Quantifying environmental (natural capital) net gain and loss - Urban development demonstration: Liverpool City Region

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Executive Summary

The 25 Year Environment Plan set the direction for embedding a natural capital approach within regional policy and decision making. A key aspect of this is measuring change in natural capital and ecosystem services based on changes in the landscape due to housing or commercial development (i.e. for measuring environmental net gain, defined here as an overall increase in ecosystem service provision).

Here, we demonstrate the use of the tool EcoservR to assess net loss or gain in ecosystem services based on real-life (anonymised) developments within the Liverpool City Region. Master plans of the developments were digitised on to the Liverpool City Region Natural Capital Asset Map. Ecosystem service demand and capacity maps were then produced using spatial models run in EcoservR, based on the asset map pre- and post- development. The difference for both the ecosystem capacity score and demand score before and after were then calculated from these outputs.

The difference in scores pre- and post- development were calculated at different extents. This allows us to show the change in ecosystem service capacity (environmental net gain/loss) and demand at site, ward, local authority and city region scale. Such an approach has real benefits in understanding change in natural capital at both a site and strategic scale and can play a key role in policy setting in planning and environmental policy within the city region.

Introduction

It is now well understood that the natural environment plays a key role in underpinning human wellbeing and creating a more resilient and healthy economy. We can refer to the world's stock of natural resources (geology, soils, air, water and all living organisms) as natural capital, and benefits which flow from them as ecosystem services, which includes processes such as air purification, water flow regulation, and so on. The application of these concepts, referred to as the Natural Capital Approach**,** provides a key mechanism to achieve sustainable development. Recent policy and legislative direction in the UK ([1]25 Year Environment Plan, [2]Agriculture Bill and [3]Environment Bill) has moved towards implementing such an approach to improve the environment for people and nature. The net gain principle and ELMs will be key drivers of the approach through investment in natural capital. Key to such policies is the ability to assess change in natural capital and ecosystem services due to the changes in the landscape from developments or habitat improvements.

With the need to build more houses, drive for sustainable development and the need to conserve biodiversity, as well as the importance of nature for our health and wellbeing, it is increasingly important to use relevant evidence to inform planning decisions, as well as using natural capital assessments to inform infrastructure investments and provision.

Here, we apply the Ecoserv approach to allow the evaluation of losses and gains in ecosystem services due to developments. The Ecoserv approach was first applied using the Ecoserv-GIS software, produced by Winn et al. (2015).

The work presented broadly uses the methodological approach used in Rouquette, (2017). We build on this work by assessing not only the impact of the development on natural capital and ecosystem service loss or gain at the site itself, but also at various geopolitical extents (ward, local authority, and city region). We also present the EcoservR tool, used here to run the Ecoserv approach. This is a development of Ecoserv-GIS, written in the free and open-source programming language R.

Ecoserv-GIS software is no longer maintained, and does not function well. It is also dependent on ArcGIS ModelBuilder, which is part of the proprietary (and costly) ArcGIS suite by Esri. EcoservR also brings a number of improvements in model stability and speed, and more technical changes to model steps - such as automatic standardisation to produce directly comparable results, and automated production of a results summary before and after an intervention.

[1] https://www.gov.uk/government/publications/25-year-environment-plan
[2] https://services.parliament.uk/bills/2019-21/agriculture.html
[3] https://services.parliament.uk/bills/2019-21/environment.html

We believe that the Ecoserv approach showcased here could be invaluable in terms of assessing environmental net gain across numerous scales, as well as allowing policy makers and developers to optimise their land use for maximum benefit and meet emerging legislative requirements. This has been demonstrated in the past through the work done by Natural Capital Solutions, who have used this approach extensively to assess natural capital and identify opportunities for stakeholders.

With the flexibility of this tool, it could also prove useful in terms of smaller projects or be used to leverage funding and support investment opportunities in environmental projects, and equally can be used to assess the effects of innovative landscape use changes, in addition to more traditional developments. In addition, this approach allows identification of multiple benefits derived from biodiversity net gain investment[4] and can be used to advise a strategic approach to planning.

The aim of this study is to demonstrate the use of this dynamic natural capital assessment tool by evaluating the gains and losses of developments to ecosystem service capacity and demand at various spatial scales in the Liverpool City Region.

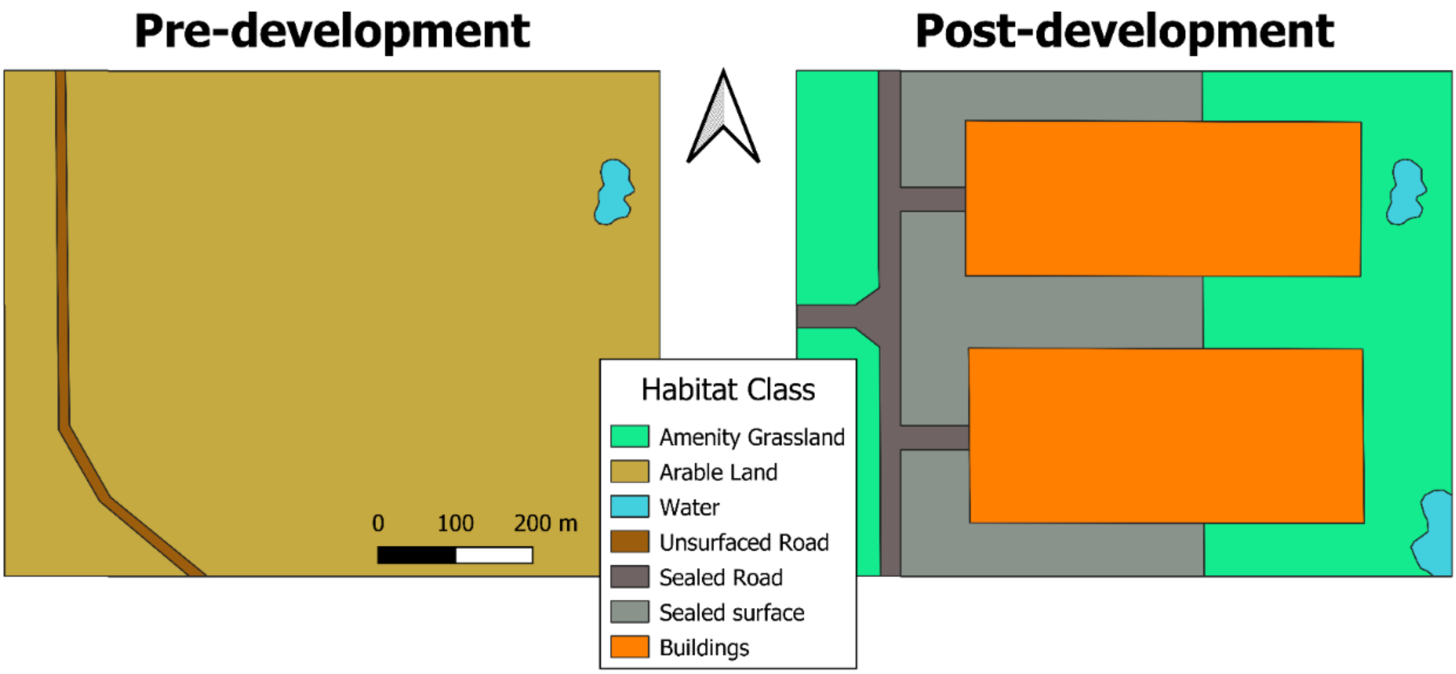
[4] The recent Government White Paper 'Planning for the Future' reaffirms commitments that biodiversity net gain will become a mandatory part of the planning process and signal a direction of movement https://www.gov.uk/government/consultations/planning-for-the-future

Methodology

Here we describe the introduction of interventions (proposed developments) to the asset map. We then analyse the effects interventions have on ecosystem service capacity and demand across a number of scales.

It is important to note that the interventions analysed here are developments that were planned under current legislation, without specific aims to achieve net gain. Additionally, they may have been mapped at a stage of development when not all mitigation efforts had been fully planned. They are presented here in an anonymised manner, for demonstration purposes only.

Figure 1 – An illustration of change to the asset map, both pre- and post-development. This demonstrates how intervention scenarios are mapped on to the asset map in order to analyse the effects of changes in land use on natural capital. Here, a mocked-up development is used for demonstration purposes.



The first step of analysing the effects of a development on natural capital and resultant ecosystem services is to digitise the intervention. This can be done by digitising master plans of the development provided by developers or authorities, or by digitally drawing a model development - for example, based on average size and type of building, proportion of greenspace, etc. In this demonstration, developments were selected from relevant examples of real-life developments planned throughout the Liverpool City Region, and anonymised. PDF files of master plans were obtained from publicly accessible planning portal pages on local authority websites and digitised using GIS software. This digitisation process is time-consuming but can be avoided altogether in cases where developers can provide shapefiles of their developments, or where CAD files are available to be converted to GIS shapefiles. We anticipate that as demand for the Ecoserv approach grows, provision of shapefiles for developments may need to become mandatory.

Development 1 consists of a subsection (approx. 0.33km^2 / 33 ha) of a large housing development, which involved the conversion of arable land to houses and gardens, as well as the addition of dedicated green spaces. Development 2 is a larger industrial development (approx. 0.42km^2 / 42 ha), where previously arable land was developed into large industrial buildings with the addition of some small roads. Finally, the smallest site, Development 3 (approximately 0.002km^2 / 0.2 ha), involved the conversion of an unused area of mostly sealed surfaces to a small building complex. The habitat composition of each of these sites, both before and after development, is summarised in Table 1.

Sites used for analysis in this document have been anonymised and are presented here to demonstrate the effectiveness of the tool. However, this comes with the caveat that maps of such results, which are a very important output of this toolkit, are not shown. We envisage that when the tool is applied for “real-life” decision making, the asset map before and after the development (see Figure 1) and changes in ecosystem services would be published alongside the results of such analyses for evidence base purposes (see also Rouquette, 2017).

Table 1 - Site habitat composition by percentage, pre- and post-development.

	Habitat	% Cover Pre-development	% Cover Post-development
Development 1	Arable land	93.6%	0.0%
	Amenity grassland	0.1%	11.5%
	Broadleaved woodland	1.4%	3.4%
	Grass road verge	0.5%	1.3%
	Improved grassland	0.1%	10.6%
	Private garden	0.5%	37.1%
	Tall ruderal	0.0%	0.0%
	Unimproved grassland	0.3%	0.0%
	Parkland	0.0%	1.1%
	Buildings	0.4%	1.7%
	Built-up area, sealed surface	1.4%	0.0%
	Domestic buildings	0.0%	13.8%
	Roadside/Pavement	0.0%	8.0%
	Surfaced road	1.3%	10.9%
	Water	0.4%	0.6%
Development 2	Arable land	98.3%	0.0%
	Amenity grassland	0.0%	27.6%
	Broadleaved woodland	0.0%	0.0%
	Grass road verge	0.0%	0.0%
	Buildings	0.0%	34.6%
	Built-up area, sealed surface	0.0%	32.7%
	Surfaced road	0.0%	2.9%
	Unsurfaced road	1.4%	0.0%
	Water	0.3%	2.2%
Development 3	Amenity grassland	13.3%	13.5%
	Buildings	0.0%	38.6%
	Built-up area, sealed surface	86.7%	34.3%
	Roadside/Pavement	0.0%	13.6%

Once digitised into a site map, each newly created polygon was manually assigned an EcoServ habitat code, which are based on the Phase 1 habitat classification scheme (with minor adaptations to further differentiate between similar codes). Polygons were also assigned an accessibility value, denoting the level of access to the public. This stage is quite labour intensive depending on the development complexity, and the team are working on ways to partially automate this in future releases of the tool.

To produce the natural capital asset map, the Ecoserv approach takes spatial datasets (both open source and obtained from local authorities) and layers them in a particular order, using a complex set of rules to classify every habitat in the study region into a specific habitat category. Habitat condition is assumed to be uniform across the region (an assumption is made of average condition). We are currently investigating integrating survey data habitat condition information and remote sensing data in order to better account for habitat quality.

This asset map[5] is considered to be the starting point for the demonstration set out in this paper, with aims to update the map at regular intervals as the regional landscape changes, in order to maintain an accurate and up to date baseline asset map of the Liverpool City Region.

The site maps are then burnt on to the asset map (see Holt et al., 2019). The asset map pre- and post-development was then run through a suite of EcoservR ecosystem service spatial analysis models to produce the ecosystem service capacity and demand maps. Models took an average of around 20-30 minutes to run depending on their complexity[6], with the whole suite being run in around two working days on an area as large as the Liverpool City Region (a complex area of two million polygons). A further working day was dedicated to results analysis and output map creation. Run times will vary depending on the size and more complexity of the study area, but it is clear that EcoservR is an efficient and accessible toolkit even over such large, complex study areas.

The capacity maps produced here estimate measures of ecosystem services provided by a particular habitat (for example, woodland providing greater air purification benefits than the same amount of scrub). These models also take into account spatial features such as habitat parcel size, distance from similar habitats, terrain slope, etc.

The ecosystem service demand maps measure the societal and/or regulatory (landscape features that generate demand, e.g. roads generating noise) level of demand for a particular ecosystem service in an area. Demand maps take into account socio-economic data such as population density, deprivation, and risk scores, as well as landscape features such as urban cover depending on the particular model.

Output rasters for various ecosystem services were then analysed using a bespoke R function, which calculates the average value of each service raster over an area defined by a list of boundary polygons

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[5] The natural capital asset map for the Liverpool City Region (on to which these interventions are mapped) was produced using the EcoServ-GIS suite (Winn et al., 2015) by Natural Capital Solutions (Holt et al., 2019), commissioned by the Liverpool City Region Combined Authority http://www.natureconnected.org/wp-content/uploads/2020/06/LCR_Baseline_4_pager_Final.pdf

[6] Run times given here are based on performance on a mid-high end desktop PC in 2020 (32 GB RAM, 4.20GHz processor). Computer specifications will affect running speeds, but most computers capable of running software such as ArcGIS smoothly should run EcoservR relatively well, with performance improving further on higher end PCs

(including site boundaries, wards, local authorities and the Liverpool City Region boundary). This allows the program to automatically produce a list of ecosystem service capacity and demand values over site, ward, local authority and city region scale.

Results

Of the various ecosystem services assessed, most showed some level of change across the different development scenarios. Detailed results can be seen in Table 2 (capacity) and Table 3 (demand).

*Table 2 – **Relative** percentage change in ecosystem service capacity (from baseline levels, to 2 d.p.) for Developments 1 to 3. **Increases** are highlighted in green, decreases in red and maintained values in orange. Changes smaller than two decimal places have been detected and are shown by colour, but have been truncated here for ease of reading.*

Ecosystem Service	Scale	Development 1 - % Change	Development 2 - % Change	Development 3 - % Change
Accessible Nature Capacity (restricted to publicly accessible areas)	Liverpool City Region	0.00%	0.00%	0.00%
	Local Authority	-0.02%	-0.01%	0.00%
	Ward	-0.72%	-0.10%	-0.04%
	Site	-3.77%	-11.05%	-0.52%
Air Purification Capacity	Liverpool City Region	0.00%	-0.03%	0.00%
	Local Authority	0.00%	-0.13%	0.00%
	Ward	0.05%	-1.37%	0.06%
	Site	1.92%	-42.56%	8.36%
Carbon Storage Capacity	Liverpool City Region	0.00%	-0.04%	0.00%
	Local Authority	-0.01%	-0.17%	0.00%
	Ward	-0.23%	-1.69%	0.02%
	Site	-3.58%	-62.83%	4.05%
Local Climate Regulation Capacity	Liverpool City Region	0.01%	0.00%	0.00%
	Local Authority	0.03%	0.02%	0.00%
	Ward	2.73%	0.23%	0.00%
	Site	186.92%	1.27%	0.00%
Noise Regulation Capacity	Liverpool City Region	0.00%	-0.03%	0.00%
	Local Authority	-0.02%	-0.16%	0.00%
	Ward	-0.84%	-1.58%	0.00%
	Site	-8.03%	-24.83%	0.00%
Pollination Capacity	Liverpool City Region	0.01%	0.00%	0.00%
	Local Authority	0.04%	0.00%	0.00%
	Ward	1.10%	0.00%	0.00%
	Site	14.55%	0.00%	0.00%
Water Purification Capacity	Liverpool City Region	-0.02%	-0.06%	0.00%
	Local Authority	-0.10%	-0.27%	0.00%
	Ward	-3.24%	-2.74%	0.00%
	Site	-37.52%	-71.76%	0.00%

*Table 3 – **Relative** percentage change in ecosystem service demand (from baseline levels, to 2 s.f.) for Developments 1 to 3. **Decreases** are highlighted in green, increases in red and maintained values in orange. Changes smaller than two decimal places have been detected and are shown by colour, but have been truncated here for ease of reading.*

Ecosystem Service	Scale	Development 1 - % Change	Development 2 - % Change	Development 3 - % Change
Accessible Nature Demand	Liverpool City Region	0.06%	0.00%	0.00%
	Local Authority	0.32%	0.00%	0.00%
	Ward	4.73%	0.00%	0.00%
	Site	46.66%	-0.02%	0.72%
Air Purification Demand	Liverpool City Region	0.11%	0.06%	0.03%
	Local Authority	0.48%	0.39%	0.03%
	Ward	11.80%	3.22%	0.04%
	Site	211.22%	243.84%	0.28%
Carbon Storage Demand	Liverpool City Region	**Carbon storage demand is assumed to be uniform across the study area, as the effects of carbon on the climate occur over too large spatio-temporal scales to map at regional level (Winn et al., 2015)**		
	Local Authority			
	Ward			
	Site			
Local Climate Regulation Demand	Liverpool City Region	0.07%	0.00%	0.00%
	Local Authority	0.42%	0.03%	0.00%
	Ward	10.86%	0.28%	0.04%
	Site	652.06%	63.62%	1.65%
Noise Regulation Demand	Liverpool City Region	0.05%	0.00%	0.00%
	Local Authority	0.23%	0.00%	0.00%
	Ward	7.61%	0.00%	0.00%
	Site	91.09%	0.00%	0.00%
Pollination Demand	Liverpool City Region	-0.03%	-0.02%	0.00%
	Local Authority	-0.14%	-0.05%	0.00%
	Ward	-2.58%	-0.58%	0.00%
	Site	-17.73%	-12.00%	0.00%

Firstly, it is clear that changes in ecosystem service capacity and demand are highest at the site scale, decreasing in severity as scale increases. This is expected, as percentage change is averaged over an increasingly large area from site to city region scale.

Accessible nature capacity (restricted to publicly accessible areas) is shown to decrease across all scales in all three sites, all of which were largely inaccessible prior to development, and so decreases are fairly small – also mitigated in Development 1 by the addition of publicly accessible parkland. There is also a significant increase in accessible nature demand in Development 1, due to the sheer increase in population as a result of the houses added in this intervention.

Developments 1 and 3 show an increase in air purification capacity. Increases in Development 1 are likely due to the introduction of woodland habitats. EcoservR assumes a higher level of air purification from such habitats than in the arable land previously on site, and so this increase is expected despite the loss of arable land. Similarly, a small increase in the amount of amenity grassland in Development 3 results in an increase in capacity here. In contrast, Development 2 does not introduce a significant amount of green space, and in fact loses some – resulting in decreasing air purification capacity. Air purification demand increases across all scenarios, for two primary reasons – increasing population in Development 1, and the introduction of roads and manmade surfaces (pollution sources) in all sites.

Developments 1 and 2 show losses in carbon storage capacity at most scales, primarily due to the loss of natural surface replaced by hard surfaces. Development 3 shows a slight increase, due to the low carbon storage capacity on site previously. Carbon storage demand is assumed to be uniform across the region and intervention scenarios, as the effects of carbon on the climate occur over too large spatio-temporal scales to map at regional level (Winn et al., 2015).

Local climate regulation capacity increases across Developments 1 and 2, likely due to the addition of woodland and water bodies in these sites, which have a cooling effect on the local environment. Development 3 lacks woodland and water both before and after intervention so remains unchanged. Demand also increases across all sites due to increases in population (particularly in Development 1), increases in the proportion of manmade surfaces in the area, or both.

Noise regulation capacity decreased for the most part, which can be assumed to be caused by the loss of noise reducing habitats (usually woodland, but more likely to be caused by significant losses of arable land here), with no change in Development 3 due to a lack of these habitats. Noise regulation demand increased in Development 1 due to the increased population and addition of new major roads, with no change in the other developments. Similarly, the addition of pollinator habitat in the green spaces in Development 1 led to an increase in pollination capacity, with no change in Developments 2 or 3. Pollination demand mostly decreased due to the removal of arable land requiring pollination in Developments 1 and 2, remaining the same in Development 3.

Finally, water purification capacity decreased in both developments 1 and 2, due to the introduction of sealed surfaces increasing water run-off and the removal of green spaces. Capacity remained unchanged in Development 3, as the proportion of sealed surfaces on site remained almost identical.

Conclusion

We believe that the Ecoserv approach presents a valuable opportunity for natural capital net gain to be assessed in a consistent, reliable manner, allowing it to be integrated into decision making and policy such as the planning process. This is further supported by mentions of environmental net gain in the 25 Year Plan and [7]NPPG, presenting opportunities for the use of EcoservR to support such initiatives. The tool is supported by a strong foundation of academic literature and expert input, and continues to be updated with feedback from stakeholders. The speed and accessibility of EcoservR makes it a viable option for local authorities who may be operating on limited capacity or resources.

One of the major strengths of EcoservR is the ability to easily manipulate the asset map in order to analyse interventions from site to city region scale. This allows the tool to be used to help developers plan at a site level - for example, in terms of the level of mitigation (net gain) required. However, the effects of the development can also be captured at the strategic scale (local authority or city region), allowing policy makers to monitor the effects of change in environmental net gain based on changes across the city region.

This approach could be used to analyse the effects of region-scale plans, informing strategic planning policy. For example, users could model the effects of meeting housing requirements across the Liverpool City Region, under various scenarios such as prioritising brownfield development, prioritising net gain, and so on. There is even the possibility of temporal modelling, by producing multiple interventions at different stages of development and growth. The scalability and flexibility of this toolkit makes it an excellent option for both local authorities and developers, no matter what their project size and scope. It can also be used to strategically inform investment around Nature Recovery Networks, biodiversity net gain, ELMs and private investment in natural capital.

Additionally, this tool brings natural capital assessment to a much wider audience by providing a free, open-source platform through which to work, as well as protocol documents to guide the user throughout. However, there is a need to establish governance models around the use of EcoservR and the baselines produced through it, so that both the tool and its outputs can be maintained and updated as planning and knowledge develops.

With further development and updated and refined supplementary data, the Ecoserv approach will become more powerful and accurate. Natural capital assessments can now be completed relatively

[7] https://www.gov.uk/guidance/natural-environment

quickly and efficiently provided that the correct data inputs are provided, and at minimal cost – wherever possible, EcoservR uses free datasets and free, open-source software.

With plans to add models for water flow, carbon sequestration, and biodiversity, as well as the addition of habitat condition data, EcoservR will cover a wide range of ecosystem services, allowing developers and authorities to analyse and prioritise specific services and optimise their sites based on these. The authors are also constantly revising code to make EcoservR even more efficient and flexible, allowing users to include extra unique datasets if they wish, as well as setting their own model parameters specific to their use-case – and of course, reducing costs in terms of working hours for users.

We believe that this toolkit could be invaluable to local authorities and developers alike as natural capital becomes increasingly important in policy, and hope that it will be used widely to help inform the planning process from the scale of individual developments up to regionally.

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