Blue-Green Cities – Multiple Benefit Toolbox

Introduction

The Blue-Green Cities Multiple Benefits Toolbox was created in 2015 by Dr Malcolm Morgan at the University of Cambridge, Department of Engineering, as part of the EPSRC funded Blue-Green Cities research project. It is provided 'as is' and will not be supported in the future. For more information on the tool and the Blue-Green Cities project visit http://www.bluegreencities.ac.uk/ (and www.bluegreencities.ac.uk/bluegreencities/publications/multiple-benefit-toolbox.aspx)

The tool was developed as a proof of concept to show that it was possible to assess the multiple benefits of Sustainable Urban Drainage Schemes (SuDS) in a manner that is spatial and context aware. As the tool is a prototype it should not be used for actual design or planning decisions. This is due to the simplistic models used to calculate the spatial distribution of different characteristics; however, the benefit evaluation tools are functional, and could be used.

The benefit evaluation approach encompasses three principles:

1. Normalisation – different types of benefit such a reduction in flood damage and increased access can be compared because they normalised to a common scale.
2. Spatial – the evaluation identifies where the benefits accrue and how the benefits are spatially distributed.
3. Context sensitive – the benefit evaluation depends on the existing context of the location, thus the same intervention in two different locations may have different results.

Required Software

The toolbox was developed for and requires **ArcGIS 10.X** with the **Spatial Analysist add-on**.

How the Multiple Benefits Toolbox works

The multiple benefit toolbox is divided into three stages.

1) Characteristic Modelling
2) Single Benefit Evaluation
3) Multiple Benefit Evaluation

Characteristic modelling takes some input data and creates a raster to present the spatial distribution of a physical characteristic of interest. For example, modelling the distribution of air pollution or noise. In each case the raster represents something that can be measured with appropriate units (e.g. μgm^{-3} or dB). Characteristic modelling should be done twice with different input data to reflect the Reference Case and the Scenario Case.

Single Benefit evaluation take the output of the characteristic modelling and normalises the results onto a scale of 0-10. The normalisation process is unique to each characteristic and requires the setting of maximum and minimum values, and an equation that links the modelled characteristic to the normalisation process.

Finally, Multiple Benefit Evaluation takes the output from each single benefit evaluation and combines them in a weighted or unweighted way to identify the locations where different benefits co-exist.

Figure 1: Characteristic Modelling, Single Benefit Evaluation, and Multiple Benefit Evaluation
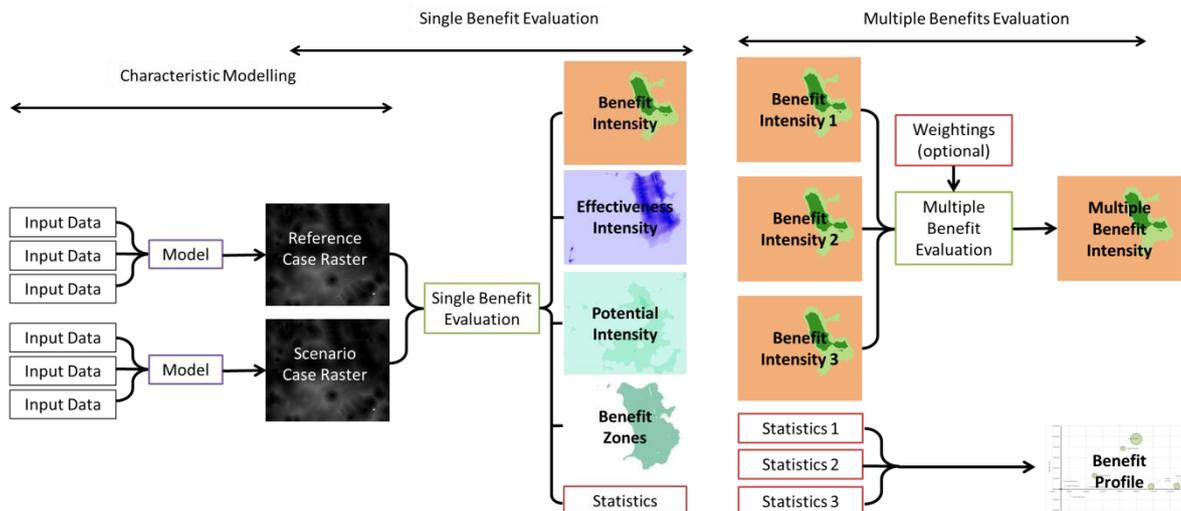
Key Concepts

Reference Case – The base line that you wish to compare against. In most case this will be your before or current situation

Scenario Case – the case that you wish to test. In most cases this will be your after or proposed situation

Benefit Score (B) – the score between -10 and +10 that represent the (dis)benefit experienced by a location. Where +10 would be the transition from worst case to best case and -10 would be from best case to worst case.

Benefit Curve – This is how the change in a characteristic is related to the benefit score.

Figure 2: Linear Benefit Curve showing the derivation of Benefit Score and Potential Benefit
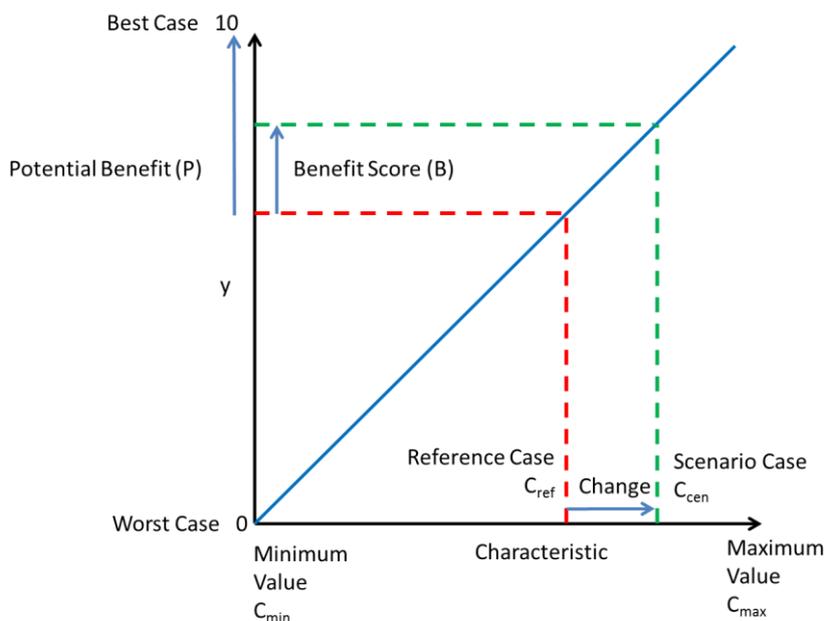
Benefit Intensity – A raster map of the benefit scores

Potential Benefit (P) – The difference in benefit score between the Reference Case and the Best Case. Thus the maximum benefit score that would be obtainable in that location. Potential Benefit values can be between 0 and 10.

Effectiveness (E)– The ratio of the Benefit Score to the Potential Benefit. Thus a measure of where the scenario case was successful in delivering a benefit in that location. Effectiveness values can be between 0 and 1.

Benefit Zone – locations that have experienced the same (dis)benefit and are geographically close together.

Parts of the Tool Box

Additional Tools

These tools provide some form of additional functionality that were used as part of the Blue-Green Cities project.

CityCAT to GIS

This tool iterates thought a folder of .txt or .csv files that are the output from the Newcastle University CityCAT flood inundation model to create point features in a File Geodatabase. This allows CityCAT output to be used in ArcGIS. Please contact Vassilis Glenis (Vassilis.Glenis@newcastle.ac.uk) for all queries regarding CityCAT.

Max Flood Depth

This tool takes in many flood depth rasters and finds the maximum depth for each location.

Point to Raster

This tool takes the points from the CityCAT to GIS tool and converts them to rasters. It also approximates the flood depth within the buildings which is not considered by CityCAT.

Resample

Resamples a raster to 1m resolution.

Characteristic Benefits

Access to Greenspace

MasterMap Topo Area – The Ordnance Survey (OS) MasterMap Topographical Layer

Road Network – The OS Integrated Transport Network (ITN) Polyline Link Layer

Output – The Location and name of the Output Raster

Extent Raster – A raster that provides the processing extent of the model

The model takes the vegetated surfaces and water as defined by the LEGEND field of the OS MasterMap Topographical Layer and performs a cost distance calculation along the road network for 2 cases. First, for all areas of Greenspace larger than 50m^2, second for areas greater than 500m^2. Distances to area of greenspace between 50 m^2 and 500 m^2 are multiplied by 2 to recognise their reduced utility.

Air Pollution (PM10)

MasterMap Topo Area – The Ordnance Survey (OS) MasterMap Topographical Layer

Road Network – The OS Integrated Transport Network (ITN) Polyline Link Layer

Output – The Location and name of the Output Raster

Extent Raster – A raster that provides the processing extent of the model

The model assigns a PM10 concentrating to roads of 0,30,40,50 μgm^{-3} depending on the road type. For each concentration a Euclidean Allocation is performed distributing the pollution based on distance from source. Certain land covers remove a percentage of the pollution from 3-7% depending on the surface type.

Carbon Sequestration

MasterMap Topo Area – The Ordnance Survey (OS) MasterMap Topographical Layer

Output – The Location and name of the Output Raster

Extent Raster – A raster that provides the processing extent of the model

The model selects the natural surfaces and assigns a sequestration rate depending on the surface.

Flood 6 RP (Return Periods)

MasterMap Topo Area – The Ordnance Survey (OS) MasterMap Topographical Layer

Output – The Location and name of the Output Raster

Extent Raster – A raster that provides the processing extent of the model

Building Classes – Point Data of building types

Return Period 1 – The Return Period of Event 1 in years

Extent 1 – The raster of maximum flood depth for each cell during event 1

Note that there are 6 return periods required in the model, and that they must be entered in order from longest to shortest return period e.g. 200,100,50,30,10,2 years.

From the MasterMap eight land use categories are identified: Residential High Density, Residential Low Density, Commercial, Industrial, Mines / Construction, Recreation, Nature, Water. Each land use has its own depth damage curve which range from £88/m^2 for Nature to £3385/m^2 for a 3m deep flood (the maximum depth considered).

Figure 3: Depth damage curves used in the tool
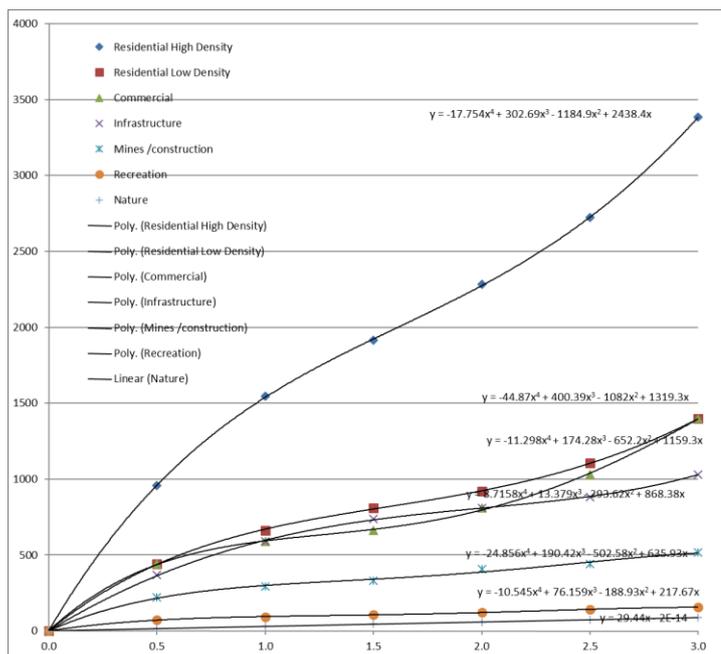
The damage from each return period is then use to calculate the annual risk of damage in £/m^2.

Figure 4: Example damage probability curve, for converting discrete flood events into annualised flood risk
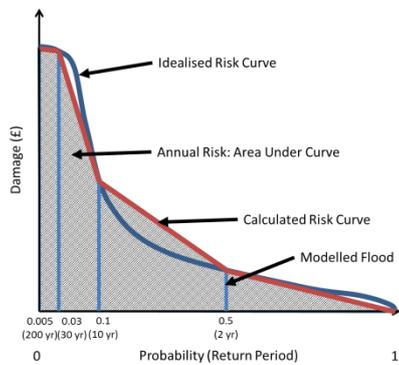
Habitat Size

MasterMap Topo Area – The Ordnance Survey (OS) MasterMap Topographical Layer

Output – The Location and name of the Output Raster

Extent Raster – A raster that provides the processing extent of the model

The model identifies areas of greenspace or water from the MasterMap that are connected and then measures the total area of that habitat. The total area is assigned to each cell in the raster. Manmade surfaces and gardens are excluded and thus assigned a value of 0.

Noise

MasterMap Topo Area – The Ordnance Survey (OS) MasterMap Topographical Layer

Road Network – The OS Integrated Transport Network (ITN) Polyline Link Layer

Output – The Location and name of the Output Raster

Extent Raster – A raster that provides the processing extent of the model

Digital Terrain Map – A raster containing elevation data

The model assigns a noise level to each road based on type. Values range from 85 dB for minor roads to 117 dB for Motorways. Noise is then distributed using a Cost Distance calculation. Noise is reduced by terrain, buildings, and vegetation.

Multiple Benefits

Weighted Sum
Combines the outputs of the different benefit layers into a multi-benefit layer

Single Benefits
These models take two raster layers representing the Reference (Before) and Scenario (After) cases and calculate the benefit intensity and profile. Six models are customised for the characteristics described above and several generic ones are provided as examples. All take the same inputs:

Reference Case – Input Raster for the reference case

Scenario Case – Input Raster for the scenario case

Effectiveness Layer – Output Raster showing the effectiveness

Benefit Layer - Output Raster showing the benefit intensity

Potential Benefit Layer - Output Raster showing the potential benefit intensity

Statistics – Output table of summary statistics

Benefit Zones - Output Raster showing the grouped zones and their numbers

Grouping Distance – Minimum distance in metres required to designate a new zone.