LecoS - A QGIS plugin for automated landscape ecology analysis

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Abstract:

The quantification of landscape structures is an important part in many ecological analysis dealing with GIS derived satellite data. This paper introduces a new free and open-source tool for conducting landscape ecology analysis. LecoS is able to compute a variety of basic and advanced landscape metrics in an automatized way by iterating through an optional provided vector layer. It is integrated into the QGIS processing framework and can thus be used as a stand-alone tool or within bigger complex models. Finally a potential case-study is demonstrated, which tries to quantify pollinators responses on landscape derived metrics at various scales.

Key-words: QGIS, automation, landscape ecology, landscape metrics, Python, GIS tools, pollinators

Introduction:

The use of free and open-source software in ecological research has gained increasing attention in the last years (Steiniger & Hay, 2009; Boyd & Foody, 2011). Freely available open-source software has several advantages in research such as that the computational and statistical background of the analysis can be independently investigated and verified. Furthermore free software can enhance biological research and knowledge transfer in developing countries, where financial constraints can prevent the access to proprietary alternatives (Steiniger & Hay, 2009).

Within ecological research the field of landscape ecology features a number of free and open-source tools (Steiniger & Hay, 2009). Scientific studies in landscape ecology study the relationship between spatial patterns and ecological processes on a variety of spatial and organizational levels (Turner, 1989; Wu, 2006). Landscapes are here often seen as mosaics of differently structured and composed land-cover patches which are potentially connected by spatial dynamics (Pickett & Cadenasso, 1995). The landscape structure can be quantified by size, shape, configuration, number and position of land use patches within a landscape. Those quantified values and metrics are invaluable for various fields of ecological research like for instance studies on the influence of habitat fragmentation on wildlife (Fahrig 2003).

Landscape metrics are usually derived from classified land-cover datasets using specialist software and graphical information systems (GIS). See Steiniger & Hay (2009) for an extensive overview of freely available open-source software for landscape ecologists. Out of those software products FRAGSTAT is most likely the most comprehensible software package for the calculation

PeerJ PrePrints | https://peerj.com/preprints/116v2/ | v2 received: 9 Dec 2013, published: 9 Dec 2013, doi: 10.7287/peerj.preprints.116v2

of landscape and patch metrics (McGarigal & Marks, 1995; McGarigal et al., 2012). However the analysis in FRAGSTAT is separated from the visualization in a GIS program and does not run natively on all operating systems such as Mac-OS or Linux derivatives. Other widely used open-source software suites include the r.li extension for GRASS GIS (Baker & Cai, 1992) and SDMTools for the R software suite (VanDerWal et al., 2012). Those solution however depend on prior raster formating and cropping or can not be used in complex hierarchical models without knowledge of programming or scripting.

Here a new tool is introduced which is capable of analyzing various landscape and patch metrics within a freely available open-source GIS suite and is thus being able to combine the ability of calculating complex landscape metrics within sophisticated GIS models.

Landscape ecology analysis in QGIS

The QGIS project provides a free and open source desktop and server environment and ships with all functionalities of a modern GIS system (QGIS Development Team, 2013). It furthermore allows the easy extension of its core functions through user-written plugins, which can be downloaded within the desktop suite. Since the last stable version – codename 'Dufour' – the popular spatial data processing framework SEXTANTE has been integrated into QGIS. This new 'Processing toolbox' not only integrates existing geoprocessing functions into a similar toolbox as in the prominent ArcGIS suite, it also allows the creation of automatized models, which are able to combine several individual spatial calculations into single sequential models. Additionally, users are able to add their own python or R scripts to the Processing toolbox.

Here a new plugin for QGIS called LecoS (**L**andscape **eco**logy **S**tatistics) is introduced. It makes heavy use of the scientific python libraries SciPy and Numpy (Jones et al., 2001; Oliphant, 2007) to calculate basic and advanced landscape metrics and provides several functions to conduct landscape analysis. Up to now over 16 different landscape metrics are supported. LecoS furthermore comes with two different interfaces. Core functions like the computation of landscape metrics have their own graphical interface, while more advanced functionalities are only supported in the QGIS Processing toolbox.

Table 1: List of functions to date (Version 1.9.2). All functions need installed ***python-osgeo, python-scipy*** *and* ***python-pil*** *bindings within QGIS 2.0.1 Dafour.*

Name	Interface (Graphical|Processing)	Description
Landscape preparation		
Create random landscape (Distribution)	no | yes	Allows to create a new raster layer based on a chosen statistical distribution. The user can specify the

		extent of the output and distribution parameters.
Intersect Landscapes	no | yes	Takes a source and target raster layer as input and calculates the intersection of both layers.
Match two landscapes	no | yes	Reprojects and interpolates a raster layer to the projection and extent of a target raster.
Landscape statistics		
Count Raster Cells	no | yes	Returns the number of cells per unique cell value inside a raster layer
Landscape wide statistics	yes | yes	Allows to calculate various landscape metrics for an input raster layer
Patch statistics	no | yes	Computes patch metrics for a given land cover class.
Zonal statistics	no | yes	Performs a zonal statistics analysis with a raster layer containing zones and a raster layer containing values as input.
Landscape vector overlay		
Overlay raster metrics (Polygons)	yes | yes	Allows to compute landscape or patch metrics for each polygon feature of an input vector layer. Results can be generated as new separate table or added to attribute table of the vector layer.
Overlay vector metrics (Polygons)	yes | no	Can calculate basic metrics for attribute derived classes inside a polygon vector layer.
Query raster values (Points)	no | yes	Returns all raster values of the cells below a given point layer
Landscape modifications		
Clean small Pixels in patches	yes | yes	Cleans a given classified raster layer of small isolated pixels.
Close holes in patches	yes | yes	Closes holes (inner rings) in all patches of a specified land cover class.
Extract patch edges	yes | yes	Extracts the edges from each patch of a given land cover class.
Increase/Decrease patches	yes | yes	Allows the user to increase or decrease all landscape patches of a given land cover class.
Isolate smallest/greatest patches	yes | yes	Returns a raster layer with the greatest or smallest identified land cover patch. If multiple patches fulfill this criteria, than all of them are returned.
Label Landscape patches	no | yes	Conducts a connected component labeling (chessboard structure) of all raster cells with a given value. The output contains a raster layer where all individual patches have a single unique identifier.

Neighbourhood Analysis (Moving Window)	no | yes	Calculates statistics for cells in a raster layer using a moving window approach.

Since LecoS version 1.9 the set of available functions can be divided into the categories *Landscape preparation*, *Landscape modification*, *Landscape statistics* and *Landscape vector overlay* (Table 1). Landscape preparation functions allow the user to prepare and match input layers to each other, while landscape modification functions can modify or generate derivatives of raster layers. Users can calculate landscape metrics or raster properties with the Landscape statistics functions and are also able to automatize those calculations for all features of a given vector layer (Figure 1).

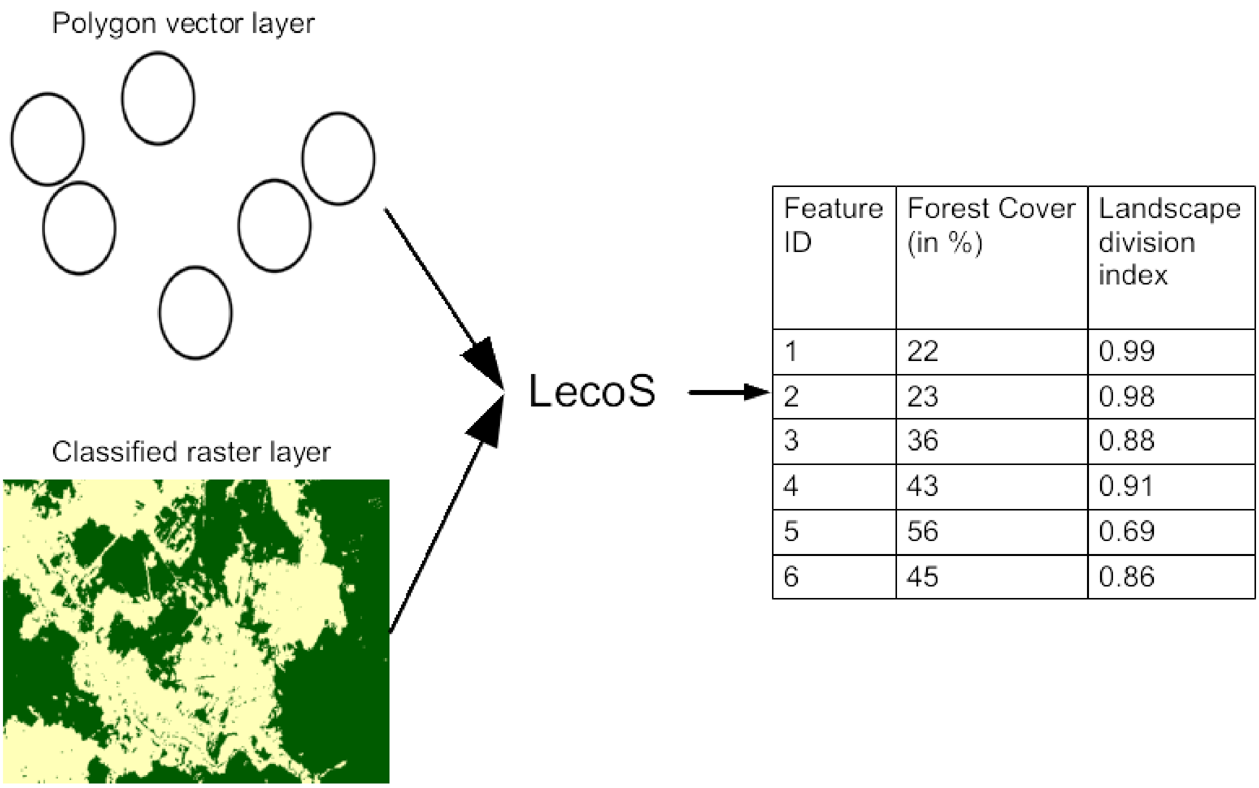

Figure 1: Illustrating the power of the Landscape vector overlay functions. The intended goal is to calculate the percentual proportion of forest cover and Jaegers landscape division index for every single study site (Jaeger, 2000) Using the vector overlay function LecoS is able to automatically compute the selected landscape metrics for every feature of the provided vector layer.

LecoS can be acquired through the QGIS plugin manager or directly downloaded from the QGIS plugin hub (http://plugins.qgis.org/plugins/LecoS/). The python libraries SciPy, NumPy and the imaging library PIL have to be installed and correctly configured in QGIS beforehand.

Case-study

In the following paragraphs a exemplary use-case of LecoS is demonstrated using real sampled field data. Pollinators are of increasing concern in recent ecological studies due to their reported declines which might endanger ecosystem service provisioning worldwide (Klein et al., 2007; Potts et al., 2010). The drivers of pollinator decline are various and habitat loss is certainly one of many reasons (Potts et al., 2010). Semi-natural habitats provide resources and nesting opportunities for many pollinators such as bees or hoverflies. However not only the primary habitat, but also the surrounding landscape is important as resource. Here it has been shown that different taxonomic units of pollinators show opposing responses to landscape structure and remoteness from their primary habitat (Meyer et al., 2009; Jauker et al., 2009). The goal of this little case-study will be to characterize the heterogeneity and characteristics of the landscape at various scales using an automatized model framework within QGIS.

All locality and species data was taken from Mudri-Stojnić et al, (2012), who conducted an assessment of pollinator abundance and diversity in 16 grassland habitats in northern Serbia. The study sites were all located within or next to agricultural used grasslands, while the amount of semi-natural habitats such as forests is generally spare (Mudri-Stojnić et al, 2012). Methodology of sampling and site selection can be read in the originial paper. For this study the sampled pollinators were separated and aggregated per study-site into bees and non-bees such as hoverflies. The information of forest cover in the vicinity was taken from available Pan-European forest cover maps at a spatial resolution of 25m (Kempeneers et al., 2011). To get spatial information on the amount of grassland and other land-cover types the CORINE land-cover dataset was obtained, clipped to the respective region and resampled to a 25m resolution (EEA, 2013).

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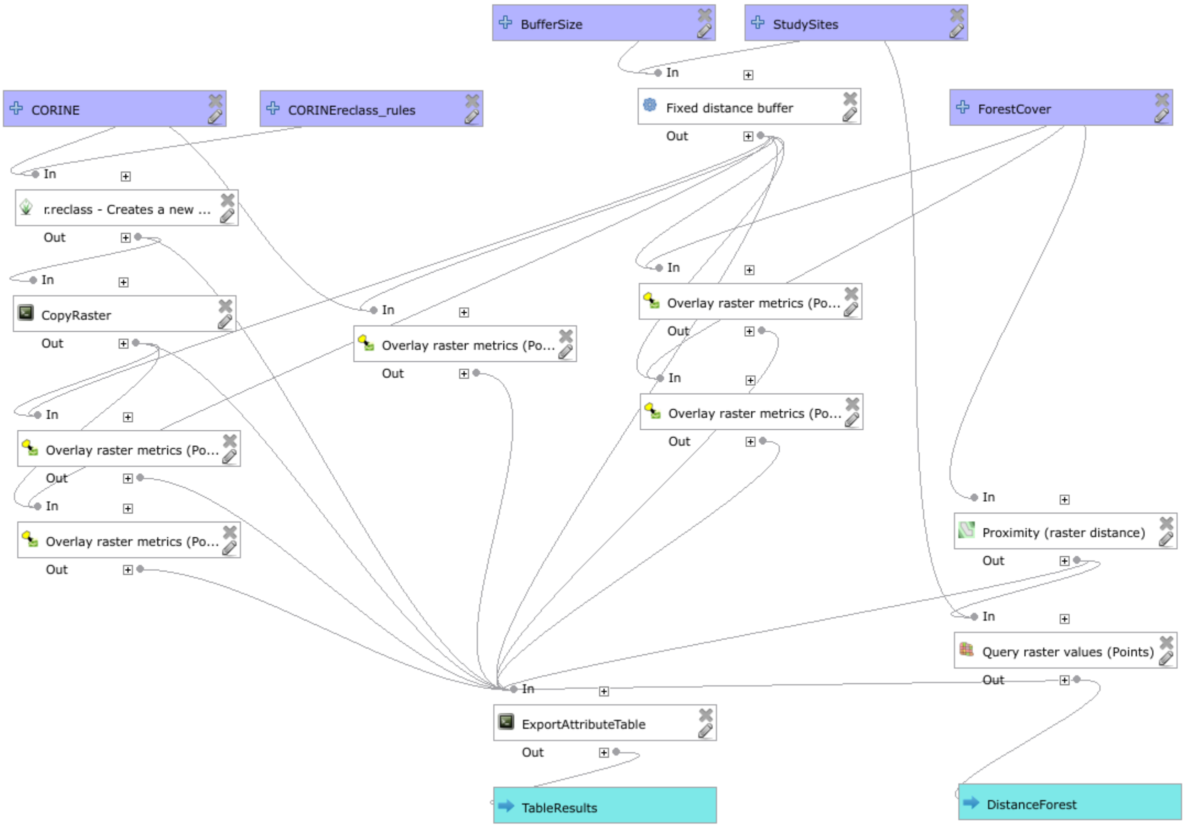

Figure 2: Shows the full model in QGIS to calculate a number of different landscape metrics for a given buffer size around the study sites. The full model was then executed in a batch-process with increasing buffer-size to calculate all metrics at various scales.

As potentially interesting predictors the percentage of forest cover (in %), edge density (edge length divided by number of forest patches), the total amount of agricultural used land in the vicinity (in m^2), the number of wetland patches and the landscape heterogeneity were calculated. All predictors were estimated in a circular buffer around the individual study sites at various scales which were stepwise increased from 100m up to 3000m (100m per step) and thus represent a potential dispersal range (Jauker et al., 2009). Additionally the distance from the forest edge was calculated for each study site. All landscape analysis was done in a single model using LecoS and the QGIS processing model builder (Figure 2, Supplementary Data). The resulting data is then analyzed in R (R Core Team, 2013), by calculating a generalized linear model of the distance to the next forest against pollinator abundance and diversity. Furthermore the correlation coefficient of pollinator abundance and diversity against the landscape derived predictors was calculated for all buffer increments similar to other existing studies (Meyer et al., 2009).

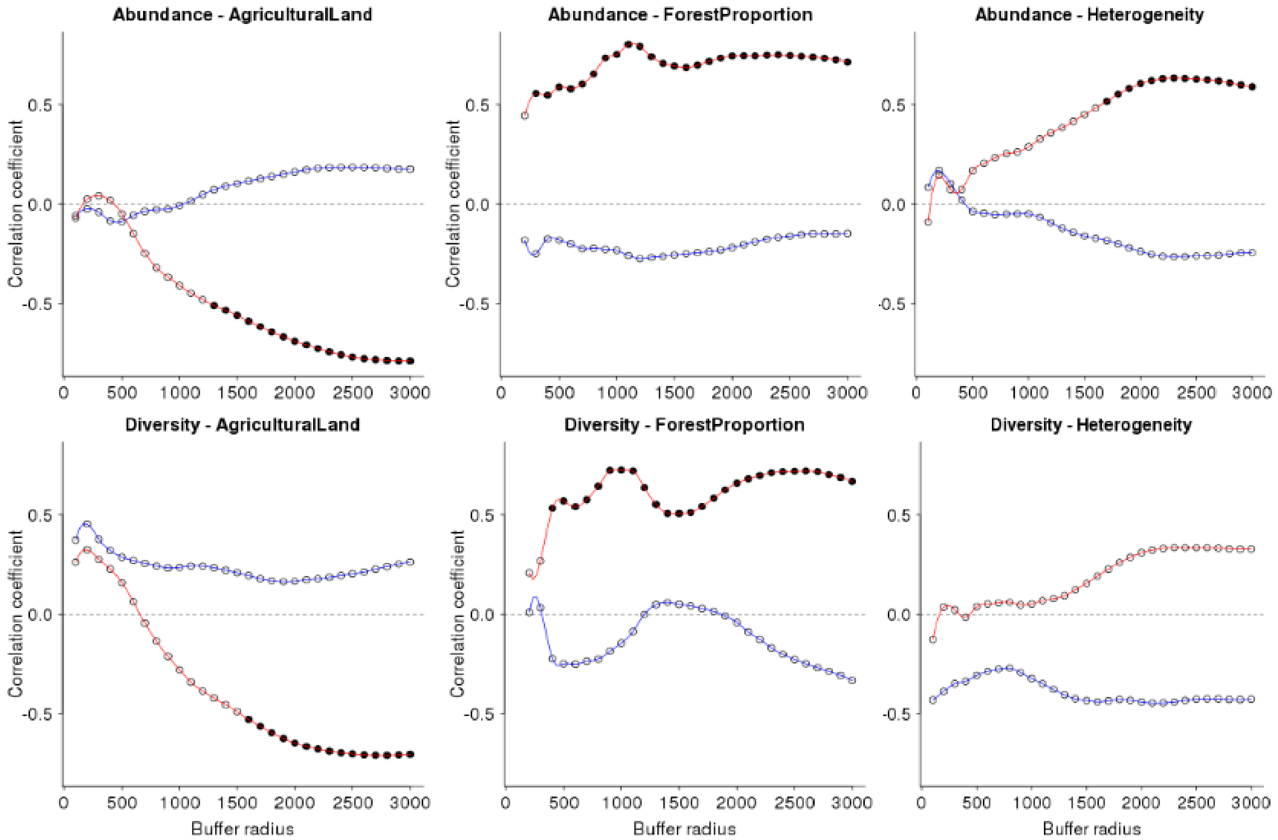

Figure 3: Pearson correlation coefficients between pollinator abundance and diversity and selected landscape metrics. Blue smoothed splines indicate bee species, while red splines show syrphid species. Coefficients are shown for all scales between 100m and 3000m buffer size. Filled circles denote significant correlations ($p < 0.05$) between the response and the predictor variable. Species richness and abundance was square-root transformed for analysis. The remaining figures can be found in the appendix.

Results and discussion

No significant relationship between the distance to main habitat at the study-site and bee or hoverfly diversity and abundance could be detected. However it could be shown that bee and hoverfly species indeed often have opposing responses at various landscape scales (Figure 3). Especially hoverfly abundance and diversity was significantly correlated with an increasing proportion of agricultural and forested land. Noteworthy is also the significant response of hoverfly abundance to increasing landscape heterogeneity at larger buffer scales (Figure 3). No significant correlation between any of the landscape metrics and bee abundance or diversity could be detected.

Although the pollinator survey conducted by Mudri-Stojnić et al, (2012) might be under-sampled and thus most likely does not fully reflect the whole existing species community, it is still able to show the often reported opposing difference between bees and hoverflies in response to landscape influences (Meyer et al., 2009; Jauker et al., 2009). Hoverfly abundance and diversity is supposed to be much more affected by land-cover change in the vicinity due to its dependency on microhabitats especially in forests (Branquart & Hemptinne, 2000). That might be the reason why hoverfly diversity and abundance correlated so strongly with forest cover on the landscape level.

However the reader shall be reminded that this case-study can not be considered robust evidence of general pollinator response to landscape influences due to its small sample size and design simplicity. It is rather thought of as a demonstration of a possible study scenario where the new QGIS plugin LecoS could potentially be used. In the authors opinion future studies should especially focus on decomposing community responses to individual species responses to landscape-wide resource provisioning. This has for instance already been done for some bumblebee species, who surprisingly experience landscapes differently at various spatial scales (Westphal et al., 2006).

Overview

Here a new plugin for QGIS is presented which allows the computation of landscape-wide and single patch metrics for use in ecological studies. The plugin itself is free and open-source and can be modified and redistributed by potential users. Due to its functional integration into the existing QGIS data processing framework it can be used in complex spatial models. The author hopes that this plugin might be useful for ecologists and other people working with open-source GIS products.

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