The open discussion version of this paper is available at: Antognelli S, Vizzari M. (2016) LISAM: an open source GIS-based model for liveability spatial assessment. PeerJ Preprints 4:e2133v2 https://doi.org/10.7287/peerj.preprints.2133v2

LISAM: an open source GIS-based model for liveability spatial assessment

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Abstract
Ecosystem Services (ES) and Urban Services (US) influence place liveability in a comparable manner so that assessing landscape liveability considering both types of services can result effective for landscape planning and policy-making purposes. Considering that liveability is strongly dependent also on landscape perception by local population, stakeholder involvement results essential for a more coherent liveability assessment.
In this study a Spatial Multicriteria Decision Aiding (S-MCDA) approach guided the development of a LIveability Spatial Assessment Model (LISAM). Using a combination of GIS techniques (euclidean distance, kernel density estimation, network analysis, viewshed analysis), implemented in open-source geo-spatial software (QGIS, PostGIS and PostgreSQL), consistent and comparable ES and US spatial indices were calculated in a study area located in central Italy. These indices, according to the Analytical Hierarchy Process (AHP), were integrated with their percentage weights on liveability deriving from stakeholders interviews. Then, to investigate the liveability levels of local population, main statistics of liveability values were calculated per census section.
Results include overall liveability indices at a local scale, and key statistics of liveability related to resident population. The work highlights the effectiveness of LISAM to assess local liveability and to deliver important information for policy-makers. However, together with ES and US, a more comprehensive assessment of perceived landscape liveability will require the integration of ecosystem and urban disservices within the same approach to consider those factors generated by landscape components that reduce the overall level of place liveability.

Background

Liveability - the suitability of a landscape to be inhabited by people - is an anthropocentric concept (van Kamp et al., 2003) becoming a leading objective in landscape planning and management (de Haan et al., 2014). This means that new and efficient tools for its assessment are needed. Landscape liveability implies an anthropocentric view of landscape, where ecosystems are able to fulfil important societal needs by providing ecosystem services (ES) similarly to Urban systems which provide the more traditional Urban Services (US). Moreover, liveability is also dependent on subjective stakeholders' perception. Hence, the assessment of landscape liveability integrating ES and US with stakeholders' perception, can result very effective for landscape planning and policy-making purposes.

To explore the relationship between liveability and local population, the analysis of the spatial relationship between liveability level and resident population can prove very useful for suggesting new strategies for landscapes planning oriented towards a sustainable development and liveability increase, not only through the traditional urban services management, but also – and especially - through the ES management. In this vein, the present study aims at developing a methodology for liveability spatial assessment based on ES and US mapping and stakeholders involvement to quantify their relative relevance.

Please cite this paper as: Sara Antognelli, Marco Vizzari (2018) LISAM: an open source GIS-based model for liveability spatial assessment. In Marchesini I. & Pierleoni A. (Eds.) Proceedings of the 4th Open Source Geospatial Research and Education Symposium (OGRS2016). Perugia, 12-14 October 2016.
https://doi.org/10.30437/ogrs2016_paper_19

Methodology

In a previous study by Antognelli and Vizzari (2016) LIAM, a model for calculating a liveability services classification and ranking through stakeholders involvement was implemented and applied in the Perugia area, (Umbria, Italy; Figure 1). This study area, approximately 998 km^2 wide, covers seven different municipalities: Perugia, Magione, Passignano sul Trasimeno, Corciano, Umbertide, Torgiano and Deruta. In this study, a hierarchical classification of liveability services, based on the Common International Classification of Ecosystem Services (CICES), was designed to include both ES and US. Then, the relative weights on liveability of each service class, division and section were calculated according to an Analytical Hierarchy Process (AHP) approach (Saaty, 1980).

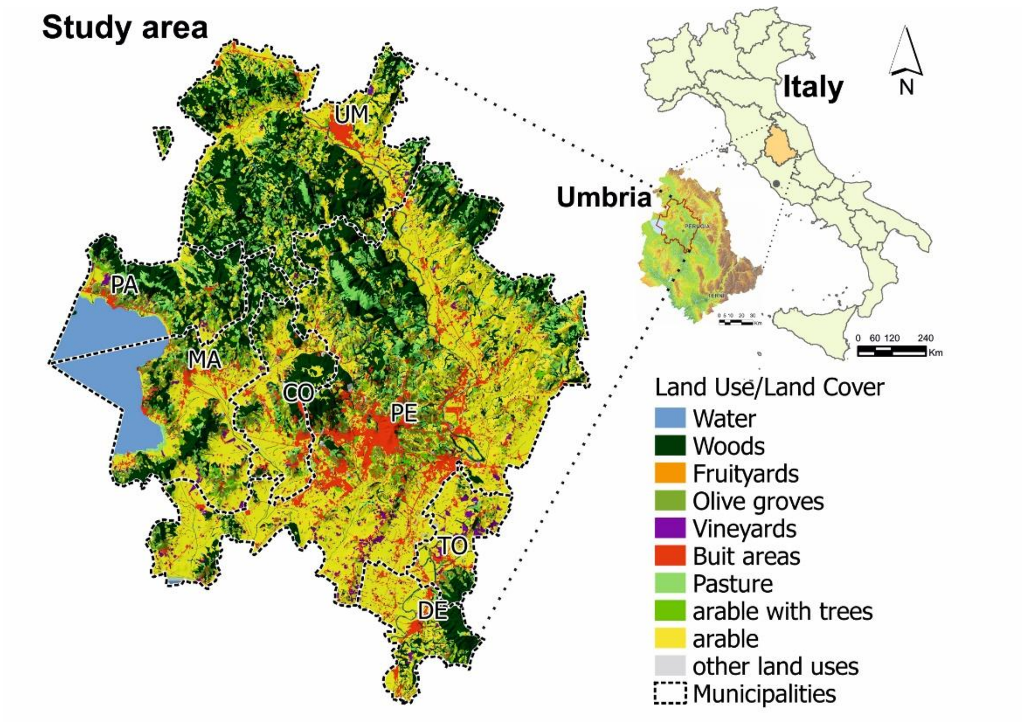

Figure 1: Localization of the study area and its land use / land cover (CORINE 2006, personal elaboration)

Starting from LIAM by means of a Spatial Multicriteria Decision Aiding (S-MCDA) approach (Malczewski, 2006) a LIveability Spatial Assessment Model (LISAM) was developed. To this purpose, spatial indices of ES and US accessibility of service delivery points were calculated through four main different approaches (tab.1) using data collected from local authorities and open databases. Other specific approaches, based on land use - land cover data, were used for some regulating ES. QGIS scripts (an example is reported in Figure 2) were implemented using the graphical modeller in order to calculate intermediate and final spatial indices of liveability. Using weighted linear combinations, ES and US spatial indices were progressively aggregated with their weights on liveability calculated in LIAM, according to the hierarchical classification. Thus, intermediate and overall spatial indices of liveability were calculated.

Table 1: ecosystem and urban service mapping approaches adopted in LISAM.

Approach	Main GIS steps	Service type
Euclidean distance	- Proximity analysis of delivery points	services whose proximity of delivery point is intended as easiness of connection to a network

		(e.g. water networks, sewage networks).
Density analysis	- Kernel Density Estimation (KDE) on delivery points location (bandwidth = 500 m)	services whose local availability level is dependent on the density of delivery points within a certain distance (e.g. historical sites).
Minimum driving time (MDT)	- Road network graph building of study area in PostgreSQL using Open Street Map data - Calculation of MDT to the nearest delivery point with pgrouting pgr_drivingDistance function - spline interpolation of MDT linked to road nodes	services for which a single delivery point can fulfil the local people's need (e.g. pharmacies, food shops)
Viewshed analysis	- Areas of interest (AOIs) conversion to a regular sample grid (50 m) - For each pixel, calculation of number of visible sampling points falling into AOIs	aesthetical services by high quality landscapes

Spatial indices of 43 on 67 services included in LIAM classification were calculated in this first LISAM application. As a consequence, only a percentage of the total liveability was mapped. For this reason, we calculated the *explained liveability* (EL) as the sum of the weights of the mapped services in each point of the study area (Figure 2). EL is variable on the map, since respondents weights were spatialised using Inverse Distance Weighting (IDW), based on their place of living.

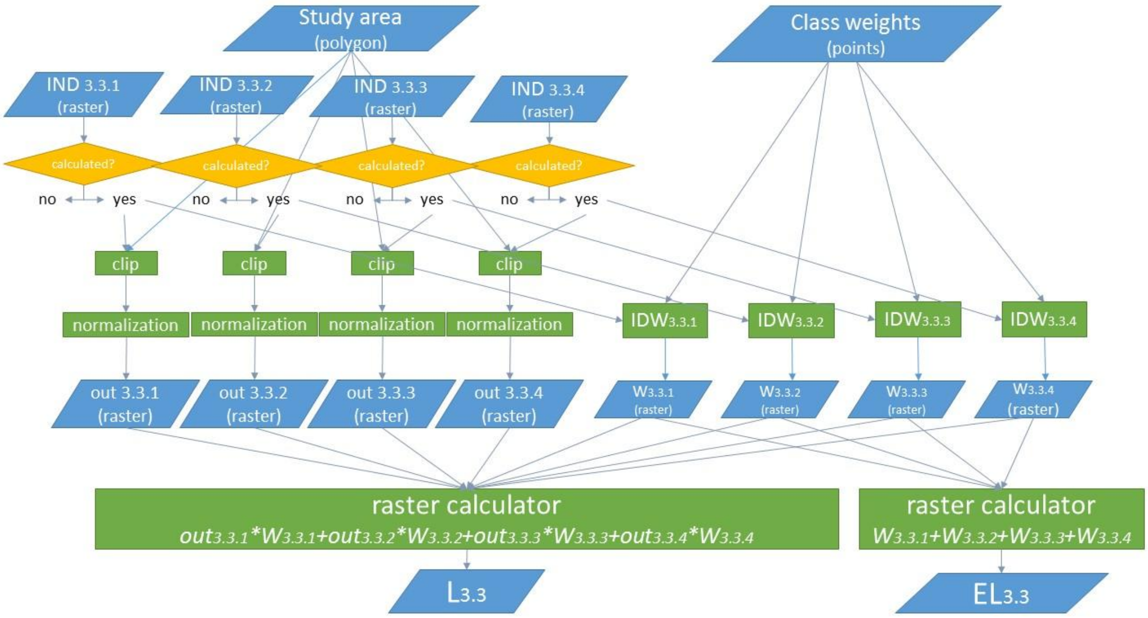

Figure 2: QGIS model for calculation of Liveability index (L) and Explained Liveability (EL) of division 3.3. IND: spatial index; out: clipped and normalized spatial index; IDW: inverse distance weighting; W: spatialised weights; subscript indicates codes of classes in division 3.3.

After the calculation of the final liveability index using LISAM, average liveability level in each census section was calculated to explore the relationships between liveability levels and resident population. A liveability class, defined based on mean and standard deviation of liveability (tab.2), was attributed to each census section. Then, total resident population and average population density were calculated for each liveability class.

Table 2: Liveability classes definition. M: mean; SD: Standard Deviation

Class value	Liveability interval	Area (sqKm)	Area (%)
1	Min – (M–2SD)	6.107	1%
2	(M–2SD) – (M–1SD)	127.778	13%
3	(M–SD) – M	472.416	47%
4	M – (M+SD)	274.266	27%
5	(M+SD) – (M+2SD)	66.070	7%
6	(M+2SD) – Max	51.008	5%
	-	997.645	100%

Results and discussion

Results include the overall liveability index map, with EL reported by isolines, and the population statistics for each liveability class. The final liveability map is able to explain from 73 to 87% of the total liveability, depending on the area considered (Figure 3). Reading together the map and the graph, it appears clear that the areas with the highest perceived liveability (class 6) are also the most densely populated, since population density is about 7,5 times higher than the average of the area. So, liveability values become higher where anthropogenic features related to US occurs, as emerges from the comparison of the final liveability map with the Land Use-Land Cover map (Figure 1).

Results highlight that the great majority of population (85%) live in areas where liveability level is higher than the average (class 4, 5, and 6). These areas covers less than one half of the total study area (39%). Population density is directly related to the liveability level, while the cumulated population show a different trend, since it is manly located in liveability class 4 or 6. Results show also that urban areas show higher levels of liveability if compared to rural or natural ones. However, Ecosystem Services provisioning may be undervalued in this liveability assessment due to the difficulties in ES assessment. In fact, all the services not mapped in LISAM implementation, determining the quota of unexplained liveability described in Figure 3, are all ecosystem ones.

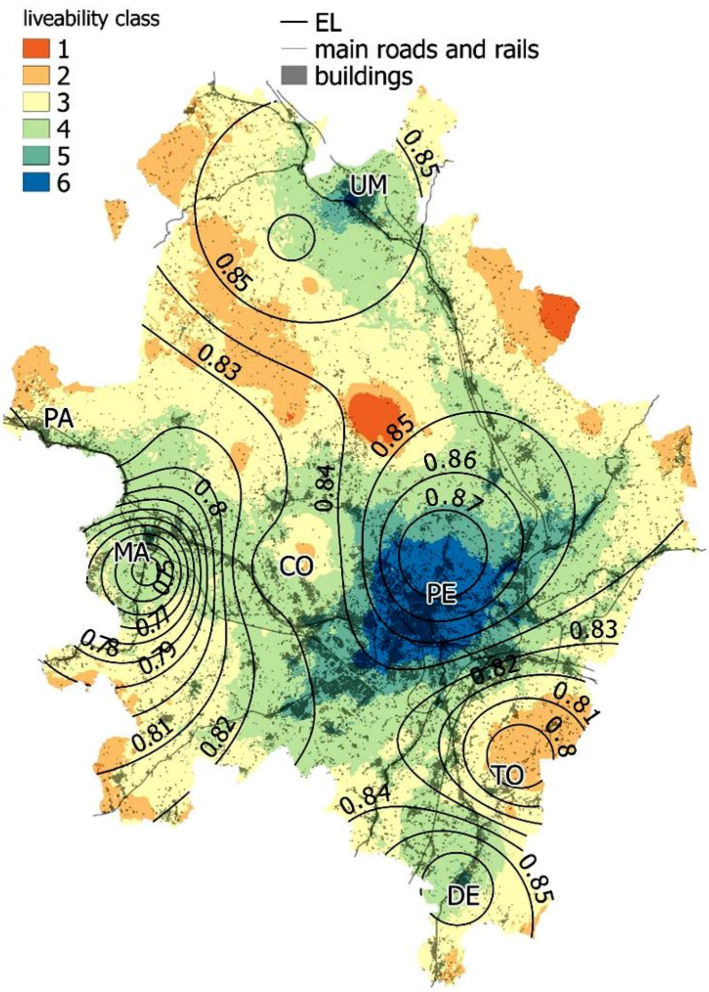

Figure 3. Overall liveability map. Key: CO: Corciano, DE: Deruta, MA: Magione, PA: Passignano S.T., PE: Perugia, TO: Torgiano, UM: Umbertide

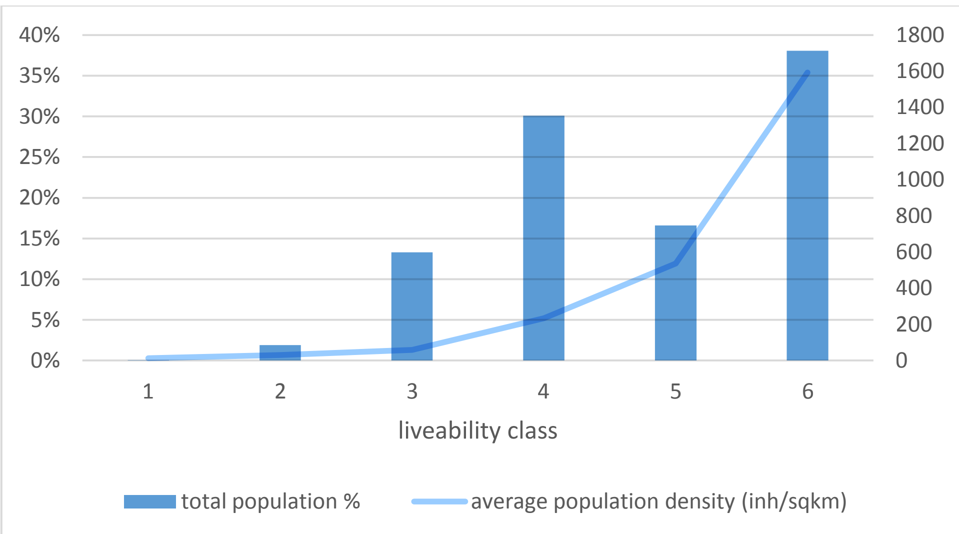

Figure 4. Liveability classes, total population and average population density. Percentage of resident population is reported on the left axis, population density on the right axis.

Conclusions

LISAM has proved to be an innovative, open-source based tool for locally determining the relative value of landscape liveability, which could help to overcome the difficulties related to the introduction of the ES approach in local landscape planning and policy development as sacked by different authors (see e.g. Geneletti, 2011; Müller et al., 2010). LISAM results highlights that the more densely populated areas are also the more liveable ones, and that the greatest part of population lives in areas where liveability is higher. LISAM results open new considerations about landscape planning strategies oriented towards sustainable development, since they highlight that the increase of liveability is related to an increase in population density and so, could generate urbanization dynamics. The reported results clearly highlight also the urgency of define more affordable ES accessibility indicators as well as ecosystem and urban disservices to integrate in the model for a more complete liveability assessment. Indicators and weights uncertainty assessment methods should also be included to better validate the final outputs' reliability.

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