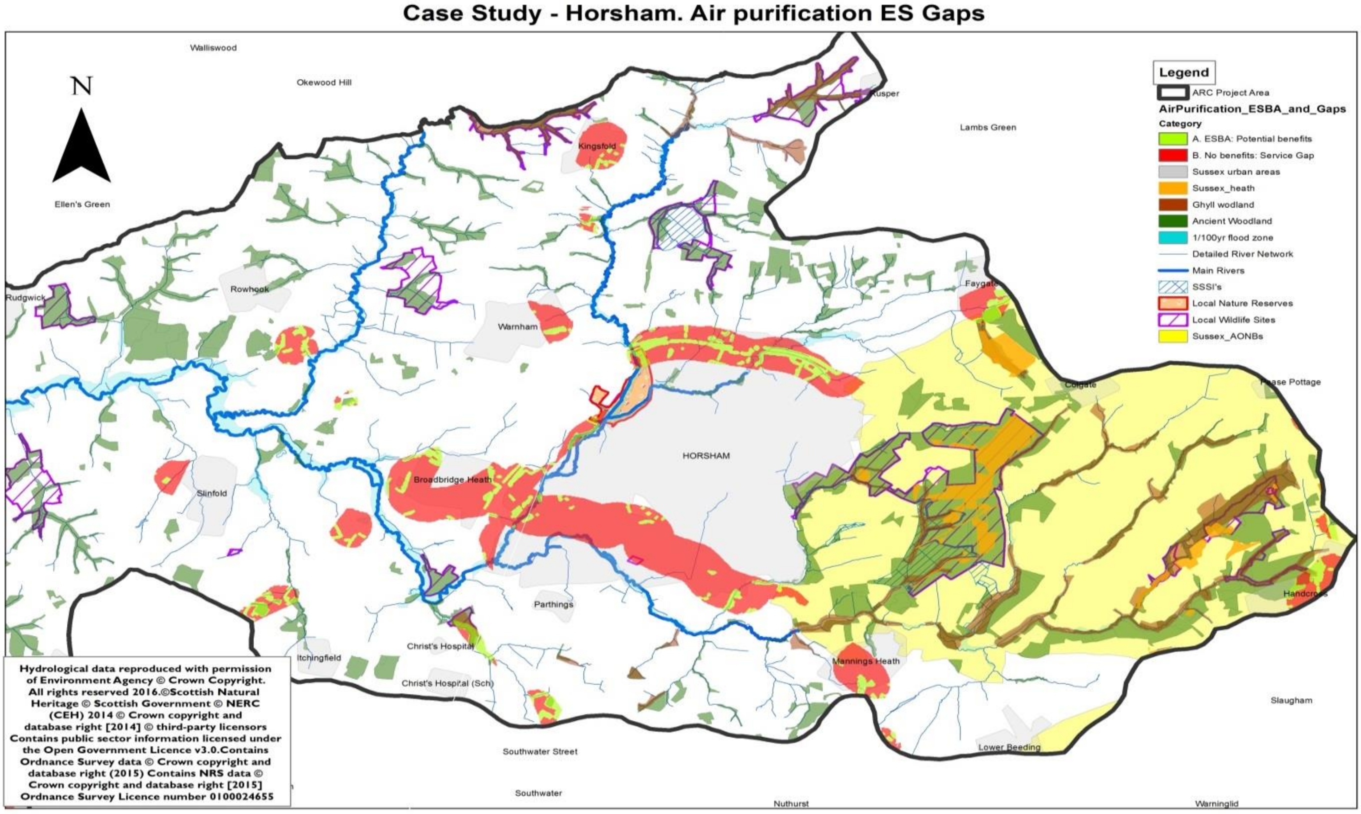
Horsham is situated in the North Eastern corner of the Arun river catchment. A range of protected habitats and landscapes are present both within and around the town. See APPENDIX 5 for enlarged legends.

Case Study - Horsham. Existing Protected Habitats

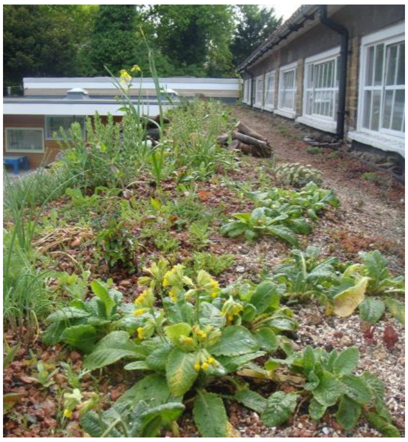


Air purification needs in and around Horsham

Case Study - Horsham. Air purification ES Gaps



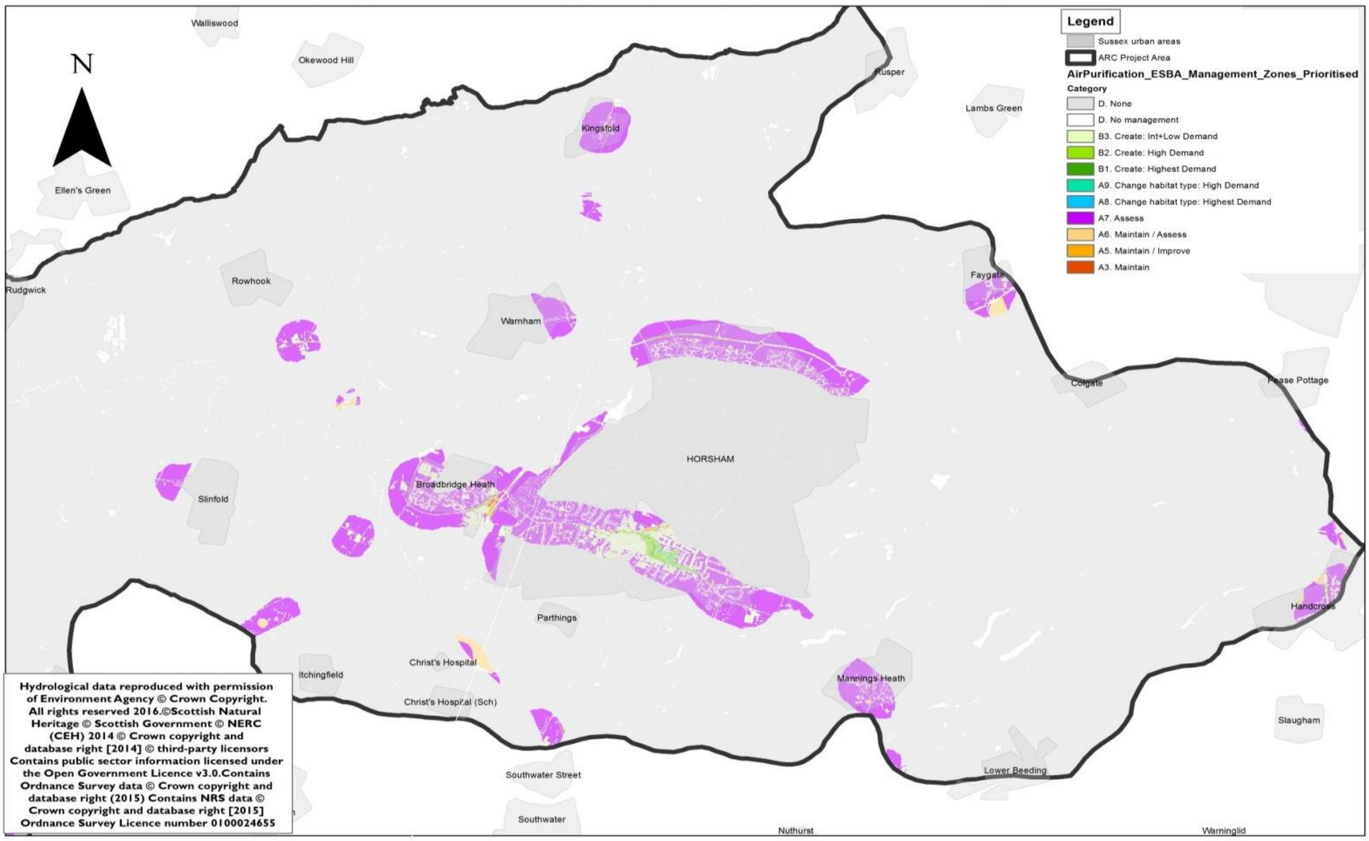
(Map above) St Leonards Forest and the High Weald landscape to the east of the town are providing obvious air purification benefits for East Horsham. In contrast, there is huge demand for air purification to the South and North of the town (red areas), within landscapes which have limited capacity to provide this Ecosystem service for the residents. Where there is insufficient air purification, associated health issues such as asthma are likely to arise with Horsham residents, particularly in vulnerable groups such as school children. In this example, town planners can use the Ecoserv-GIS outputs to target the creation of green space and green infrastructure such as green roofs (image right © D Gedge), to areas of high air purification demand.



There is an obvious strip of high demand for air purification running across the North of Horsham between the North of Warnham Nature Reserve and the North West of the High Weald Area of Outstanding Natural Beauty (AONB). There is a recognisable capacity here (light green areas, map above) to review Town Planning and to integrate more green infrastructure into the urban fringe. This could be in the form of more tree planting, the 'greening' of local cycle ways, or encouraging more community wildlife gardening.

There are at least four smaller parcels of land in the Horsham District (and Mid Sussex District in the far Eastern corner of the catchment) where there is demand for air purification which can be satisfied. At Bashurst Hill, Clemsfold Farm, North west Handcross, and Faygate South, in theory land management changes and enhancements such as tree and hedgerow planting could be implemented to supply the demand for air purification. The high demand for air purification to the South of the town is more problematic. In this area, residents and wildlife are likely to experience increasingly poor air quality unless imaginative solutions to air quality issues are found.

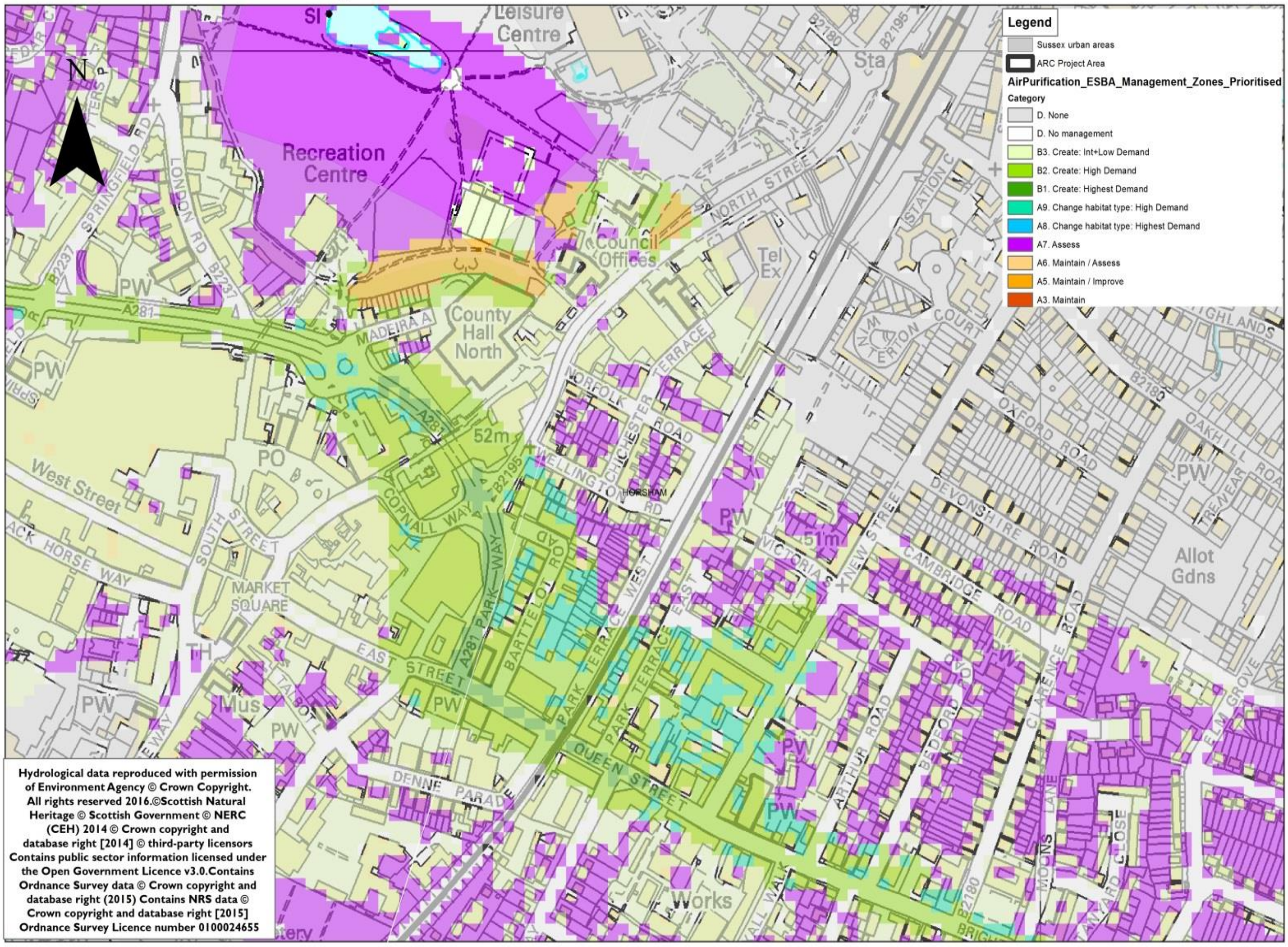
Case Study - Horsham. Air purification - Recommended Management Zones



The Ecoserv-GIS model suggests that large areas where air purification demand is high should be assessed further to review the potential for land management change to supply this demand (purple areas, map above). Two small outlying areas are highlighted for a need to maintain existing land use (peach colour areas, map above) and assess potential for enhancement at Sparrows copse (Christ's Hospital) and Hooks Copse (Faygate).

There is also a large area in the central South of Horsham town, where the model suggests a comprehensive review of current land use, due to a high demand for the creation of more air purification capacity. In particular, areas South east of the County Hall North along the A281 and along East Street and Queen Street are suggested for land use change and creation of air purification capacity. (See map below)

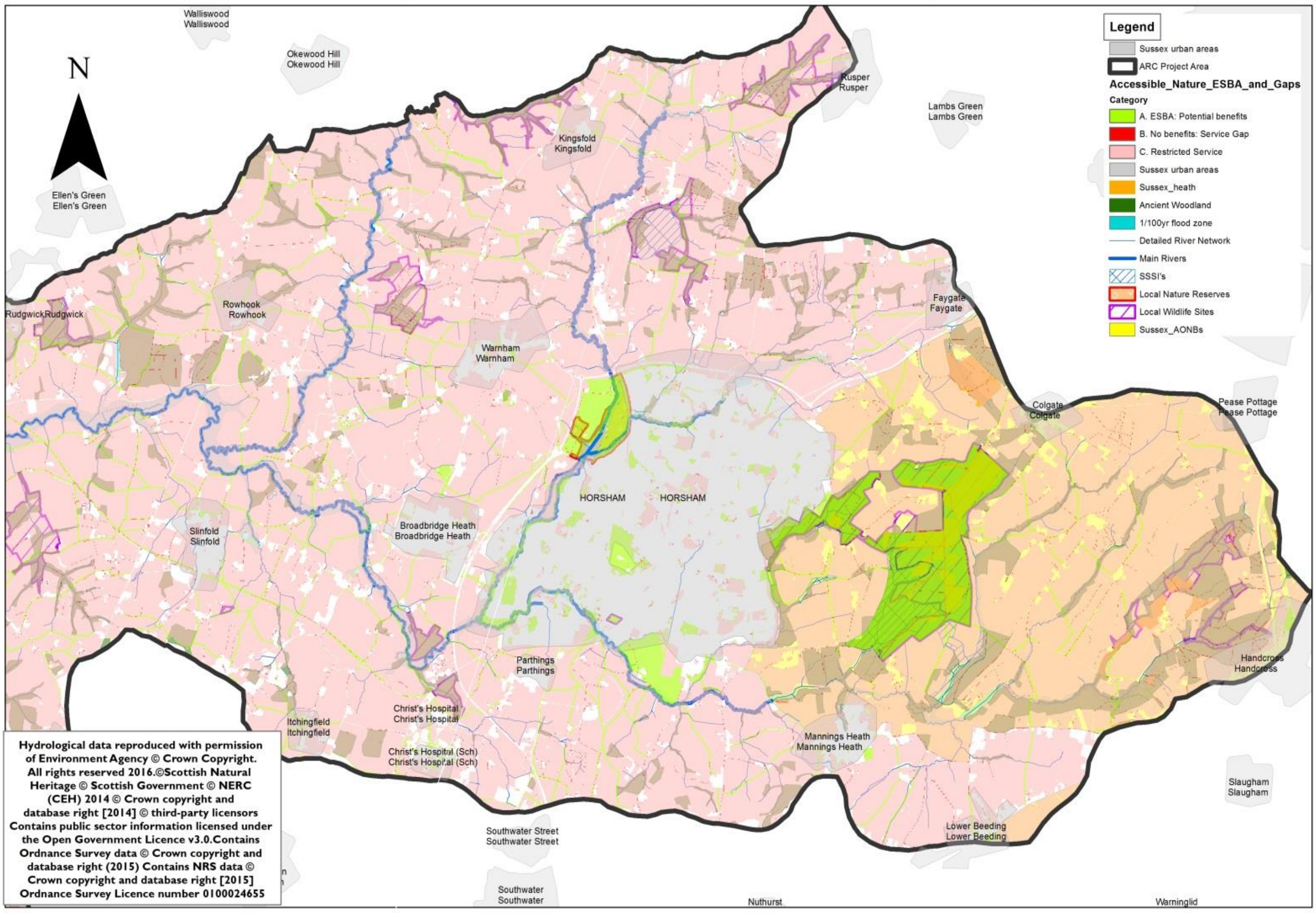
Case Study - Horsham. Air purification - Recommended Management Zones



The light blue areas in the map above are where the Ecoserv-GIS model suggests that the habitat use is changed, due to a high demand for air purification. The areas highlighted include some gardens and roundabouts where habitat could be enhanced relatively easily to provide more protection against air pollution. In light green areas, there is a need to create more habitat to keep up with demand for air purification. The light green areas follow some of the main transport routes through the town. Mitigation for the pollution being produced along these routes could take the form of the creation of SUDS features such as green roofs and swales, avenues of trees, or traffic calming measures and sustainable transport schemes. One particular area is highlighted for 'maintenance and improvement' of existing habitat, just north of County Hall.

Accessible Nature in and around Horsham

Case Study - Horsham. Accessible Nature - ES Capacity and Gaps



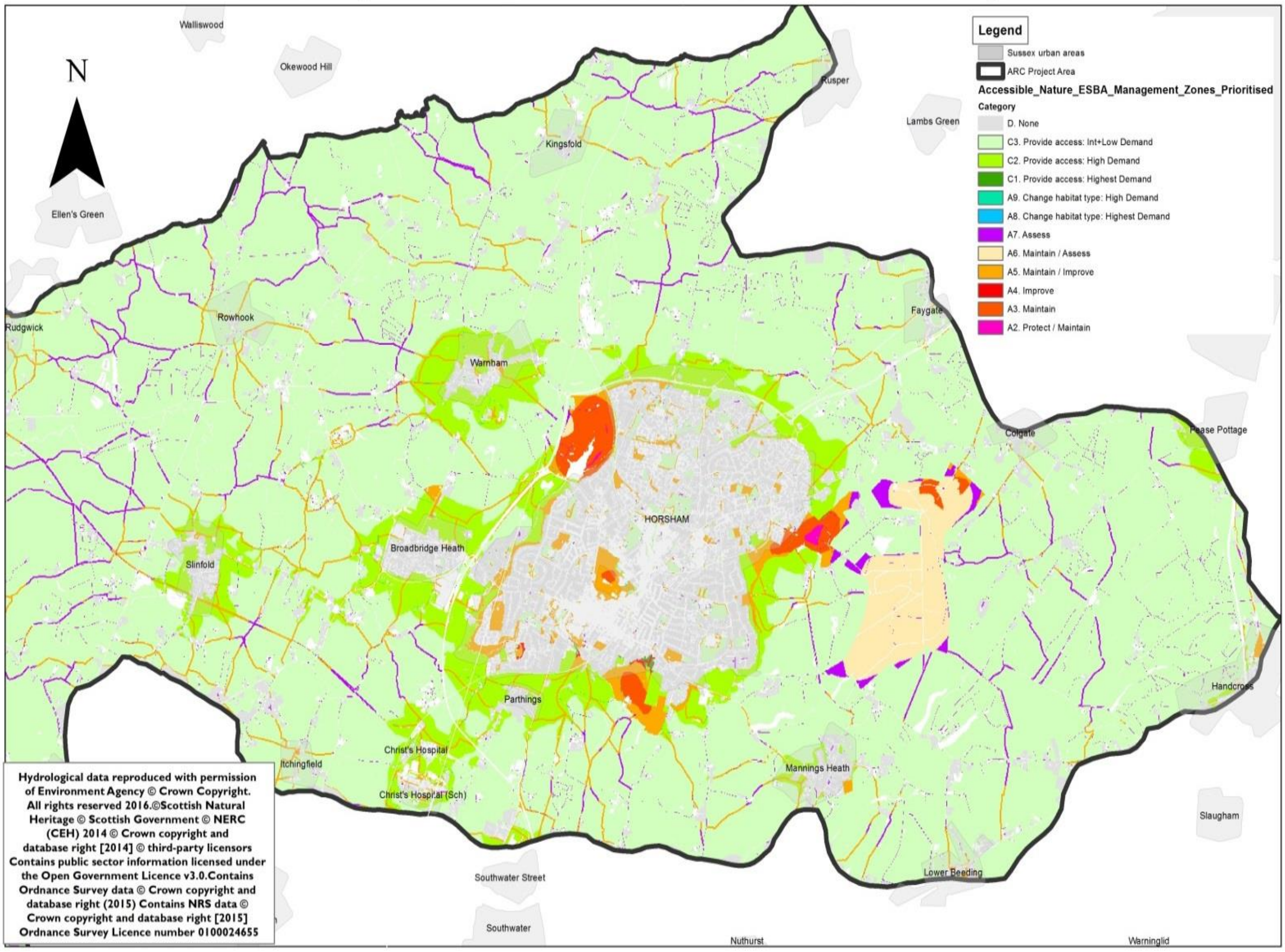
The map above shows that Warnham Nature Reserve, St Leonards Forest, Chesworth Farm, Horsham park, Owlbeech and Leechpool woods are providing important capacity for Horsham residents to access nature (light green). Access to nature has repeatedly been shown to provide a range of mental and physical health benefits to all age ranges but particularly to children and the elderly. Where people are able to access nature, there are generally less anti-social behaviour issues, and fewer health and welfare issues.

The majority of the rest of the area around Horsham is providing only restricted benefits for accessible nature, possibly because land is privately owned or managed, and/or public transport and accessible footpaths to these areas are limited. A number of key routeways / pathways are shown (light green) as being important for local access to nature however, and where possible these should be maintained.

There are hundreds of small pockets of demand for accessible nature scattered across both Horsham town and the Horsham District. With this in mind it might be pertinent for local Councils to create a suite of geographically interspersed 'hub' sites across the mapped area, which provide 'honeypot' access to nature for the communities around them in more rural areas. At any time, the capacity of a site to accommodate the level of footfall which is needed should be considered. Sites which become degraded due to too much public access may cease to provide the level of access to nature which can provide health and welfare benefits. For instance a walk in a local park which has been vandalised, littered or covered in dog mess is likely to provide less 'beneficial health services' than a pristine, quiet and undisturbed nature reserve full of interesting wildlife species.

The map below shows recommended management in the Horsham area to maximise Accessible Nature benefits for those who need them. There is high demand for improved access to nature around the fringes of Slinfold, Broadbridge Heath, Warnham, Pease Pottage, Christ's Hospital and Horsham. The model also suggests maintaining and assessing the accessible nature benefits around St Leonards forest, and maintaining and improving around Warnham Nature Reserve, Horsham park and Chesworth Farm. It recommends protecting and maintaining land at Leechpool and Owlbeech, and shows keys paths and tracks which need either maintaining (orange) or assessing (purple) for their ability to provide improved access to nature.

Case Study - Horsham. Accessible Nature - Recommended Management

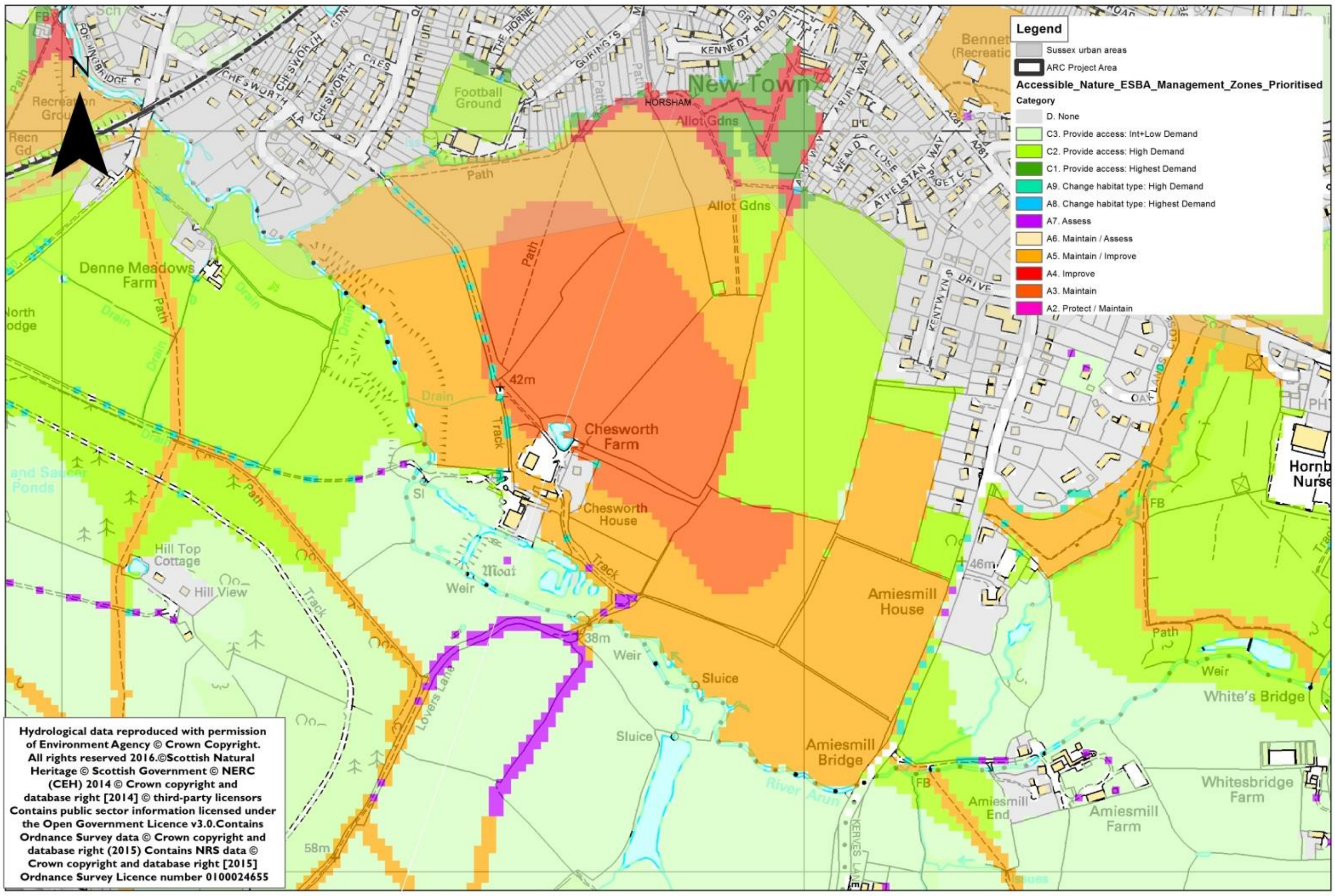


There are a range of options available for Councils and Planners wishing to preserve the integrity of the accessible nature network. These include :-

- Ensuring the benefits of sites to local communities are recognised in management plans and funding bids for wildlife sites and nature reserves
- Considering demand maps and improvement areas during large housing schemes and redevelopments
- Assessing if the funding available to support site management is in proportion to the predicted benefits to people at different sites, parks or reserves

If we zoom in to one of the key locations on the map we can see more detail.

Case Study - Chesworth Farm. Accessible Nature - Recommended Management



To the north of Chesworth Farm at New Town is the highest demand locally for access to nature (dark green). Areas adjacent to the high demand are highlighted for the need to improve access to nature (red). A small area to the north of the recreation ground adjacent to Horsham Cricket ground / Barrackfield Crossing also has high demand for access to nature and the highest potential to fill this demand.

The rest of Chesworth is highlighted as being a high priority for maintaining and improving access to nature, as are many of the trackways and footpaths leading into the site (dark and light orange areas). To the south west of Chesworth, one footpath could be assessed to see if it can be enhanced to enable better access (purple area), although at present there is limited demand locally for this.

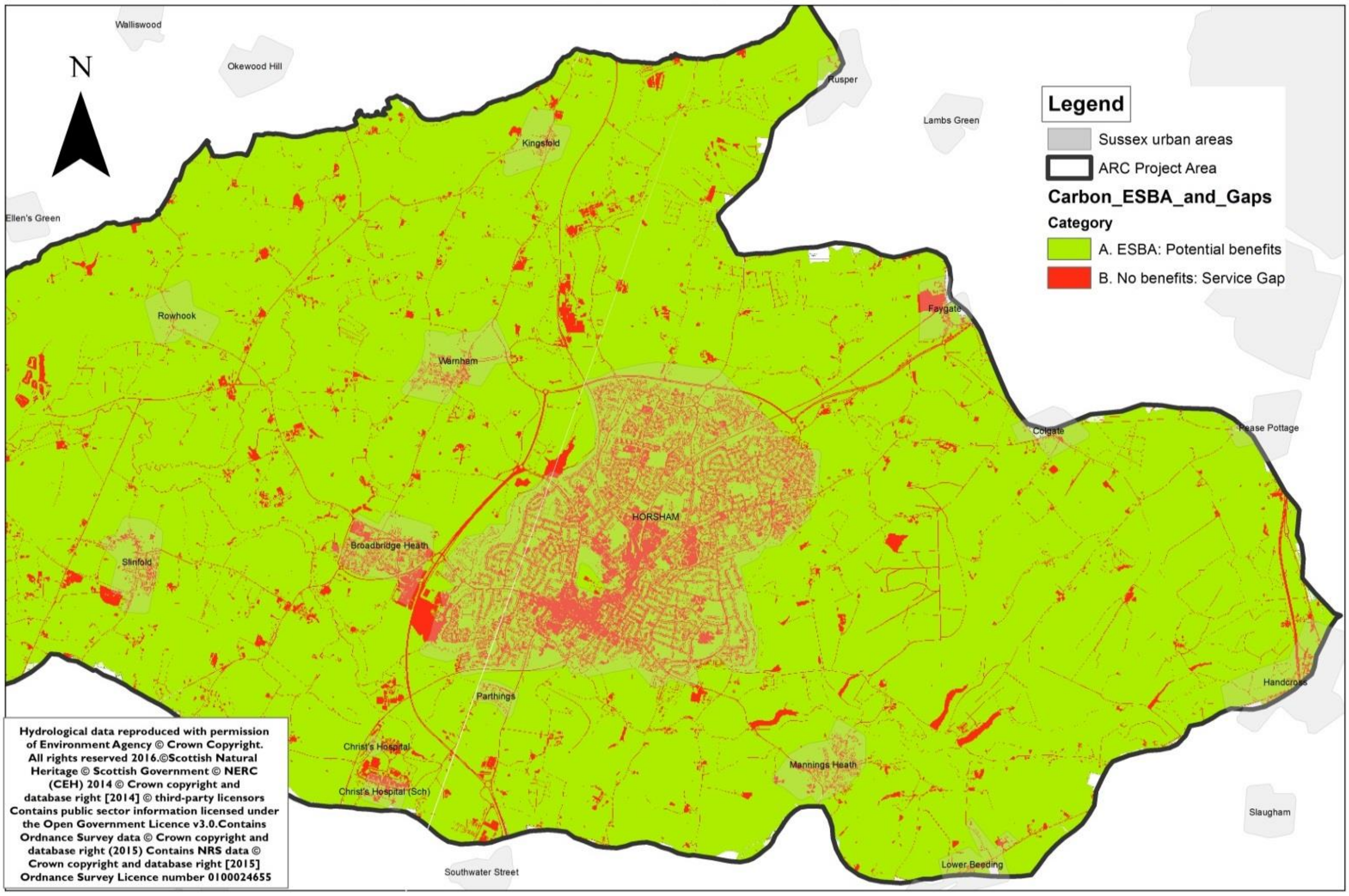
Farmland and other greenspace to the West and East of Chesworth Farm is highlighted as having the potential to fill the high demand for accessible nature (light green areas). Particularly along some of the roads in the area, there is high demand to change the habitat type in order to provide more opportunities for accessible nature (light blue areas). This could be in the form of creating / enhancing flowering roadside verges, planting more hedgerows and fruit trees, or improving sustainable transport or disabled access along these routes

Chesworth farm has a partially restored visitor centre which is increasingly used as an educational centre for engaging people with nature. A great deal of work has also been done to improve the paths and access throughout the site. The Ecoserv-GIS model provides evidence that the investment in the infrastructure and restoration of Chesworth Farm has been well founded, and helps to justify future spend on the Farm's maintenance.

Carbon Capacity in and around Horsham

The maps below demonstrate that there is a need to create greater carbon capacity everywhere, but that the red areas are those where there is a much higher demand for carbon storage which is not able to be met. These are primarily urban / man made surfaces.

Case Study - Horsham. Carbon Capacity - ES Capacity and Gaps

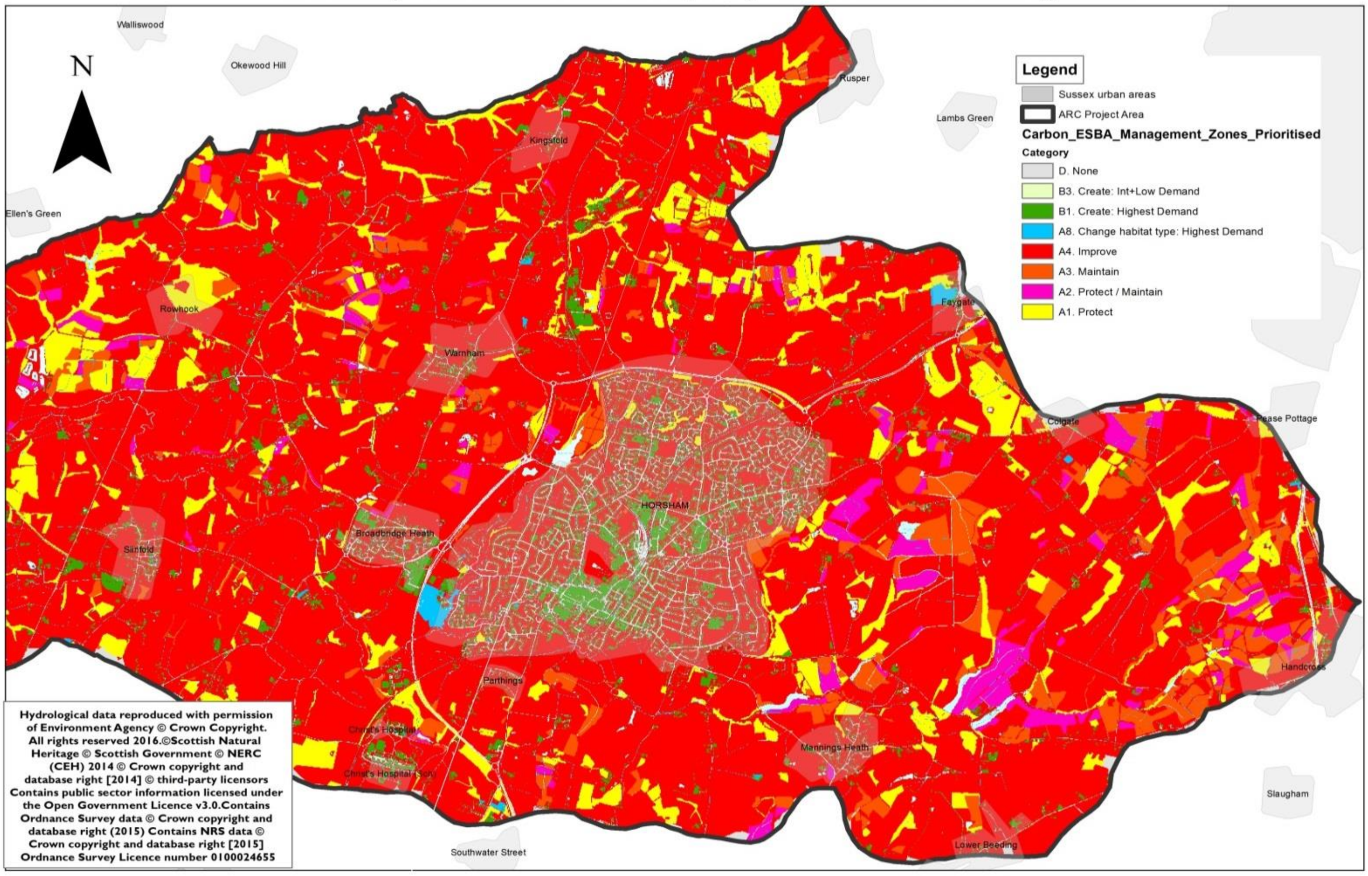


Carbon capture is important for climatic stability, and with climate change now a fact of life, Government are now expecting Local Authorities and others to show progress in the reduction of carbon emissions. The effects of carbon release on the climate and the resulting mal-effects on the environment and people occur over spatio-temporal scales too large to map at a county scale. However, what we can map is the landscape's capacity to capture the carbon being produced by the local populous.

The map below shows where there is highest need to maintain, enhance and create more carbon capacity in the Horsham landscape. There are significant areas of the landscape which the model suggests are protected (yellow) in order to retain their function as carbon stores, along with pink areas which it suggests are protected and maintained in their current land management states.

The main colour of the maps is red, which indicates that there is further capacity in the landscape to store carbon. Some of these areas may be areas which could be targeted for Forestry and Countryside Stewardship schemes and/or habitat restoration in order to help provide greater carbon capacity in the long term. Light blue areas such as that between the south of Horsham and Broadbridge Heath and north of Faygate indicate areas where the existing land use or habitat could be changed in order to provide more capacity for carbon storage in areas of high demand.

Case Study - Horsham. Carbon Capacity - Recommended Management



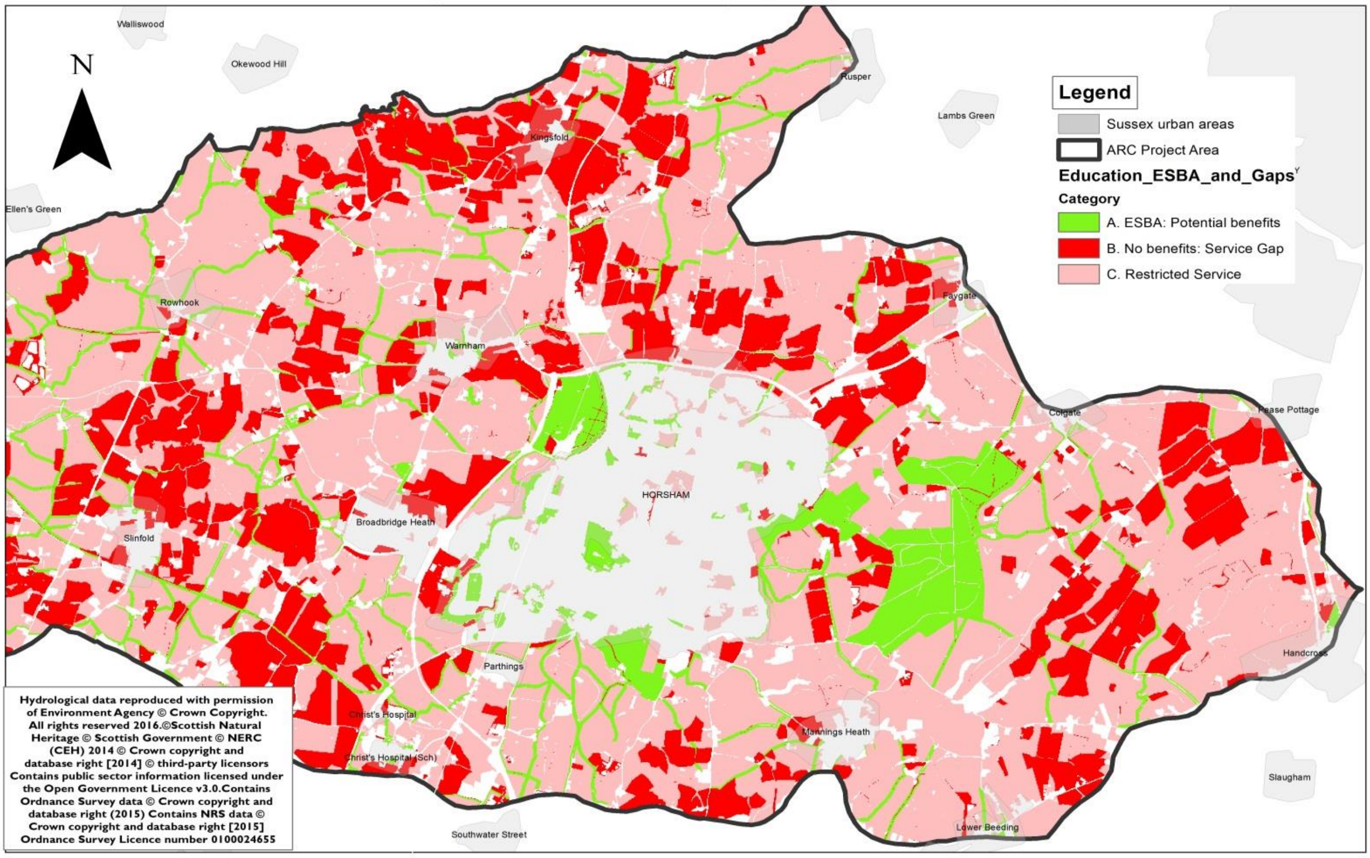
This map exposes some of the limitations of the Ecoserv-GIS model in as much as it cannot highlight one of the most important elements which is needed for us to reduce our carbon emissions. This is that individual people and communities need to take responsibility for reducing their carbon footprints unilaterally / globally by taking steps to consume less, use public transport more, conserve resources such as water and fuel, travel by plane less and generally reducing consumption, re-using and recycling.

Providing public transport, encouraging recycling and local food networks, promoting wildlife gardening and offsetting the carbon footprint of new housing developments by creating associated greenspace are just a few of the ways in which Carbon emissions could be reduced. Local Government can play a part by delivering comprehensive education campaigns to local residents. Increasing carbon storage capacity is more problematic, as effectively we all produce far more carbon than the natural environment can absorb. Local and National Governments and others would need to commit to large scale, UK and global habitat and landscape restoration schemes employing a whole suite of methods to even begin to start to balance out our carbon consumption, and to help stabilise climate change. A gesture of good will would be to protect existing habitats which provide carbon storage such as woodlands and ponds.

Ponds can store large amounts of carbon relative to their size.
Creating a more ponded landscape can help create carbon capacity

Education Capacity in and around Horsham

Case Study - Horsham. Education Capacity - Benefits and Gaps



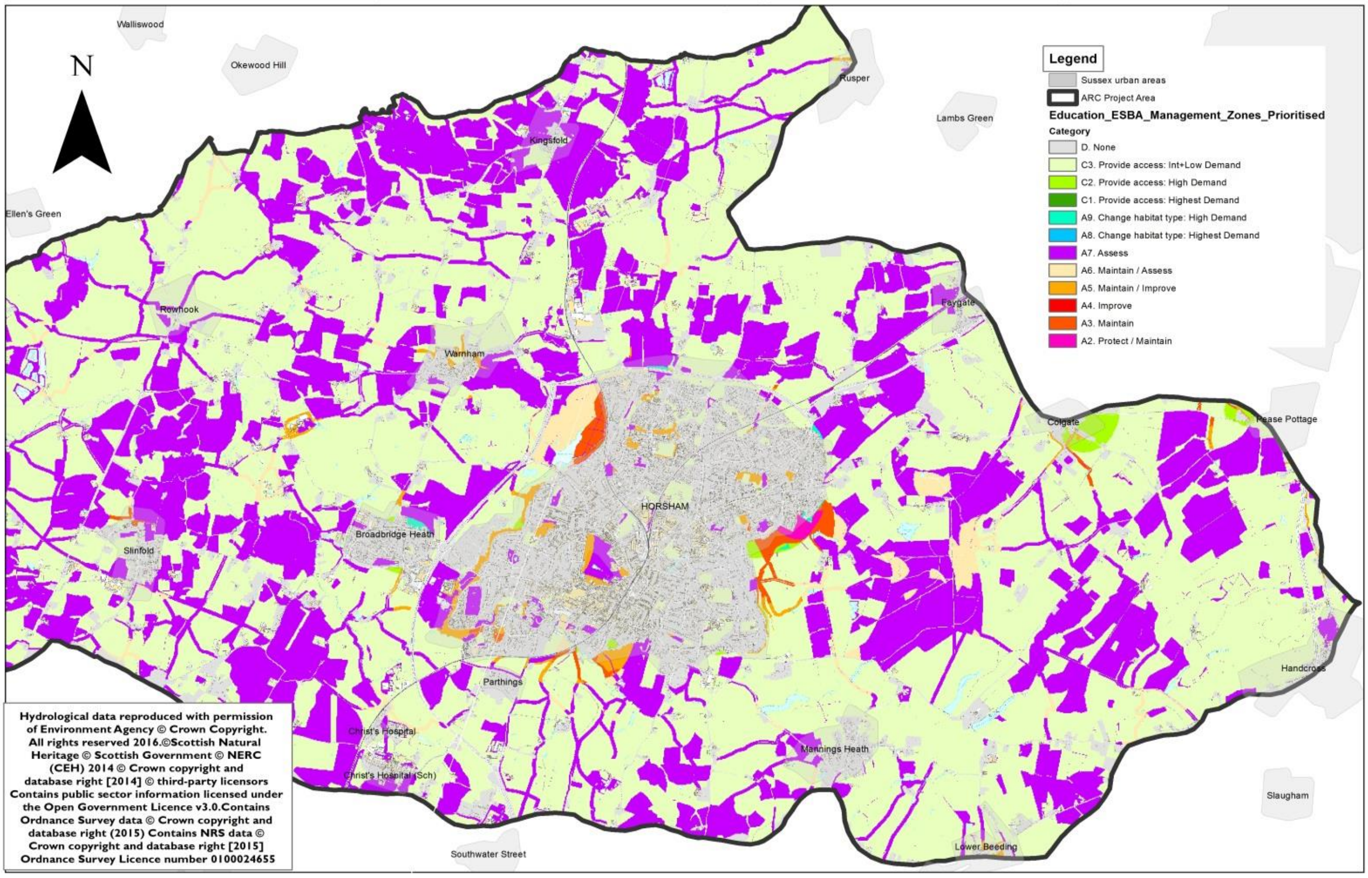
The natural environment provides both adults and children with valuable opportunities to gain knowledge and practical skills, although generally children are cited as benefiting most from environmental education. Although an under-researched area, a recent review of the links between the environment and development in young childhood noted that access and use of greenspaces may be important for children's cognitive and motor development (Christian et al. 2015). The potential adverse effects of lack of nature contact amongst children has been proposed as a potential "Nature Deficit Disorder" (Louv 2010).

Both formal and informal educational resources can be important. School grounds can be as important as school buildings for providing educational experiences. Informal opportunities for education occur where local neighbourhoods, parks or greenspaces might inspire thought, consideration or attention. Many of these include display panels or provide leaflets about the history, management or species present, offering learning experiences, whilst guided walks, green gyms etc. may also be publically available.

Access to nature at greenspace sites, nature reserves or country parks can also be used by schools to provide education opportunities not otherwise available within school. Whether accessed by foot or via short coach journeys, access to habitats such as woodland, rivers or meadows allow experiential learning and practical examples to be seen by students rather than learning through verbal lessons or media presentations.

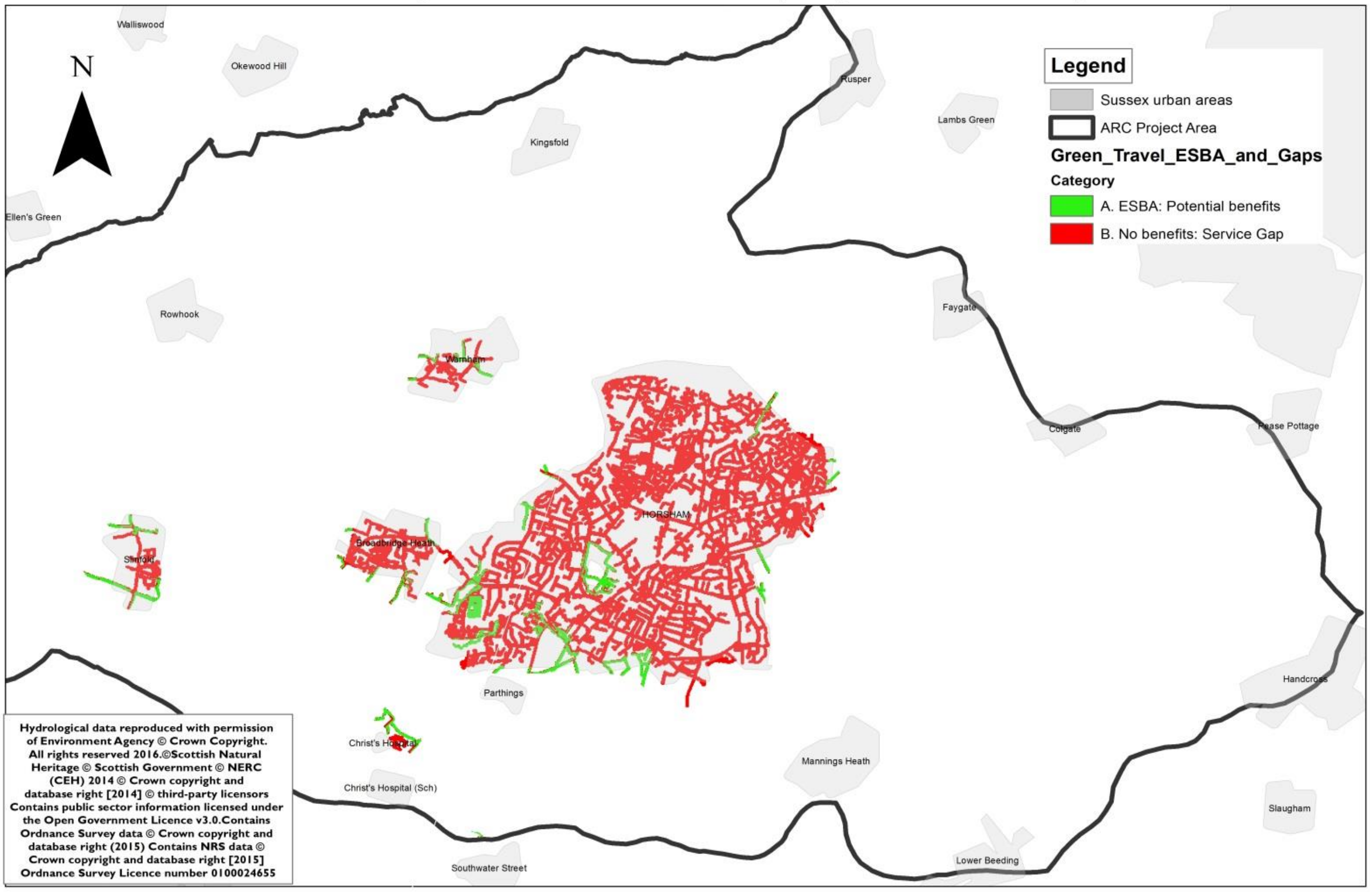
There are clearly defined areas around Horsham where there are gaps in the educational services being provided. These areas should considered by Councils and others when targeting the provision of educational activities and hubs, school and community greenspaces. St Leonards, Chesworth, Warnham and Owlbeech/Leechpool are very clearly providing Educational ecosystem services (see map below).

Case Study - Horsham. Education Capacity - Recommended Management

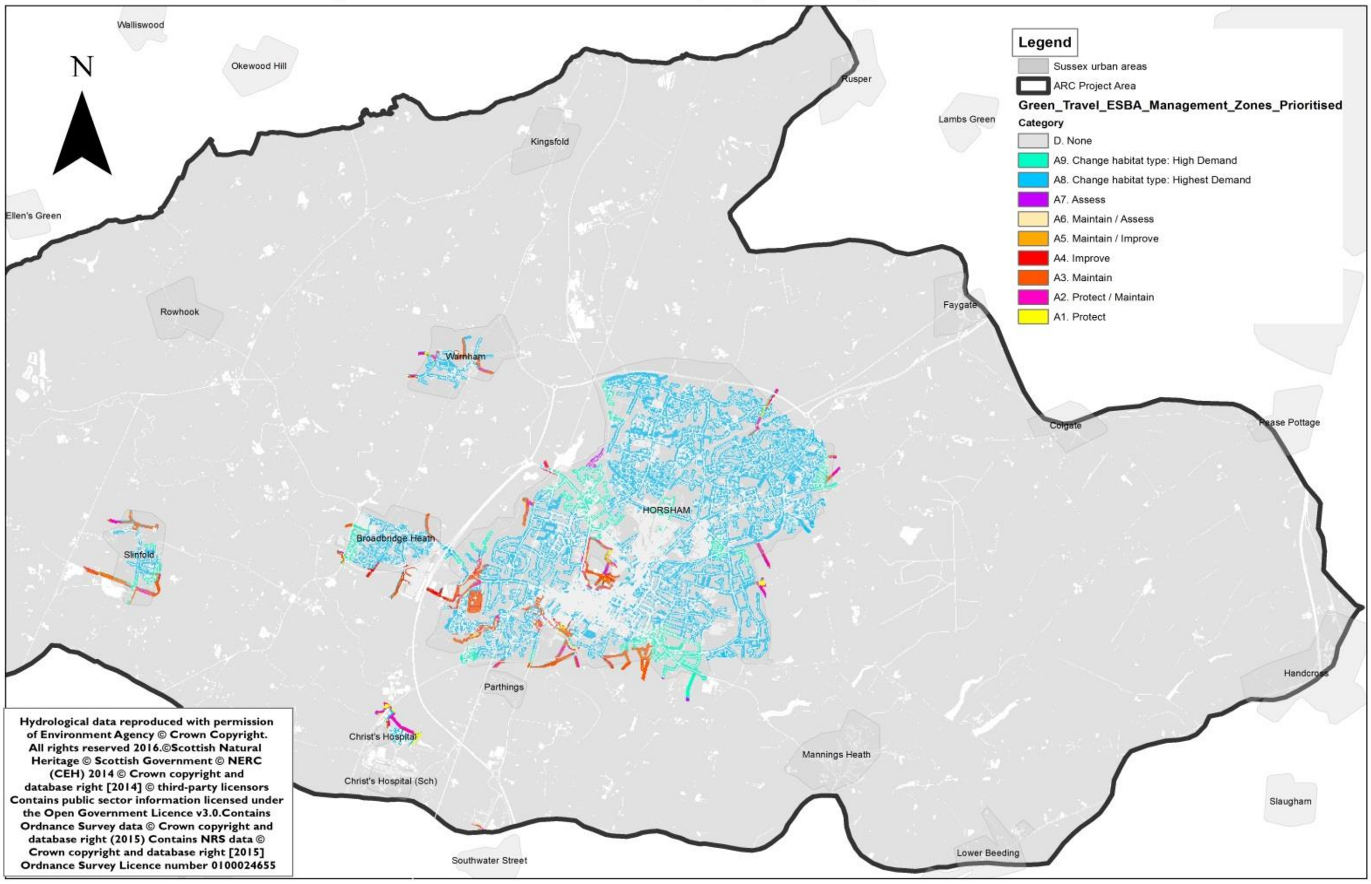


Green Travel Capacity in and around Horsham

Case Study - Horsham. Green Travel Capacity - Benefits and Gaps



Case Study - Horsham. Green Travel Capacity - Management Recommendations



Active travel, such as walking or cycling, is beneficial to health but there has been a decrease in physical activity levels over recent decades. Active travel can potentially allow a larger proportion of the population to meet the recommended targets for physical activity (Buehler et al. 2011). Economic analysis also indicates that there would be benefits to the NHS in England and Wales from increased walking and cycling by people in urban areas (Jarrett et al. 2012). In addition to the emphasis on physical health research indicates that active travel is significantly associated with mental well-being (Martin et al. 2014). The potential risk of being exposed to hazards such as traffic and pollution if travelling along roads and public highways, also supports the creation and enhancement of more green route-ways. Safe travel is particularly important for children for example if they need to commute or travel to school.

The model of the green travel capacity and demand identifies potential travel routes (pavements, paths, cycle routes) and creates a route corridor map linking these. It selects longer linear routes so that only the larger areas of well-connected travel are examined. Small areas of isolated paths or pavement are ignored. The travel routes are then buffered. Areas of greenspace are analysed in terms of perceived naturalness. Only some areas of the mapped travel routes will hold any greenspace, and may not occur close enough together to positively impact the character of the route.

The maps indicate that particularly in south and central Horsham, and some parts of outlying urban areas, there would be benefits to maintaining and improving travel routes, and / or changing habitat use along some of these routes to enhance green travel. This might, for example entail the creation of an enhanced cycle lane to link existing green routeways, or the creation of SUDS or corridors of trees along existing route-ways. There is high demand across all urban areas to change the habitat type along existing routes.

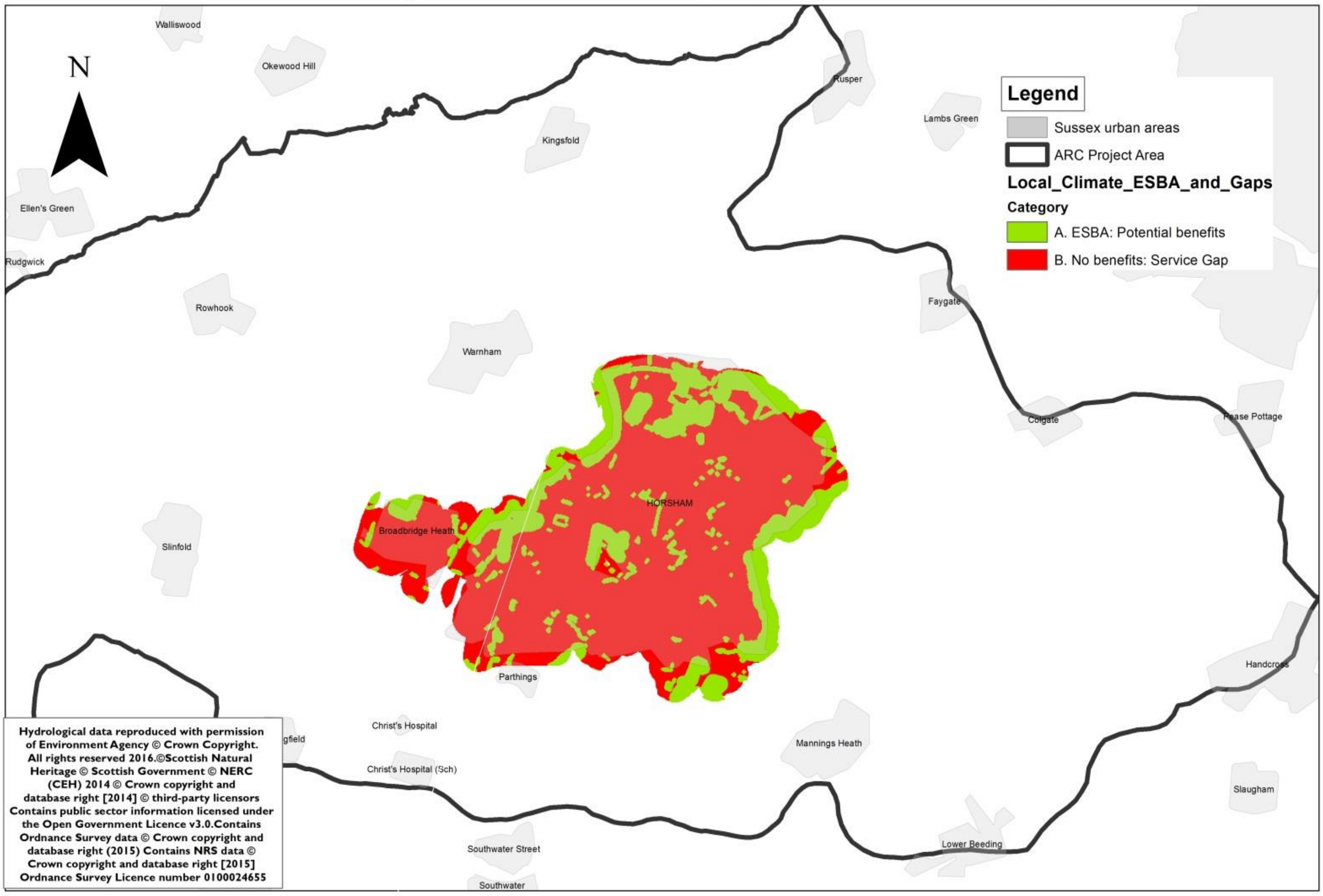
Local Climate Regulation Capacity in and around Horsham

Local climate regulation is a recognised ecosystem service in urban areas (Bolund & Hunhammar 1999). 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). Temperatures within urban areas are often one or two degrees warmer than surrounding countryside, and global climate change is likely to amplify these differences (Gill et al. 2007; Diana E. Bowler et al. 2010). The capacity of the natural environment to regulate local climate is mapped based on the presence of various types of vegetation and green space. Population vulnerability to raised temperatures and heat waves based on age is also mapped.

In the Horsham area, the majority of small towns and rural areas are providing sufficient local climate regulation for their local populations to mitigate the urban heat island effect (at least currently). The conurbation of Horsham itself is providing limited local climate regulatory services, and it therefore requires changes in land use which can bridge the service gap and help to improve local climate regulation in the town, and reduce heat associated health risks particularly to older people.

There are obvious areas of the main town (map below, light green) which are providing local climate regulation for residents in their vicinity and it would be wise for any future town plan to articulate, recognise and preserve the climate services these provided.

Case Study - Horsham Local Climate Capacity - Benefits and Gaps

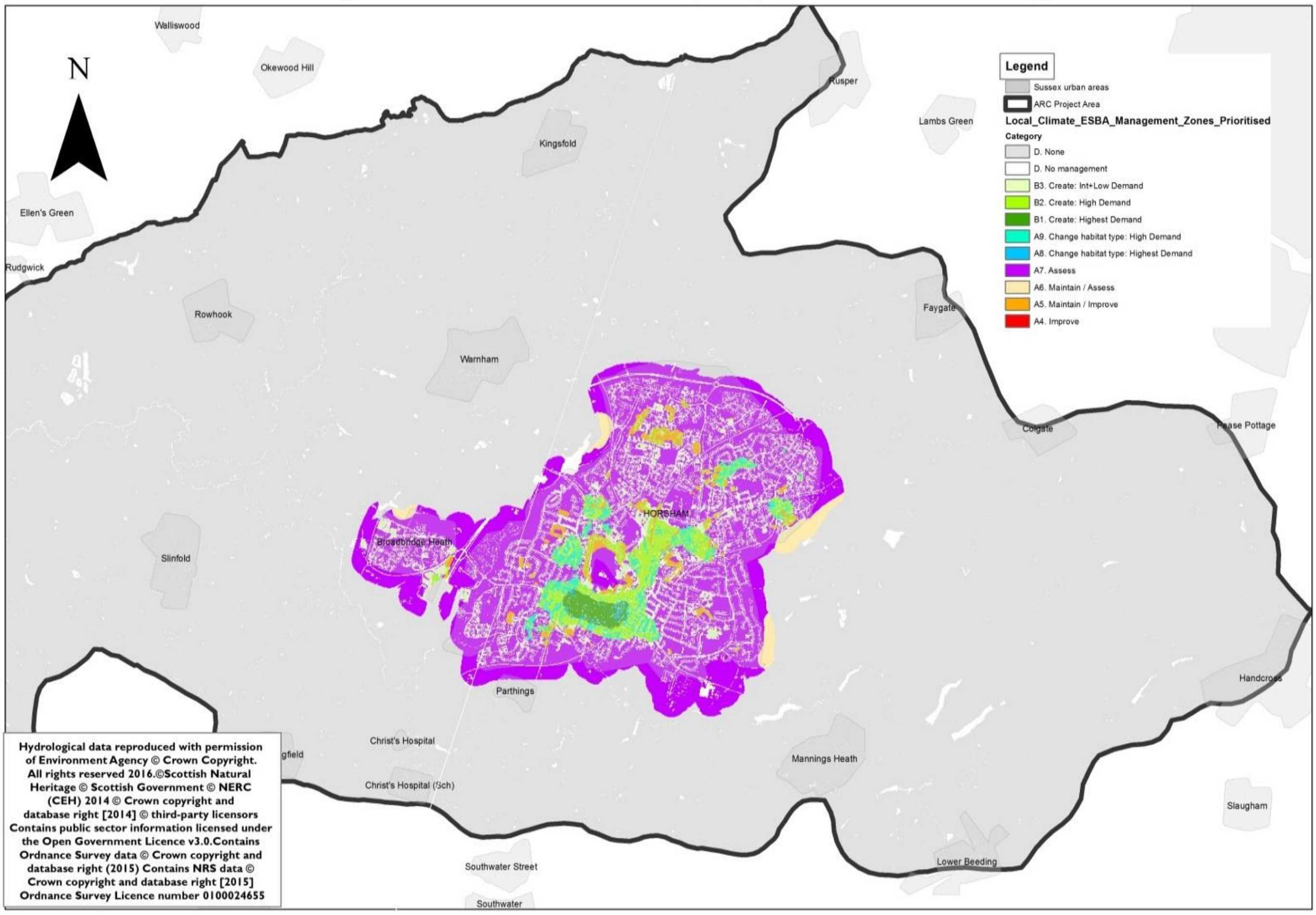


Studies in the subtropics have also shown that parks can lead to cooler conditions in cities, and have suggested that smaller parks may not consistently hold the same benefits as larger parks, e.g. sites less than 2 ha (Chang et al. 2007). Recent work has confirmed positive impacts of urban greenspace in a UK context (Hall et al. 2012; Armson et al. 2012; Doick et al. 2014). Urban grassland and tree cover can help ameliorate the urban heat island effect and both together are preferable to either in isolation (Armson *et al.* 2012).

The map below shows that changes in land use could provide significant local climate regulating capacity in areas of the central town, as could maintaining and improving some of the existing land use. It would be useful for town planners to consider the demand maps and suggested improvement areas (map below) during large housing schemes and redevelopments. This might take the form of increasing urban tree cover, green roofs and green walls, allotments and gardens, managing grass verges, increasing SUDS and rain gardens and working with schools to enhance school grounds.

There are large areas of the map below (purple) which show that further assessment of much of the urban infrastructure could help identify opportunities for local climate regulation. For example, green roof experts could be asked to carry out a study of aerial photos of the town to identify the potential for green roofs. Blue infrastructure innovations such as rooftop rain gardens could also be considered, as these too can help to mitigate urban heat island effects.

Case Study - Horsham Local Climate Capacity - Recommended Management



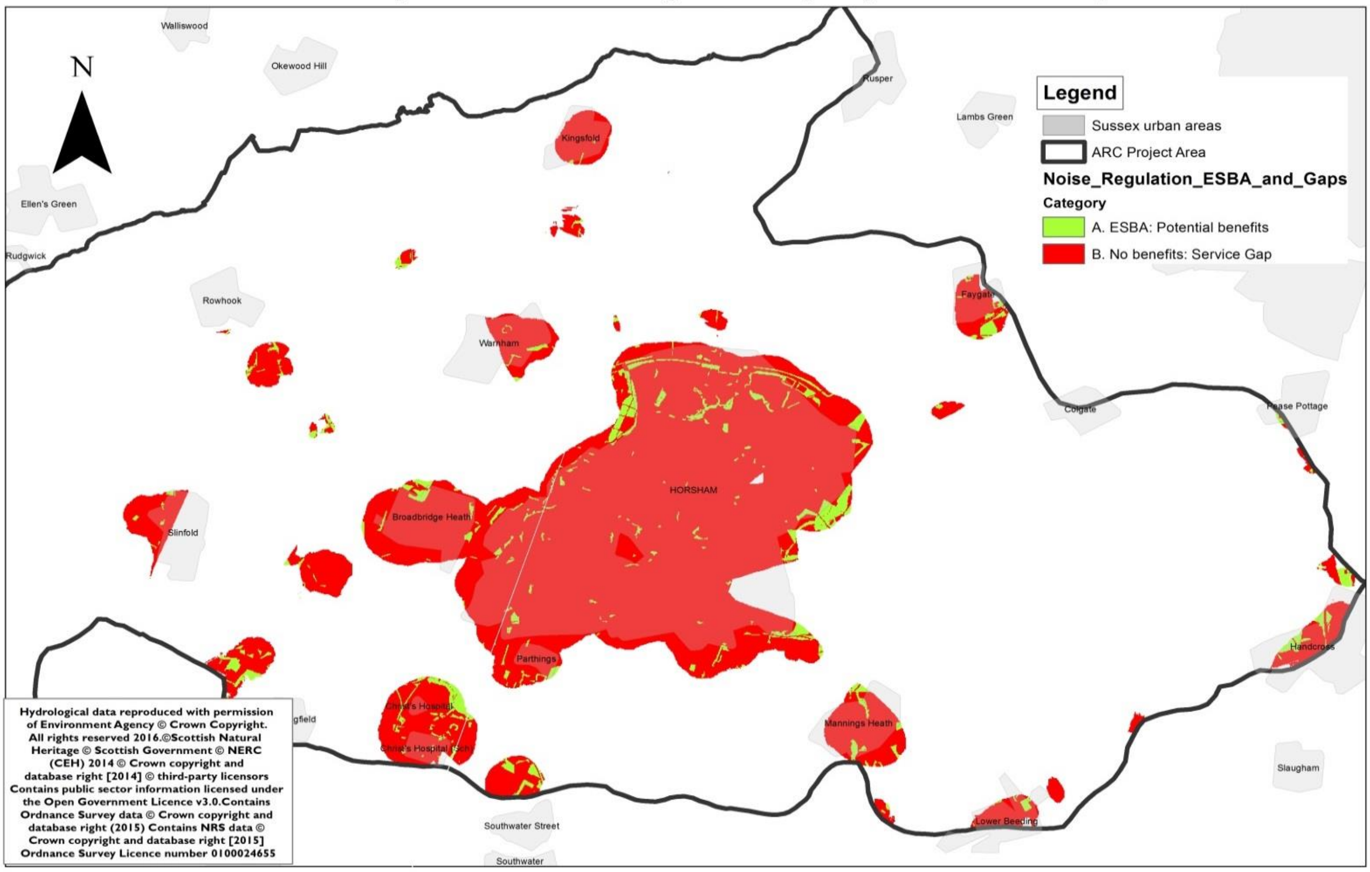
Local Noise Regulation Capacity in and around Horsham

Noise regulation is a recognised ecosystem service of vegetation and greenspace (Bolund & Hunhammar 1999; Greenspace Scotland 2008). In the UK about 10% of the population live in areas of excessive daytime sound levels, although up to 30% of the population express dissatisfaction in surveys of their local noise environment (HPA 2010). Noise can be produced from various sources, such as road traffic, air traffic, construction work, building noise and domestic activities, with varying negative impacts on people (Berglund & Lindvall 1995).

Noise pollution can lead to various health impacts and has been implicated in increased stress levels and is thought to be an influencing factor in a range of mental health problems (Tzivian et al. 2015; HPA 2010). These impacts are greatest closer to the source of noise. Examples include a recent study that showed negative impact of noise on blood pressure in children (Liu et al. 2014). Reviews indicate that noise may impact cardiovascular heart disease and raise blood pressure (HPA 2010). In addition to impacting health, noise can have economic impacts such as being associated with lower house prices (Łowicki & Piotrowska 2015).

The map below shows that large parts of urban areas in and around Horsham are suffering from high levels of noise pollution, which the existing environment is not able to dissipate.

Case Study - Horsham Noise Regulation Capacity - Benefits and Gaps

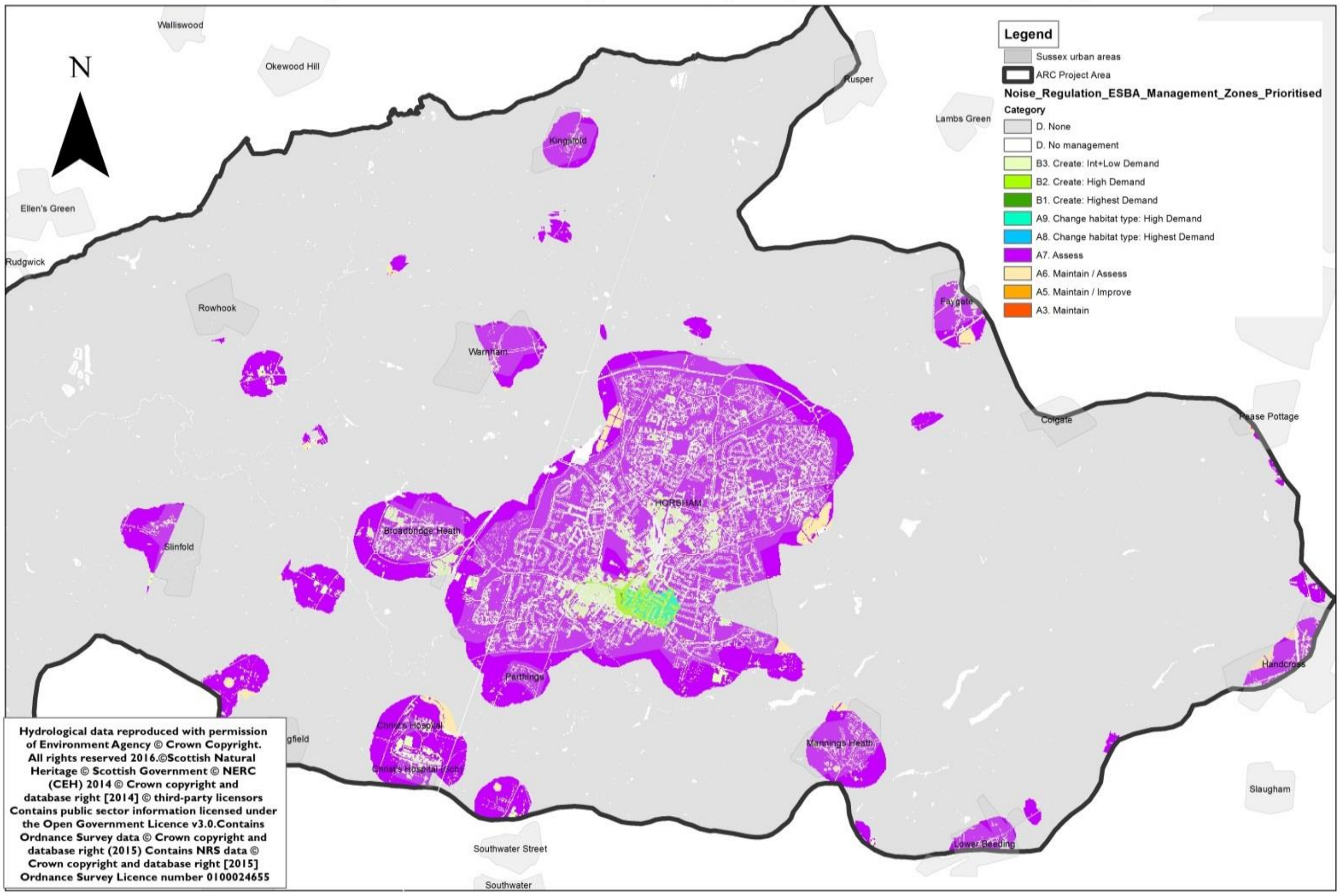


Greenspace provides varying effectiveness as a noise barrier relating to the structure, size and density of the vegetation in it (Fang & Ling 2005). Complex areas of vegetation, and trees and shrubs are best at scattering noise. Evergreen vegetation provides a more enhanced noise reduction function all year round. Noise levels can be reduced by 5 – 10 decibels for every 30 m of woodland (Cook & Haverbeke 1972).

Absorbent vegetation cover on the ground can also absorb more noise in comparison to sealed surfaces such as concrete (Department of Transport 1998).

The creation and maintenance of green buffers has been shown to help to screen undesirable noise levels along roads (Bentrup 2008). Guidance in the US recommends that for moderate road speeds (<40 mph) a barrier of 6 to 15 m width is appropriate, for high speed roads a barrier of 20 to 30 m is advised (Bentrup 2008). Noise reduction ability is relative to tree belt width (Van Renterghem 2014), although even narrow hedges can cause reduction in noise levels (Van Renterghem et al. 2014). Vegetated walls, lines of trees and green roofs may also have positive impacts on noise reduction (Van Renterghem et al. 2015). There is a maximum distance beyond which additional buffers, trees or woodland is no longer effective or necessary, this depends on the level of noise pollution present but is in the range of 300 to 500 m (Bentrup 2008). Noise pollution from industrial and other sources may be more complex to reduce.

Case Study - Horsham Noise Regulation Capacity - Recommended Management



As with the local climate capacity model, there is a large area of mid-southern Horsham where there is a high demand for the creation of more complex vegetation around noise creating infrastructure, in order to help reduce the impacts of noise pollution on local residents. Similarly areas of Leechpool/Owlbeech, Warnham and other greenspace should be maintained as they are providing an existing noise regulation function, which could potentially be enhanced in some areas. Large parts of the Horsham area need further assessment to review if they are able to provide greater noise regulating ecosystem services with changed land use.

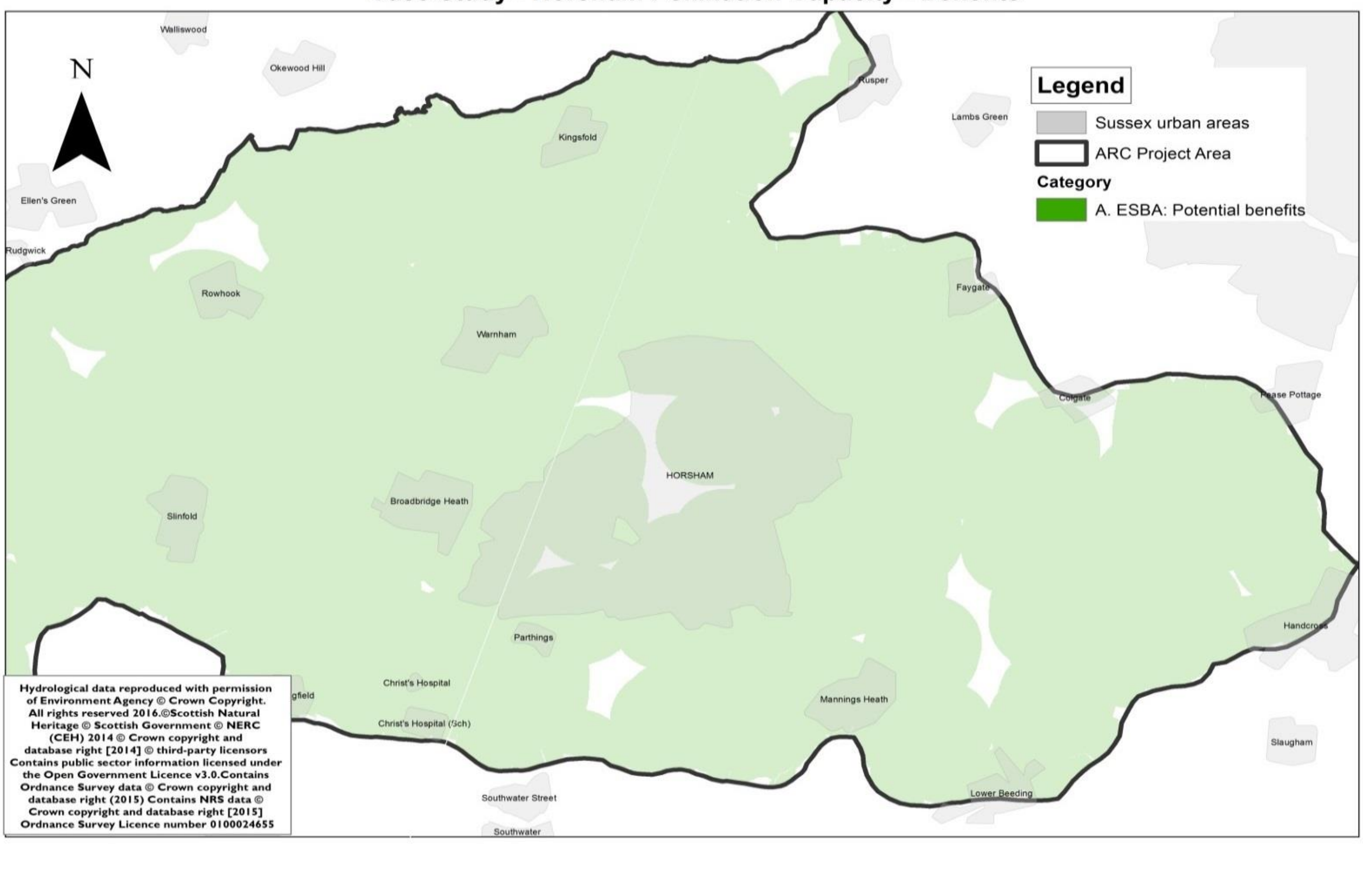
Local Pollination Capacity in and around Horsham

This model shows the potential increases in yield and stability of food crops which are / could be provided by insect pollinators. UK pollination services have a high economic value (Breeze et al. 2015), and insect pollinated crops are important in UK agriculture (Breeze et al. 2011; Vanbergen et al. 2014) i.e. insect pollinators are important to the apple industry by affecting both crop yield and quality (Garratt et al. 2014). A review of land use was shown to be an important determinant of pollinator occurrence (Defra 2013).

There is now a strategy focussed on sustaining pollinators in England (DEFRA 2014). The natural and semi-natural environment helps to sustain populations of bees and other pollinators, providing a free source of pollination. By protecting natural and semi-natural habitats close to arable agriculture, pollination of plants can be ensured e.g. the beneficial impact of flower-rich field margins (Dicks et al. 2010). Studies have indicated that wild pollinators are required, in addition to honey bees to help pollinate crops (Button & Elle 2014). Schulp et al. 2014 devised a method where the location and number of wild bees are representative of pollinators as a whole. With the exception of agricultural land, all open natural and semi-natural sites, and areas of woodland 100 m from open areas are counted as habitat for bees. 688 m was taken as the distance bees will travel (Ricketts et al. 2008). The likelihood of a pollinator travelling to a focal cell from its habitat is used as a proxy for the amount of pollination within each cell.

The Ecoserv-GIS model shows that there are few parts of the landscape around Horsham which are not already providing potential pollination benefits. The model provides significant evidence to back the protection and enhancement of large areas of the local countryside / green infrastructure in order to provide pollination services at the level they are needed.

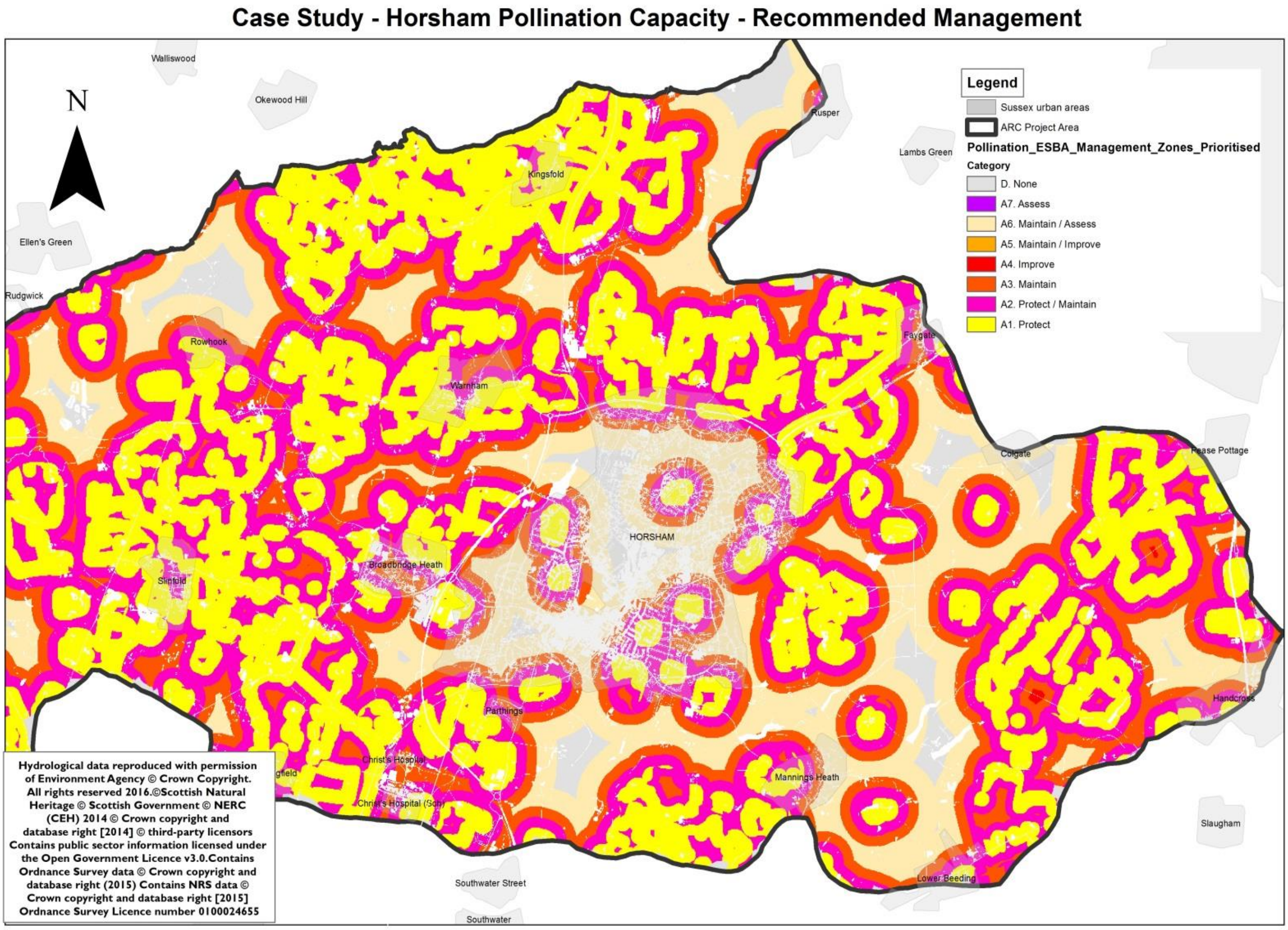
Case Study - Horsham Pollination Capacity - Benefits



The map below shows the areas where it would be most useful to maintain, improve and protect existing areas of habitat in order to continue to provide the required pollination services.

Whether this is through wildlife gardening, maintenance of road verge meadows and trees, or the protection of flower rich meadows and countryside, there is an opportunity to be more creative about how pollination benefits are provided i.e. the creation of green roofs and walls, of flower rich fen, and the provision of organic allotments & forest gardening.

In this case study, there are notable opportunities for the provision of pollination services within most of the smaller urban conurbations. Although there are less opportunities within Horsham itself, the maps highlight again, the importance of existing green networks, parks and nature reserves in providing pollination services for agricultural land around Horsham.



Local Water Purification Capacity in and around Horsham

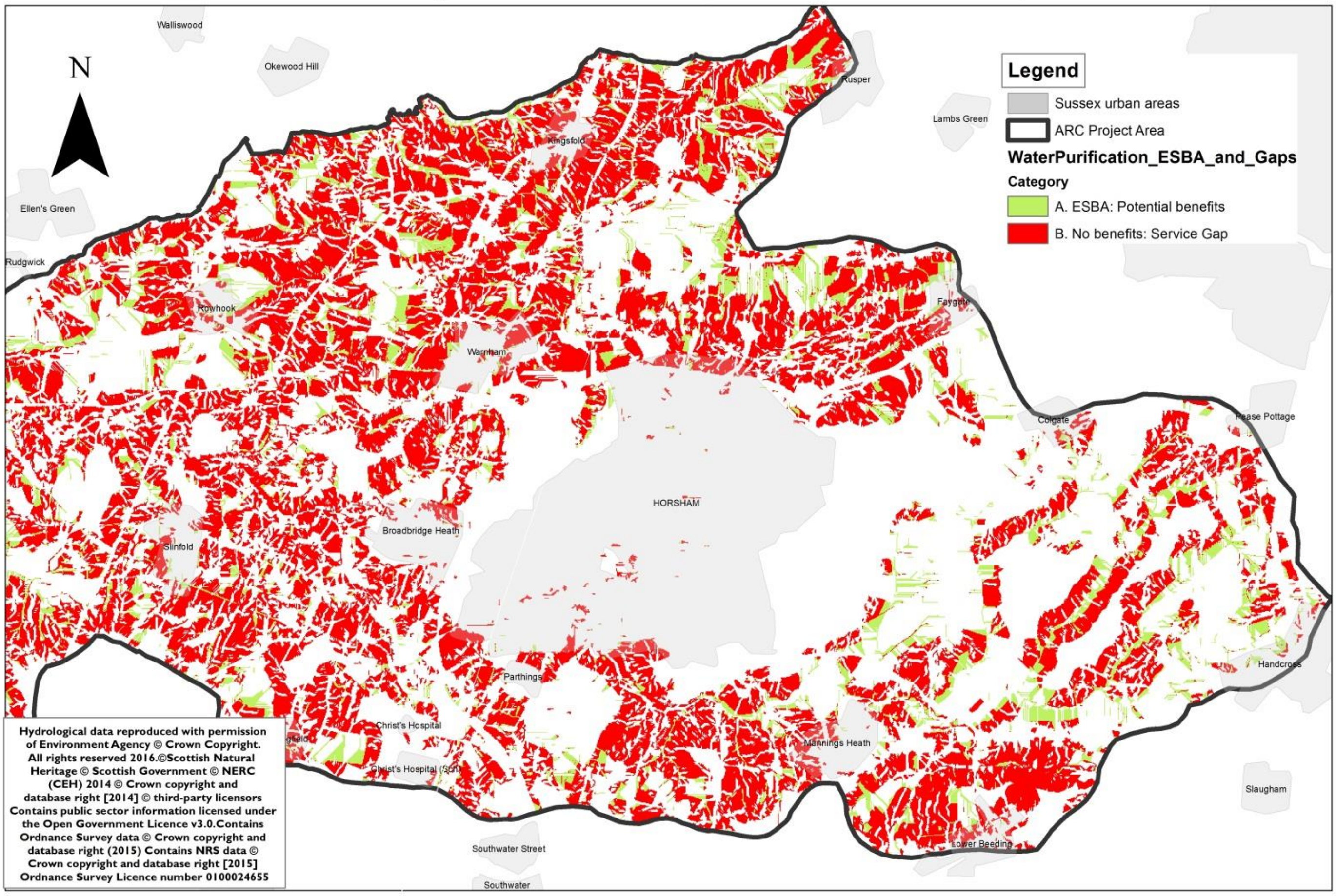
Water purification (water quality regulation) is a key ecosystem service (Brauman et al. 2007). This toolkit models the diffuse agricultural and urban pollution which can affect local water courses and water supplies.

The detrimental impact of soil erosion, fertilisers and other run off from farms is well known (Defra 2005) fine sediment and soluble pollutants (such as pesticides, nitrogen and phosphorus) 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.

However, agriculture has been reported to have less of a damaging effect on water quality compared to urban cover (Brabec 2002). Missed sewer connections (where household waste water directly enters streams), or the cumulative impact of small pollution events on urban roads, streets and pavements, and an increased cover of sealed surfaces has been shown to be associated with degraded stream ecosystems (Brabec 2002). Studies have confirmed that linear features such as roads or tracks can influence water movement and pollution risk in farmed (Heathwaite et al. 2005) and urban landscapes.

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 health problems such as stomach cancer (Koo & O'Connell 2006). Low water quality can impact humans by creating additional bill costs for drinking water treatment or through effects on recreation use in, or along, watercourses (walking, swimming, fishing).

Case Study - Horsham Water Purification - Benefits and Gaps



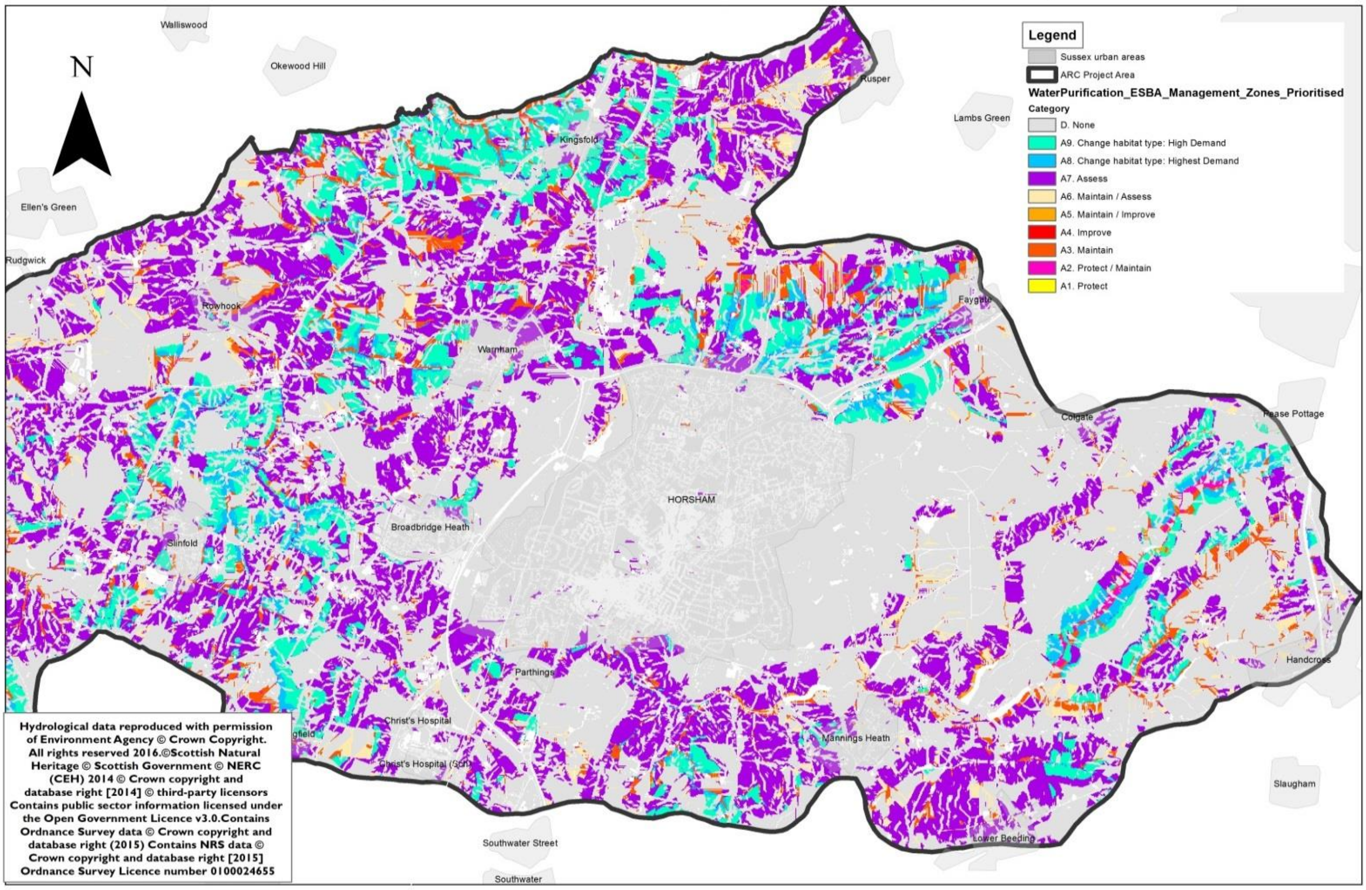
In many cases there are limited opportunities for land to deliver water purification ecosystem services within towns and cities. Nevertheless, land planning strategies to reduce pollution by implementing restoration, e.g. of wetlands, have been shown to be financially viable (Trepel 2010), and Sustainable Urban Drainage Systems (if well planned) can derive large benefits to local water quality.

Areas where pollution is likely, and those downslope, have a high need for habitats that can slow run off and help to reduce water pollutant loads before they enter watercourses. Strategies to reduce pollution to water courses should concentrate on areas of land use close to streams, such as by buffering streams with planted woodland or fencing to prevent access by livestock (Monaghan et al. 2009). Positive land stewardship of areas of permeable geology such as chalk and greensand will also have a positive effect on underlying water aquifers. Other methods which are known to enhance water quality include :-

- Using urban greenspace to contribute to water purification services (Yang et al. 2015).
- Grass strips near watercourses are locally effective in reducing pollution loads before they reach watercourses (Liu et al. 2015).
- A 50m hedgerow at the bottom of a 1ha field can reduce field run offs and store between 150 and 375 cubic metres of water during rainy periods for slow release down slope during dry periods.

The Local Water Purification Capacity map shows a lack of capacity for the landscape to provide the water purification services at the level that the local population requires (red areas, and purple areas depending on review), but these areas could be targeted for land use change were possible. There is a need to change the habitat use across the area (blue) to provide more water purification services, and to assess large parts of the rest of the landscape for the potential to provide additional water purification benefits.

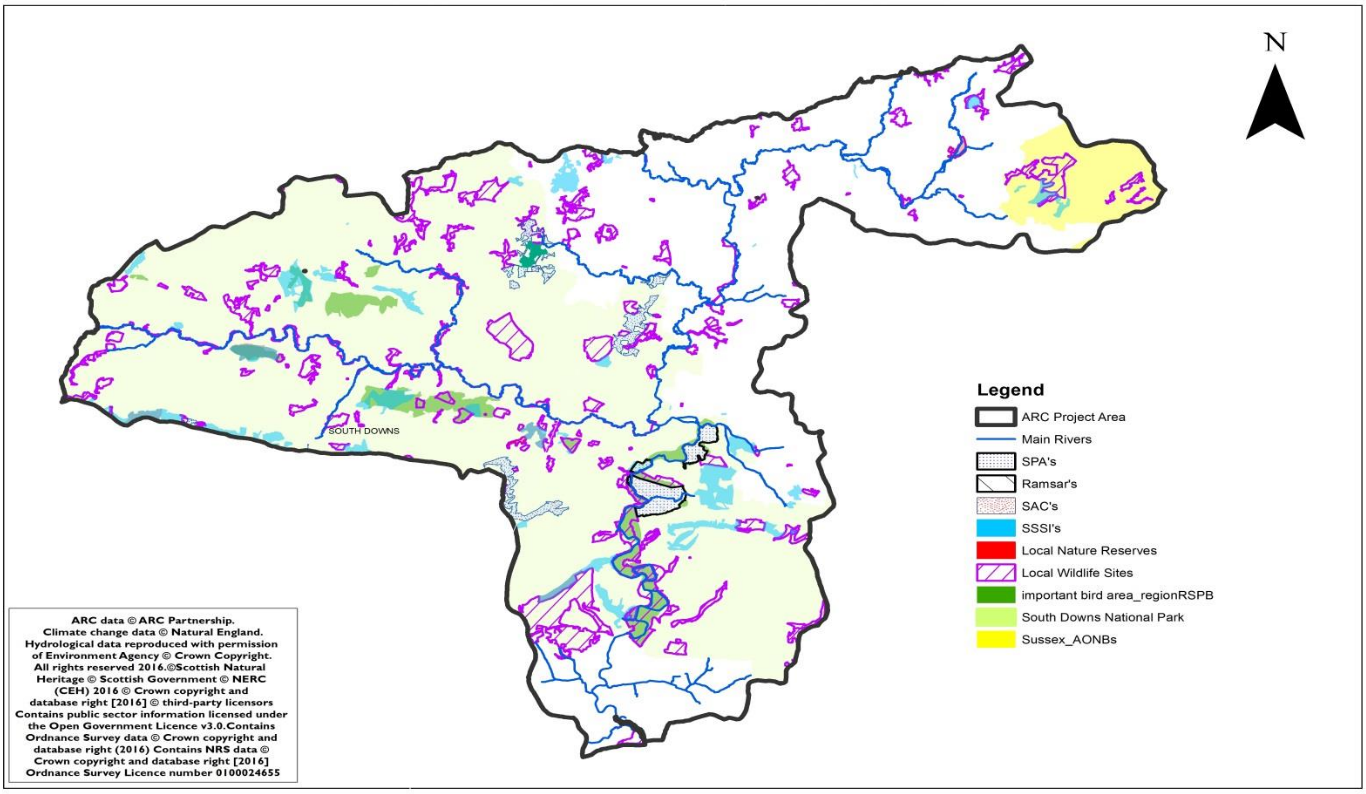
Case Study - Horsham Water Purification - Recommended Management



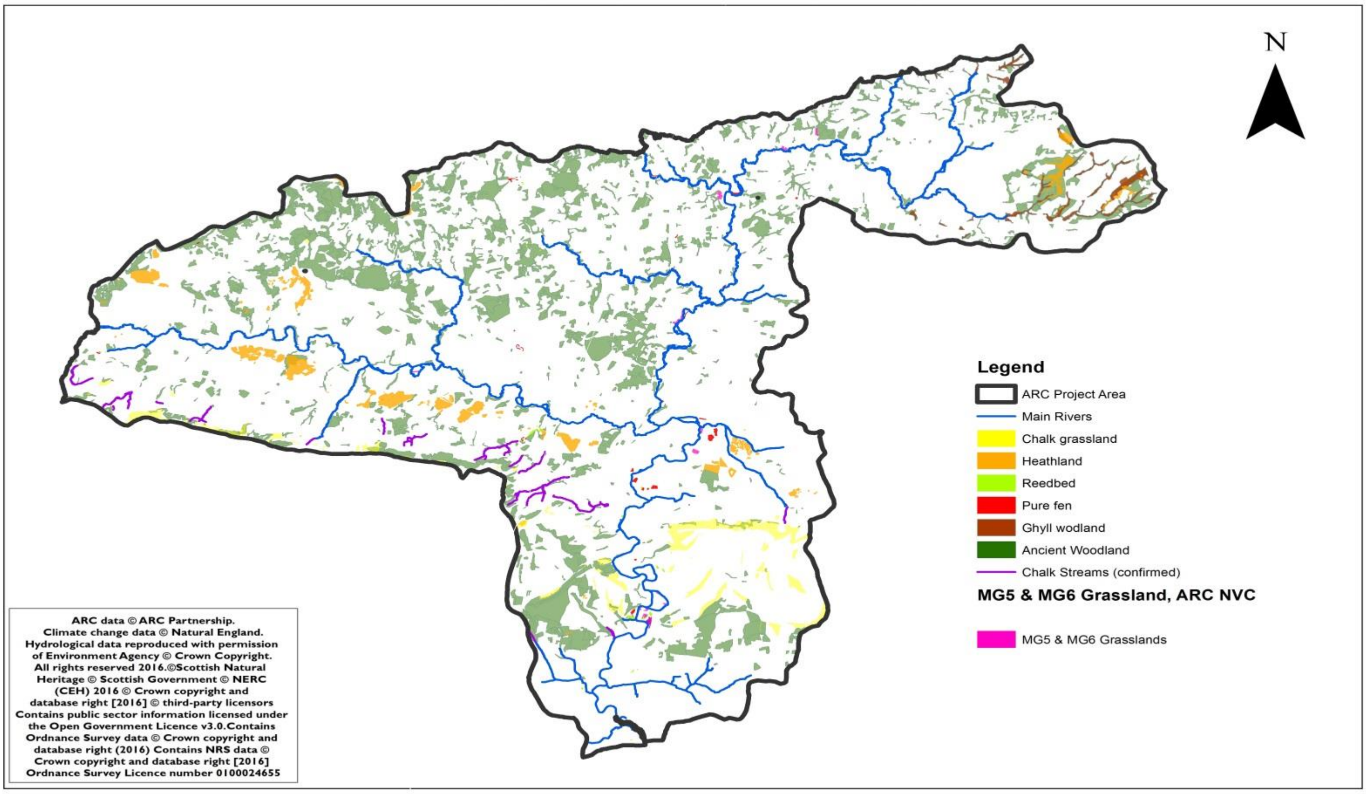
Identifiable landscapes providing ecosystem services

Maps of protected sites and landscapes across the ARC project area (maps below), help to identify key landscapes / habitat types which are providing ecosystem service benefits to local residents. Examples of this are the St Leonards forest to the east of Horsham, Rewell Wood ancient woodland to the West of Arundel, and parts of the Ebernoe Common woodland complex. There are also numerous areas within the South Downs National Park which are providing multiple ecosystem services to local populations.

Major protected landscapes in the ARC Project area.



Priority habitats in the ARC Project area.



How did ARC help to contribute to the maintenance of key Ecosystem services in the Project area?

The ARC project which was Heritage Lottery Funded over a four year period had four key aims :-

1. Promote a thriving river system where wildlife flourishes and people value and enjoy the landscape, natural and cultural heritage.
2. Work with others to protect, restore and reconnect wildlife habitats.
3. Improve water quality and eliminate non-native invasive species.
4. Better connect the community to the catchment, through access improvements, engagement and interpretation of the natural and cultural heritage of the project area.

Over a period of four years, ARC has supported a multitude of projects across the Arun & Western Rother river catchments. These have had many and diverse benefits for both people and the environment across this 77,000 hectare area.

In the Horsham area :-

- **Chesworth Farm** – Improved carbon capacity, access to nature, education, air, pollination and water purification capacity via a new boardwalk, pond dipping platform, river restoration and habitat enhancement, and educational events (otter and water vole outreach)
- **Warnham Nature Reserve** – Improved carbon capacity, access to nature, education, air and water purification capacity via river and floodplain restoration, black poplar tree planting, new disabled access path and bird hide.
- **River restoration –** Improved water purification, access to nature, carbon capture, pollination and more via various enhancements to the river South west of Broadbridge Heath
- **Non-native invasive giant hogweed** - Removal to improve access to nature.
- **St Leonards forest** – Gaining national notification via the UK Priority river habitat map of its value as a watershed and habitat – an important means of helping to protect, maintain and enhance this area into the future given its importance for providing multiple ecosystem service benefits.
- **Christ's Hospital** – Providing educational access and access to nature, pollination and carbon capacity benefits via pond and meadow enhancement, black poplar planting and more.

Wider work

- Planting trees and hedgerows and restoring ponds, meadows, wet heaths and wetlands for Carbon Storage
- Engaging with and creating better education capacity for primary schools in the project area
- Producing an educational rivers pack to encourage greater contact with the local environment
- Creating the ARC app to create greater engagement with the natural environment
- Helped to set up Riverfly monitoring, training local people to survey their local rivers
- Led numerous free events, and funded transport to events which get people out in nature
- Assisting access to nature, air purification and better water purification and carbon storage via the Littlehampton, Pulborough and Horsham park Sustainable Urban Drainage Schemes
- Our pond project to create and restore ponds is helping to store carbon. Ponds have been shown to store more carbon than the oceans relative to their size.

APPENDICES

APPENDIX 1 - Definition of terms used in model

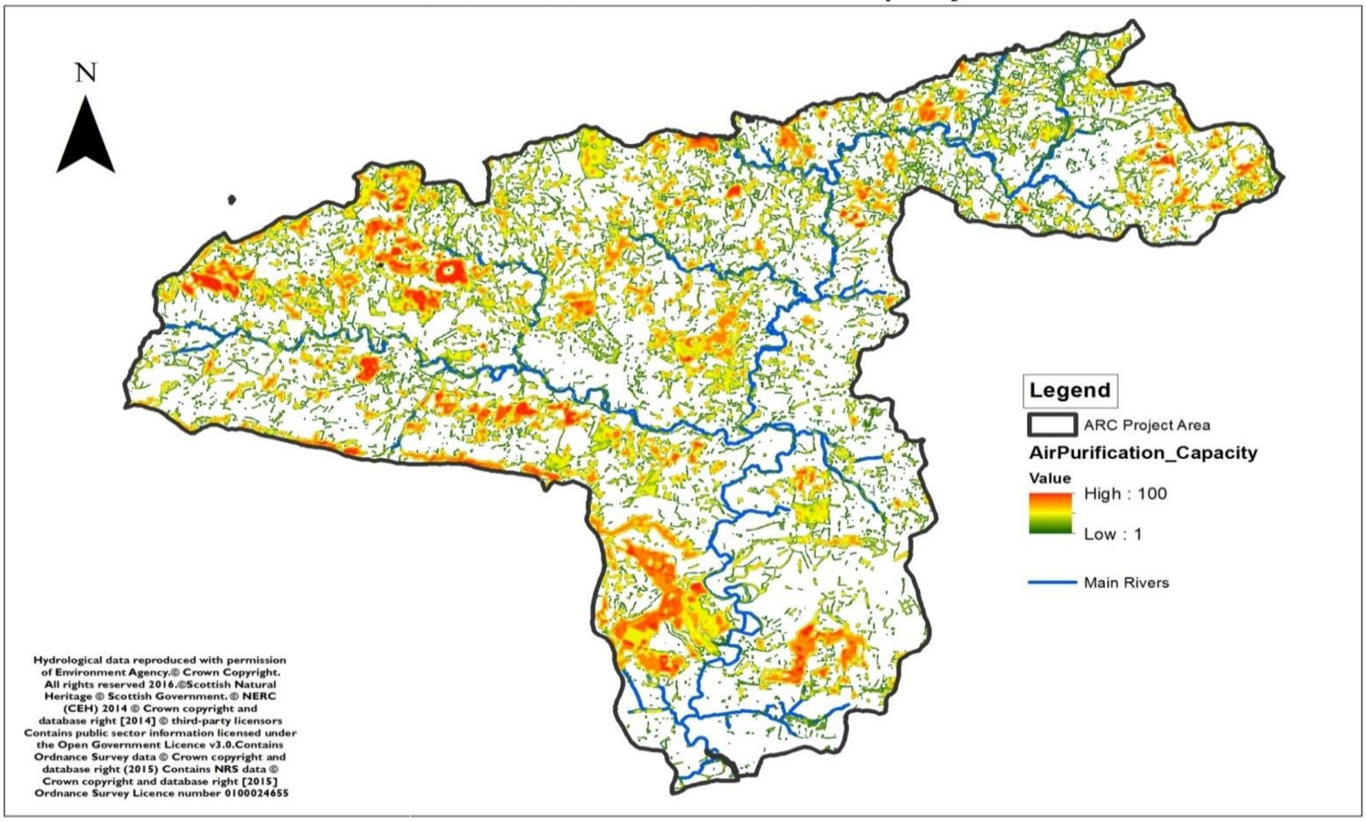
EcoServ-GIS map terms

Term	Definition
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 Benefiting 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 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.

APPENDIX 2 - Areas of Capacity versus Demand for the mapped Ecosystem Services

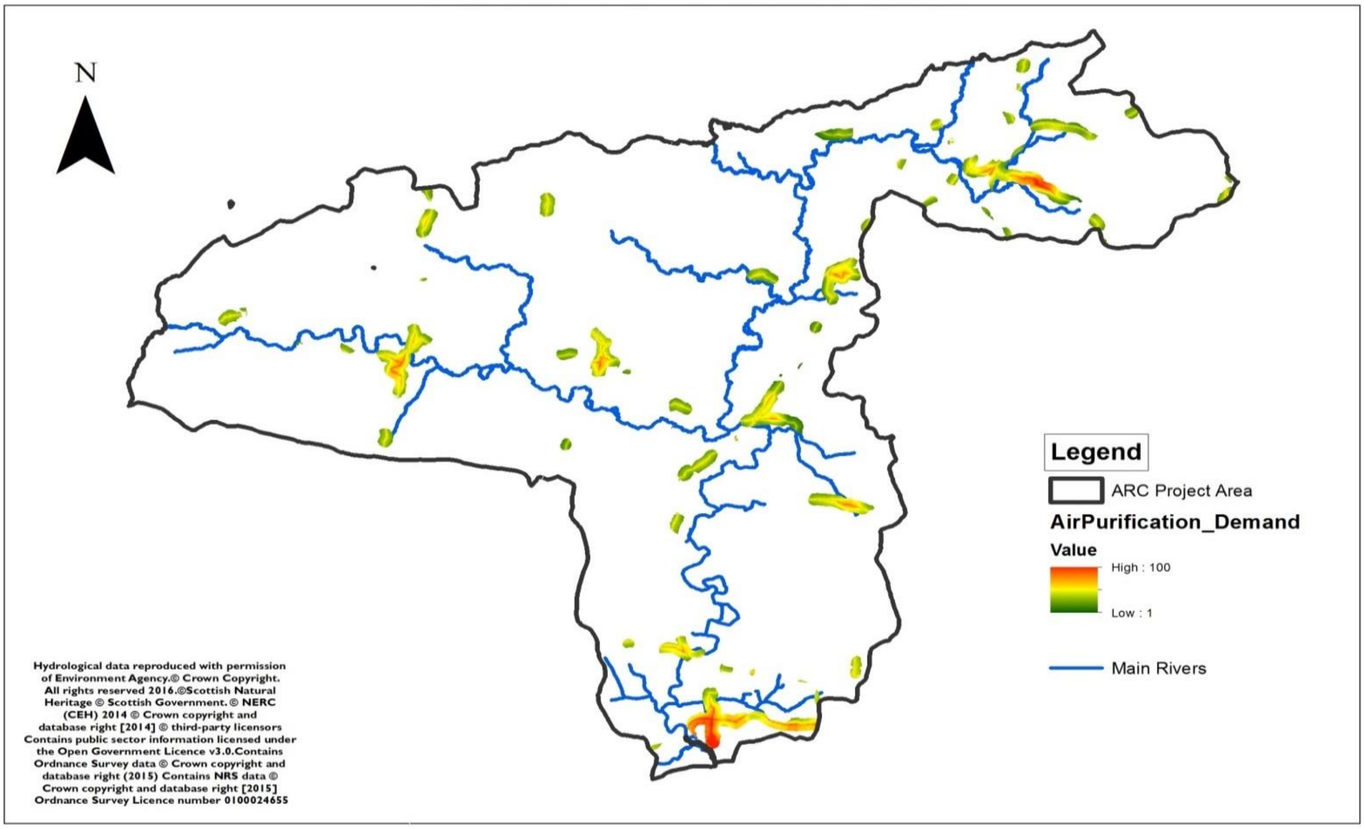
Air Purification Capacity

ARC Catchment Air Purification Capacity

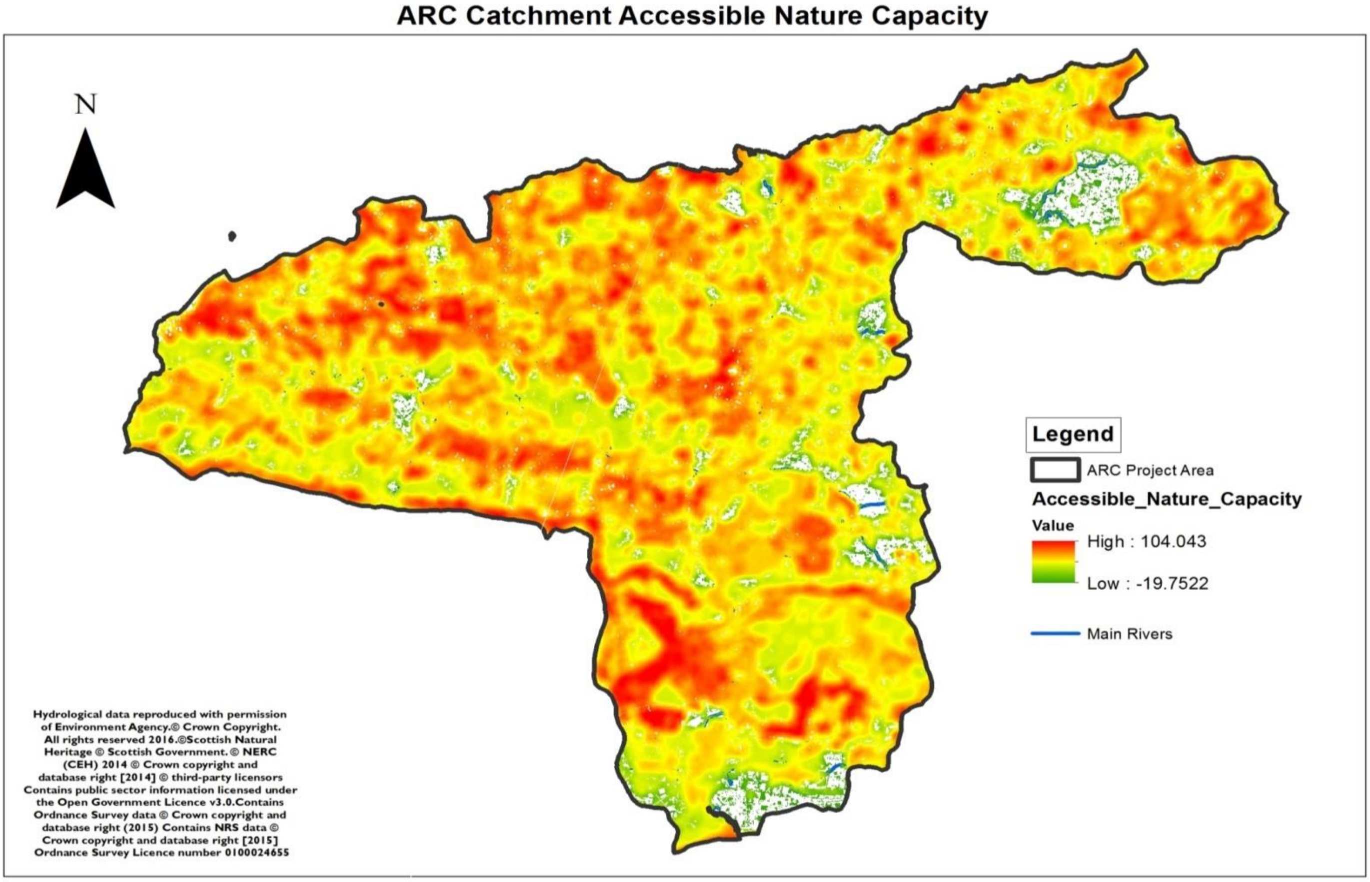


Air Purification Demand

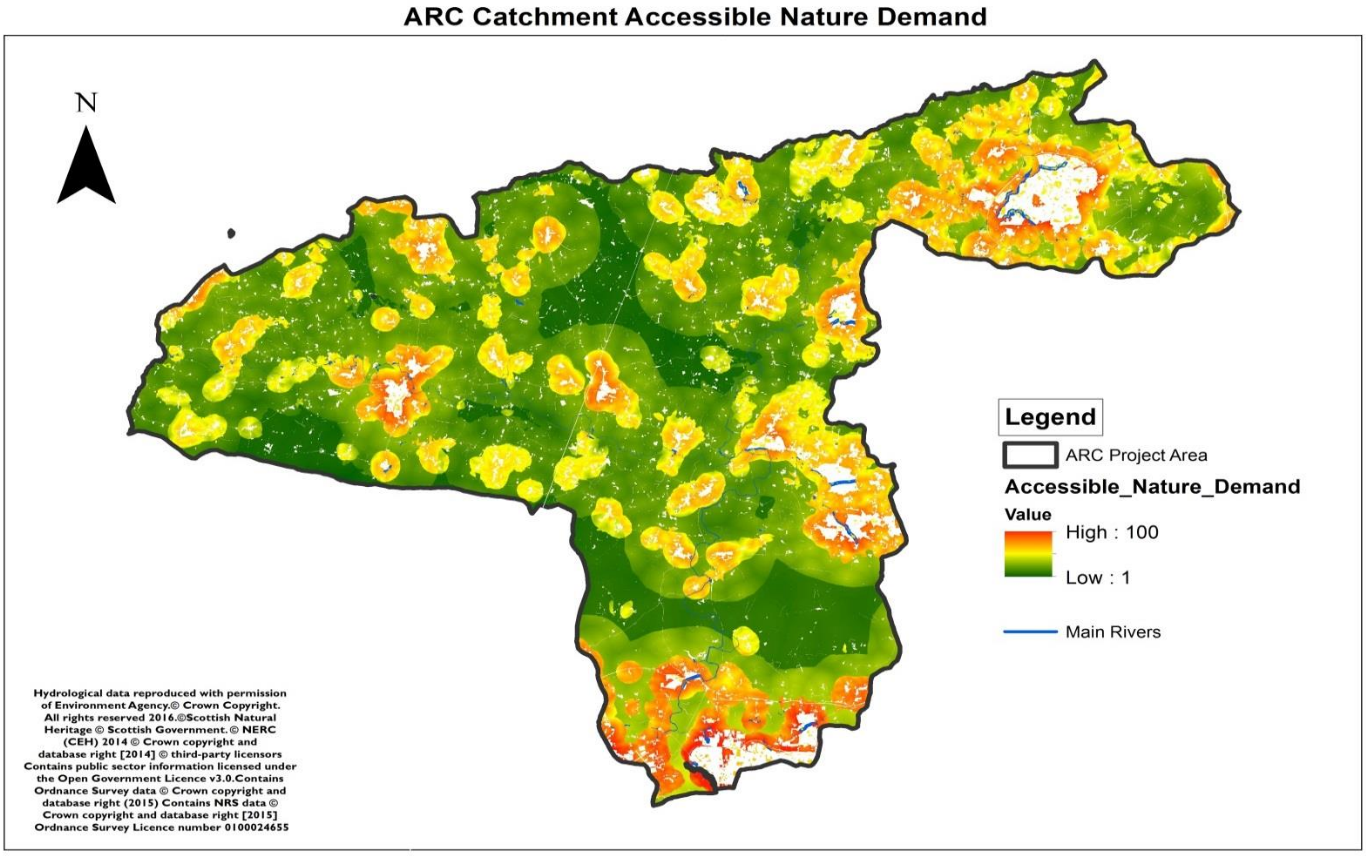
ARC Catchment Air Purification Demand



Accessible Nature Capacity

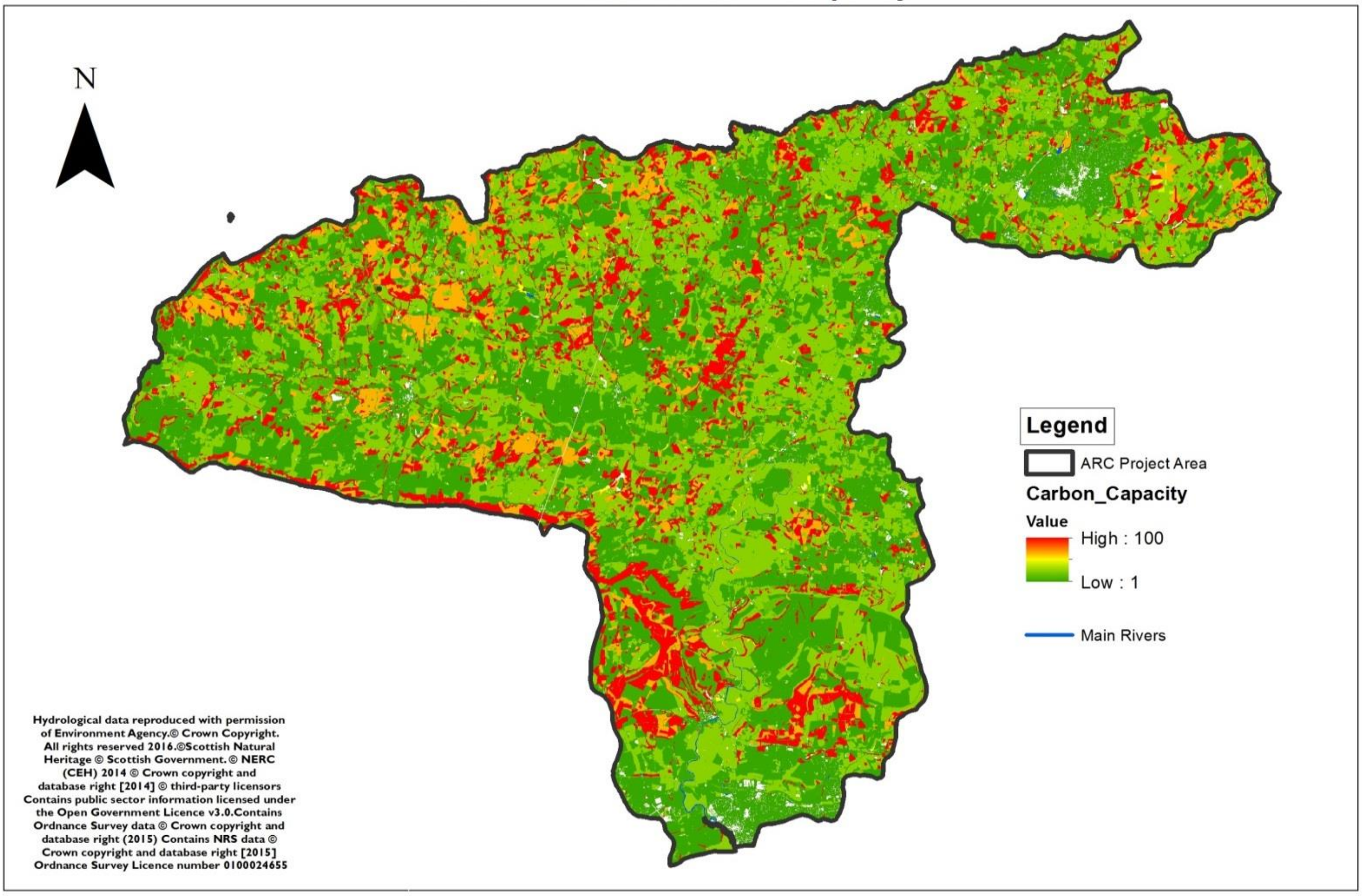


Accessible Nature Demand



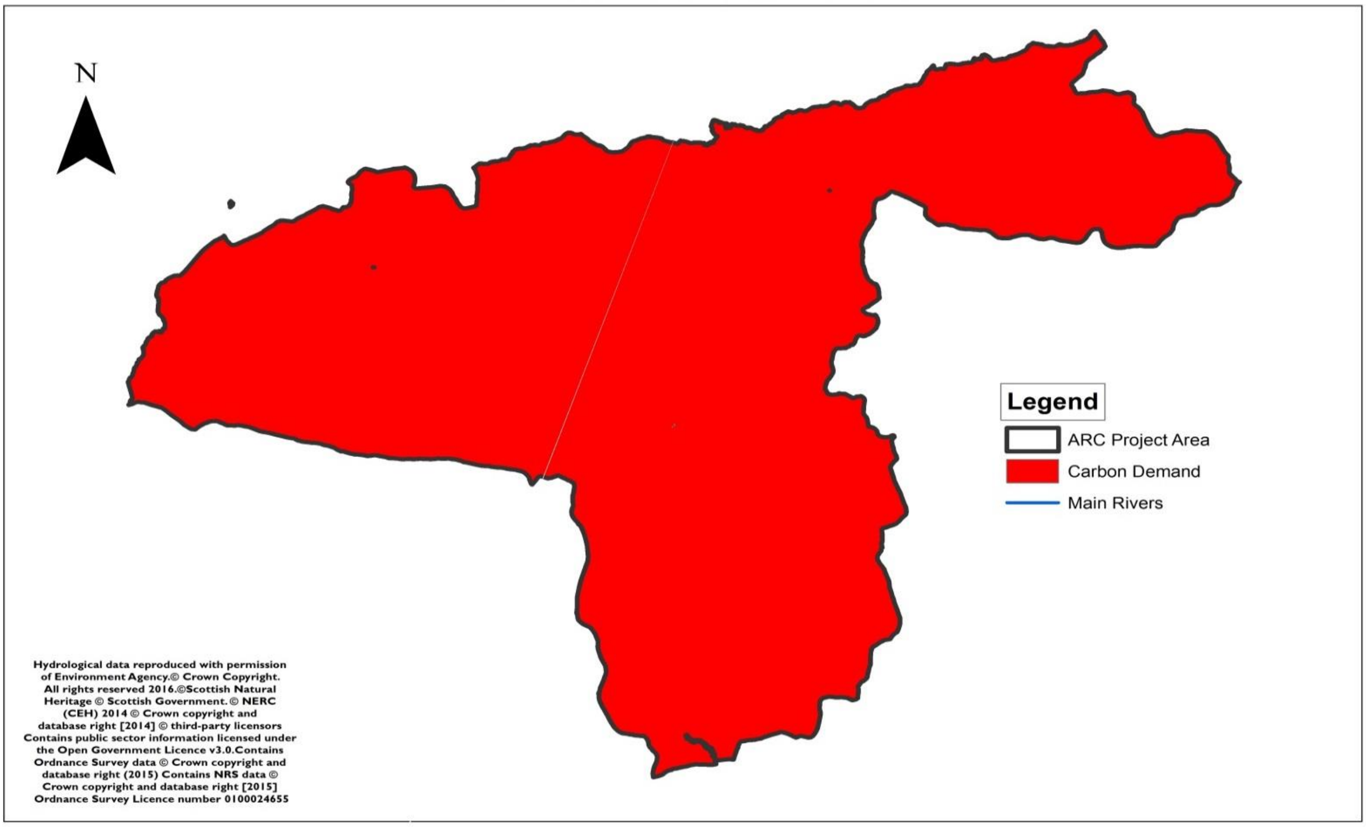
Carbon Capacity

ARC Catchment Carbon Capacity

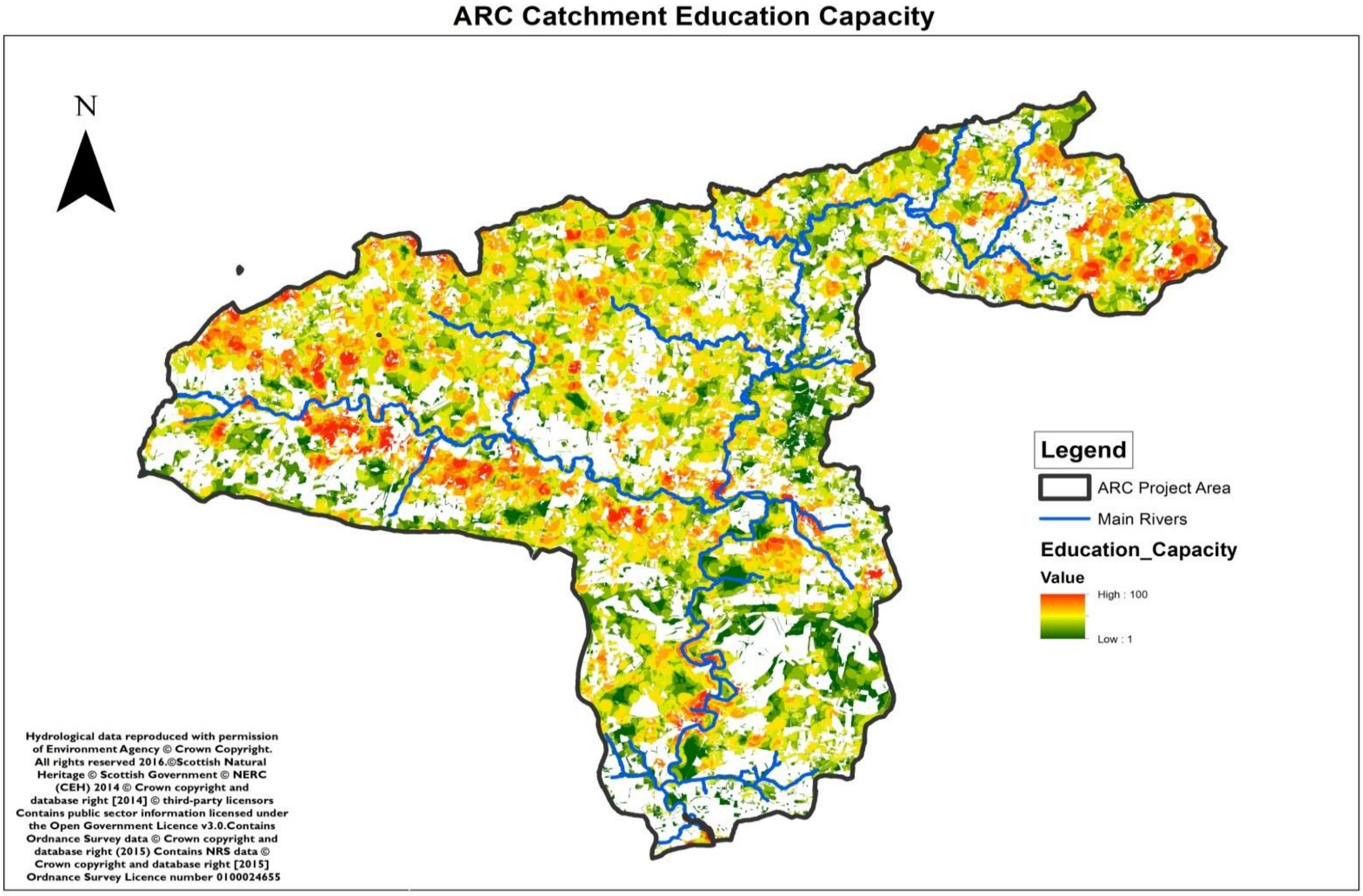


Carbon Demand

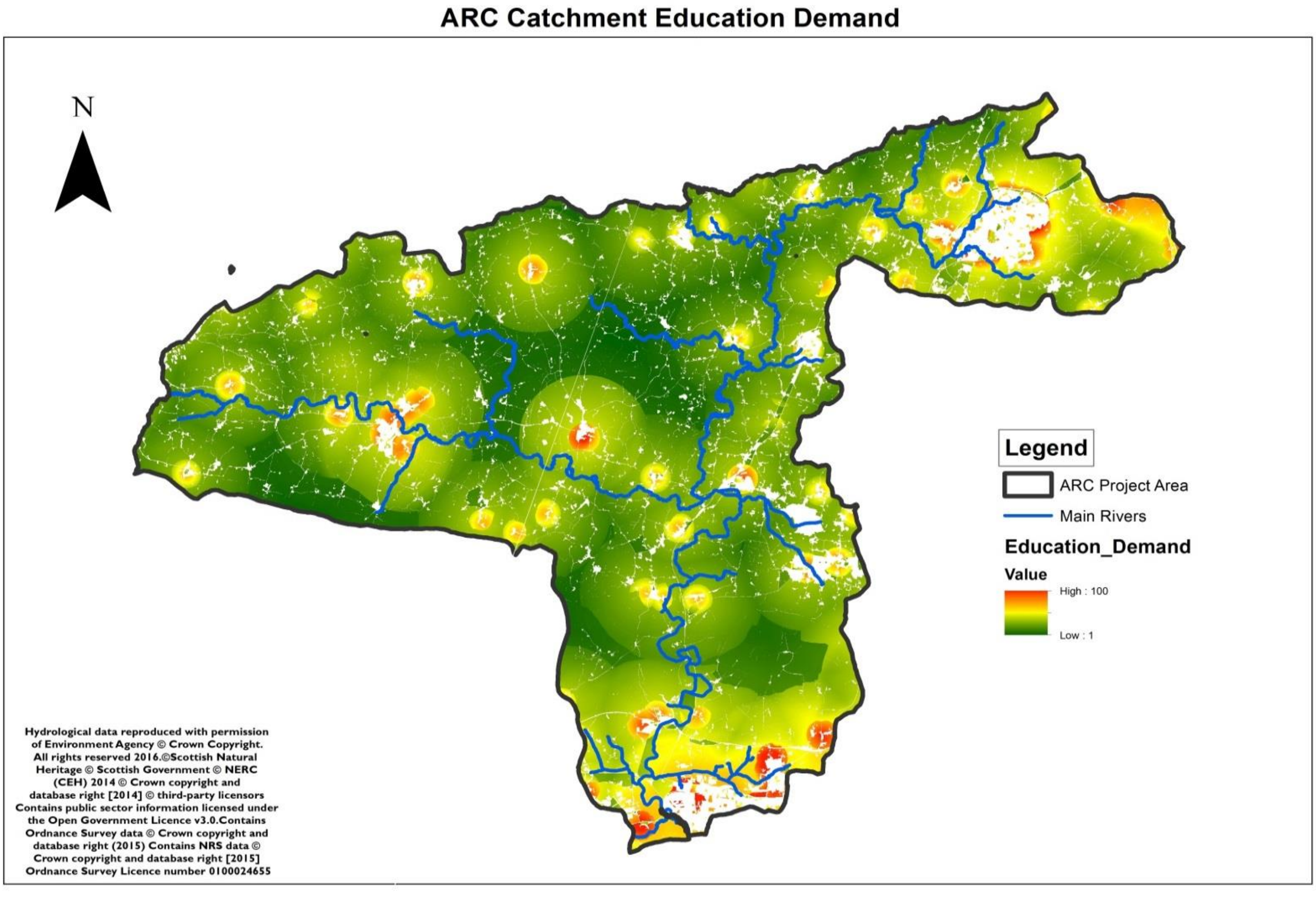
ARC Catchment Carbon Demand



Education Capacity

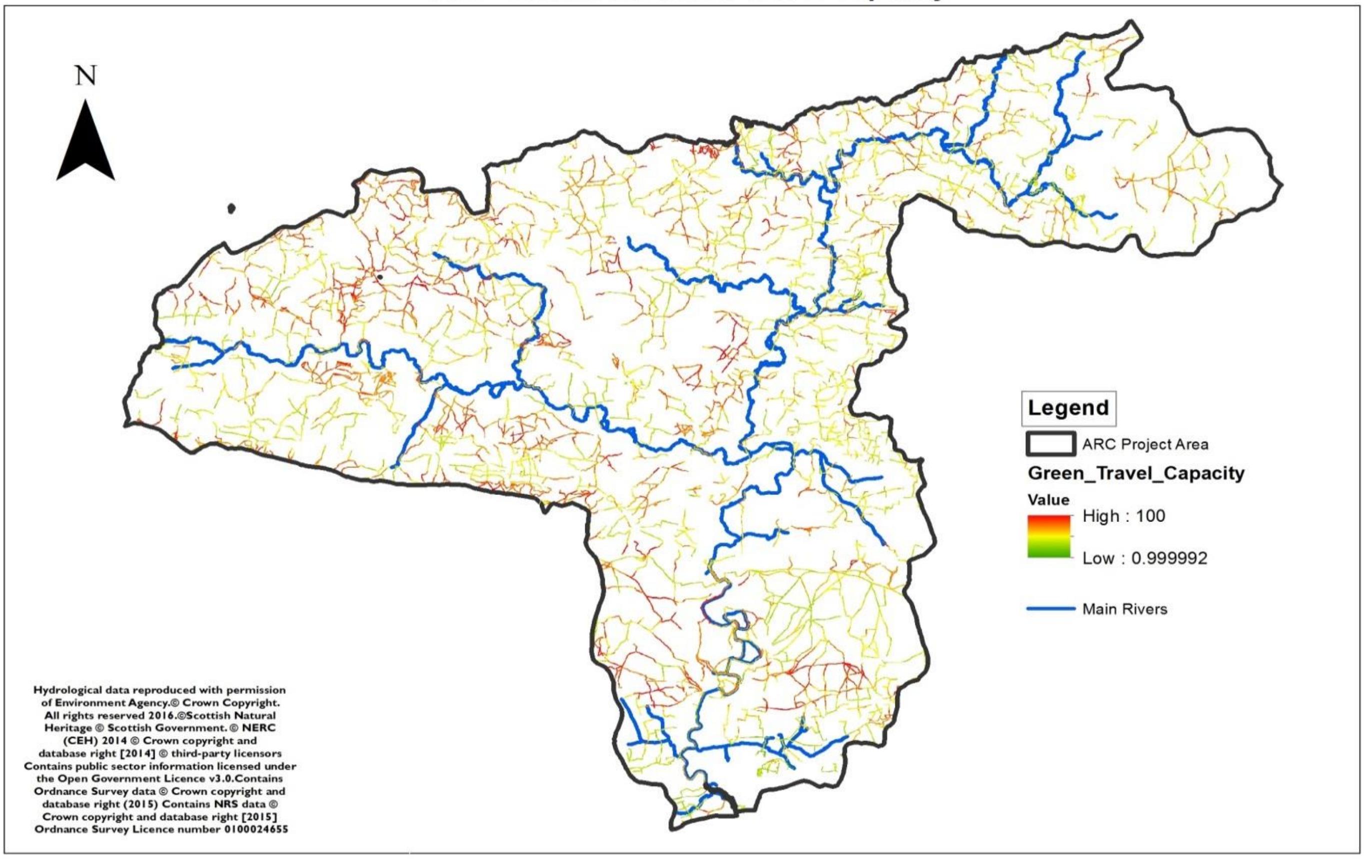


Education Demand



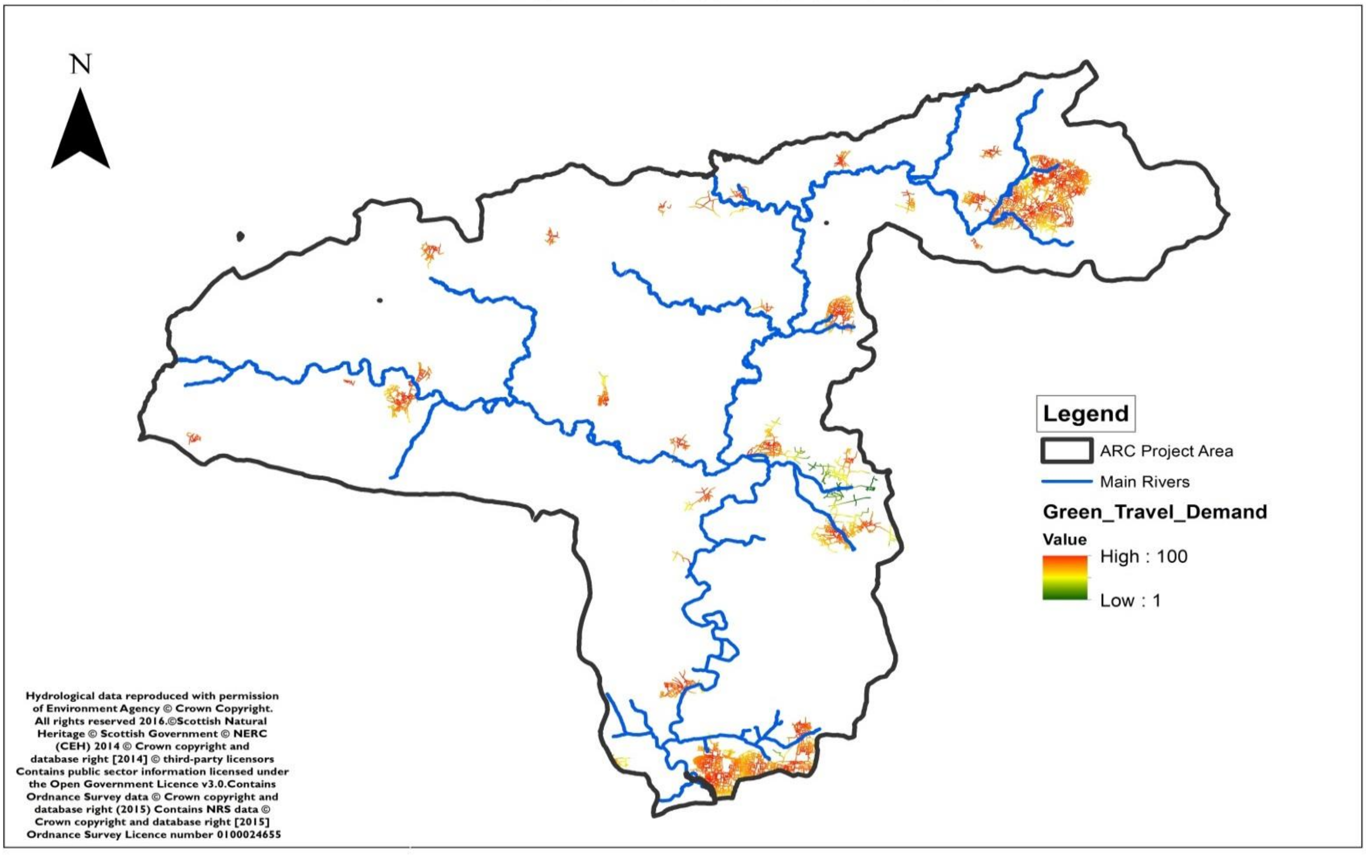
Green Travel Capacity

ARC Catchment Green Travel Capacity

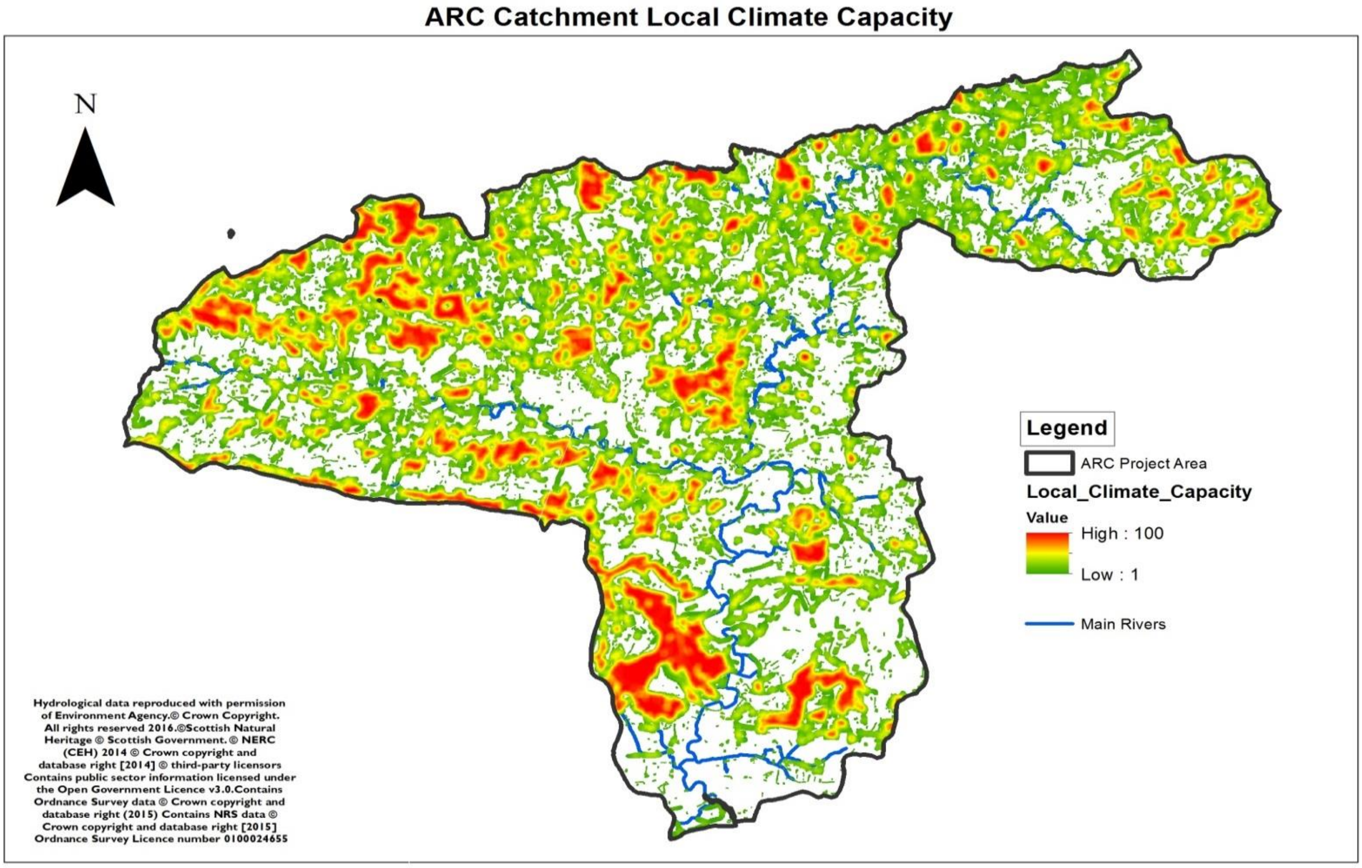


Green Travel Demand

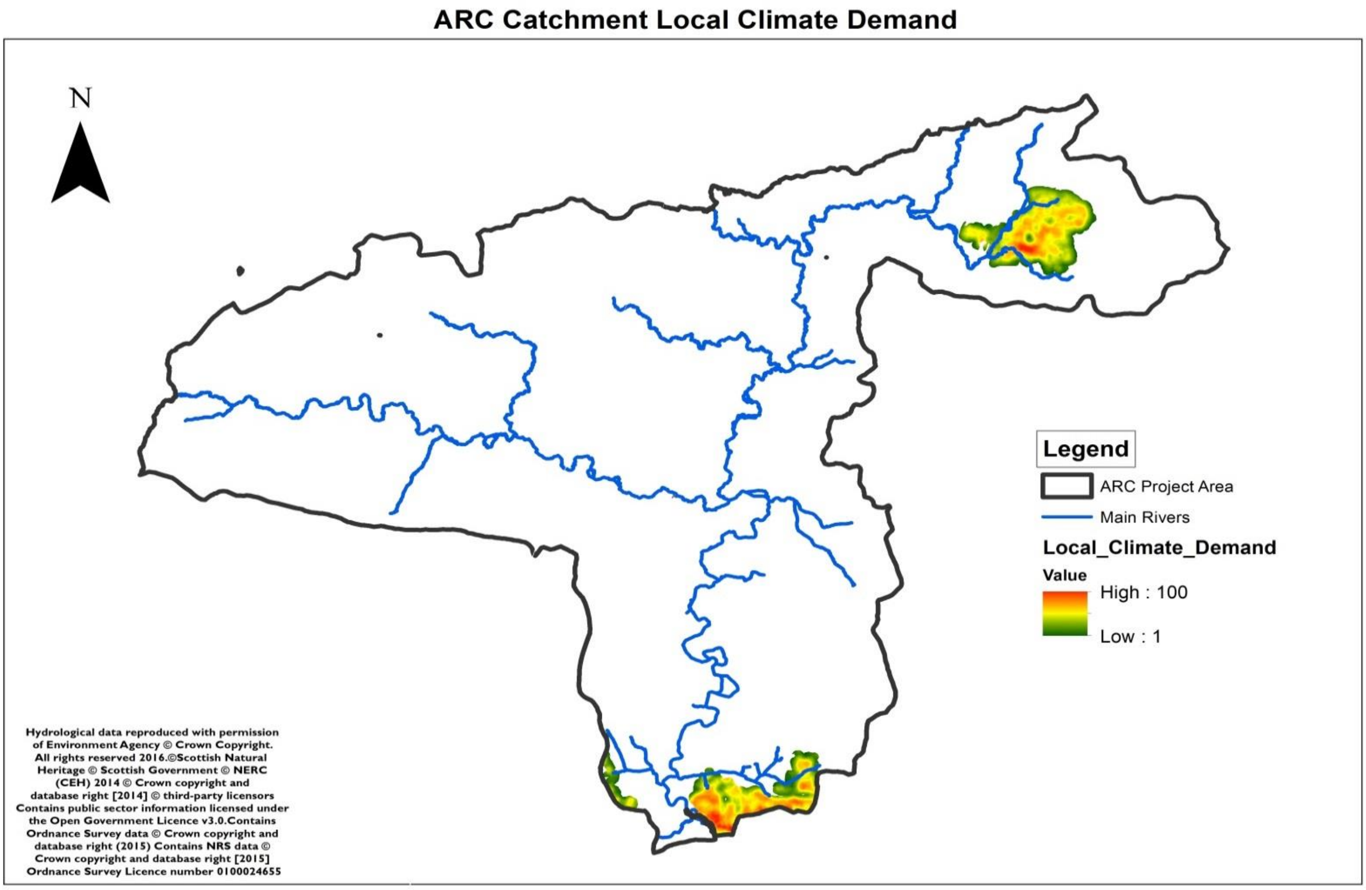
ARC Catchment Green Travel Demand



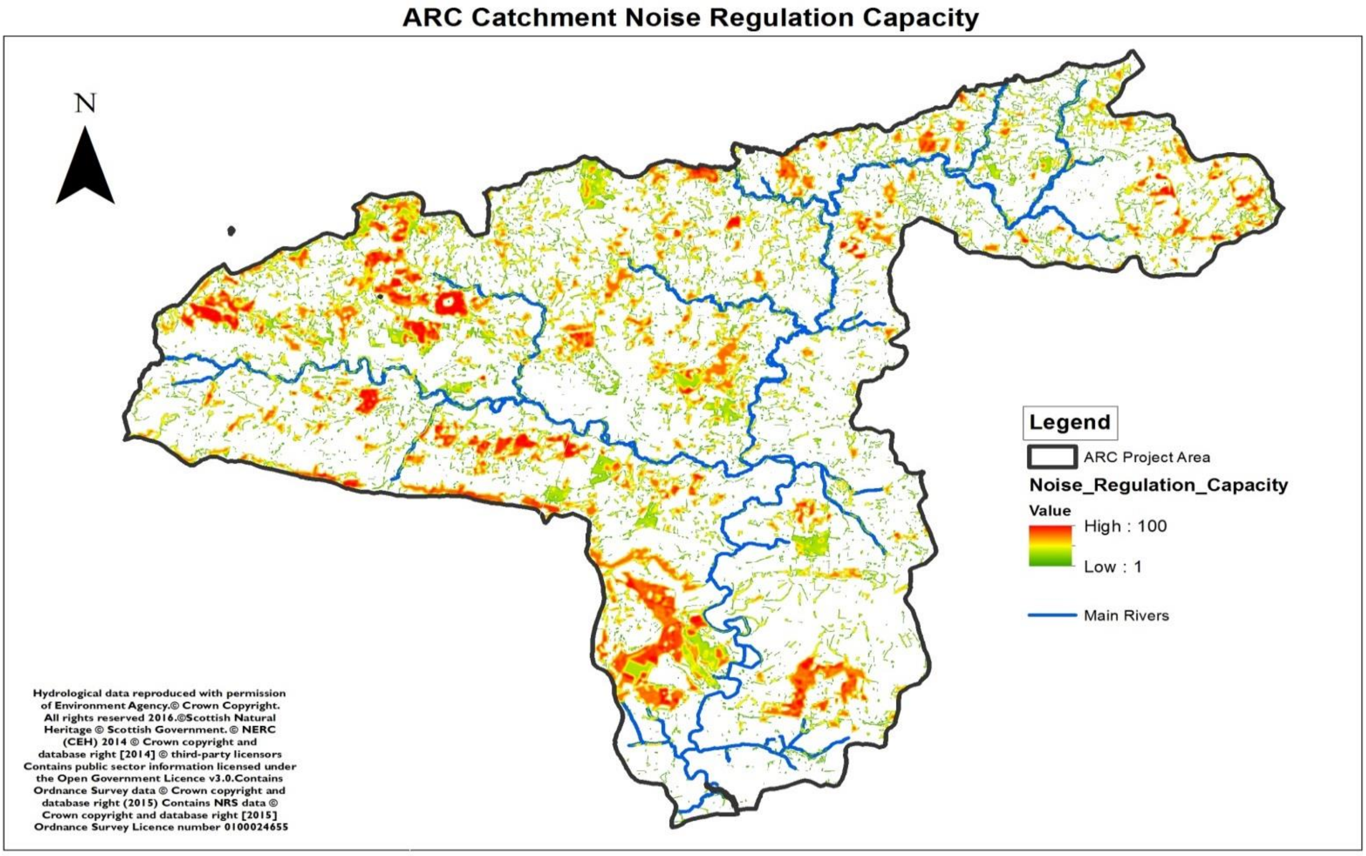
Local Climate Capacity



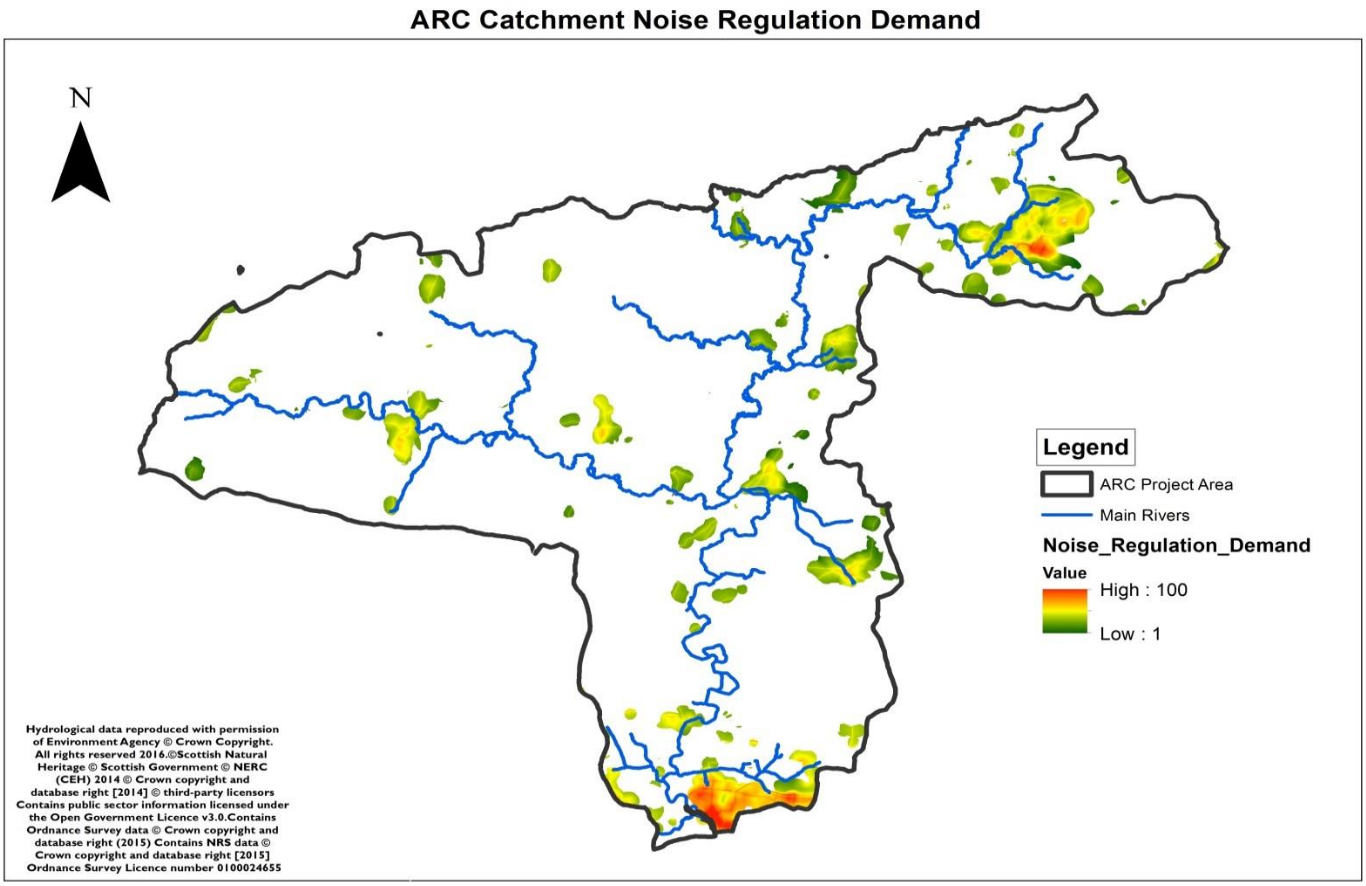
Local Climate Demand



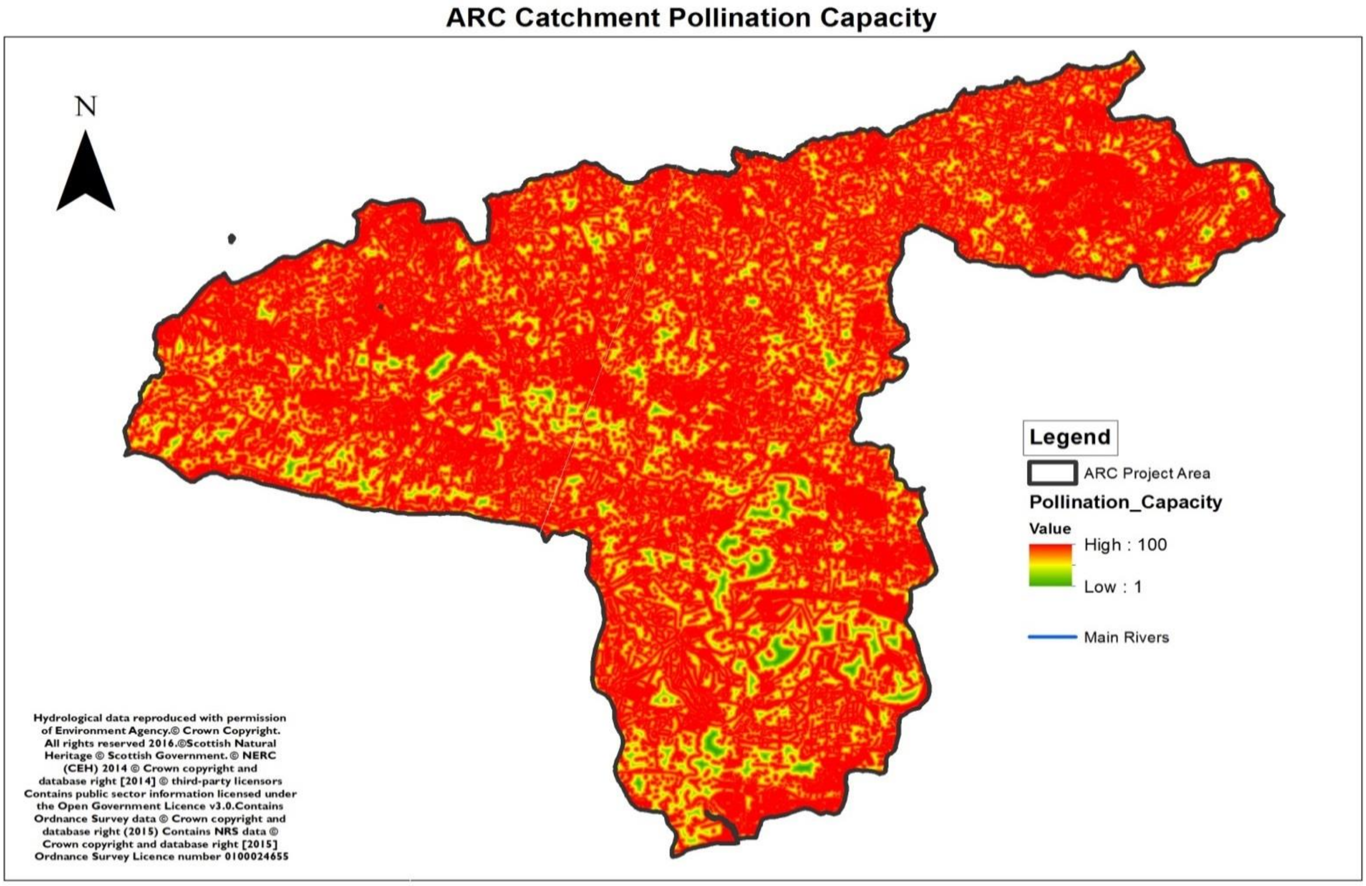
Noise Regulation Capacity



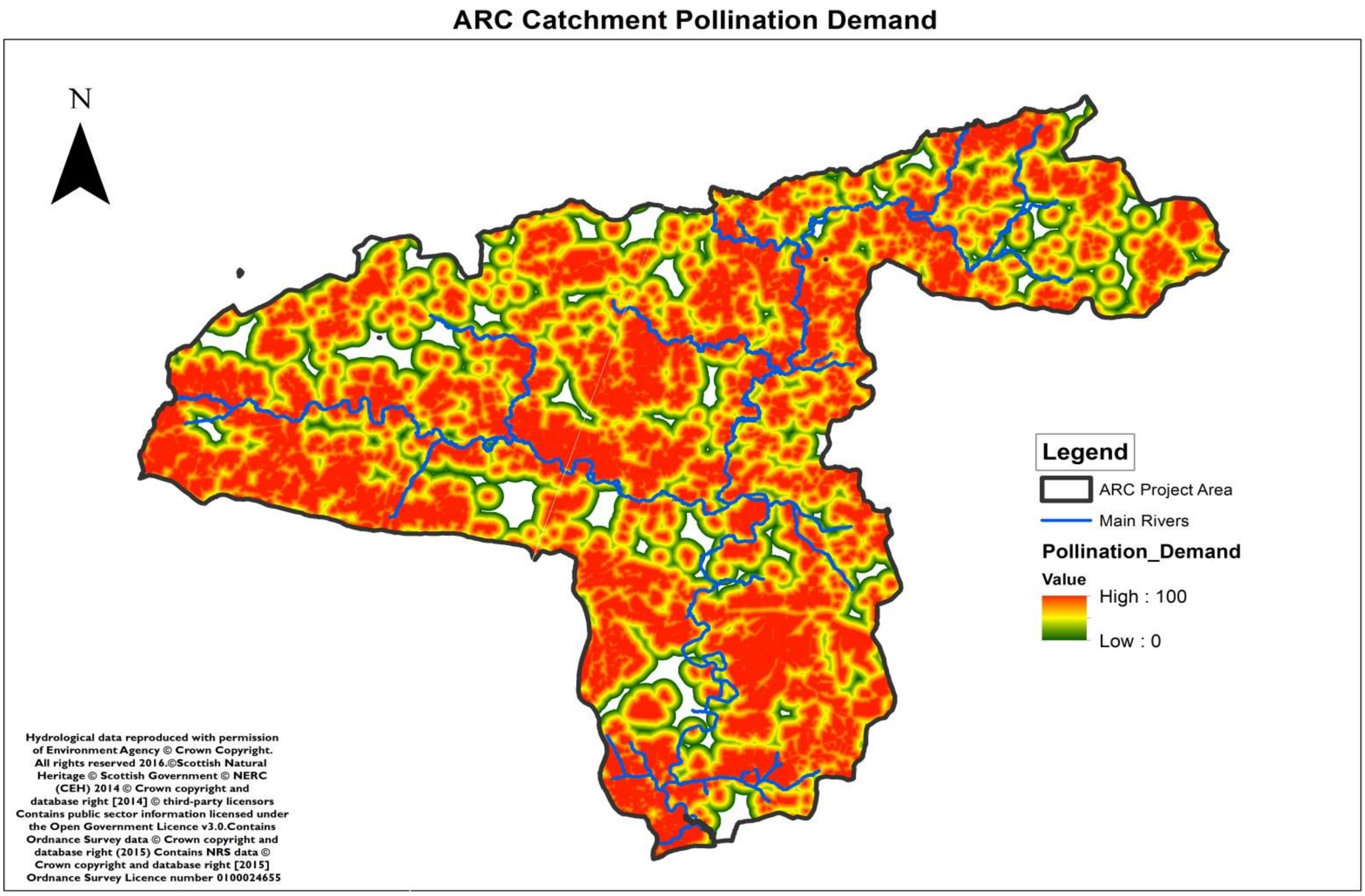
Noise Regulation Demand



Pollination Capacity

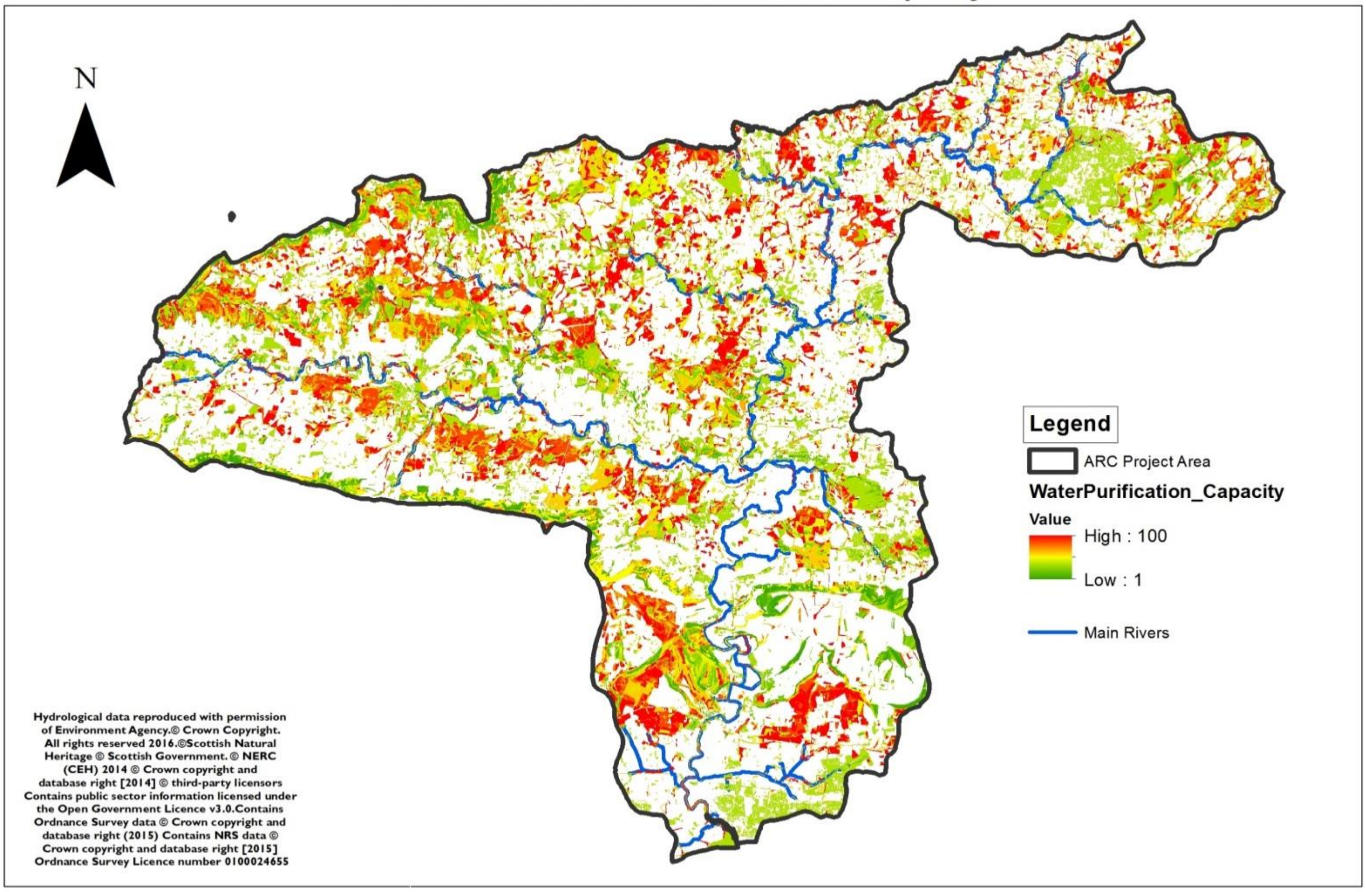


Pollination Demand



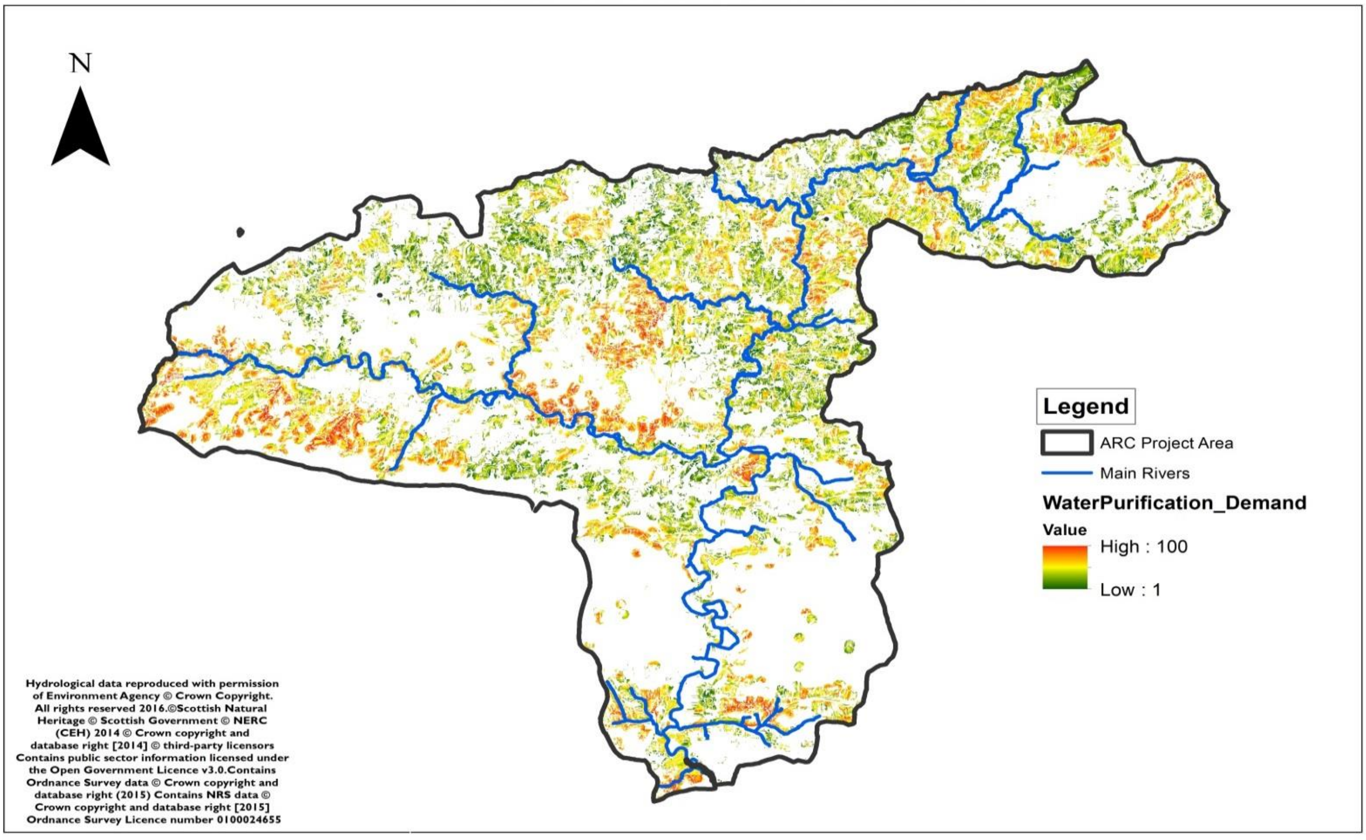
Water Purification Capacity

ARC Catchment Water Purification Capacity



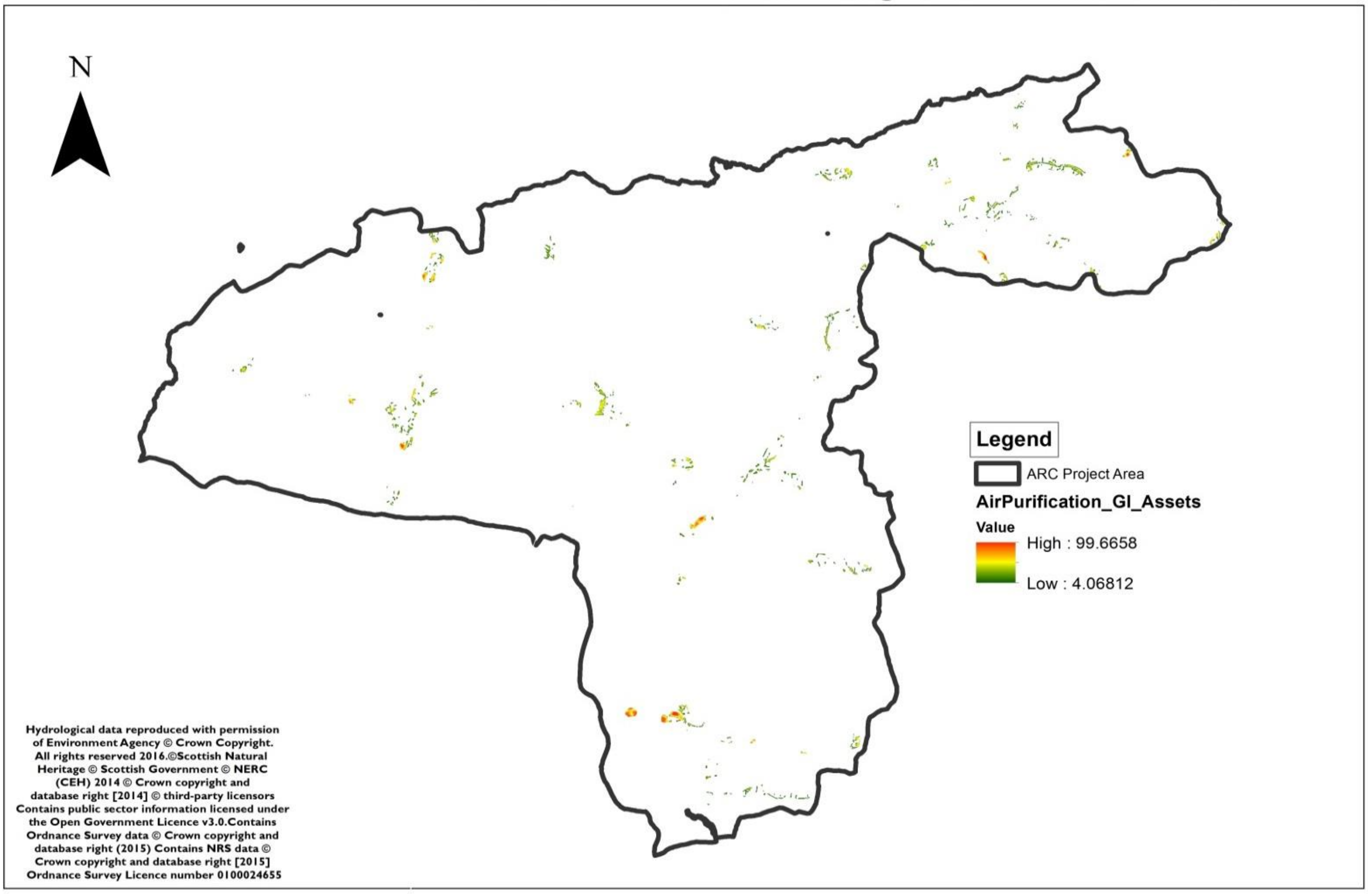
Water Purification Demand

ARC Catchment Water Purification Demand

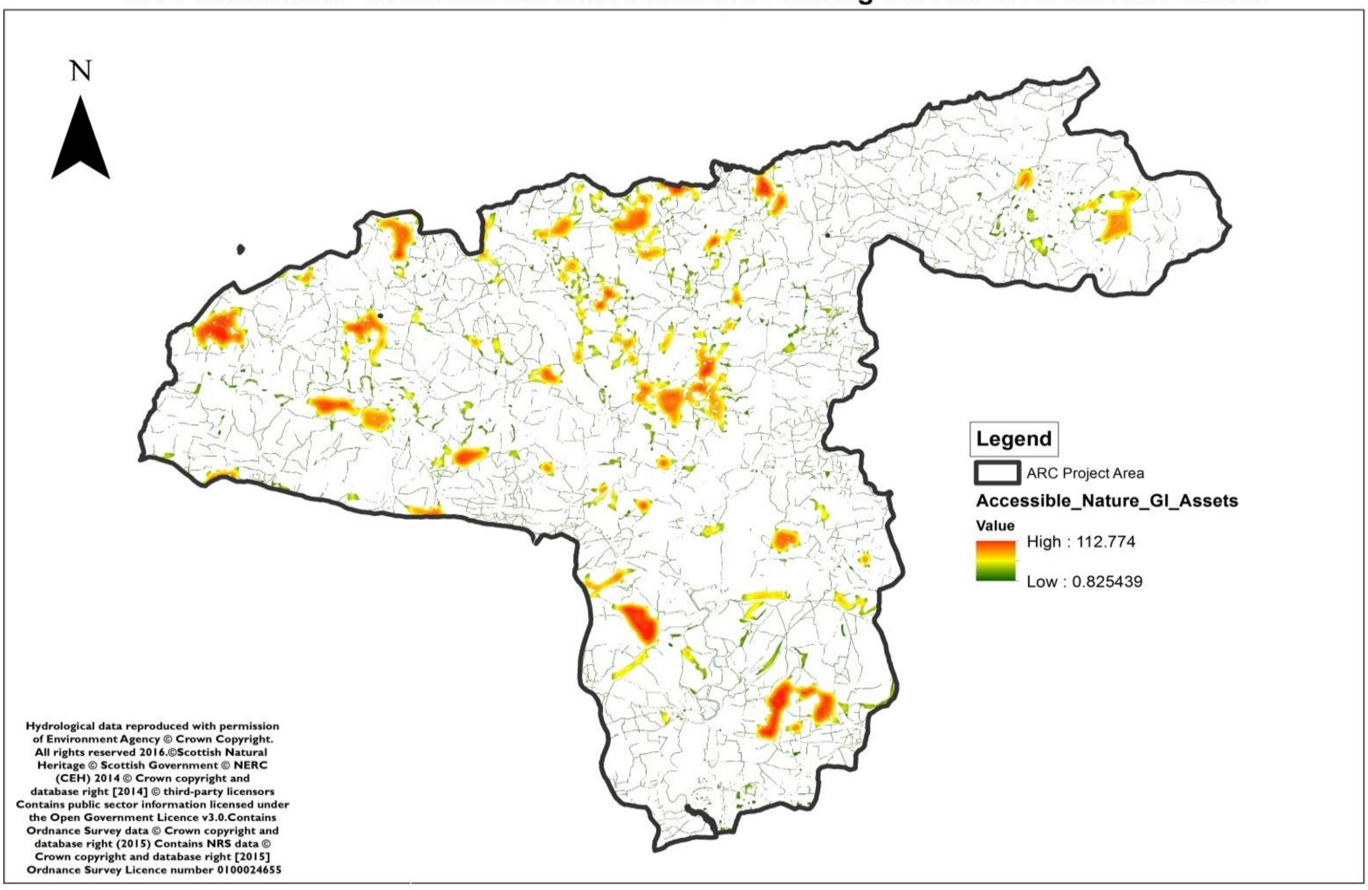


APPENDIX 3 - Areas of green infrastructure providing ecosystem services to the ARC project area

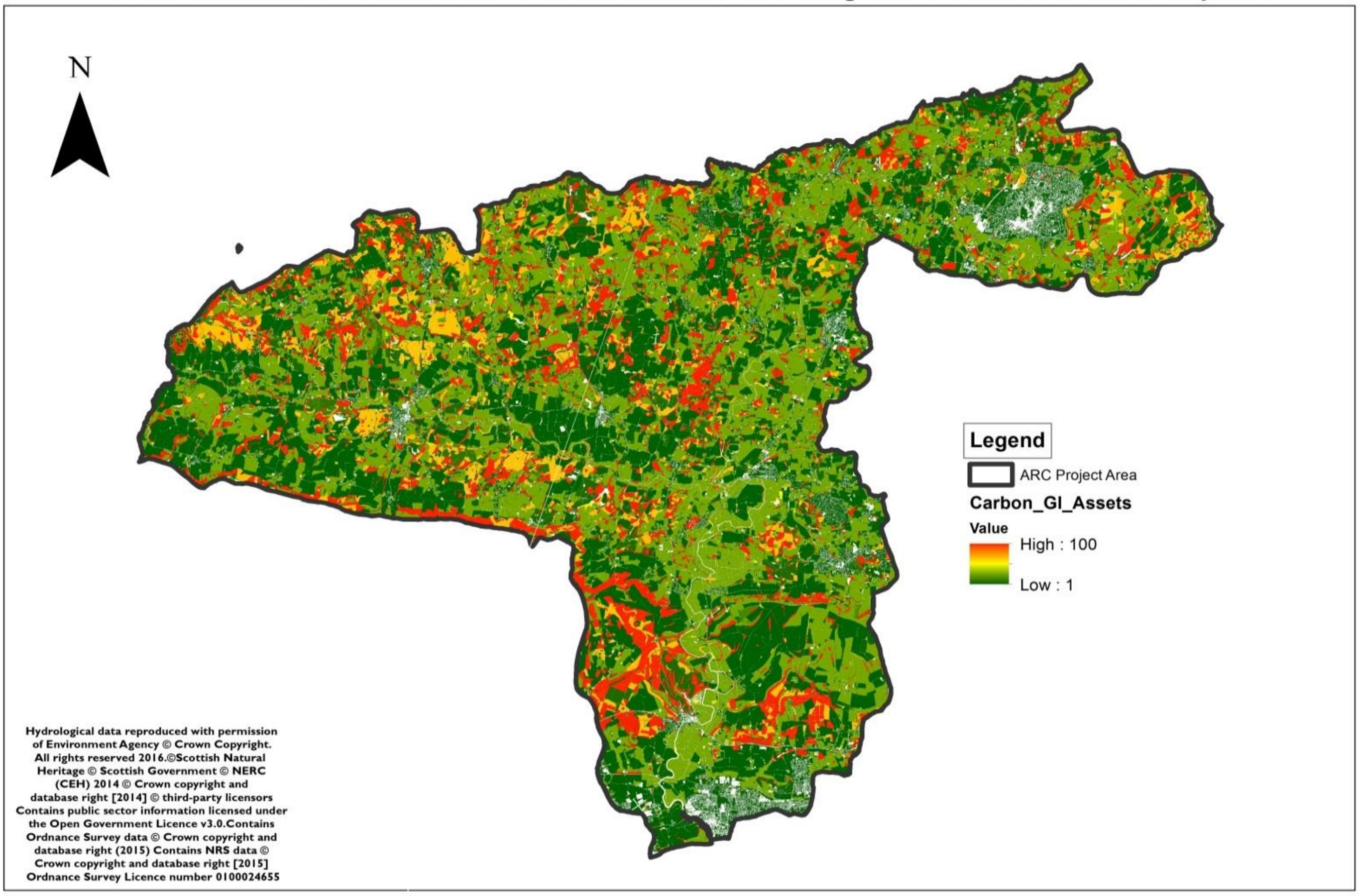
ARC Catchment - Green Infrastructure Assets Providing Service of Air Purification



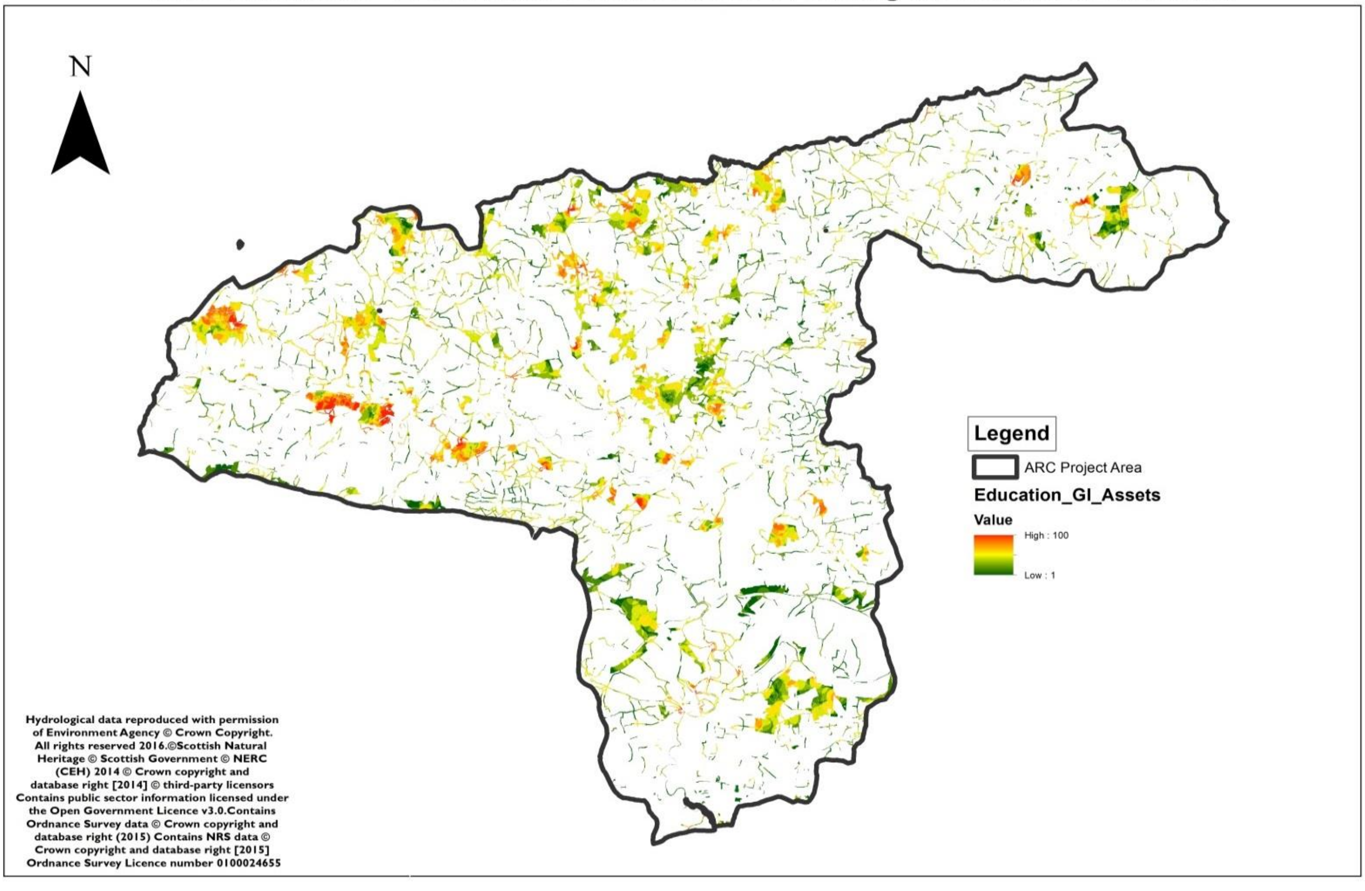
ARC Catchment - Green Infrastructure Assets Providing Service of Accessible Nature



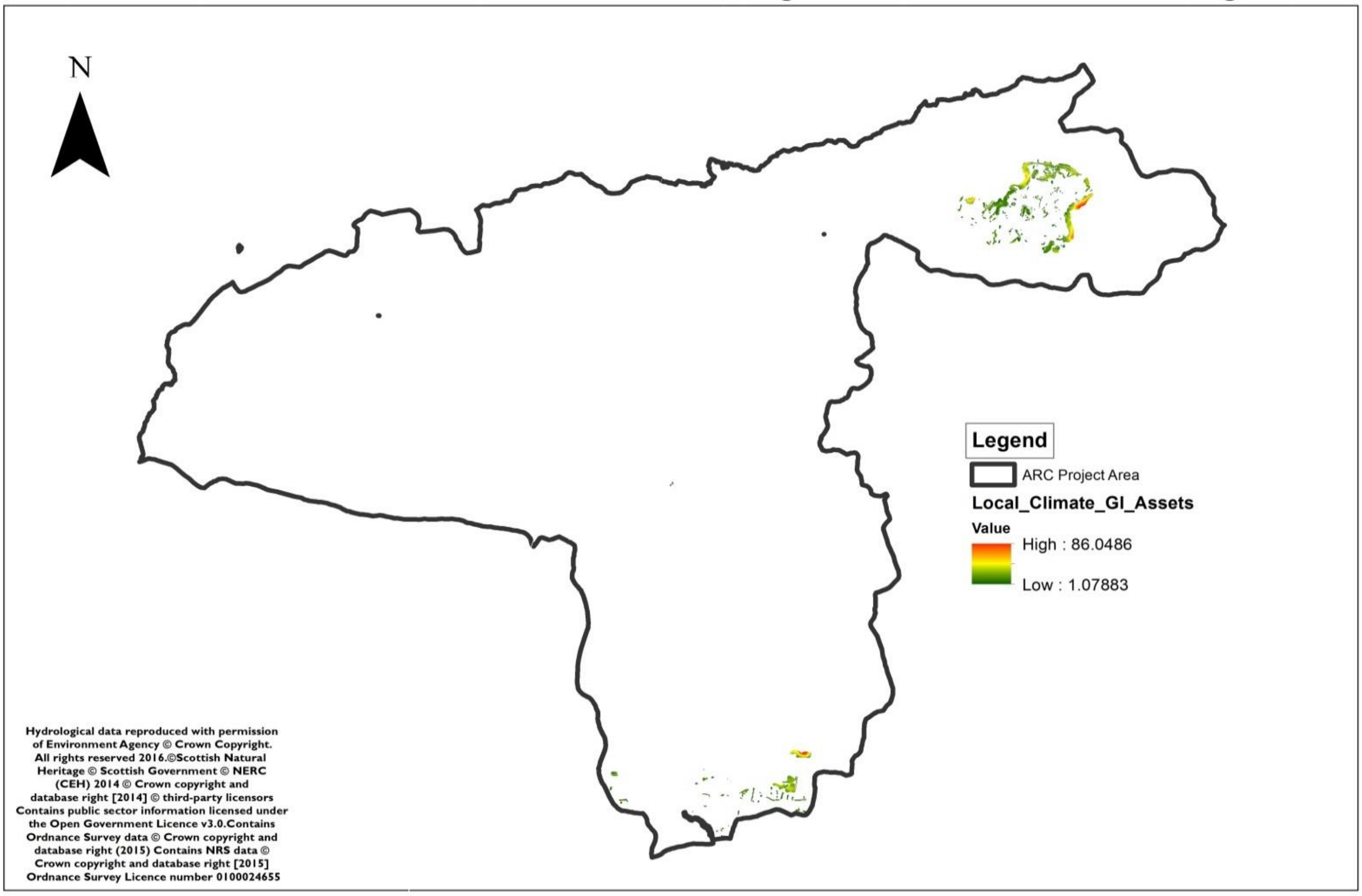
ARC Catchment - Green Infrastructure Assets Providing the Service of Carbon Capture



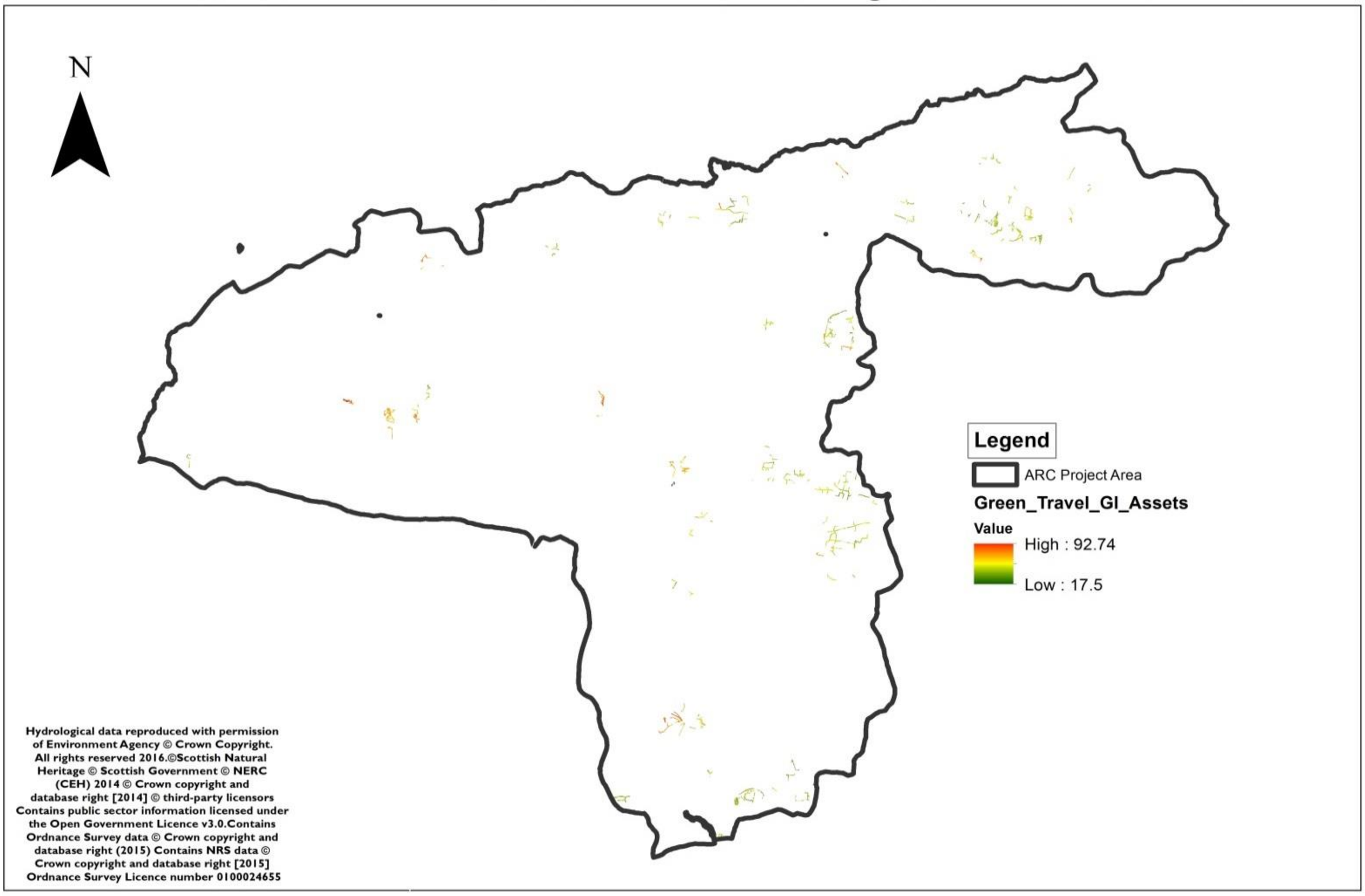
ARC Catchment - Green Infrastructure Assets Providing the Service of Education



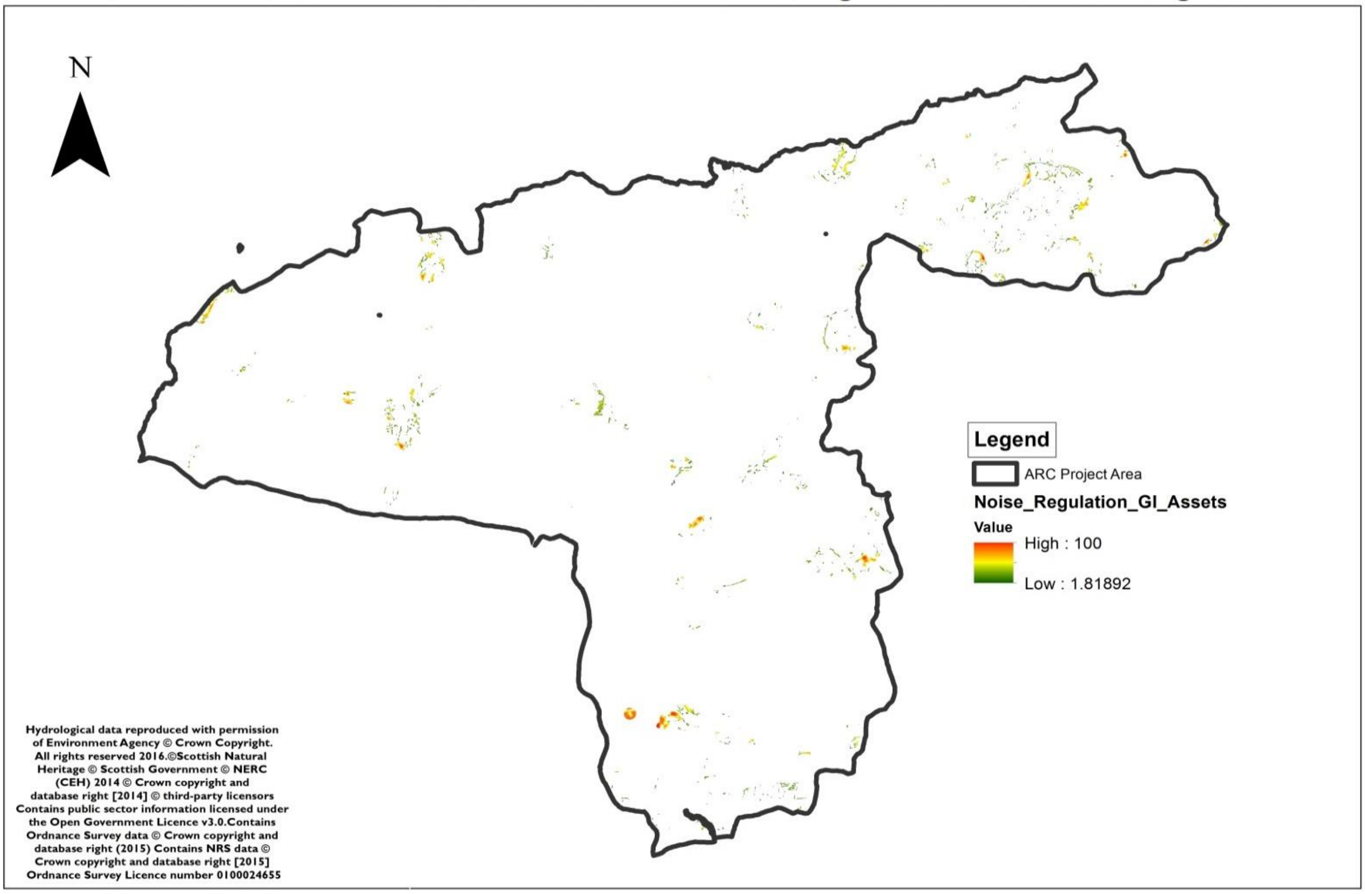
ARC Catchment - Green Infrastructure Assets Providing the Service of Local Climate Regulation



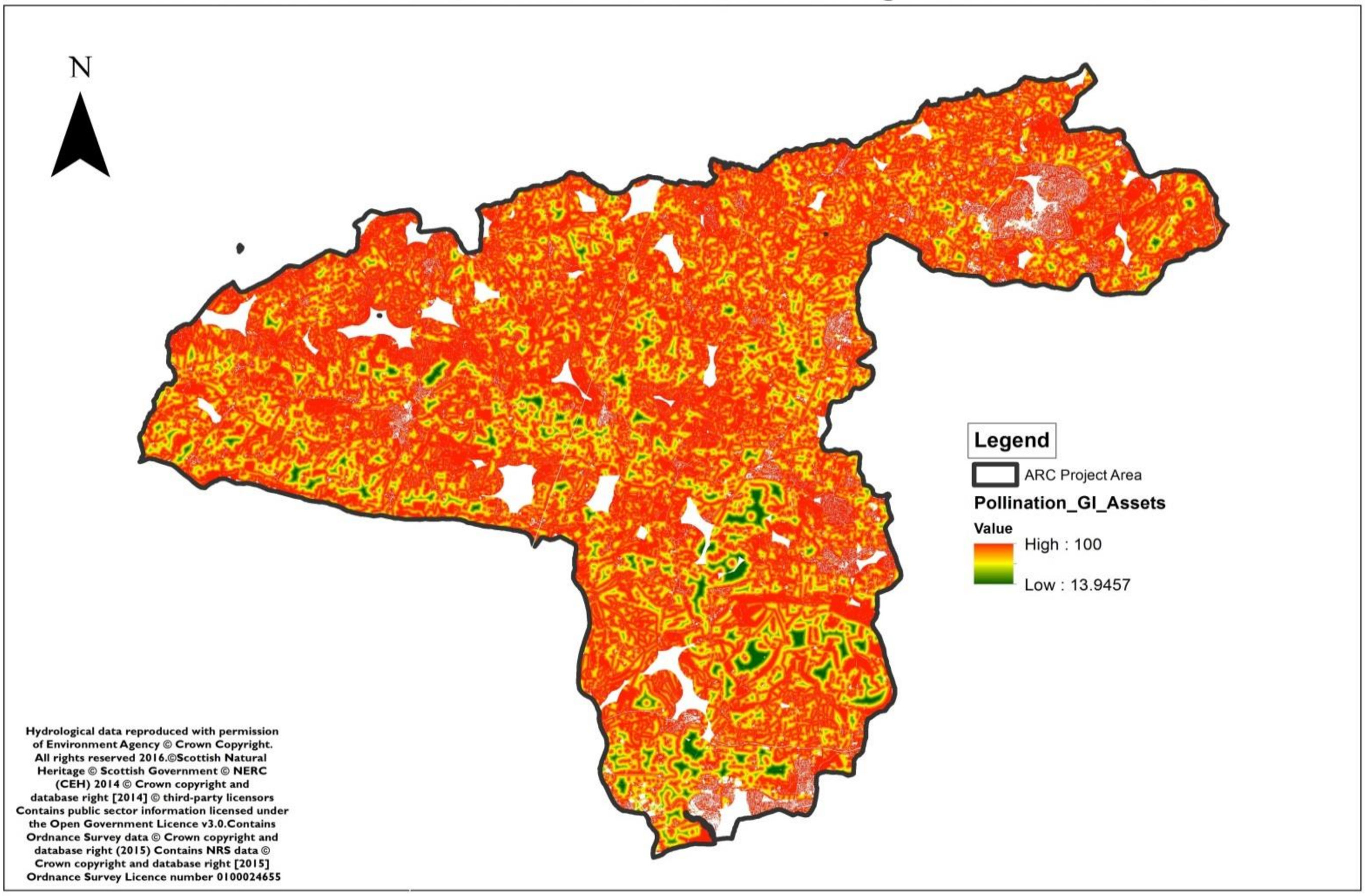
ARC Catchment - Green Infrastructure Assets Providing the Service of Green Travel



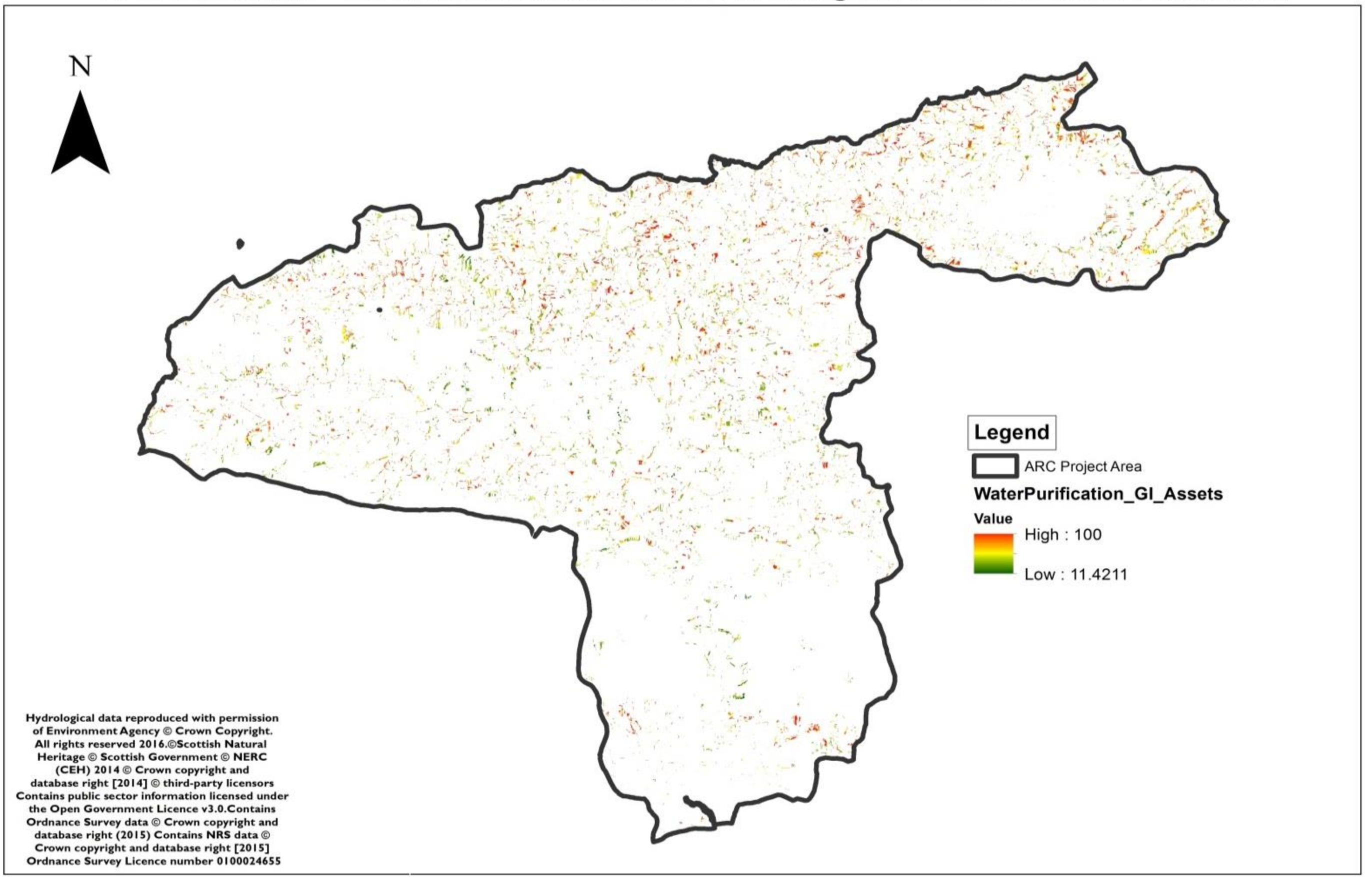
ARC Catchment - Green Infrastructure Assets Providing the Service of Noise Regulation



ARC Catchment - Green Infrastructure Assets Providing the Service of Pollination

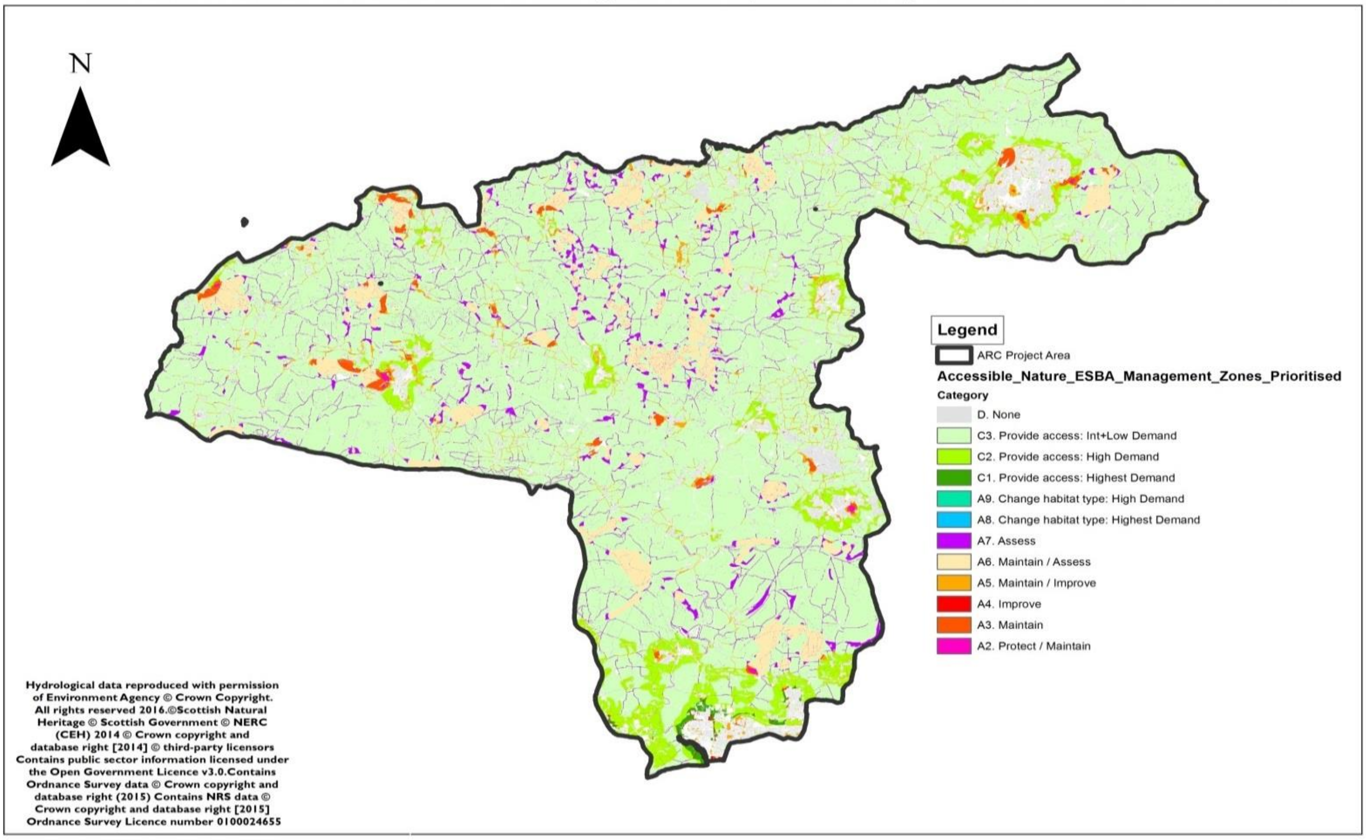


ARC Catchment - Green Infrastructure Assets Providing the Service of Water Purification

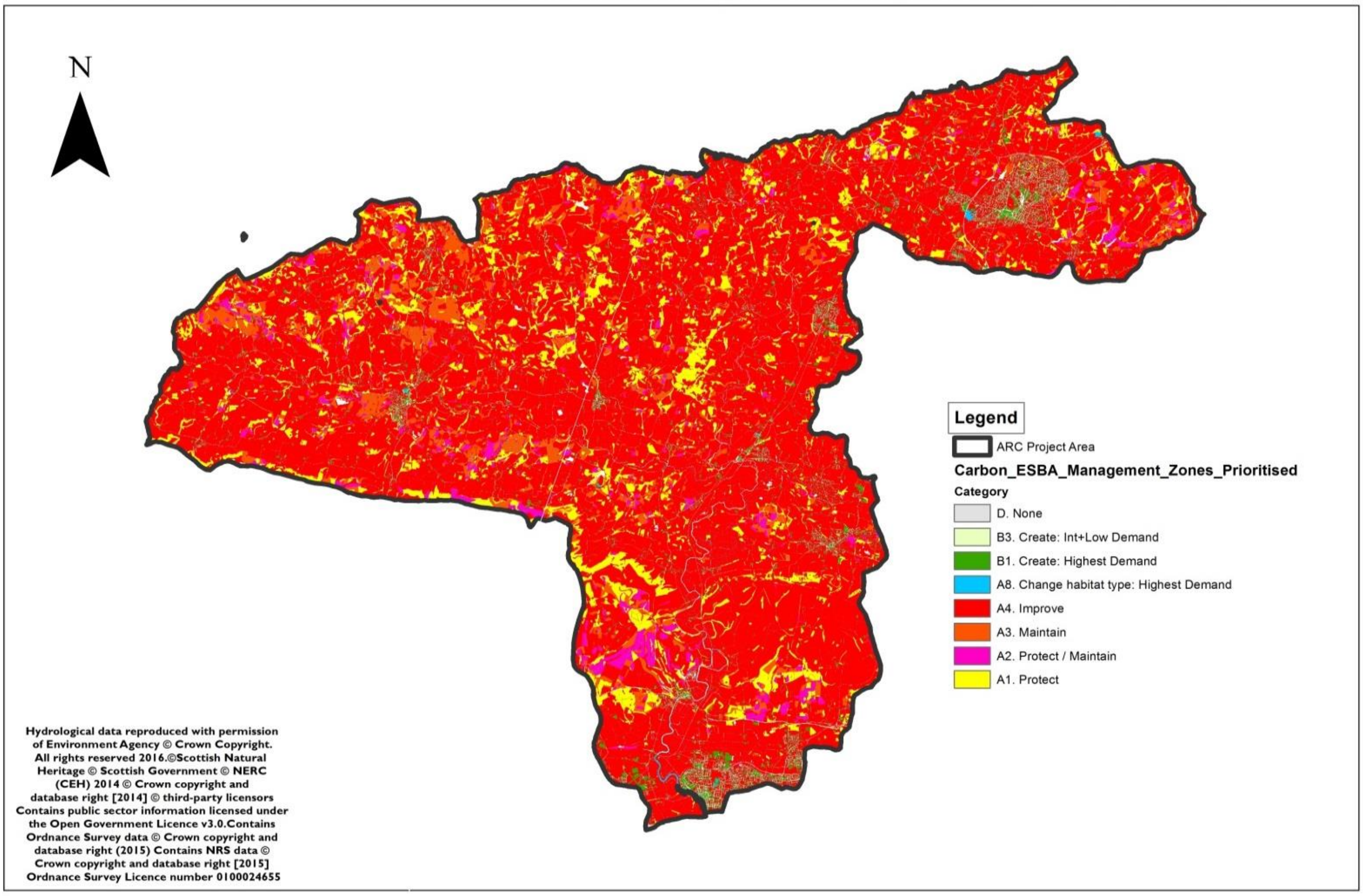


APPENDIX 4 - Recommended management change to enhance ecosystem service provision to the ARC project area

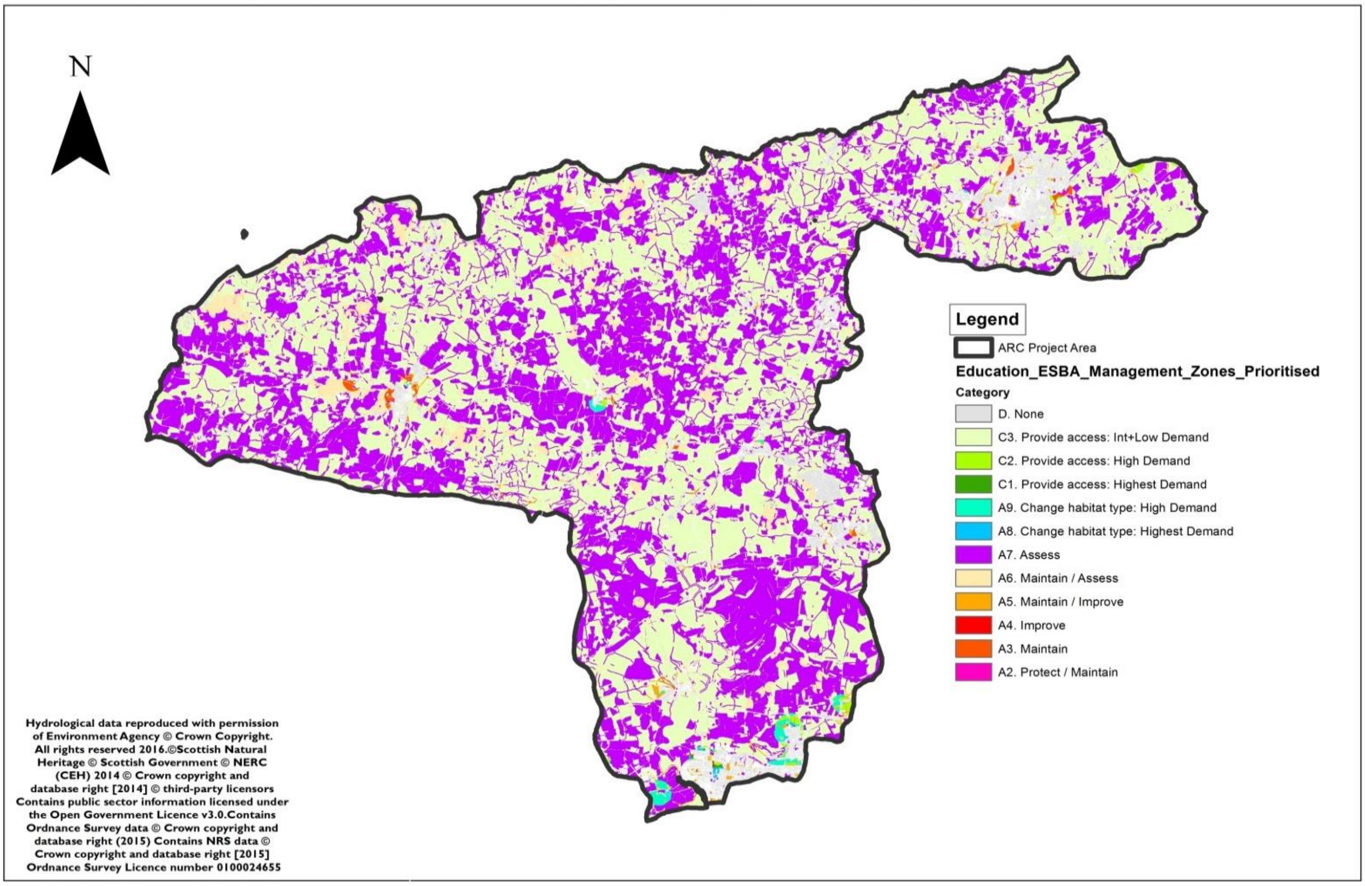
Accessible Nature : Recommended Management to Optimise Ecosystem Service Benefit Provision



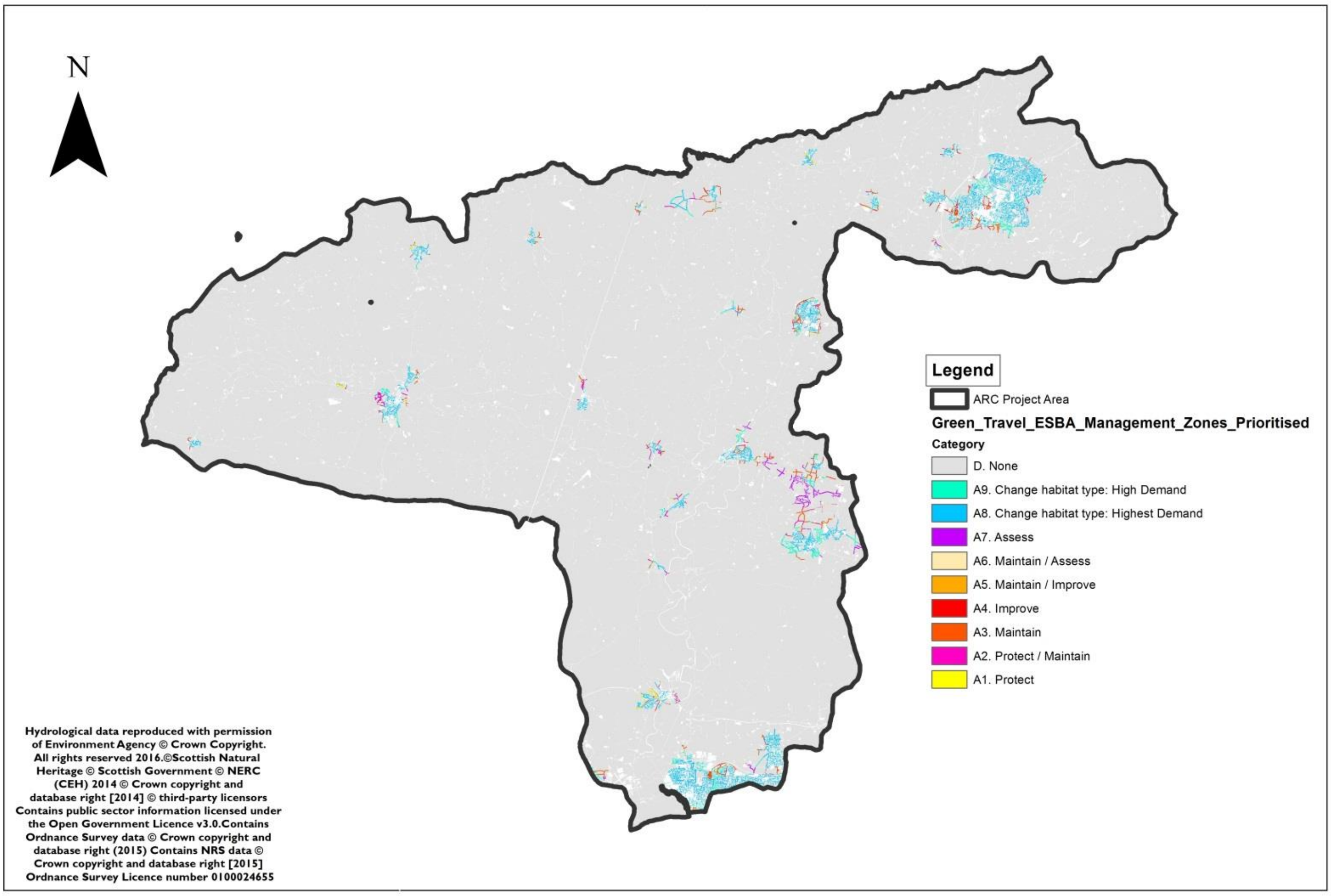
Carbon Storage : Recommended Management to Optimise Ecosystem Service Benefit Provision



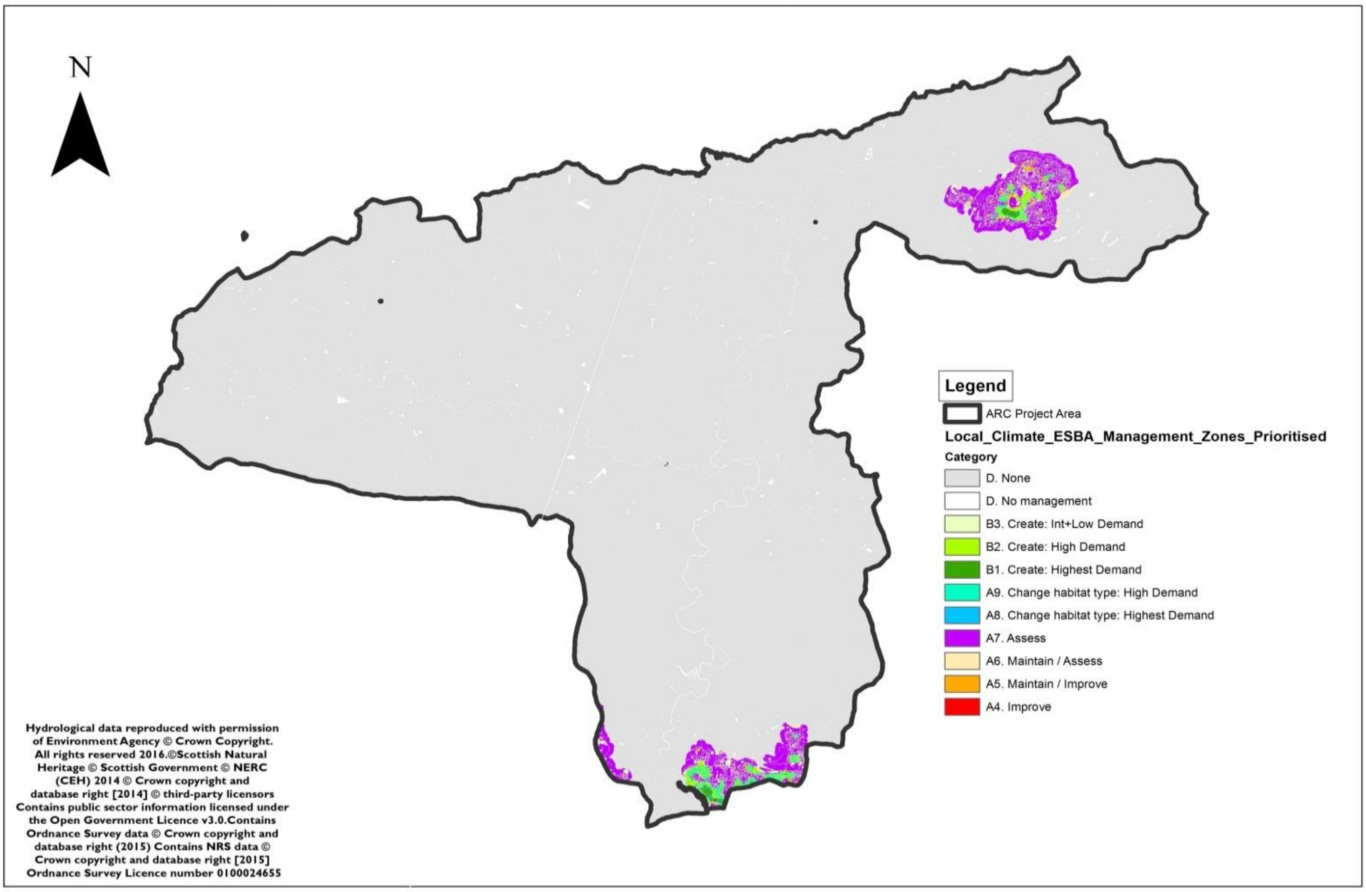
Education Capacity : Recommended Management to Optimise Ecosystem Service Benefit Provision



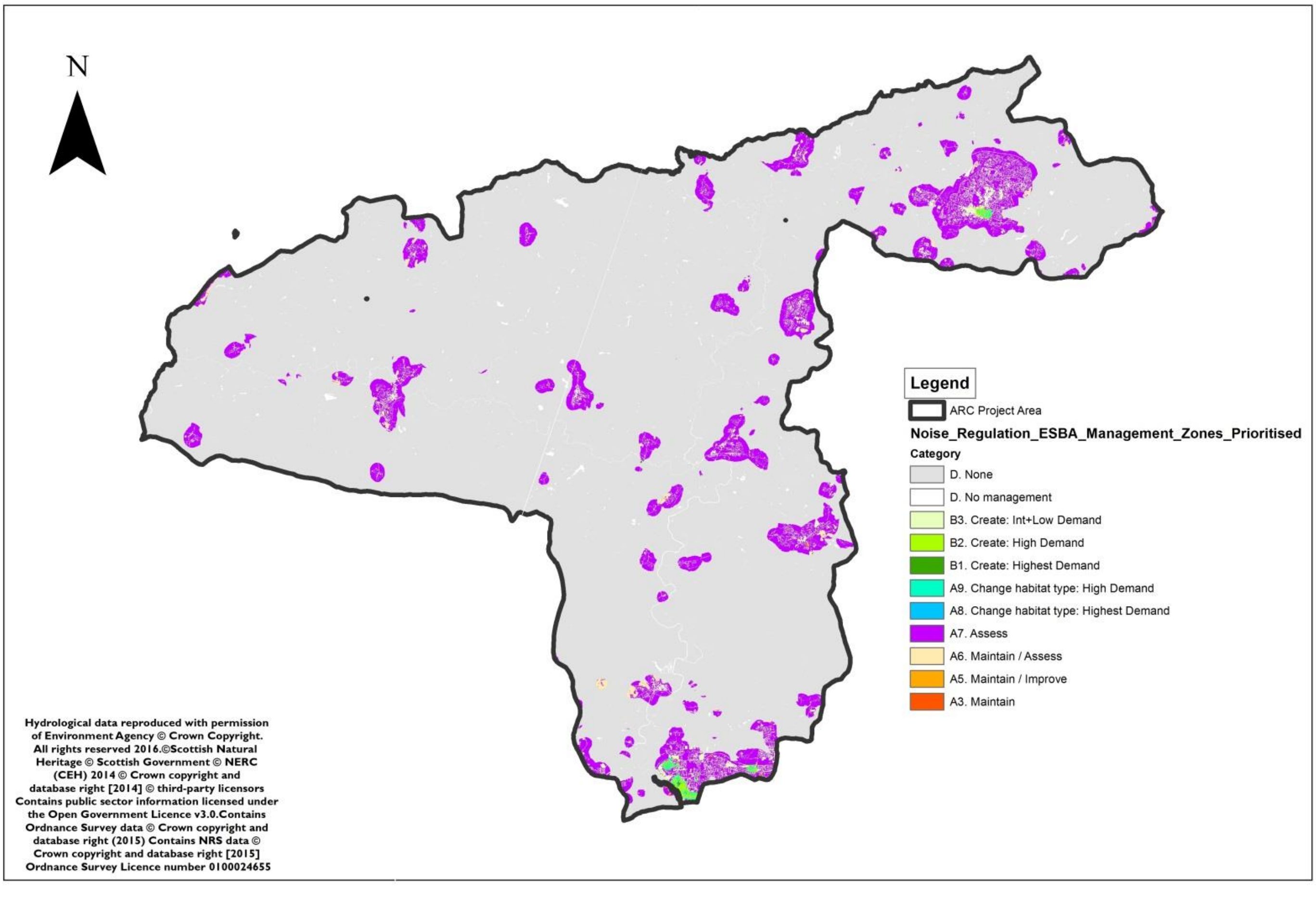
Green Travel : Recommended Management to Optimise Ecosystem Service Benefit Provision



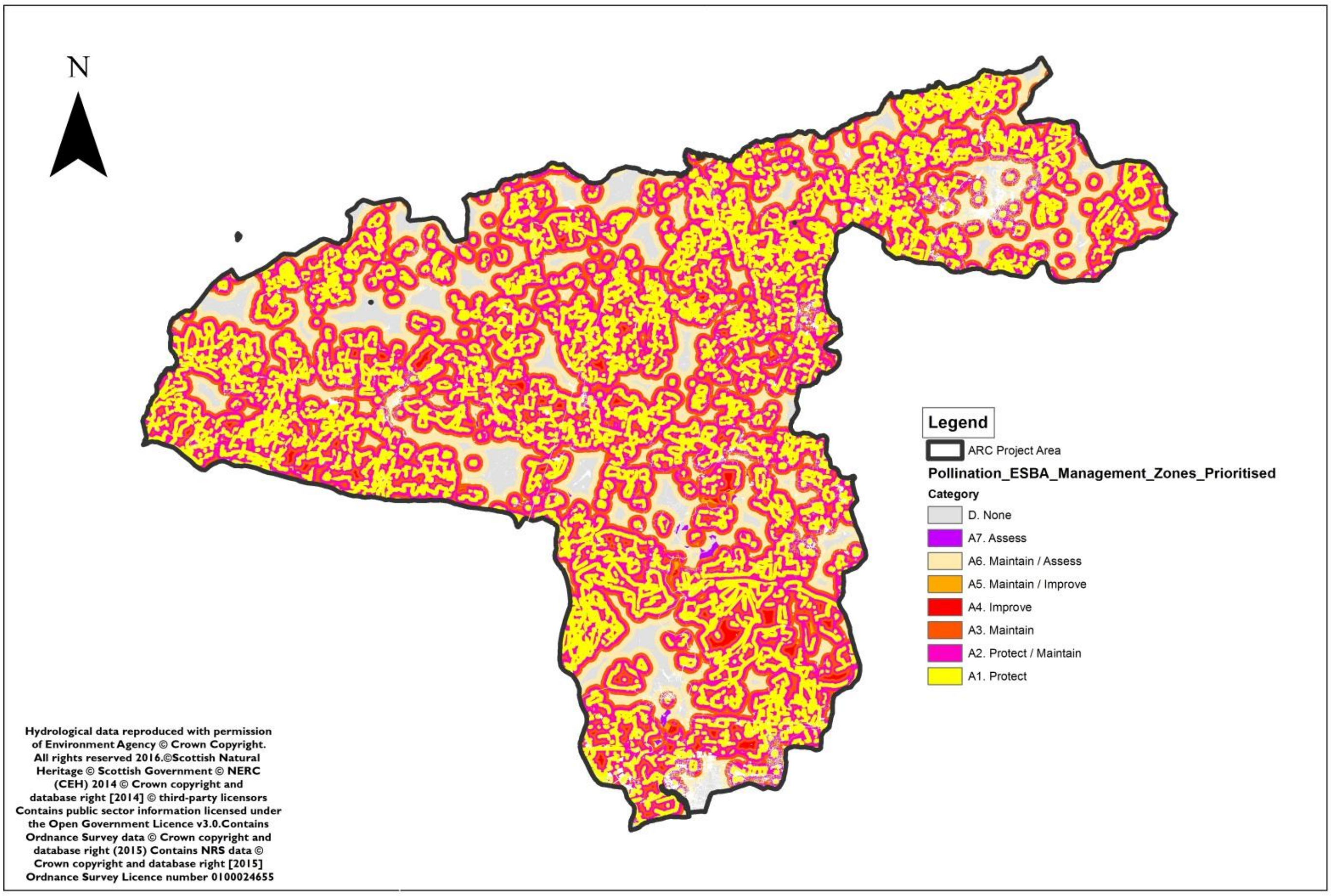
Local Climate Regulation : Recommended Management to Optimise Ecosystem Service Benefit Provision



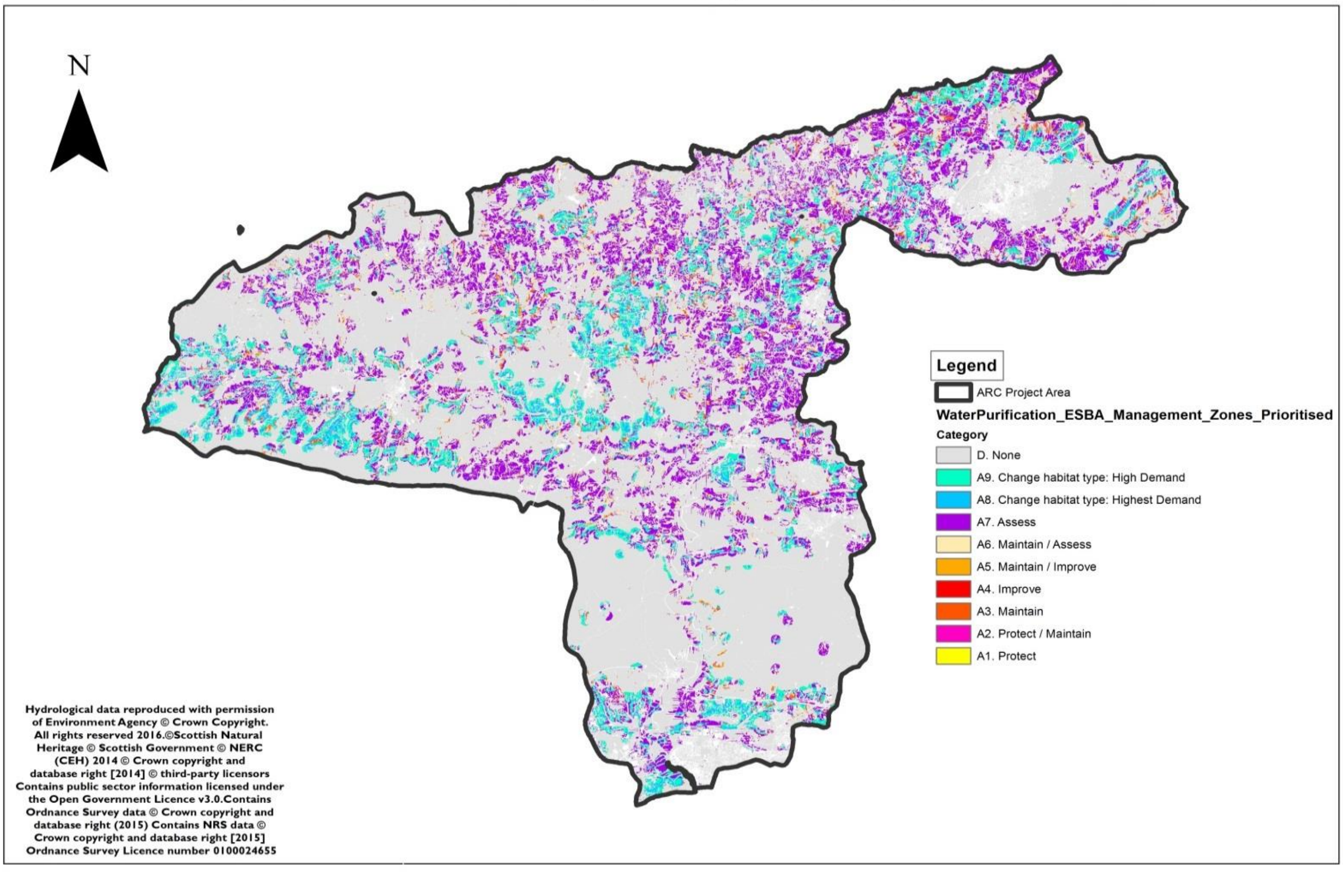
Noise Regulation : Recommended Management to Optimise Ecosystem Service Benefit Provision



Pollination Services : Recommended Management to Optimise Ecosystem Service Benefit Provision



Water Purification : Recommended Management to Optimise Ecosystem Service Benefit Provision



APPENDIX 5 – Reference legends for maps

Category

- D. None
- D. No management
- B3. Create: Int+Low Demand
- B2. Create: High Demand
- B1. Create: Highest Demand
- A9. Change habitat type: High Demand
- A8. Change habitat type: Highest Demand
- A7. Assess
- A6. Maintain / Assess
- A5. Maintain / Improve
- A3. Maintain
- A4. Improve
- A2. Protect / Maintain
- A1. Protect

Legend

- ARC Project Area
- Main Rivers
- Detailed River Network
- 1/100yr flood zone
- Sussex_AONBs
- SSSI's
- Local Nature Reserves
- Local Wildlife Sites
- Sussex_Pond_Inventory
- Sussex_heath
- Reedbed
- Pure fen
- Ghyll wodland
- Ancient Woodland

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