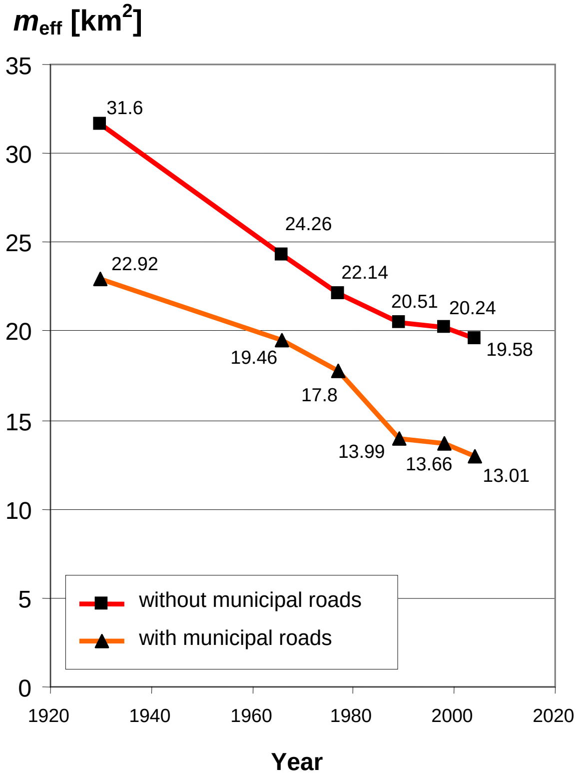
Example: Time series from Baden-Wurttemberg since 1930

The effective mesh size has decreased by 40% since 1930.



These results have been calculated at the University of Stuttgart in collaboration with the Center of Technology Assessment in Baden-Wurttemberg and the State Institute for Environmental Protection Baden-Wurttemberg (see Jaeger et al. 2001, Esswein et al. 2002).

The degree of fragmentation can also be expressed as the **effective mesh density**, *s*, (i. e., the effective number of patches per 100 km^2) which increases with increasing landscape fragmentation ($s = 1/m_{eff}$).

Literature

On the method:

Esswein, H., Jaeger, J., Schwarz-von Raumer, H.-G. 2003. Der Grad der Landschaftszerschneidung als Indikator im Naturschutz: unzerschnittene verkehrsarme Räume (UZR) oder effektive Maschenweite (m_{eff})? – In: NNA-Berichte 16(2): 53-68

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Schupp, D. 2005. Umweltindikator Landschaftszerschneidung. – *GAIA* 14(2): 101-106

Case studies applying the method (selection):

Esswein, H., J. Jaeger, H.-G. Schwarz-von Raumer, M. Müller 2002. *Landschaftszerschneidung in Baden-Württemberg. Zerschneidungsanalyse zur aktuellen Situation und zur Entwicklung der letzten 70 Jahre mit der effektiven Maschenweite.* – Arbeitsbericht der Akademie für Technikfolgenabschätzung Nr. 214, Stuttgart

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Zurich, April 2004, revised version January 2006

Measuring Landscape Fragmentation with the Effective Mesh Size m_{eff}

by Jochen Jaeger, Heide Esswein und Hans-Georg Schwarz-von Raumer

What is so problematic about landscape fragmentation?

Fragmentation of landscapes is a major cause of the alarming loss of species in Europe (e. g., due to the isolation of populations and the separation of complementary types of habitat). In addition, transportation infrastructure, a leading cause of fragmentation, detrimentally affects the recreational quality of landscapes (e. g., due to noise pollution and the reduction in size and quality of recreation areas). As early as 1985, the German Government set the political goal of preserving large un-fragmented low-traffic areas. However, landscape fragmentation has increased as rapidly as before due to new roads and railroads, enhanced traffic volume, and urban development.

Why is the effective mesh size better than other methods?

Former measures of landscape fragmentation are severely limited in their sensitivity (e. g., the density of traffic lines neglects the structure of the traffic network which may be evenly distributed or bundled; the total area of large un-fragmented low-traffic areas > 100 km^2 neglects what happens to patches that are smaller). The new method has important advantages. It fulfils all scientific, functional, and pragmatic requirements of environmental indicators (Esswein et al. 2003), it is simple and transparent and has an intuitive interpretation (see below). It takes into account all patches according to their size. Furthermore, testing the effective mesh size against a systematic set of nine scientific criteria has proven its accuracy and suitability (e. g, low sensitivity to small patches, monotonous reaction to different fragmentation phases, detection of structural differences, and advantageous mathematical characteristics; see Jaeger 2000, 2002, 2004). The effective mesh size is suitable for comparing the degree of fragmentation of landscapes with differing total size and with differing proportions of urban development and traffic area.

What does the value of the effective mesh size mean?

The effective mesh size is based on the probability of two points chosen randomly in a region will be connected. The more barriers in the landscape, the lower the probability that the two points will be connected, and the lower the effective mesh size. If a landscape is fragmented evenly into patches all of size m_{eff}, then the probability of being connected is the same as for the fragmentation pattern under investigation. It can also be interpreted as the expected size of the patch a point will be located in that is chosen randomly anywhere in the region, or as the ability of two animals of the same species – placed randomly in a region – to find each other.

The probability is converted into the size of a patch – the effective mesh size – by multiplying it by the total size of the region investigated. Thus, the unit of m_{eff} is that of area (e. g. ha or km^2). The value of m_{eff} is between 0 (entirely fragmented or developed) and the size of the region investigated (un-fragmented). In the case that all patches are of the same size, the effective mesh size assumes the size of the patches and, therefore, of the average patch size. However, as the size of patches usually differs, the effective mesh size is generally not equal to the average patch size. The measure m_{eff} has been developed by Jochen Jaeger at the Center of Technology Assessment in Baden-Wurttemberg, Stuttgart, and at the ETH Zurich (Jaeger 2000, 2002, 2004).

How are these results useful?

The degree of landscape fragmentation is an important environmental indicator in the fields of biodiversity and recreational quality and, more generally, sustainability. In addition, information on the degree of landscape fragmentation is relevant in regional planning and for decisions about infrastructure placement or removal. Time series show how strong the current trends are and what their direction is.

Where has the effective mesh size been used so far?

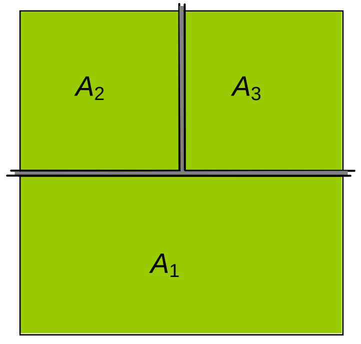
m_{eff} has already been used in Baden-Wurttemberg (see example on other side), Bavaria, Hesse, Thuringia, Saxony, Schleswig-Holstein, and South Tyrol (Italy). In 2004, the German Conference of the Ministers of the Environment adopted the recommendation by the German State Committee »Core Indicators« to use a standardized procedure for calculating m_{eff} in all German states. The m_{eff} method has also been used by the European Environmental Agency. Currently, m_{eff} is being calculated in Switzerland and Canada.

Example of how to calculate the effective mesh size

$$m_{eff} = \frac{1}{A_{total}}\left(A_1^2 + A_2^2 + \ldots + A_i^2 + \ldots + A_n^2\right)$$

where n = number of patches, A_{total} = total area of the region investigated, and A_i = size of patch i (i = 1, …, n).

Example: A landscape is fragmented by highways into three patches.



A_{total} = 4 km^2

The probability that two randomly chosen points will be in patch 1 (and, therefore, will be connected) is

$$\left(\frac{A_1}{A_{total}}\right)^2 = 0.5 \cdot 0.5 = 0.25.$$

The corresponding probability is $0.25^2 = 0.0625$ for both patches 2 and 3. The probability that the two points will be in patch 1 *or* 2 *or* 3 is the sum of the three probabilities which results in 0.375.

Multiplying this probability by the total area of the region finally gives the value of the effective mesh size:

$$0.375 \cdot 4\ km^2 = \mathbf{1.5\ km^2}.$$