A Green Infrastructure Mapping Method

Please note that this version of the method has since been superseded. For more up-to-date versions, please refer to the Liverpool Green Infrastructure Strategy and the Liverpool City Region Green Infrastructure Framework.

This paper describes a method that has been developed by the North West Green Infrastructure Unit for mapping green infrastructure assets, their functionality, and need for that functionality. It is intended for use within the methodological framework presented in the North West Green Infrastructure Guide\(^1\), which consists of five steps. In the Guide these are organised sequentially, but experience has shown that in practice it is more effective to organise them more like in the following diagram.

![5 Steps to GI Planning Diagram]

The method described here comprises steps 2, 3 and 4, which consist largely of mapping and analysis using a Geographic Information System (GIS). It can be applied either to existing assets, functionality and need (which is how it has been used so far), or to a proposed or speculative future situation. This may take the form of a design for a particular site or area, with a different arrangement of GI assets and hence functionality than the existing, and/or a possible future arrangement of need, for example as brought about by climate change. It can be applied to any part of the UK, and the general principles could be applied anywhere in the world.

The ultimate purpose of the method is to provide the evidence needed for the construction of an intervention plan. The intervention plan will consist of a series of recommendations or even commitments for changes to the green infrastructure arrangement in the area and its management, that the partnership believe will improve the functionality performed relative to

\(^1\) [http://www.greeninfrastructurenw.org.uk/resources/GIguide.pdf](http://www.greeninfrastructurenw.org.uk/resources/GIguide.pdf)
the needs of the inhabitants. So for example, step 4 may highlight a particular need for the soil stabilisation function in a particular part of the study area, and step 3 may highlight the fact that this need is not currently being fulfilled, i.e. the function is not currently being performed by the green infrastructure of that part of the study area. The intervention plan would therefore include an action to help remedy this situation, if possible, bearing in mind other constraints such as politics, resources and conflict with other GI functions that may be more important in the circumstances.

**Step 2: Data Audit & Resource Mapping**

Step 2 consists of three main tasks: an assessment of data needs and availability, data acquisition, and typology mapping. Typology mapping determines where the green infrastructure assets are in the study area and what type of GI each is. It is carried out by first dividing the study area into polygons of land (a parcel system), which are then each assigned a GI type from a master list (or identified as not GI), consistently following a set of rules.

The most important dataset required is the parcel system itself. This method uses Ordnance Survey MasterMap Topography Layer², for the following reasons.

- It is readily available to public bodies under the Pan Government Agreement³ and the Mapping Services Agreement⁴ with Ordnance Survey.
- It is generally accepted as the UK’s foremost mapping system.
- The parcels are relatively small, which gives a high level of detail and a high level of fidelity to reality. For example, the mean area of parcels in a Northwich pilot study area is just 646m², about the same as the penalty area on a football pitch.
- It is regularly updated.
- The parcels are designed to correspond well to real parcels of homogeneous land cover on the ground.
- Ordnance Survey have given the parcels several attributes that help with assigning types to them.

The main disadvantage of this parcel system is that because the parcels are relatively small, there are a relatively large number of them in any given study area, which means that classifying them by typology and later mapping this to functionality are relatively time consuming processes. In Merseyside, for example, there are about 3,000 parcels per square kilometre (although this density varies considerably across the sub-region and the country). An experienced GIS operator can, with the help of the automated techniques described in this paper, achieve a rate of typology mapping of about twenty parcels per minute, which means that it would take on average about two and a half hours to cover each square kilometre of Merseyside. The functionality mapping then takes a similar amount of time, and on top of that there is the needs assessment (for which data are not yet available).

The parcel system also effectively defines the sizes of study area for which this method is appropriate. Large areas, such as whole counties, are likely to be ruled out due to resource restrictions, and less specific recommendations are likely to be expected anyway. However, it may be desirable to apply this method to smaller, high priority parts of a county or similar where perhaps there is a particular opportunity for green infrastructure change. At the other end of the spectrum, the method is unlikely to be appropriate for individual sites because the

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² [http://www.ordnancesurvey.co.uk/oswebsite/products/osmastermap/layers/topography](http://www.ordnancesurvey.co.uk/oswebsite/products/osmastermap/layers/topography)
⁴ [http://www.ordnancesurvey.co.uk/oswebsite/business/sectors/government/local/mapping-services-agreement](http://www.ordnancesurvey.co.uk/oswebsite/business/sectors/government/local/mapping-services-agreement)
parcel system limits the level of detail. The kinds of study areas that it is likely to be appropriate for include clusters of sites, towns and villages, and other areas between roughly 1km² and 100km².

A second crucial dataset is aerial photography. This must be of sufficient resolution to allow different GI types to be distinguished from one another by eye; 25cm is ample. It must also be usable within the GIS where the GI mapping is to be carried out. Online aerial photography datasets, and especially the Bird’s Eye photography available on Multimap⁵ and the new Street View photography available on Google Maps⁶, can be invaluable as a supplement where the local holding is slightly out of date or insufficiently detailed, but cannot replace the local holding entirely.

Many other datasets are useful, including those listed below. Of particular note are open space surveys, which most local authorities have carried out, and are useful for distinguishing between various kinds of public open spaces containing green infrastructure.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Possible source(s)</th>
<th>URL(s)</th>
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<tbody>
<tr>
<td>Open space surveys</td>
<td>Local authorities</td>
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<tr>
<td>Public Rights of Way</td>
<td>Local authorities</td>
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<td>Sustrans routes</td>
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<td><a href="https://www.landis.org.uk/">https://www.landis.org.uk/</a></td>
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<tr>
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<td>Ordnance Survey, private companies</td>
<td><a href="http://www.ordnancesurvey.co.uk/">http://www.ordnancesurvey.co.uk/</a></td>
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<tr>
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<td>Ordnance Survey</td>
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<tr>
<td>New woodland planting</td>
<td>Community Forests</td>
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A key step is to define the boundary of the study area. It is usually a good idea to apply a substantial buffer to any given physical or political boundary (such as the edge of a town

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⁶ [http://maps.google.co.uk/](http://maps.google.co.uk/)
where the buildings stop, or a district boundary), because green infrastructure outside is likely to be performing functions that benefit the inhabitants inside. However, resource issues must be taken into account of course, and it should be recognised that any boundary is, due to the global interconnectedness of natural systems, a compromise that must be imposed artificially. Once a boundary has been defined, the MasterMap polygons intersecting it should be exported to a new dataset.

In general, MasterMap polygons do not overlap each other, and there are no gaps in between them, giving complete coverage. However, there are exceptions to this rule that should be dealt with at this stage. All features with the following attributes should be deleted, because they overlap other features.

- descriptiveGroup LIKE ‘*Landform*’
- physicalLevel = 51

The data are now ready to be classified by typology. A new field should be created in the MasterMap export to store the results of this classification. Types are picked from the following list.

- Agricultural land
- Allotment, community garden or urban farm
- Cemetery, churchyard or burial ground
- Coastal habitat
- Derelict land
- General amenity space
- Grassland, heathland, moorland or scrubland
- Green roof
- Institutional grounds
- Orchard
- Outdoor sports facility
- Park or public garden
- Private domestic garden
- Street trees
- Water body
- Water course
- Wetland
- Woodland
- (Not GI)

This list has been developed from the list to be found in Planning Policy Guidance Note 17\(^7\), which is a generally recognised standard for open space assessments, but is not entirely suitable for an assessment of green infrastructure assets. Most of the changes made reflect a general principle that states that the main purpose of typology mapping is to provide a basis for mapping functionality. This means that there is no need to distinguish between two types that provide the same set of functions, and in general each type should be indivisible into sub-categories that provide different sets of functions. However, the latter point is not adhered to strictly because to do so would give a very long, mixed, unintuitive list of types that would not reflect what is generally understood by the terms ‘land cover’ or ‘land use’. The sub-categories are effectively resolved by the next step, functionality mapping. The main differences between the PPG17 typology and the list above are explained below.

\(^7\) [http://www.communities.gov.uk/publications/planningandbuilding/planningpolicyguidance17](http://www.communities.gov.uk/publications/planningandbuilding/planningpolicyguidance17)
• PPG17 only concerns open space ‘of public value’, in a fairly restrictive sense. This means that it doesn’t include types associated with private land, such as agricultural land, institutional grounds and private domestic gardens, or derelict land. These types have therefore been added.

• Natural and semi-natural greenspaces has been split into six components, because it was felt that these provided different sets of functions.

• Green corridors was excluded because it is to a certain degree incompatible with OS MasterMap Topography, due to its linear nature. However, since this type provides a unique function it was decided that it should be mapped separately.

• Provision for children and teenagers was deemed to be covered by other types, without any significant difference in function.

• Accessible countryside in urban fringe areas was deemed to be covered by the natural and semi-natural types.

• Civic spaces was deemed to be covered by general amenity space.

• Orchards and street trees were added because they provide distinctive sets of functions.

The process of typology mapping can effectively be split into three stages.

1. Bulk typing of polygons from MasterMap attributes and by intersection with other datasets
2. Manual typing of the remainder one at a time by hand
3. Automated analysis of aerial photography for ‘tidying up’

Stages 1 and 2 are described, largely, by the following decision tree. Several abbreviations are used as follows.

• MM: MasterMap
• APs: aerial photographs
• PRoW: Public Rights of Way
• OSS: Open Space Survey

In addition, the abbreviated forms of MasterMap field names are used, as they usually appear in the dataset itself.

It is likely that in putting this method into practice, decisions will be encountered that are not covered by the tree below. For example, the coastal habitat type does not appear on the decision tree as shown here, because this method has not yet been carried out for any study area that includes such habitats. In fact it may be necessary to split this type because there are a wide variety of coastal habitats that may perform different sets of functions. Additionally, data availability and quality will affect the ability to make informed decisions. In short, the decision tree should not be adhered to religiously, but rather used as guidance along with common sense and the general principles of green infrastructure planning.

Note that Ordnance Survey use some words in MasterMap attributes in a way that does not reflect common usage. For example, a lot of green infrastructure is manmade according to the most commonly understood sense of the word, but MasterMap polygons with the ‘make’ attribute set to ‘Manmade’ very rarely consist of green infrastructure.
All of the GI mapping using this method so far has been carried out in ESRI’s ArcGIS Desktop, which includes a selection of tools that help to speed up this process. In addition, custom tools can be created. For example, a tool has been created that pans the display to the ‘next’ unclassified polygon on the click of a toolbar button, which one operator found highly useful for stage 2. Another operator, however, preferred to move between adjacent polygons rather than being sent to a different corner of the study area on each click.

Stage 3 involves an automated process that identifies the locations of particular colours on aerial photography that correspond approximately to tree canopy and all green infrastructure respectively. The former can then be used to identify roadside polygons with high densities of street trees, and a combination of both to exclude polygons with little green cover. Despite the fact that it is automated, though, it is quite time consuming, both in terms of machine time and human set-up time. If necessary it can be omitted, and either the consequent reduction in accuracy can be accepted, or it can be replaced by additional vigilance during stage 2.

The automation relies on the fact that aerial photography is usually made up of three bands corresponding to the red, green and blue components of light. Each pixel has a value of between 0 and 255 associated with it for each band, representing the intensity of that component on the photograph. This means that there are $256^3 = 16,777,216$ possible colours. What the human eye perceives as green includes a significant proportion of these that can be approximately expressed as an inequality, as follows.

$$R^2 + (G - 255)^2 + B^2 < x$$

where $R$, $G$ and $B$ are the pixel’s red, green and blue values respectively, and $x$ is a constant determined from a manual sample that is usually about 40,000, but varies between and within aerial photography datasets.

A slightly less elegant conditional statement gives colours that typically appear in tree canopies. Using these inputs, the GIS can calculate what proportion of each MasterMap polygon is covered by each of the two colour ranges, and the results can be used to exclude and reclassify polygons. The following rules have been found to improve the accuracy of typology mapping significantly.

- Exclude features where the proportion of green from the aerial photography analysis is less than 0.05 AND the proportion of trees from the aerial photography analysis is less than 0.05 AND the type is not one of the semi-natural types (grassland, heathland, moorland or scrubland; water body; water course; wetland; woodland) AND the area is less than a hectare. The last condition is to avoid excluding large polygons of agricultural land (ie. fields) that do not appear green, yet can be classified as green infrastructure.
- Classify features as street trees where the proportion of trees from the aerial photography analysis is more then 0.1 AND the MasterMap descriptiveGroup attribute is ‘Roadside’.

This technique may also be useful for identifying green roofs.

MasterMap ‘Positioned Tree’ points may also be useful in identifying street trees polygons.

The following map is an example of completed typology mapping, in Northwich.

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Step 3: Functionality Assessment

Step 3 consists of identifying the range of green infrastructure functions that each parcel of land performs, based on the type assigned in step 2 plus as many additional useful datasets as can be obtained. Each parcel can perform multiple functions, taken from the following list.

- Recreation - public
- Recreation – private
- Recreation – public with restrictions
- Green travel route
- Aesthetic
- Shading from sun
- Evaporative cooling
- Trapping air pollutants
- Noise absorption
- Habitat for wildlife
- Corridor for wildlife
- Soil stabilisation
- Heritage
- Cultural asset
- Carbon storage
- Food production
- Timber production
- Biofuels production
- Water supply
• Wind shelter
• Learning
• Inaccessible water storage
• Accessible water storage
• Water interception
• Water infiltration
• Coastal storm protection
• Water conveyance
• Pollutant removal from soil/water
• Flow reduction through surface roughness

This list is an attempt to break functionality down into the smallest possible units, influenced by several previous studies and lists\(^9,10,11,12\) that have tended to group some functions together, giving constructs more similar in the view of the author to benefits than functions. Using the smallest possible units of functionality allows a distinction to be made between parcels that perform different selections of functions that might otherwise be called just one function, but also provides a platform for grouping functions (eg. into benefits) at a later date. However, it is recognised that the list is not perfect, especially in relation to hydrological issues, and advice is being sought from experts in each field in order to improve it. This also applies to the individual methods for determining whether each parcel performs each function.

The following table indicates which types are considered to provide which functions. It has been decided that measuring or indicating to what degree each type provides each function in a consistent manner is not feasible, so instead a type is judged to provide a function only if it is considered to do so at a level above a reasonable threshold. Also, in some cases a particular type only provides a particular function at a level above its threshold if another condition applies, so suggested additional datasets have been identified to spatially articulate these conditions. A good example of both of these points is the carbon storage function. All plants store some carbon, but only moorland on peaty soil and trees store a significant amount of it for a significant time, at the scale at which carbon storage is important for climate change mitigation. Therefore types consisting of trees are said to always provide this function, and the grassland, heathland, moorland & scrubland type is said to sometimes provide it, conditional on the underlying soil type, for which a suitable dataset is suggested.

Elements of step 3 are carried out in different ways, analogous to stages 1 and 2 of step 2 except for that they are likely to be sequential only within functions, not during the assessment as a whole.

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10 Barber A (2005) Green Future, GreenSpace Publications (CLERE model)
12 http://www.millenniumassessment.org/
Some idiosyncrasies of this table explained:

- The green travel route function will be mapped separately due to its linear nature.
- The aesthetic function is said to always be provided by all types because it is purely subjective and therefore no reasonable threshold can be set.
- The evaporative cooling function is provided to a significant extent by all plants and open water.

The green travel route function is mapped simply by identifying sections of Public Rights of Way and Sustrans routes that are within 1m of MasterMap polygons identified as GI.

Once it has been determined which parcels of land provide which functions, not only can separate maps be produced showing where each function of green infrastructure is performed in the study area, but also the total number of functions for each parcel can be calculated, giving a map of multifunctionality. Such a map may be useful as an overview of the existing situation, but should always be taken with a pinch of salt because it implies that all functions are somehow commensurate and interchangeable, which is of course not the case. Instead the individual function maps should be consulted when constructing a detailed intervention plan.

The following maps are an example of an individual function map, for the public recreation function, and a multifunctionality map, respectively, both in Northwich.
Once the functions have been mapped, the benefits that result from them can also be mapped. There are many ways of dividing up the benefits that green infrastructure provides, but the system of eleven proposed by Natural Economy North West is now widely politically accepted, at least in the North West. It was originally intended as a list of just economic benefits, but with a small adjustment of perception it can easily extend to cover all benefits of green infrastructure. The list follows.

- Climate change adaptation and mitigation
- Flood alleviation and water management
- Quality of place
- Health and well-being
- Land and property values
- Economic growth and investment
- Labour productivity
- Tourism
- Recreation and leisure
- Land and biodiversity
- Products from the land

For mapping purposes, climate change adaptation and mitigation are separated because the functions that lead to them are so different.

It has been observed that there are many chains of causality through this list, which mean that whilst one function may result in a given benefit directly, another may result in the same benefit indirectly, via other benefits. For example, water supply directly leads to a products benefit, whereas carbon storage only leads to that benefit because it first leads to a climate change mitigation benefit. Drawing all of these links has proved impractical, and many of the longer chains of causality result in links that are decidedly tenuous (not to

mention the difficulty of representing such a complex system geographically), so only first- and second-order causality are considered for the sake of mapping, with a couple of exceptions. Benefits that result directly from particular functions are identified, as are benefits that result indirectly from particular functions via only one other benefit, but benefits that only result indirectly from particular functions via a longer chain are ignored. The exceptions to this rule are economic growth & investment and labour productivity, neither of which have been found to result by first-or second-order causality from any of the functions. However, both of these result from most (if not all) of the functions indirectly via longer chains, and it is felt important to highlight this fact. The result of all this thought was the following table.

The temptation is to assume that more direct provision of a benefit is always more desirable or effective or important than less direct, but this is not the case, partly due to the arbitrary way in which the benefits have been divided up. Therefore the benefits mapping resulting from this method is arguably misleading, and certainly not very informative, and it is not recommended that it is referred to when constructing an intervention plan. Instead, the functionality mapping should be used, as explained above. However, the list of benefits and explanations of how particular types perform particular functions which lead to particular benefits are very useful when persuading landowners, planners etc to support particular green infrastructure interventions.
D = this function DIRECTLY provides this benefit (first-order causality)

I = this function INDIRECTLY provides this benefit, via ONE benefit which is provided directly by the function (second-order causality)

* = this function INDIRECTLY provides this benefit, via MORE THAN ONE other benefit (for special benefits only)

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>climate change adaptation</th>
<th>climate change mitigation</th>
<th>flood alleviation &amp; water management</th>
<th>quality of place</th>
<th>health &amp; well-being</th>
<th>land &amp; property values</th>
<th>economic growth &amp; investment</th>
<th>labour productivity</th>
<th>tourism</th>
<th>recreation &amp; leisure</th>
<th>land &amp; biodiversity</th>
<th>products from the land</th>
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<tbody>
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This table is used to map roughly where each benefit is provided by green infrastructure across the study area, based on the functionality assessment previously completed. The following map is an example of the result, for the recreation and leisure benefit in Northwich.
Step 4: Needs Assessment

No method has yet been fully developed or put into practice for this step that is fully compatible with the methods described here for the previous two steps. It is considered vital that any such method maps the need for all of the functions, because they are all important, and maps each function separately, because there is need for different functions in different places. It is often suggested that Natural England’s Accessible Natural Greenspace Standard\textsuperscript{14} could be used as the basis for a needs assessment, but whilst they may help with need for the public recreation function and maybe one or two others, they are useless for mapping need for any of the other functions. Therefore they could form part of a needs assessment, but many other equivalent standards relating to the other functions would be required as well.

Another requirement of a needs assessment methodology is that it does not take into account whether the needs are currently being fulfilled (ie. whether the functions are currently being performed). This is assessed by comparison of the results of the needs assessment with the results of steps 2 and 3. Because the needs assessment is carried out independently of the previous two steps, there is no need for it to use the same parcel system, although a parcel system of similar resolution will be preferable.

The study area for the needs assessment will probably need to be significantly larger than that used for the previous two steps, because green infrastructure functionality within the latter can also fulfil the needs of those who live elsewhere. However, as when buffering to create the original study area, constraints must apply.

\textsuperscript{14} http://www.naturalengland.org.uk/ourwork/enjoying/places/greenspace/greenspacestandards.aspx
Much like the functionality assessment, it is probably impractical to attempt to determine to what extent there is a need for each function at each point, and it is important to present a picture to decision makers that does not ask for too much, so instead the locations of greatest need for each function should be mapped. In other words, a need should only be deemed to be present where it is above a reasonable, and relatively high threshold. For example, it may be deemed that there is only need for the public recreation function where population density is above the 75th percentile for the study area, whereas in reality there is also need where the population density is lower. For expediency’s sake, ‘need’ has been made synonymous with ‘greatest need’. Meanwhile, it may be deemed that there is need for the soil stabilisation function where there are particularly steep slopes in combination with at risk soils. These examples, despite being too crude (probably) to use, clearly show how need for different functions is likely to occur in different places.

Three main starting points have been established that could contribute to a suitable needs assessment methodology.

- Three groups of students from the Department of Civic Design at the University of Liverpool\(^\text{15}\) are currently undertaking projects which aim to devise needs assessment methodologies compatible with the functionality assessment methodology described here. Each should be based upon a review of existing literature on the subject, and will be applied to a different case study area in Liverpool. Whilst the students are unlikely to come up with something entirely acceptable, their research will no doubt be valuable in devising the final method.
- A study called ‘Green Infrastructure Solutions to Pinch Point Issues in North West England\(^\text{16,17}\) has recently been published which implements something approximating a green infrastructure needs assessment for the whole of the North West. It uses a similar function list, but attempts to map ‘pinch’, which is slightly different from need. However, again a lot of relevant thought has certainly gone into it.
- The Forestry Commission and the North West Regional Development Agency have developed a Public Benefit Recording System\(^\text{18}\) which attempts to take a holistic approach to need for the benefits of site and landscape improvement projects. Since it does not do so independently of opportunity and the existing character of the site or landscape, it is not suitable for use here unmodified, but there may be elements of it that can be incorporated into this method, and lessons that can be learned.

Future Improvements

This method is to some extent experimental and work in progress: it is certainly far from perfect and constant improvement is being sought. The details of what datasets and thresholds are used to map functionality and need are being refined as an improved understanding of how green infrastructure works is gradually amassed, by experience, research and consultation with experts. There will always be a degree of compromise because ultimately the method attempts to represent an almost unimaginably complex system using a much simpler system, but that does not preclude room for improvement. More data will be collected as time goes on, facilitating improvement, and more of the process will be automated, also facilitating improvement by removing some of the burden of data processing. No intervention plan has yet been constructed using the outputs from this

\(^{15}\) http://www.liv.ac.uk/info/researchdept/cd

\(^{16}\) http://www.greeninfrastructurenw.org.uk/resources/Exec_sum_23rd_March_lores.pdf

\(^{17}\) http://www.greeninfrastructurenw.org.uk/resources/Critical_GI_23rd_March_lores.pdf

\(^{18}\) http://www.pbrs.org.uk/
method; that experience will surely suggest improvements, as the sole aim of the method is to provide an evidence base for an intervention plan. And finally, the method will be adapted for different scales and ends, feeding back into the original method and expanding its usefulness. One example of this is already underway at Alder Hey Children's Hospital in Liverpool, where there is a significant opportunity for GI change due to rebuilding. Rather than create one GI plan for the site, a model is being developed that incorporates both the thinking outlined in this paper and the ecosystem services approach to assess different designs against each other in terms of functionality. The scale is too small for MasterMap, so a finer parcel system is to be used, along with a modified typology system. The most impressive innovation, however, is an attempt to put currency values on as many functions as possible so that different designs can be assessed against each other financially.

Contact

For more information on this green infrastructure mapping method, and for help putting it into practice, please contact Tom Butlin at The Mersey Forest on 01925 816217 or at tom.butlin@merseyforest.org.uk.