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ENVIRONMENTAL FRAGMENTATION TENDENCY: THE SPRAWL INDEX

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ABSTRACT

About the matter of the environmental fragmentation due to settlement structure, an important issue is the "fragmentation tendency". This phenomenon is linked to territorial sprawl sensibility and determined by different land and urban characteristics.
If general ecological conditions are good, we can be sure that every animal species will increase the number of their individuals and will occupy larger areas and places. So we can say that this phenomenon is the same for the human component, when morphological, economic, climatic and social conditions are favourable.
This means that we can draw the probable evolution of the settlement pattern in the future in relation to particular aspects of the territory, such as the altitude, slope, land use, land exposure, infrastructure and urban location.
We can also obtain a particular index (the sprawl index) from the cited parameters, to measure territorial sensibility toward the urban sprawl phenomena and identify which areas are more critical than others in terms of future environmental fragmentation.
The SIX (Sprawl Index) that we present in this paper has been developed and experimented in the case study of the Umbria Region (Italy) in the context of the studies finalized at the RERU (Umbria Region Ecological Network).

METHODOLOGY USED

This paper fits into the scientific debate, very lively in Europe today, on the themes of ecological networks, environmental fragmentation and the interference of settlements on the ecosystem.

According to recent papers on the forms of environmental fragmentation of the territory (Romano 2002), the latter may be broken down into three categories:

- Current fragmentation
- Potential fragmentation
- Tendential fragmentation

Current fragmentation is the one observed today in the territory, which, owing to this same reason, contributes significantly to the current geography of ecosystems and conditions the present-day distribution areas and the relations among species. In other words, it may be considered part and parcel of the current ecological structure of the territory.

Potential fragmentation is what that the ecosystem geography will be subject to, owing to the implementation of currently forecast plans or those in the pipeline. It impacts the short- and mid-term environmental scenario and the re-organisation of the system of distribution ranges and species-specific relations that will occur following the implementation of urban development plans and after a period of adjustment.

Tendential fragmentation is tied to the "eco-ethology" of the human species and the expansion and "territory-conquering" thrust that it expresses constantly, providing that the environmental, economic and social conditions for it exist. As in the case of potential fragmentation, tendential fragmentation also involves the representation of a more long-term scenario developed using parameters that are complex to identify and calculate and that are tied to the environmental traits of the places, as well as social, behavioural and economic characteristics.

For the current and potential forms of fragmentation caused by settlements, it is possible to use the same indicators, such as actual state descriptors in the first case and scenario descriptors in the second (Romano 2000; Biondi *et alii* 2003).

Tendential fragmentation, which this paper focuses on, depends on the sensibility of the territory towards urban sprawl, which further breaks up the ecosystem structure.

It may be claimed that every settlement expresses latent tendential fragmentation features, characterised per types, vis-à-vis its respective environmental domain of

incidence, and that this "tendentiality" may be highlighted by some specific aspects of the social, economic, historical, traditional, cultural, and customs-related organism which clearly vary from place to place and for which it is not possible to develop generalised models.

Sensibility towards land use for widespread urbanisation, is tied, as mentioned previously, to the eco-ethological aspects of human communities and their propensity, like any other animal population, to expand in a given territory, if the environmental, morphological, climatic and trophic (economic) conditions allow it. The spread of settlements to the detriment of natural areas has always occurred and this phenomenon has always had peak-and-trough cycles (Mumford 1961).

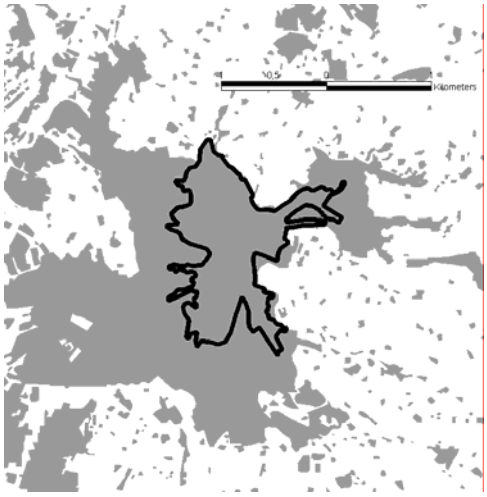


Figure 1 – Comparison between the size of the urban area of Perugia in 1954 (IGM data – outlined in black) and in 2002 (data of the Region of Umbria – in grey)

In the USA the emergence of *sprawl* ("expansion", "invasion", city that encroaches upon the countryside with its new suburbs) has now reached alarming proportions in some cases, thanks to favourable and coinciding conditions of an economic, social and physical-climatic nature (Mitchell 2001; Hess *et alii* 2001).

For some international large urban areas the sprawl represent an important phenomena that has documented and discussed by several decades (Buttenheim & Cornick 1938; Mumford 1961; Haskell 1958).

In Italy too, the phenomenon of "urban sprawl" has been considered for many years as one of the causes of urban functional disorganisation, in terms of use of services and efficiency of transportation (INU 1990). The effect that settlement disruption has on the breaking up of the eco-mosaic and ecosystem layout has been scarcely underscored.

Taking economic conditions and social models to be the same, the tendential urban sprawl is influenced by parameters such as proximity of the areas in question to urban

nodes and main roads, climatology, acclivity and exposure of the land, existing environmental resources and to a certainly more limited extent, the use of the latter for production purposes.

Planning introduces mechanisms to control the free development of settlements, but is unable, at least generally, to prevent that the thrusts generated by collective behaviour patterns and economic dynamics move towards their tendential configuration, even if over longer periods, owing to the pressure and opposition that they have in the field of the various phenomena.

Probably, but this is merely speculation, planning tools, which respond to a varying extent to the requests of economic groups and the emerging expectations of the social community, largely support territorial change which would perhaps occur spontaneously even in the absence of a plan, albeit in a less controlled manner.

This tendential movement of urban development also entails consequences for environmental fragmentation in the long term.

Drawing up a tendential scenario of urban sprawl allows us to develop a potential picture of the interference between the urban functions of the territory and the relational functions of existing biocenosis (ecological networks).

This allows planners to control, direct and relocate the same trends, mitigating the impact on ecosystem geographies.

THE SPRAWL INDEX

The Sprawl Index (SIX) is calculated, by means of specific GIS modelling, using thematic degrees of propensity to the phenomenon that depend on a set of territorial (morphological-urban development) characteristics: altitude, land acclivity, exposure of slopes, time needed to access major towns and proximity to main roads, according to the classes shown in *table 1*.

The Sprawl Index (SIX) is calculated through the following equation that contains a set of degrees of settlement location sensibility to the aforementioned territorial and morphological characteristics:

$$SIX = Calt + Csl + Casp + Cacc + Cstr \quad (1)$$

where:

Calt = Altitude sensibility degree;
Csl = Acclivity sensibility degree ;
Casp = Exposure sensibility degree;
Cacc = Urban nodes proximity sensibility degree;
Cstr = Road proximity sensibility degree

Each degree of thematic sensibility, for every area corresponding to well-defined territorial (morphological-urban development) features, takes on a value according to a geometrical progression scale, in accordance with different quality levels (*table 1*).

Categories and classes of territorial characters	Sprawl Sensibility			
	Low	Middle	High	Very High
Altitude (m a.s.l.) - Calt				
Less 300				16
Between 300 and 600			8	
Between 600 and 800		4		
Between 800 and 1000	2			
Acclivity - Csl				
Less 5%				16
Between 5 and 10%			8	
Between 10 and 20%		4		
Over 20%	2			
Exposure - Casp				
ESE-WSW			8	
Others	2			
Accessibility towards urban nodes (min) - Cacc				
Less 5				16
Between 5 and 10			8	
Between 10 and 15		4		
Between 15 and 20	2			
Proximity to the main roads (m) - Cstr				
Less 50				16
Between 50 and 100			8	
Between 100 and 150		4		
Between 150 and 200	2			

Table 1 – Degrees of sprawl propensity

Some simplifications have been introduced to make the applicability of the analysis easier, at least initially:

- the internal subdivision in classes of the five categories of territorial traits follows structured criteria, tailored to the geography of peninsular Italy.
- the altitude classes identified correspond to landscape and phytoclimatic characteristics (in peninsular Italy, the altitude of 300 metres corresponds to hills, the mountain area ranges between 600 and 800 metres in relation to the lower limits of the phytogeographical zones of the Alpinetum, Picetum and Fagetum and the upper limits of the olive groves, while on average above 1,000 metres we find the mountain surface of beech woods) (Istat 1992).
- acclivity classes are included with steady intervals tied to growing difficulties for the location of buildings and urbanisation functions.

- in the selection of the slope exposure the southern side that has a better exposure to the sun is distinguished.
- the study of accessibility to the main urban nodes leads to the selection of four classes of time need to reach cities from the outer parts of the territory with steady intervals of 5 minutes.
- by analogy with the previous category, four buffers of proximity to the main roads are selected which determine progressive location advantages for settlement and service functions.
- the five categories of territorial and morphological traits considered are not attributed different weights owing to their presumable varying influence over the settlement.
- the sensibility quality levels are four or five, with the exception of slope exposure, which only has two, as it is held to be the trait that has a less decisive impact on the distribution of built areas.

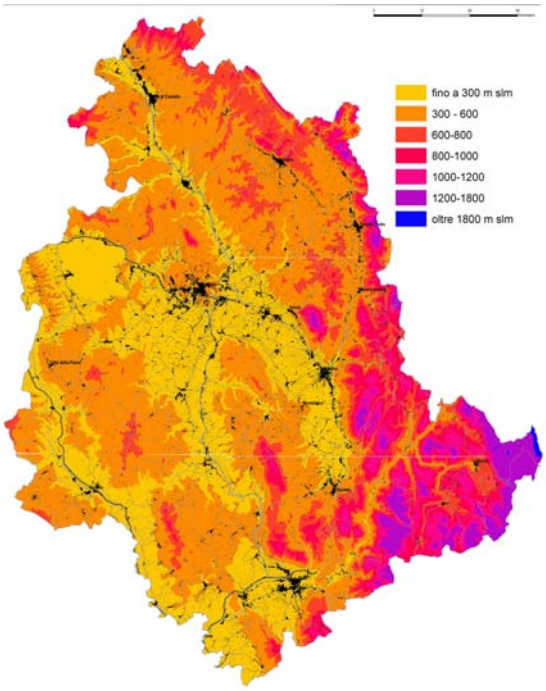


Figure 2– Altitude classes

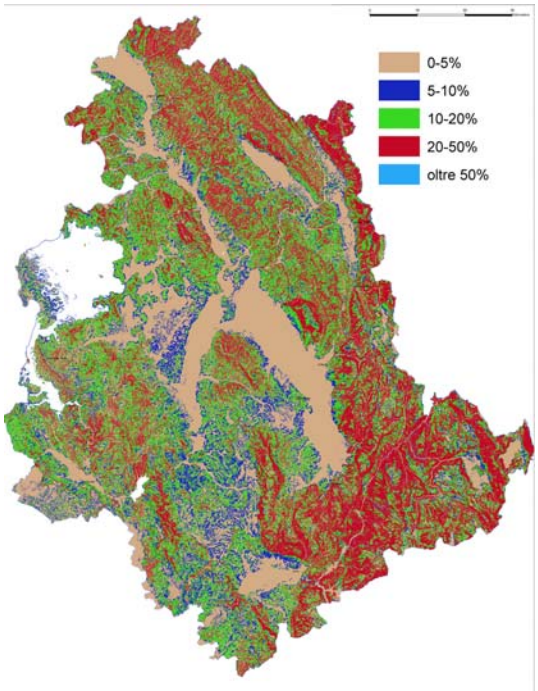


Figure 3 – Acclivity classes

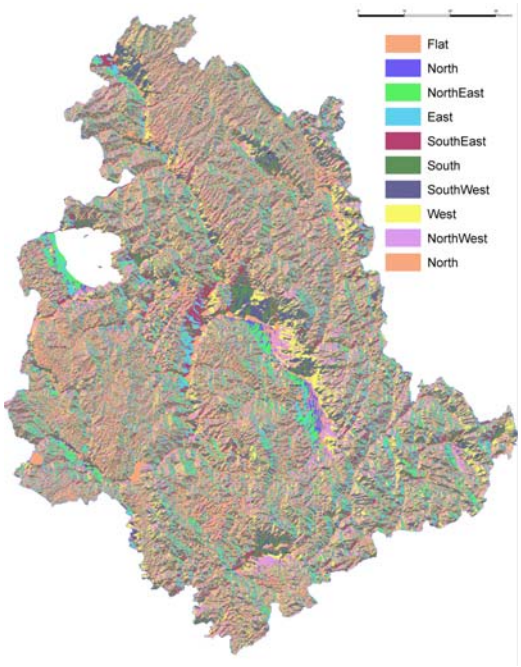


Figure 4 – Slope exposure classes

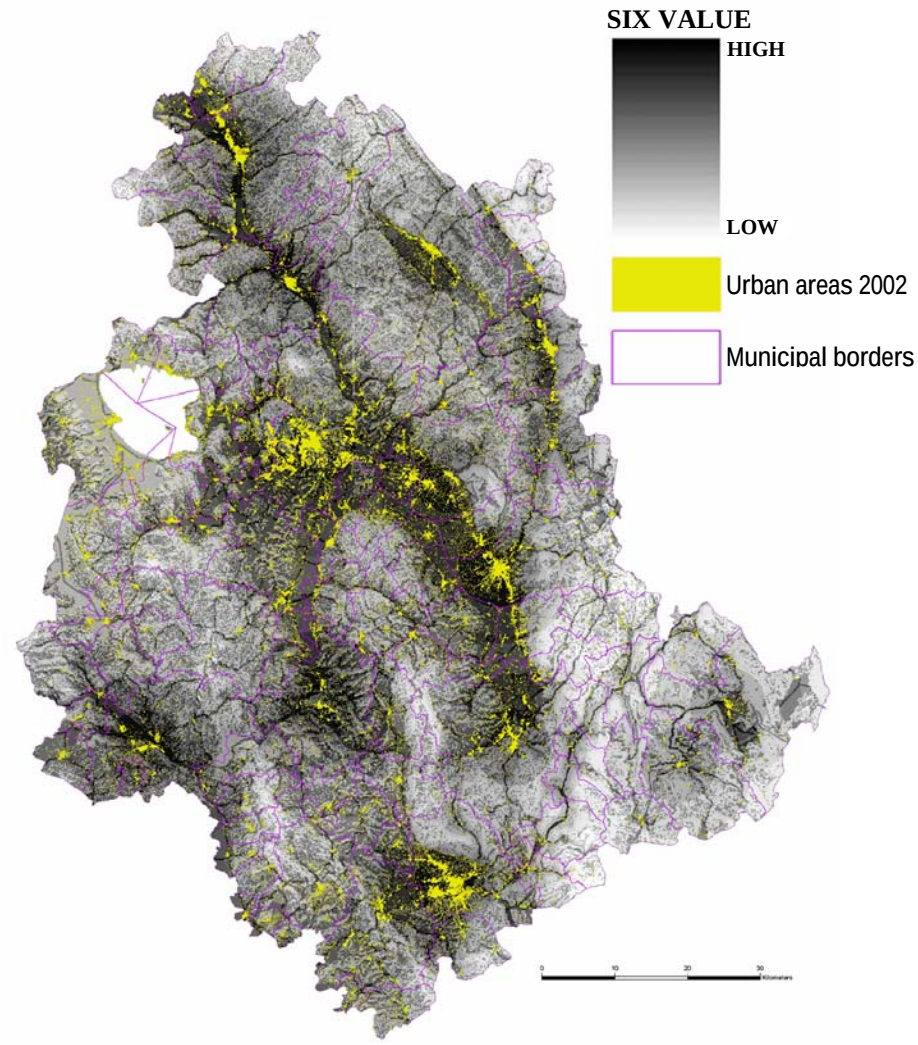


Figure 5 – Sprawl Index for the Region of Umbria

SPRAWL INDEX ON CONSISTENCY CHECK THE CASE STUDY OF THE REGION OF UMBRIA

The result obtained (*figure 5*) by means of sensibility values attributed on the basis of speculation (*table 1*) is checked subsequently against the territorial reality of the case study in question. The comparison between spatial distribution of built areas and the parameters used to calculate the SIX index provide an indication of the aspects that have conditioned the increase of settlements in Umbria the most, at least from the standpoint of their global traits. We lack data regarding the different types of buildings, on the basis of which we would obtain instead useful information on the varying sensibility of areas in particular locations, such as industrial production, residential areas and so on.

The ensuing comparative analysis shows the significant reliability of the method of definition and calculation of urban sprawl sensibility degrees and the sprawl index, since the built areas surveyed in 2002 seem to be significantly conditioned by the morphological-urban development traits identified.

SIX (Sprawl Index)	Built areas (ha)	%
<= 11 (low)	1888,83	0,06
12-17 (middle)	3473,68	0,12
18-22 (high)	3604,5	0,12
oltre 22 (very high)	21157,73	0,70
	30124,74	

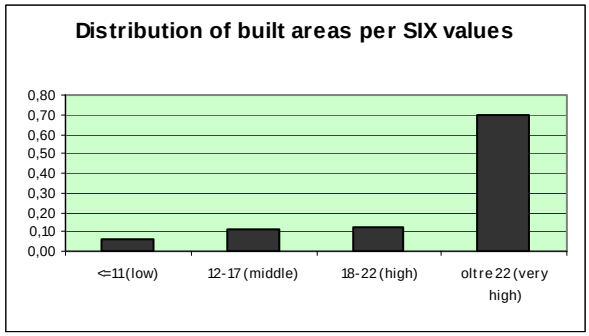


Table 2 – Distribution of built areas per SIX values

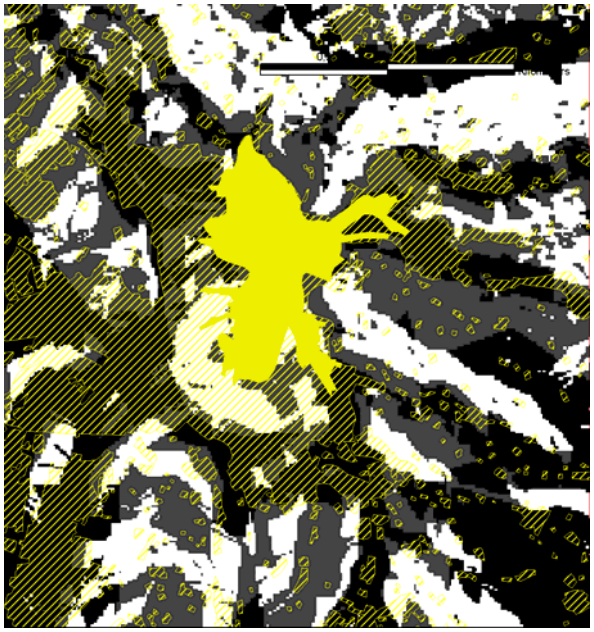


Figure 6 – Spatial matching between the urban area of Perugia in 1954 (in orange), the urban area in 2002 (yellow striped) and the higher values of the sprawl index (progressively darker shades of grey).

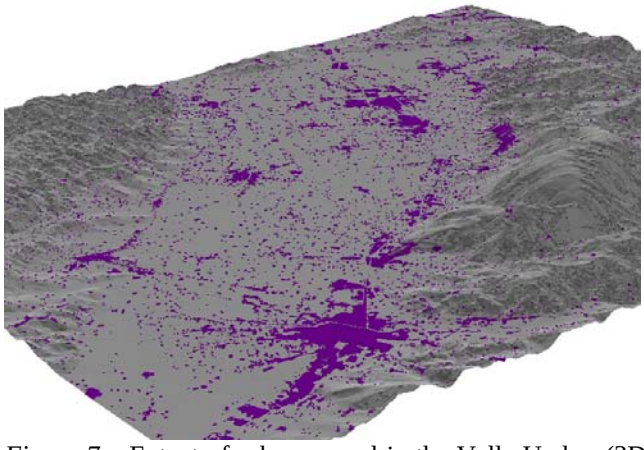
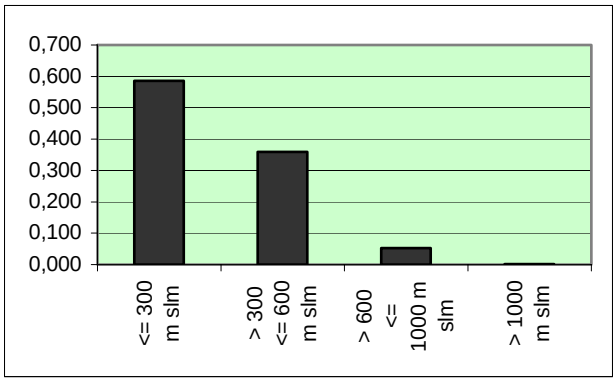


Figure 7 – Extent of urban sprawl in the Valle Umbra (3D processing of the Umbria Region Ecological Network Data)

The case study in question also considered the partial sensibility of the response of settlements to the factors of altitude, acclivity, slope exposure, proximity to major urban areas and roads broken down into the classes shown in the following diagrams:

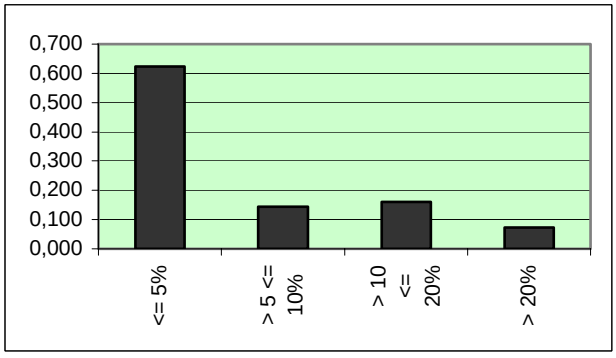
Altitude classes	Built areas(ha)	%
<= 300 m slm	17670,08	0,587
> 300 <= 600 m slm	10842,68	0,360
> 600 <= 1000 m slm	1566,74	0,052
> 1000 m slm	45,24	0,002
	30124,74	

Table 3 – Distribution of built areas per land altitude classes



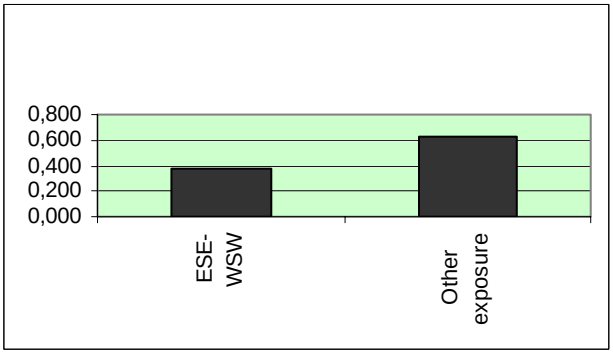
Acclivity classes	Built areas (ha)	%
<= 5%	18768,84	0,623
> 5 <= 10%	4346,5	0,144
> 10 <= 20%	4838,54	0,161
> 20%	2170,86	0,072
	30124,74	

Table 4 - Distribution of built areas per acclivity classes



Slope exposure classes	Built areas (ha)	%
ESE-WSW	11150,82	0,370
Other exposure	18973,92	0,630
	30124,74	

Table 5 – Distribution of built areas per slope exposure classes



Main road proximity classes	Built areas (ha)	%
<= 50 m	6879,34	0,228
> 50 <= 100 m	4958,34	0,165
> 100 <= 150 m	3353,12	0,111
> 150 <= 200	2457,87	0,082
> 200 m	12475,33	0,414
	30124,74	

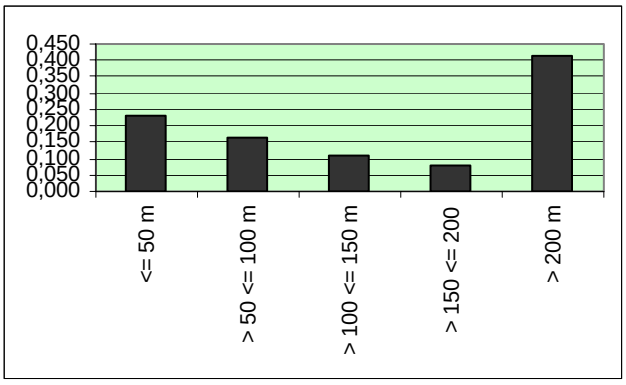


Table 6 – Distribution of built areas per main road proximity classes

Urban area proximity classes	Built areas (ha)	%
<= 10 min	19259,21	0,639
> 10 <= 15 min	5222,92	0,173
> 15 <= 20 min	2428,58	0,081
> 20 m	3214,03	0,107
	30124,74	

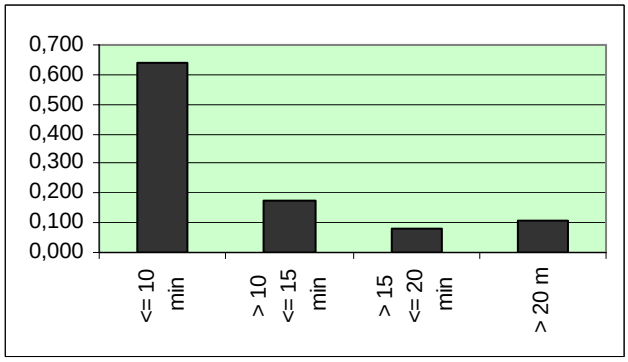


Table 7 – Distribution of built areas per urban area proximity classes

Variance in the localisation response of settlements differ considerably in the various cases of key factors considered: the greater the variance, the higher the power of selection of the parameter analysed among the five listed ones. The variance in *Table 8* clearly show that the factors that substantially condition urbanisation geographies are, in the case of Umbria, altitude, urban area proximity and acclivity.

Sensibility factors	Variance
Altitude	0,057
Urban area proximity	0,052
Land acclivity	0,047
Land exposure	0,017
Main road proximity	0,014

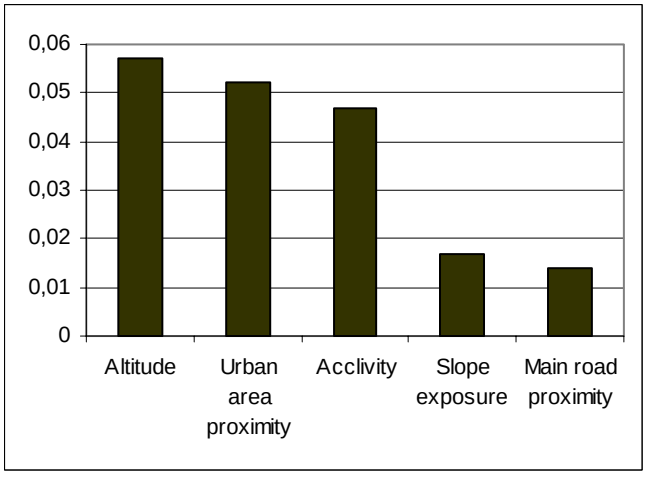


Table 8 - Coefficient of variance of sensibility factors

CONCLUSIONS

With the SIX index it is possible to make assessments at municipal level with the aim of acknowledging the average scope of urban sprawl against the map of the local

authorities. The decisions to curb the excessive sprawl of buildings throughout the territory, and related consequences on the ecosystem, have to be taken by the municipal authorities within the framework of control actions implemented through their respective urban development plans.

As shown in *Figure 8*, the administrative responsibilities, in the region taken as the case study, differ significantly and highlight a marked longitudinal prevalence of sensibility towards the phenomenon, along one of the main communication lines of the Umbria region with the areas north and south of it. In the long term, if no innovative environmental policies are adopted, this will entail the deterioration of ecosystem fragmentation in the region between the eastern and western sides, leading to the virtually total elimination of biological permeability for a large number of species.

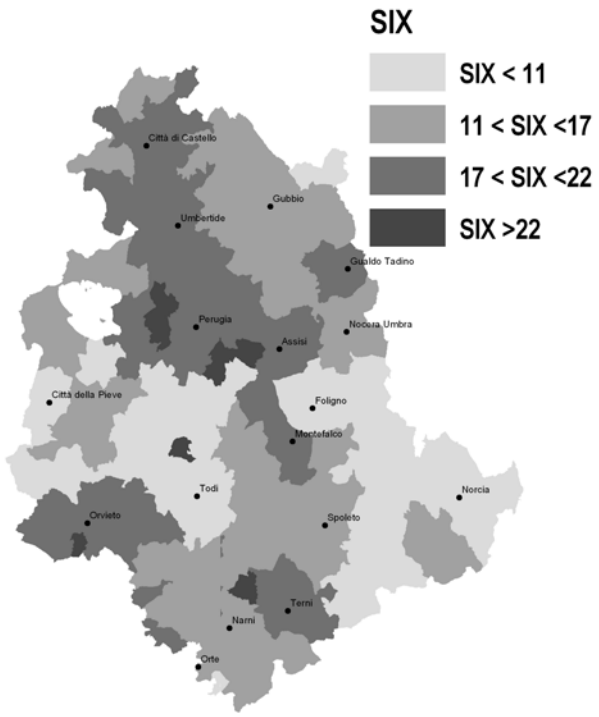


Figure 8 – Geography of the SIX index in the municipalities of the Umbria Region

The methodology presented in this paper has an application of significant interest even in comparison with existing planning tools at municipal level. It is possible to check the basic guidelines of urban development plans to determine their position vis-à-vis the tendential development of settlements, as translated into the sprawl index.

Planning can either favour or oppose the expansion pressure of social communities and economic players in the areas, if it takes into consideration its trends and can help implement adequate control procedures.

These procedures may concern criteria relating to localisation, building density regulation, reversibility in time of some changes in the area.

Knowledge of the most pronounced land sensibility towards urban sprawl - currently on the rise in an alarming manner worldwide - may provide us with an innovative tool to direct decisions relating to land, environment and ecosystem governance in a more sustainable manner.

These are, however, methods that owing to their application, require advanced GIS modelling and accurate information, which is currently very difficult to come by among Italian local governments that play a leading role in territorial planning.

REFERENCES

Biondi M., Corridore G., Romano B., Tamburini P., Tetè P., *Evaluation and planning control of the ecosystem fragmentation due to urban development*, ERSA 2003 Congress, August 2003, Jyvaskyla, Finland, 2003.

Buttenheim, H.S., Cornick P.H., 1938, *Land reserves for American cities*, The Journal of Land Public Utility Economics 14: 254-265.

Haskell, D., Whyte W., 1958, *The city's threat to open land*, Architectural Forum 108: 86-90, 166.

Hess G., 2001, *Just What is Sprawl, Anyway?*, Carolina Planning Journal, University of Carolina, 26/2.

INU (Istituto Nazionale di Urbanistica), 1990, *It.Urb. 80, Rapporto sullo stato dell'urbanizzazione in Italia*, Vol. I, INU Roma.

ISTAT, 1992, *Compendio Statistico Italiano*, Roma.

Mitchell J.G., 2001, *Tutti in città*, National Geographic Italia, luglio 2001:57-79.

Mumford L., 1961, *The City in History*, Vol. III, Harcourt, Brace and Jovanovich, Inc.

Romano B., 2000, *Environmental continuity, planning for ecological re-organisation of the territory*, Ed. Andromeda, Teramo.

Romano B., 2002, *Evaluation of urban fragmentation in the ecosystems*, Proceedings of International Conference on Mountain Environment and Development (ICMED), october 15-19 2002, Chengdu, China.