Designing Sustainable Landscapes: Habitat loss, mowing and plowing, microclimate alterations, edge predators, domestic predators, invasive plants, and invasive earthworms metrics

Kevin McGarigal
University of Massachusetts Amherst

Brad Compton
University of Massachusetts Amherst

Ethan Plunkett
University of Massachusetts Amherst

Bill DeLuca
University of Massachusetts Amherst

Joanna Grand
University of Massachusetts Amherst

Designing Sustainable Landscapes:

Habitat loss, mowing and plowing, microclimate alterations, edge predators, domestic predators, invasive plants, and invasive earthworms metrics

A project of the University of Massachusetts Landscape Ecology Lab

Principals:

- Kevin McGarigal, Professor
- Brad Compton, Research Associate
- Ethan Plunkett, Research Associate
- Bill DeLuca, Research Associate
- Joanna Grand, Research Associate

With support from:

- North Atlantic Landscape Conservation Cooperative (US Fish and Wildlife Service, Northeast Region)
- Northeast Climate Science Center (USGS)
- University of Massachusetts, Amherst

Reference:

McGarigal K, Compton BW, Plunkett EB, DeLuca WV, and Grand J. 2018. Designing sustainable landscapes: habitat loss, mowing and plowing, microclimate alterations, edge predators, domestic predators, invasive plants, and invasive earthworms metrics. Report to the North Atlantic Conservation Cooperative, US Fish and Wildlife Service, Northeast Region.

General description

This document describes a suite of stressor metrics that assess different aspects of the effects of roads and development on ecological integrity (see technical document on integrity, McGarigal et al 2017). They share a common algorithm, but each has unique parameters. These metrics are obviously highly correlated (**Fig. 1**), but each assesses a different aspect of the effects of roads and development on ecological integrity.

These metrics are elements of the ecological integrity analysis of the Designing Sustainable Landscapes (DSL) project (McGarigal et al 2017). Consisting of a composite of 21 stressor and resiliency metrics, the index of ecological integrity (IEI) assesses the relative intactness and resiliency to environmental change of ecological systems throughout the northeast. These stressor metrics range from 0 (no effect) to 1 (severe effect). See **Table 1** for parameters for each metric.

Habitat loss (**Fig. 1b**). Assesses the intensity of past habitat loss caused by all forms of development. Direct habitat loss is the primary cause of species decline and extinction; this metric is an index of indirect habitat loss—the decline of integrity in remaining natural lands due to the loss of former habitat in the neighborhood to past development.

Mowing and plowing (**Fig. 1c**). Assess the intensity of agriculture in the neighborhood as a surrogate for mowing and plowing rates, which are direct sources of animal mortality. Agricultural machinery is a well-known cause of mortality for grassland bird nestlings and terrestrial and semi-aquatic turtles.

Microclimate alterations (**Fig. 1d**). Assesses microclimatic alterations due to edge effects, such decreased moisture, higher wind, and more extreme temperatures. This metric includes the effects of both anthropogenic edges and natural edges (e.g., the effects of an open marsh on the surrounding forest).

Edge predators (**Fig. 1e**). Assesses the effect of human commensal mesopredators such as raccoons and skunks. Mesopredators often reach unusually high densities near human habitation, both due to food subsidies (garbage, bird feeders, and livestock grain) and mesopredator release.

Domestic predators (**Fig. 1f**). Assesses the effect of domestic predators (primarily housecats) due to development. Both pet and feral housecats kill large numbers of birds and small mammals.

Invasive plants (**Fig. 1g**). Assesses the effect of non-native invasive plants. Invasive plants often spread from sources in residential and agricultural areas, from human-disturbed areas, and along roads.

Invasive earthworms (**Fig. 1h**). Assesses the effect of non-native invasive earthworms. In the glaciated northeast, all terrestrial earthworms are non-native. Spreading from agricultural areas, home gardens, and fishing holes, they speed up the nutrient cycle in nearby forests, often greatly affecting understory plants and seedling regeneration.

Use and interpretation of these layers

These metrics rely on several assumptions:

- Land cover classes are correctly mapped.
- Parameterizations for each metric are reasonable. As these metrics are generic, rather than parameterized for individual species, it's not possible to use empirically-derived parameters, so the goal is to find "reasonable" parameters that adequately represent each stressor metric across all species, usually focusing on more vulnerable, wider-ranging animals.

Derivation of these layers

Data sources

- Ecological systems map (DSLland). All of these metrics are based on development, roads, and some formation-level ecological systems in the ecological systems map (see DSLland document, McGarigal et al 2017, for details).

Algorithm

These metrics share a common algorithm. All are based on a logistic kernel-weighted sum of weights by landcover class in the neighborhood of each focal cell, scaled by a kernel with maximum weight, thus all metrics range from 0 to (theoretically) 1:

$$\frac{\sum_{ij} W_{L_{ij}} K_{ij}}{\sum_{ij} \lceil W \rceil K_{ij}}$$

where ij = cells in the neighborhood of the focal cell, W = weights for each landcover class, L_{ij} = landcover class at cell ij, and K_{ij} = logistic kernel weight at cell ij.

Weights for each landcover class by metric and logistic kernel parameters are given in **Table 1**. Logistic curves used for kernels are shown in **Figure 2.** Weights are relative within each metric.

GIS metadata

These data products are distributed as geoTIFF rasters (30 m cells). The cell values are continuous, representing the intensity of each stressor in the neighborhood, ranging from 0 (no stress) to 1 (maximum stress). These data products can be found at McGarigal et al (2017):

- **Habitat loss**
- **Mowing and plowing**

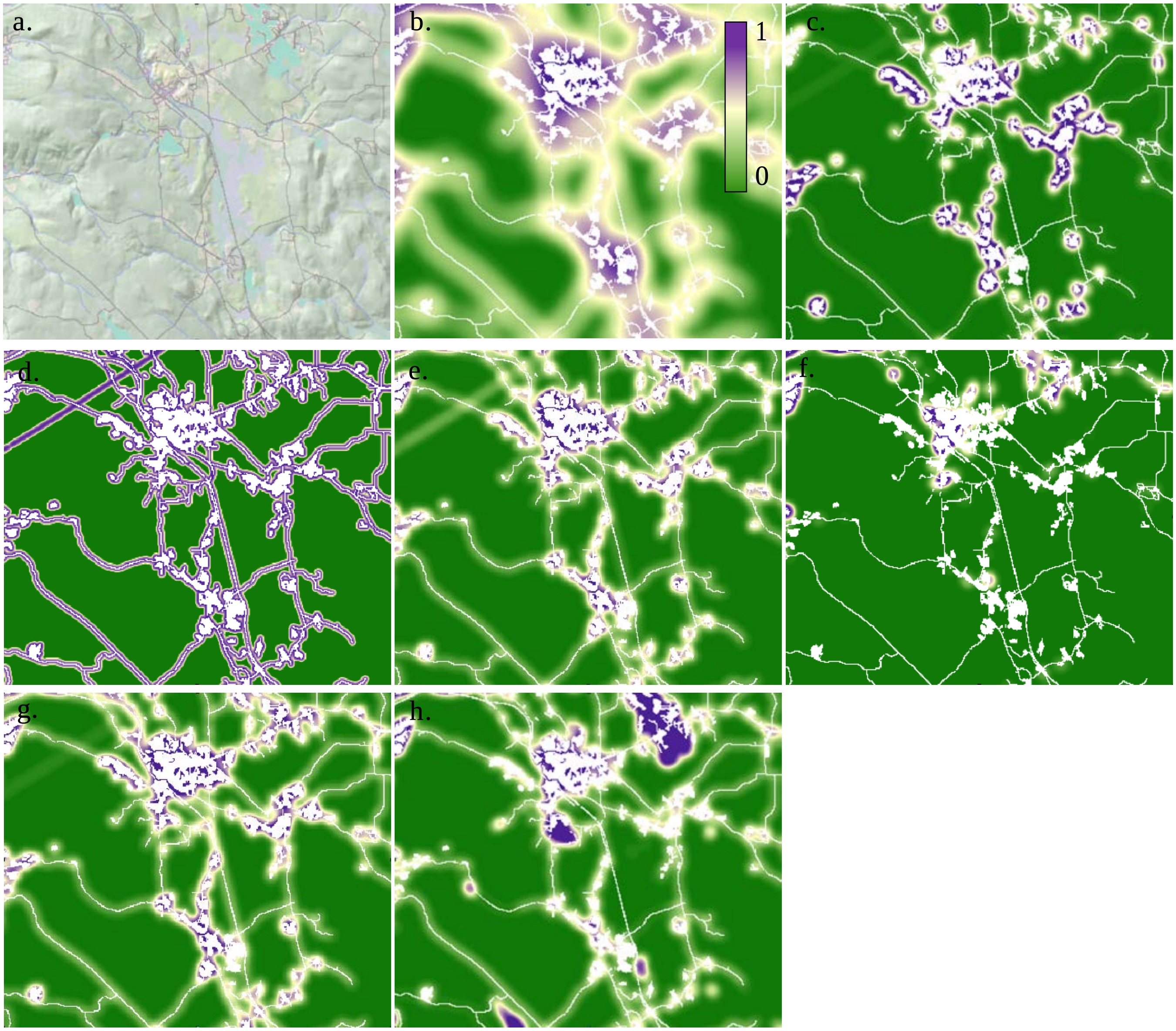

Figure 1. Examples of each metric in Hinsdale, Massachusetts: (a) landcover, with hillshading, and each metric: (b) Habitat loss, (c) Mowing and plowing, (d) Microclimate alterations, (e) Edge predators, (f) Domestic predators, (g) Invasive plants, (h) Invasive earthworms. White areas correspond to development and roads, where the metrics are not applied.

- **Microclimate alterations**
- **Edge predators**
- **Domestic predators**
- **Invasive plants**
- **Invasive earthworms**

Literature Cited

McGarigal K, Compton BW, Plunkett EB, DeLuca WV, and Grand J. 2017. Designing sustainable landscapes products, including technical documentation and data products. https://scholarworks.umass.edu/designing_sustainable_landscapes/

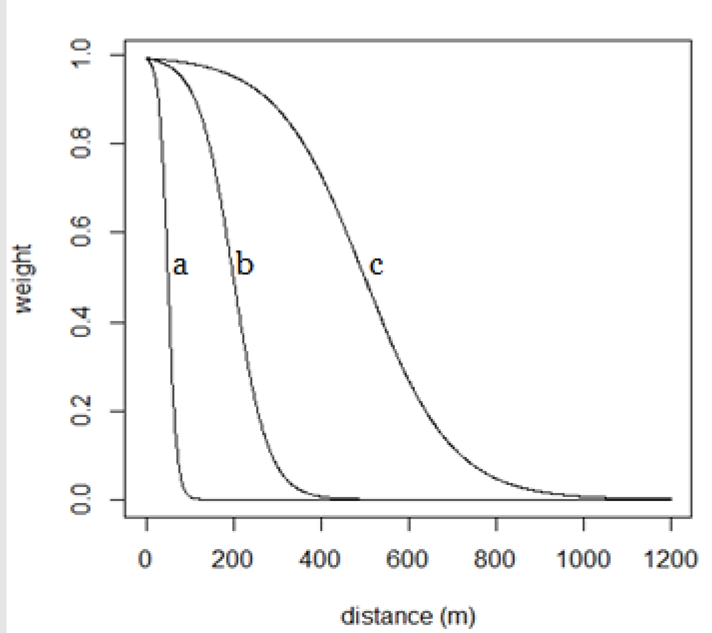

Figure 2. Logistic kernels used for these metrics. (a) microclimate alterations, inflection point = 50 m; (b) mowing and plowing, edge predators, domestic predators, invasive plants, and invasive earthworms, inflection point = 200 m; (c) habitat loss, inflection point = 500 m.

Table 1. Parameters for each metric. Weights for each landcover class are relative within each metric. Landcover classes not shown in the table have weights of 0 for all metrics.

Landcover class	Weights						
	Habitat loss	Mowing & plowing	Microclimate alterations	Edge predators	Domestic predators	Invasive plants	Invasive earthworms
Developed – high intensity	1	0.5	1	3	0.3	1.5	1
Developed – medium intensity	0.8	1	0.6	3	1	2	2
Developed – low intensity	0.8	1	0.4	2	2	1.5	2
Developed – open space	0.8	0.5	0.6	3	0.2	2	1
Barren land	0.8	0	1	1	0	0.5	0
Cultivated crops	1	1	0.8	3	0	2	1
Pasture/hay	0.5	3	0.8	2	0	2	0.5
Motorway	1	2	1	2	0	4	1
Primary road	1	1	0.8	2	0	4	1
Secondary road	1	0.5	0.7	2	0	3	1
Tertiary road	1	0.4	0.5	2	0	2	1
Local road	1	0.2	0.4	2	0	2	1
Track	0.5	0	0.3	2	0	1.5	0.2
Active train	1	0	0.4	1	0	2	0
Abandoned train	0.5	0	0.3	1	0	1	0
Culvert/bridge	1	0	0	0	0	0	2
Dam	1	0	0	0	0	0.5	2
Lentic	0	0	0	0	0	0	1
Shrubland & grassland	0	0.2	0.4	2	0	0.5	0
Ruderal Shrub Swamp	0	0	0.4	2	0	0.5	0
	Logistic kernel parameters (m)						
Inflection point	500	200	50	200	200	200	200
Scaling factor	100	40	10	40	40	40	40