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Article

Use of Land Use Change Analysis between 2012 – 2018 to assessment of sustainable development in Europe

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Abstract: The article presents the author's method of land use change assessment in the context of sustainable development and the results of its application based on the transformations that occurred in individual areas of Europe in the years 2012 - 2018. This method is based on data from the CORINE Land Cover program and local government units presenting the degree of urbanization (DEGURBA). The authors evaluate the transformations taking place in space, reducing them to economic, social and environmental dimensions. They then analyse the results in terms of space (covering the entire Europe) and in terms of division into: large cities, small towns as well as suburbs and rural areas. It has been shown that: development of the economic dimension most often takes place at the expense of natural resources; the higher the population density and more important function in the functional system of a given country, the greater the sustainable development differentiation level in the analysed dimensions, of which the social dimension is characterized by the lowest differentiation and the economic dimension is the highest; development of rural areas is less sustainable than in case of large urban centres. The result interpretation also leads to the conclusion that the areas of Europe are very diverse in terms of sustainable development. However, the method itself, despite the imperfections observed by the authors, may be used in further or similar studies.

Keywords: sustainability development, land use change, Corine Land Cover

1. Introduction

The concept of sustainable development is one of the doctrines of economics and assumes „that it meets the needs of the present without compromising the ability of future generations to meet their own needs" [1] (p. 16). This term was originally used to describe the way of forest management, i.e. rational logging so that it could always be restored. Today, the term "sustainable development" is well known, much more widely understood and constitutes an important element of international law (e.g. *Action Programme – Agenda 21*, *Leipzig Charter on Sustainable European Cities*). It refers to the balance between economic growth (economic aspect), care for nature (environmental aspect) and quality of life (social aspect).

Initially, a narrow term related only to the way of spatial development (issues of logging and forest restoration), now covers a much wider spectrum of activities (e.g. reduction of social stratification, reduction of pollutant emissions, and shaping of spatial order). The concept of sustainable development has led to the creation of a number of development models (mainly cities), including eco-city [2-4], green city [5-7], compact city [8-10], redesigning a city [11,12], and smart city [13-15] or MILU (Multi-Functional and Intensive Land Use) [16,17]. Although these models apply only to cities,

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it should be remembered that according to the European Commission's estimates, approximately 85% of Europeans live in urban areas [18].

In Europe and the world, the acceleration of the urbanization or climate change contribute to the introduction of rational space "management" - the limitations of which affect us more strongly. That is why the emphasis was placed on the aspect of organizing spatial structures. Therefore, the main objective of the study was to assess the sustainability of individual European areas on the basis of an analysis of land-use change. The analysis of the above model development concepts allowed the authors to better understand the effects of specific spatial transformations and, consequently, to assess them. A sustainable city has an orderly functional and spatial structure and aims at the most efficient use of its resources, including [19,20]:

- housing compaction (urban sprawl prevention) in mixed land use;
- revitalisation of contaminated and dysfunctional areas;
- development of urban green areas and upgrading the quality of natural areas;

minimising negative impacts on the environment, with respect for the local community and taking into account the economic calculation.

Given the importance of functional and spatial issues in the definition of sustainable development, it is considered appropriate to develop assessment methods based precisely on a spatial factor. Land use changes tangibly indicate the development directions and the way of space management. By interpreting the transformations in the time horizon, information about the trends of changes can be obtained, which in turn are a valuable guideline for further development policy.

2. Materials and Methods

2.1. Land use reference data

Data from CORINE Land Cover program (CO-oRdination of INformation on Environment) was used for the analysis of land use changes. The programme, established in 1985 by the European Community, aimed at collecting harmonised information on the condition of the geographical environment and at coordinating work at international level, thereby ensuring the consistency of the information and the compatibility of the data collected. Data are now available for the entire Europe for the years: 1990, 2000, 2006, 2012 and 2018. For some countries (including Poland), CORINE Land Cover data is the only database on land use covering the whole country, regularly updated and prepared in line with uniform principles [21].

The maps used in the study show the land cover/use in 2012 and 2018. They have been digitised using satellite imaging of similar resolution.. Therefore, these data, although generalised to objects with a minimum area of 25 ha (minimum width of 100 m), are a reliable source of information, used by academia for many analyses [22-24].

The CORINE Land Cover classes (CLC) are hierarchically organized in three levels. The first one covers five main types of land use and land cover of the globe: artificial surfaces (1), agricultural areas (2), forest and semi natural areas (3), wetlands (4) and water bodies (5). The second level is fifteen divisions (for example: 11 Urban fabric or 21 Arable land). The third level covers 44 classes (e.g. 111 Continuous urban fabric, 112 Discontinuous urban fabric or 242 Complex cultivation patterns). It should be noted that the methodological scope of individual level-3 classes is strictly defined [25], and so, for example, the class 242 includes both small, adjacent plots of land used to cultivate various crops, both annual and perennial, as well as small meadows and pastures. It also covers the areas of scattered housing development (including house clusters and entire villages) with homestead adjacent lands and home orchards and gardens). [26] (p. 34).

CLC data are used in many analyses, including urban growth monitoring and urban sprawl comparisons between different countries, regions and cities [27,28], land use forecasts [29] or modelling of road travel speeds [30]. The land recycling report is also an interesting example [31]. The analysis classifies each land use change, which is then combined into indicators: densification,

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„green" land recycling and „grey" land recycling. This publication became an inspiration for the survey described above.

2.2. Method - assessment matrices, DEGURBA classification and methodology for obtaining results

To develop the assessment matrices of land use transformation, each of the possible transformations (44 classes) in three dimensions, namely economic (Ec), social (So) and environmental (En) was analysed. When evaluating a given class change, values from -3 (very negative impact on sustainable development) to +3 (very positive impact) were assigned. The value 0 was introduced for the transformations in which no impact on sustainable development in a given aspect was found. The assessment of the transformations is presented on the matrices at the end of the article (Appendix A. Fig. A1-A3).

Analysing the economic aspect (Ec), both the classes related to industry and transport (anthropogenic areas - classes 121-133), as well as agriculture, forestry and with salt-works were taken into account. Transformation into more specialised areas was rated higher, while losses in expensive classes (e.g. ports, airports) were rated much lower. The social aspect (So) was interpreted as transformations related to housing (classes 111 and 112), urban greenery, recreation areas (classes 141 and 142), complex farming and land parcel systems (class 242). The following factors were taken into account: striving for compact urban structures (concentration) or increasing recreational areas, as the actions consistent with the sustainable development policy. On the other hand, changes related to the loss of heavily invested areas (e.g. scattered housing) were assessed negatively. The environmental aspect (En) includes transformations of classes dominated by nature, on which man (compared to others) has a low impact, e.g. meadows, forests and semi-natural ecosystems, wetlands and water bodies (i.e. other classes, not previously considered). The transformations into areas of higher biodiversity were assessed positively, while the loss of valuable natural areas into desolated and homogeneous areas was assessed negatively.

The matrices developed this way were then used to assess the changes that occurred in Europe in the years 2012-2018 (373.6 thousand test-areas). Additionally, the analysis area was trimmed (intersection option in QGIS ver. 2.14, which gave 412.6 thousand test-areas) to the EU classification presenting the degree of urbanisation (DEGURBA), i.e. the division of areas into basic units of national administrative systems according to population density and their function (class 1 - key cities, class 2 - small towns and suburbs, class 3 - rural areas) [32, 33]. The change test-areas trimmed this way (ETRS89 / ETRS-LAEA, EPSG:3035 in the reference system) were subjected to the process of determining the surface area, and the result of this operation was used to determine the percentage of the surface area of the basic unit DEGURBA with changed CLC. This percentage was then multiplied by change weights standardized to the [-1.1] range. As a result of these transformations, weighted percentages of surface area changes were obtained for 2839 major cities, 8022 small towns and suburbs and 39076 rural areas in three economic (Ec), social (So) and environmental (En) dimensions.

The obtained results are described and presented in the form of a figure for 50,000 basic units presenting beneficial changes in plus (+Ec, +So, +En) and in minus (-Ec, -So, -En) together with all intermediate options. This article also presents a commentary to the network graphs showing the average results in 35 European countries (NUTS level 0), also divided into three basic DEGURBA classes. The country abbreviations are in line with NUTS. Additionally, a HotSpot analysis was performed for the presented data – however, for the majority of basic units it did not give a statistically significant match, therefore its results will not be described in detail.

3. Results

3.1. Land use transformation change assessment on a local scale

The analyses performed show that European local and regional government units have a rather poor record of sustainability. Only 136 units scored positively in all three dimensions. Units of this type are scattered throughout Europe and do not form larger clusters. There are also relatively few basic

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units with a positive change in two dimensions and with no change in the third. There are 195 (+Ec and +So), 1617 (+Ec and +En) and 4 (+So and +En) respectively, while in this group a certain (though insignificant in the HotSpot analysis) geographical concentration can be observed (especially in the UK, the Netherlands or e.g. Spain). There are also visible areas that are developing in relation to one dimension while the other two remain unchanged. Such a tendency was identified in 1817 units in the scope of economic dimension, 781 in the scope of social dimension and 372 in the scope of environmental dimension (fig. 1).

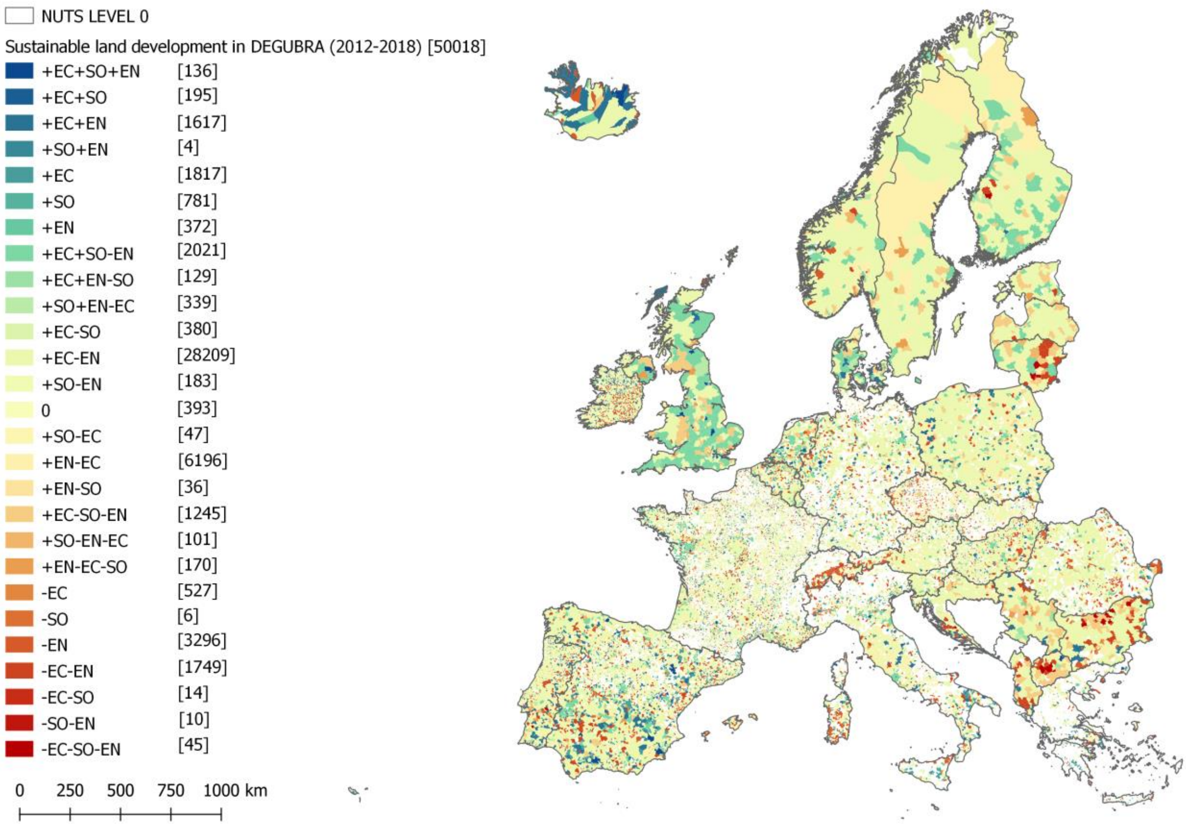

Figure 1. Sustainability assessment of local change directions.

The worst score was given to 45 areas, which concentrate negative changes in all three aspects. They are particularly visible in the northern part of Bulgaria, Northern Macedonia and Lithuania, but such units are also found in France, Spain and Portugal. A negative assessment for the two dimensions (the third unchanged) was given for the social and environmental dimension in 10 cases, for the economic and environmental dimension in 1749 cases and for the social and economic dimension in 14 cases. A negative assessment in only one dimension was given to: 3296 units for the environmental dimension, 6 units for the social dimension and 527 units for the economic dimension.

However, the European space is dominated by changes that have been evaluated in plus in economic terms, while in minus in environmental terms and unchanged in social terms. Such a change was observed in over 28.2 thousand DEGURBA units. The fig. 4 shows a quite significant concentration of units with positive environmental dimensional changes (central and northern parts of Sweden and northern part of Finland). This change takes place mainly on a European scale in 1749 units due to the shrinking of divisions assigned to the economic dimension, so what can be seen in the Scandinavian space is illusory - related to the size of basic spatial units and not to the statistical significance of the changes described.

3.2. Land use transformation change assessment – cross-sectional results

Weighing percentage of the area that has changed within large cities makes it possible to conclude that the most stable situation occurs within the changes classified in the social dimension.

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The yellow line is generally close to zero and deviates slightly for CY (Cyprus), EL (Greece) and LT (Lithuania). However, the biggest changes mainly concern the economic dimension. The highest weighted increment in this area (by approx. 3.5) was observed in large cities of PT (Portugal) and LU (Luxembourg). Large cities in these countries are also characterised by a significant decrease in the weighted area in the environmental dimension (by about 2.0) (fig. 2).

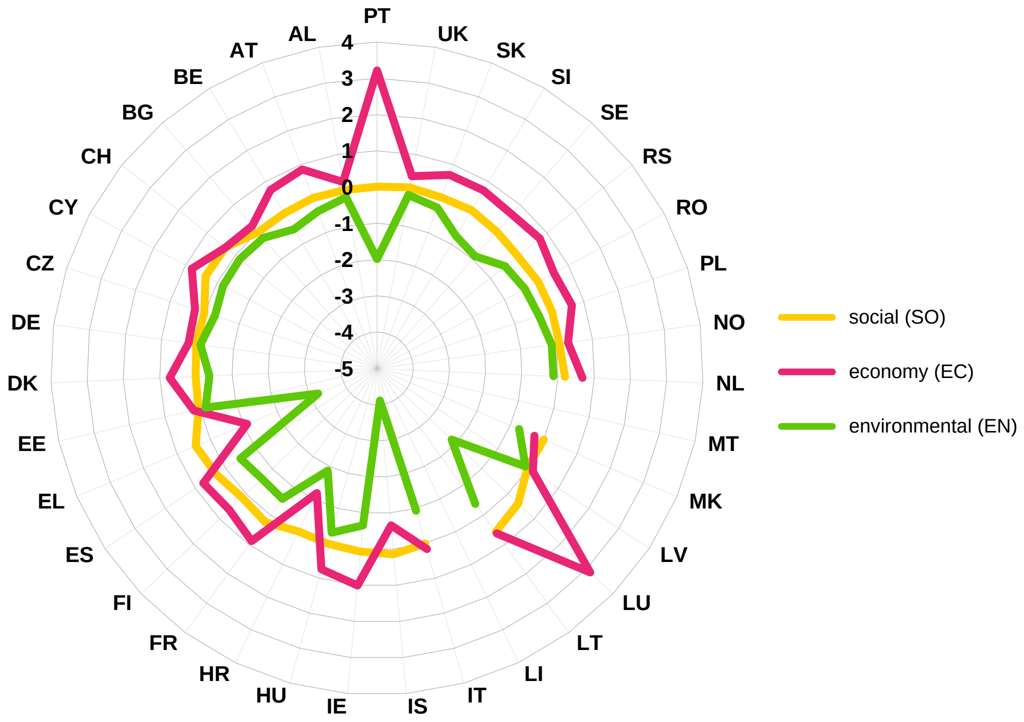

Figure 2. Sustainability assessment of local change directions - big cities.

However, the largest decreases in the weighted area classified in the environmental dimension were recorded in the large cities of IS (Island - a decrease of 5.0), EL (Greece - a decrease of 4.5), HR (Croatia - a decrease of about 2.0). In addition, all the big cities in these countries were characterised by a negative assessment of economic changes (at the level of ca. 1.0). The smallest (average) changes were observed in large cities in countries, such as: AL (Albania), BG (Bulgaria), CZ (Czech Republic), DE (Germany), LV (Latvia), NO (Norway) and UK (United Kingdom). Large cities (according to the DEGURBA classification) do not exist in countries, such as: LI (Lichtenstein) and MT (Malta).

As in case of large cities, also in small and suburban areas, the least weighted change values concerned the social dimension. Generally, the change was around 0. However, small towns located in MT (Malta), for which the weighted percentage of land has fallen to almost -1.0, stand out from this standard. Definitely, there are more and more separated areas in these areas, which prove positive economic changes – the most visible is in case of PT (Portugal – an increase of almost 3.0) and EE (Estonia - an increase of almost 2.5). These changes take place mainly at the expense of space predisposed to development in the environmental dimension. Small towns in these countries recorded a decrease in the weighted mean of these areas by about 2.5 (fig. 3).

The situation was slightly different for small towns and suburbs in EL (Greece), IS (Island) and MT (Malta), which recorded an average economic growth of about 1.5 and 1.0 (the latter two) respectively, with an almost unchanged weighted percentage for the environmental dimension of 0. The average spreads by country are slightly higher in this cross-section than in case of large cities, with AL (Albania), DE (Germany), DK (Denmark) and LT (Lithuania) being the most stable.

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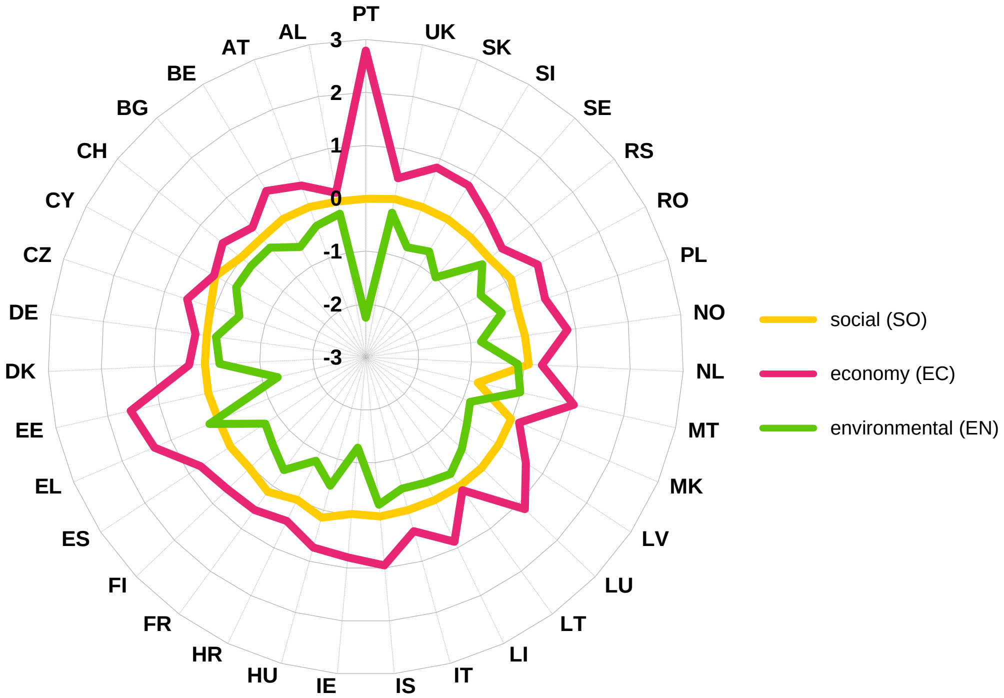

Figure 3. Sustainability assessment of local change directions – small towns and suburbs.

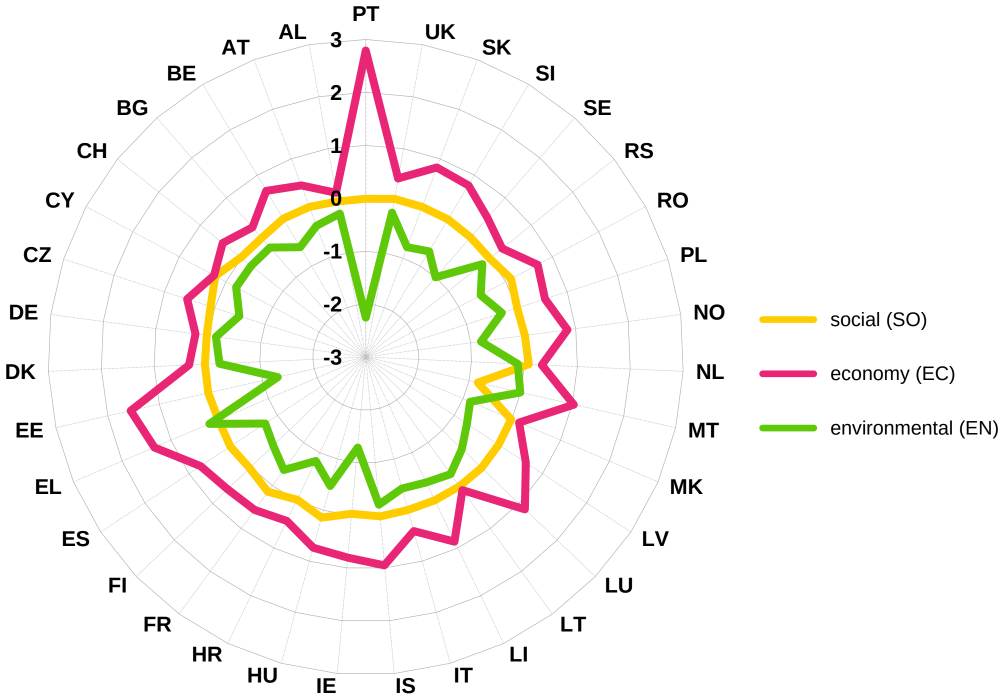

Figure 4. Sustainability assessment of local change directions – rural areas.

Rural areas on a pan-European scale are not identified in LI (Liechtenstein). The changes in the weighted mean of assessment for the social dimension are very stable (at around 0). However, this does not apply to the changes in the economic and social dimension. The biggest discrepancies in this respect are found in PT (Portugal – economic dimension increase slightly above 2.0 with a simultaneous decrease in environmental dimension at the level of nearly 3.0) and EE (Estonia – economic dimension increase of almost 1.5 with a decrease in the weighted mean percentage of area for environmental dimension by approx. 1.75). A slightly smaller discrepancy can be observed for CY (Cyprus), IE (Ireland), LU (Luxembourg) and LV (Latvia). (fig. 4).

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The highest average stability is found in rural areas of countries, such as CH (Switzerland), DE (Germany), DK (Denmark), IS (Island), LT (Lithuania) and NL (Netherlands). The countries of Central and Eastern Europe and the Balkan countries, including: BG (Bulgaria), CZ (Czech Republic), HR (Croatia), HU (Hungary), PL (Poland), RO (Romania), SI (Slovenia) and SK (Slovakia) compensate for economic growth with an almost proportional decline in the areas considered important for environmental sustainability.

4. Discussion

Arranged functional and spatial structure, which effectively uses the existing resources, is the aim of rational land development. However, this is impossible without a number of actions aimed at, on one hand, concentration of housing development (preventing urban sprawl) and mixed land use using also rehabilitated and revitalised areas. Managing changes in the economic aspect, which should minimise the negative impact on the environment, including acting with respect for the local community while taking into account the economic calculation, is not a simple task. It should also be remembered that development is not complete without blue-green infrastructure that lays the foundations for biological life in a specific area. The development of urban greenery and the improvement of the quality of natural areas contribute to the preservation of biodiversity and can significantly reduce negative climate change. Observing the direction and intensity of changes in this respect can be considered not as an intellectual adventure but a duty of all actors shaping the future of spatial units, including local communities and other groups inhabiting them.

The research method presented may be useful in this respect, since it uses a research method based on geographical data that is harmonised in the European context. Admittedly, it has a few drawbacks. According to the authors, the most important are two: the author's assignment of weights to the observed changes and taking the elements connecting land use and land cover as a basis for analysis, and at the same time relatively generalised objects with a minimum area of 25 ha (minimum width of 100 m). Weighing can be objectivised by using, for example, an expert method. However, it is more difficult to limit the impact of CLC methodological assumptions on the results achieved, it would require using Urban Atlas data or reference data at national level, collected and methodologically standardised across the continent. This is not possible currently. On the other hand, the presented method breaks with the research conducted on the basis of public statistics that have been generalised to quasi-natural units or are difficult to compare during panel research. An unquestionable advantage of this method is the ability to generate results for a large area in quasi-natural units or in an analytical grid with a selected resolution and the ability to generate time lists (for individual CLC editions) with a relatively uniform methodological basis, which encourages further analysis following this route.

5. Conclusions

The article presents the results of application of the author's assessment method of land-use change that occurred in the European space in terms of sustainable development. This method is an integrated approach to studying the direction and intensity of changes taking place in the economic, social and environmental dimensions of this process. Basing the method on assessment matrices (used to construct weighs) and territorial units presenting the degree of urbanization (DEGURBA) allowed observing the following trends in the 2012 -2018 time horizon:

- Development that can be considered sustainable (in terms of land-use change) is observed in a relatively small number of basic territorial units of the countries concerned. Despite declarative intentions (expressed on websites and in official conceptual documents), territorial units perceive their development as more of an economic dimension than a social one, which is difficult to convert into space. This development often takes place at the expense of sound management of spatial and environmental resources, such as blue-green infrastructure.
- The higher the population density and the more important the function in the functional system of a given country, the greater the differentiation of the weighted mean of the area determined within the described dimensions. Of which the lowest diversity is in the social dimension and

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the highest in the economic dimension. The economic dimension is often shaped at the expense of the environmental dimension. The smaller the population density and lower the importance of the unit, the more often this type of situation is observed. It can therefore be concluded that large cities are growing faster and that rural development is less sustainable.

- In the European space, significant concentration of areas with similar statistical characteristics of the weighted percentage of area in the described dimensions of sustainable development is relatively rare. However, there are indications that Portugal (PT), Luxembourg (LU) and Estonia (EE) are the countries with the greatest asymmetries in sustainable development. The countries with the least asymmetry are Albania (AL) and Germany (DE). The countries of Central and Eastern Europe and the Balkans compensate for economic growth at the expense of the areas considered important in spatial terms.

It would be important for the results obtained to repeat the survey in the remaining time frames (at least for the 2000-2006 and 2006-2012 periods). This would allow the method to be tested against a slightly different spatial range (during these periods, the DEGURBA classification, among other, was changed) and to generate and interpret information on the stability of the observed change trends (which could be, both, cognitively valuable and empirically beneficial for further development policy at local, regional, national and international level).

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Conflicts of Interest: The authors declare no conflict of interest.

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Appendix

sustainable development in a economic (EC) context (weight)

-3	-2	-1	0	1	2	3	(grey)
(-EC weight)			not effect	(+EC weight)			does not apply to economic sustainability

FUTURE

	PAST	111	112	121	122	123	124	131	132	133	141	142	211	212	213	221	222	223	231	241	242	243	244	311	312	313	321	322	323	324	331	332	333	334	335	411	412	421	422	423	511	512	521	522	523
Continuous urban fabric	111			3	2	2	2	2	1	1					1	1	1	1		1		1	1							2									2						
Discontinuous urban fabric	112			3	2	2	2	2	1	1					1	1	1	1		1		1	1							2									2						
Industrial or commercial units	121	-3	-3		-1	1	1	-1	-3	1	-3	-2	-3	-3	-1	-1	-1	-1	-3	-1	-2	-1	-1	-3	-3	-3	-3	-3	-3	-1	-3	-3	-3	-3	-3	-3	-3	-3	-1	-3	-3	-3	-3	-3	-3
Road and rail networks and associated land	122	-2	-2	2		2	2	-1	-3	1	-3	-2	-3	-3	-1	-1	-1	-1	-3	-1	-2	-1	-1	-3	-3	-3	-3	-3	-3	-1	-3	-3	-3	-3	-3	-3	-3	-3	-1	-3	-3	-3	-3	-3	-3
Port areas	123	-2	-2	1	-1		0	-2	-3	1	-3	-2	-3	-3	-2	-2	-2	-2	-3	-2	-2	-2	-2	-3	-3	-3	-3	-3	-3	-2	-3	-3	-3	-3	-3	-3	-3	-3	-2	-3	-3	-3	-3	-3	-3
Airports	124	-2	-2	1	-1	0		-2	-3	1	-3	-2	-3	-3	-2	-2	-2	-2	-3	-2	-2	-2	-2	-3	-3	-3	-3	-3	-3	-2	-3	-3	-3	-3	-3	-3	-3	-3	-2	-3	-3	-3	-3	-3	-3
Mineral extraction sites	131	-2	-2	2	1	2	2		-3	2	-2	-2	-2	-2	2	2	2	2	-2	2	-2	2	2	-2	-2	-2	-3	-3	-3	2	-3	-3	-3	-3	-3	-2	-2	-3	0	-3	-1	-1	-1	-1	-1
Dump sites	132	0	0	3	3	3	3	3		3	0	0	0	0	3	3	3	3	0	3	0	3	3	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Construction sites	133	0	0	3	3	3	3	-2	-3		0	0	-2	-2	-1	-1	-1	-1	-3	-1	0	-1	-1	-2	-2	-2	-3	-3	-3	-1	-3	-3	-3	-3	-3	-3	-3	-3	-2	-3	-3	-3	-3	-3	-3
Green urban areas	141			1	1	1	1	1	0	1					1	1	1	1		1		1	1							1									1						
Sport and leisure facilities	142			1	1	1	1	1	0	1					1	1	1	1		1		1	1							1									1						
Non-irrigated arable land	211			3	3	3	3	3	2	3					3	3	3	3		3		3	3							3									3						
Permanently irrigated land	212			3	3	3	3	3	2	3					3	3	3	3		3		3	3							3									3						
Rice fields	213	-2	-2	2	2	2	2	2	-2	2	-1	-1	-1	-1		0	0	0	-2	0	-1	0	0	-2	-2	-2	-3	-3	-3	0	-3	-3	-3	-3	-3	-2	-2	-3	2	-3	-1	-1	-1	-1	-1
Vineyards	221	-2	-2	2	2	2	2	2	-2	2	-1	-1	-1	-1	0		0	0	-2	0	-1	0	0	-2	-2	-2	-3	-3	-3	0	-3	-3	-3	-3	-3	-2	-2	-3	2	-3	-1	-1	-1	-1	-1
Fruit trees and berry plantations	222	-2	-2	2	2	2	2	2	-2	2	-1	-1	-1	-1	0	0		0	-2	0	-1	0	0	-2	-2	-2	-3	-3	-3	0	-3	-3	-3	-3	-3	-2	-2	-3	2	-3	-1	-1	-1	-1	-1
Olive grove	223	-2	-2	2	2	2	2	2	-2	2	-1	-1	-1	-1	0	0	0		-2	0	-1	0	0	-2	-2	-2	-3	-3	-3	0	-3	-3	-3	-3	-3	-2	-2	-3	2	-3	-1	-1	-1	-1	-1
Pastures	231			3	3	3	3	3	2	3					3	3	3	3		3		3	3							3									3						
Annual crops associated with permanent crops	241	-2	-2	2	2	2	2	2	-2	2	-1	-1	-1	-1	0	0	0	0	-2		-1	0	0	-2	-2	-2	-3	-3	-3	0	-3	-3	-3	-3	-3	-2	-2	-3	2	-3	-1	-1	-1	-1	-1
Complex cultivation patterns	242			1	1	1	1	1	1	1					1	1	1	1		1		1	1							1									1						
Land principally occupied by agriculture, with significant areas of natural vegetation	243	-2	-2	2	2	2	2	2	-2	2	-1	-1	-1	-1	0	0	0	0	-2	0	-1		0	-2	-2	-2	-3	-3	-3	0	-3	-3	-3	-3	-3	-2	-2	-3	2	-3	-1	-1	-1	-1	-1
Agro-forestry areas	244	-2	-2	2	2	2	2	2	-2	2	-1	-1	-1	-1	0	0	0	0	-2	0	-1	0		-2	-2	-2	-3	-3	-3	0	-3	-3	-3	-3	-3	-2	-2	-3	2	-3	-1	-1	-1	-1	-1
Broad-leaved forest	311			2	2	2	2	2	2	2					1	1	1	1		1		1	1							2									2						
Coniferous forest	312			2	2	2	2	2	2	2					1	1	1	1		1		1	1							2									2						
Mixed forest	313			2	2	2	2	2	2	2					1	1	1	1		1		1	1							2									2						
Natural grasslands	321			3	3	3	3	3	2	3					3	3	3	3		3		3	3							3									3						
Moors and heathland	322			3	3	3	3	3	2	3					3	3	3	3		3		3	3							3									3						
Sclerophyllous vegetation	323			3	3	3	3	3	2	3					3	3	3	3		3		3	3							3									3						
Transitional woodland-shrub	324	-2	-2	2	2	2	2	2	-2	2	-1	-1	-1	-1	0	0	0	0	-2	0	-1	0	0	-2	-2	-2	-3	-3	-3	0	-3	-3	-3	-3	-3	-2	-2	-3	2	-3	-1	-1	-1	-1	-1
Beaches, dunes, sands	331			3	3	3	3	3	2	3					3	3	3	3		3		3	3							3									3						
Bare rocks	332			3	3	3	3	3	2	3					3	3	3	3		3		3	3							3									3						
Sparsely vegetated areas	333			3	3	3	3	3	2	3					3	3	3	3		3		3	3							3									3						
Burnt areas	334			3	3	3	3	3	2	3					3	3	3	3		3		3	3							3									3						
Glaciers and perpetual snow	335			3	3	3	3	3	2	3					3	3	3	3		3		3	3							3									3						
Inland marshes	411			2	2	2	2	2	1	2					2	2	2	2		2		2	2							2									2						
Peat bogs	412			2	2	2	2	2	1	2					2	2	2	2		2		2	2							2									2						
Salt marshes	421			3	3	3	3	3	2	3					3	3	3	3		3		3	3							3									3						
Salines	422	-2	-2	2	1	2	2	0	-3	2	-2	-2	-2	-2	2	2	2	2	-2	2	-2	2	2	-2	-2	-2	-3	-3	-3	2	-3	-3	-3	-3	-3	-2	-2	-3		-3	-1	-1	-1	-1	-1
Intertidal flats	423			3	3	3	3	3	2	3					3	3	3	3		3		3	3							3									3						
Water courses	511			1	1	1	1	1	1	1					1	1	1	1		1		1	1							1									1						
Water bodies	512			1	1	1	1	1	1	1					1	1	1	1		1		1	1							1									1						
Coastal lagoons	521			1	1	1	1	1	1	1					1	1	1	1		1		1	1							1									1						
Estuaries	522			1	1	1	1	1	1	1					1	1	1	1		1		1	1							1									1						
Sea and ocean	523			1	1	1	1	1	1	1					1	1	1	1		1		1	1							1									1						

Figure A1. Land-use change assessment matrix in the economic aspect.

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sustainable development in a social (SO) context (weight)

-3	-2	-1	0	1	2	3
(-SO weight)			not effect	(+SO weight)		

does not apply to social sustainability

	PAST / FUTURE	111	112	121	122	123	124	131	132	133	141	142	211	212	213	221	222	223	231	241	242	243	244	311	312	313	321	322	323	324	331	332	333	334	335	411	412	421	422	423	511	512	521	522	523
Continuous urban fabric	111		-3	1	-1	-1	-3	-3	-3	-1	1	1	-2	-2	-1	-1	-1	-1	-3	-1	-1	-1	-1	-1	-1	-1	-2	-2	-3	-1	-2	-3	-2	-3	-3	-3	-3	-3	-3	-3	-2	-2	-2	-2	-2
Discontinuous urban fabric	112	2		1	-1	-1	-3	-3	-3	-1	1	1	-2	-2	-1	-1	-1	-1	-3	-1	-1	-1	-1	-1	-1	-1	-2	-2	-3	-1	-2	-3	-2	-3	-3	-3	-3	-3	-3	-3	-2	-2	-2	-2	-2
Industrial or commercial units	121	2	2								2	2									2																								
Road and rail networks and associated land	122	2	2								2	2									2																								
Port areas	123	3	3								3	3									3																								
Airports	124	3	3								3	3									3																								
Mineral extraction sites	131	3	3								3	3									3																								
Dump sites	132	3	3								3	3									3																								
Construction sites	133	3	3								3	3									3																								
Green urban areas	141	-2	-2	-2	-2	-3	-3	-3	-3	-3		2	-3	-3	-2	-2	-2	-2	-3	-2	-1	-2	-2	-1	-1	-1	-3	-3	-3	-2	-2	-3	-2	-3	-3	-3	-3	-3	-3	-3	-2	-2	-2	-2	-2
Sport and leisure facilities	142	-2	-2	-2	-2	-3	-3	-3	-3	-3	-1		-3	-3	-3	-3	-3	-3	-3	-3	-2	-3	-3	-2	-2	-2	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-2	-2	-2	-2	-2
Non-irrigated arable land	211	2	2								3	3									3																								
Permanently irrigated land	212	2	2								3	3									3																								
Rice fields	213	1	1								3	3									2																								
Vineyards	221	1	1								3	3									2																								
Fruit trees and berry plantations	222	1	1								3	3									2																								
Olive grove	223	1	1								3	3									2																								
Pastures	231	3	3								3	3									3																								
Annual crops associated with permanent crops	241	1	1								3	3									2																								
Complex cultivation patterns	242	3	2	-1	-1	-2	-2	-3	-3	-2	3	3	-2	-2	-1	-1	-1	-1	-3	-1		-1	-1	-1	-1	-1	-2	-2	-3	-1	-2	-3	-2	-3	-3	-3	-3	-3	-3	-3	-2	-2	-2	-2	-2
Land principally occupied by agriculture, with significant areas of natural vegetation	243	1	1								3	3									2																								
Agro-forestry areas	244	1	1								3	3									2																								
Broad-leaved forest	311	1	1								3	1									1																								
Coniferous forest	312	1	1								3	1									1																								
Mixed forest	313	1	1								3	1									1																								
Natural grasslands	321	1	1								3	3									2																								
Moors and heathland	322	2	2								3	3									3																								
Sclerophyllous vegetation	323	2	2								3	3									3																								
Transitional woodland-shrub	324	1	1								3	2									2																								
Beaches, dunes, sands	331	2	2								3	2									2																								
Bare rocks	332	3	3								3	3									3																								
Sparsely vegetated areas	333	2	2								3	3									3																								
Burnt areas	334	3	3								3	3									3																								
Glaciers and perpetual snow	335	3	3								3	3									3																								
Inland marshes	411	3	3								3	3									3																								
Peat bogs	412	3	3								3	3									3																								
Salt marshes	421	3	3								3	3									3																								
Salines	422	3	3								3	3									3																								
Intertidal flats	423	3	3								3	3									3																								
Water courses	511	1	1								1	1									1																								
Water bodies	512	1	1								1	1									1																								
Coastal lagoons	521	1	1								1	1									1																								
Estuaries	522	1	1								1	1									1																								
Sea and ocean	523	1	1								1	1									1																								

Figure A2. Land-use change assessment matrix in the social aspect

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sustainable development in a environmental (EN) context (weight)

-3	-2	-1	0	1	2	3
(-EN weight)			not effect	(+EN weight)		

(grey) does not apply to environmental sustainability

FUTURE

PAST		111	112	121	122	123	124	131	132	133	141	142	211	212	213	221	222	223	231	241	242	243	244	311	312	313	321	322	323	324	331	332	333	334	335	411	412	421	422	423	511	512	521	522	523
Continuous urban fabric	111												1	1					1					1	1	1	1	1	1		1	1	1	-3	1	1	1	1		1	1	1	1	1	1
Discontinuous urban fabric	112												1	1					1					1	1	1	1	1	1		1	1	1	-3	1	1	1	1		1	1	1	1	1	1
Industrial or commercial units	121												1	1					1					1	1	1	1	1	1		1	1	1	-3	1	1	1	1		1	1	1	1	1	1
Road and rail networks and associated land	122												1	1					1					1	1	1	1	1	1		1	1	1	-3	1	1	1	1		1	1	1	1	1	1
Port areas	123												1	1					1					1	1	1	1	1	1		1	1	1	-3	1	1	1	1		1	1	1	1	1	1
Airports	124												1	1					1					1	1	1	1	1	1		1	1	1	-3	1	1	1	1		1	1	1	1	1	1
Mineral extraction sites	131												2	2					2					2	2	2	2	2	2		2	2	2	-3	2	2	2	2		2	2	2	2	2	2
Dump sites	132												3	3					3					3	3	3	3	3	3		3	3	3	-3	3	3	3	3		3	3	3	3	3	3
Construction sites	133												1	1					1					1	1	1	1	1	1		1	1	1	-3	1	1	1	1		1	1	1	1	1	1
Green urban areas	141												1	1					1					1	1	1	1	1	1		1	1	1	-3	1	1	1	1		1	1	1	1	1	1
Sport and leisure facilities	142												1	1					1					1	1	1	1	1	1		1	1	1	-3	1	1	1	1		1	1	1	1	1	1
Non-irrigated arable land	211	-1	-1	-1	-1	-1	-1	-2	-3	-1	-1	-1		0	0	0	0	0	-1	0	-1	0	0	3	3	3	1	1	-1	0	-1	-1	1	-3	-2	-1	-1	-2	-2	-2	-1	-1	-1	-1	-1
Permanently irrigated land	212	-1	-1	-1	-1	-1	-1	-2	-3	-1	-1	-1	0		0	0	0	0	-1	0	-1	0	0	3	3	3	1	1	-1	0	-1	-1	1	-3	-2	-1	-1	-2	-2	-2	-1	-1	-1	-1	-1
Rice fields	213												0	0					1					3	3	3	1	1	1		1	1	1	-3	1	2	2	1		1	2	2	2	2	2
Vineyards	221												0	0					1					3	3	3	1	1	1		1	1	1	-3	1	2	2	1		1	2	2	2	2	2
Fruit trees and berry plantations	222												0	0					1					3	3	3	1	1	1		1	1	1	-3	1	2	2	1		1	2	2	2	2	2
Olive grove	223												0	0					1					3	3	3	1	1	1		1	1	1	-3	1	2	2	1		1	2	2	2	2	2
Pastures	231	-1	-1	-1	-1	-1	-1	-2	-3	-1	-1	-1	-1	-1	-1	-1	-1	-1		-1	-1	-1	-1	3	3	3	0	2	-1	1	-3	-3	-1	-3	-3	0	0	-3	-2	-3	0	0	0	0	0
Annual crops associated with permanent crops	241												0	0					1					3	3	3	1	1	1		1	1	1	-3	1	2	2	1		1	2	2	2	2	2
Complex cultivation patterns	242												1	1					1					1	1	1	1	1	1		1	1	1	-3	1	1	1	1		1	1	1	1	1	1
Land principally occupied by agriculture, with significant areas of natural vegetation	243												0	0					1					3	3	3	1	1	1		1	1	1	-3	1	2	2	1		1	2	2	2	2	2
Agro-forestry areas	244												0	0					1					3	3	3	1	1	1		1	1	1	-3	1	2	2	1		1	2	2	2	2	2
Broad-leaved forest	311	-2	-2	-2	-2	-2	-2	-3	-3	-2	-1	-2	-2	-2	-2	-2	-2	-2	-1	-2	-2	-2	-2		-1	-1	-1	-1	-1	-2	-3	-3	-2	-3	-3	-1	-1	-3	-3	-3	0	0	0	0	0
Coniferous forest	312	-2	-2	-2	-2	-2	-2	-3	-3	-2	-1	-2	-2	-2	-2	-2	-2	-2	-1	-2	-2	-2	-2	1		1	-1	-1	-1	-2	-3	-3	-2	-3	-3	-1	-1	-3	-3	-3	0	0	0	0	0
Mixed forest	313	-2	-2	-2	-2	-2	-2	-3	-3	-2	-1	-2	-2	-2	-2	-2	-2	-2	-1	-2	-2	-2	-2	1	-1		-1	-1	-1	-2	-3	-3	-2	-3	-3	-1	-1	-3	-3	-3	0	0	0	0	0
Natural grasslands	321	-1	-1	-1	-1	-1	-1	-2	-3	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	-1	-1	-1	-1	3	3	3		-1	-1	1	-2	-2	-2	-3	-1	1	1	-1	-2	-1	2	2	2	-2	-1
Moors and heathland	322	-1	-1	-1	-1	-1	-1	-2	-3	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	-1	-1	3	3	3	1		-1	1	-2	-2	-2	-3	-1	1	1	-1	-2	-1	2	2	2	-2	-1
Sclerophyllous vegetation	323	-1	-1	-1	-1	-1	-1	-1	-2	-1	-1	-1	1	1	1	1	1	1	1	1	-1	1	1	3	3	3	1	1		1	-2	-2	-2	-3	-1	1	1	-1	-1	-1	2	2	2	2	2
Transitional woodland-shrub	324												0	0					-1					2	2	2	-1	-1	-1		-3	-3	-2	-3	-3	2	2	1		1	2	2	2	-2	-1
Beaches, dunes, sands	331	-1	-1	-1	-1	-1	-1	-1	-2	-1	-1	-1	1	1	1	1	1	1	2	1	-1	1	1	3	3	3	2	2	2	2		0	1	-3	-1	1	1	-1	-1	-1	2	2	2	-1	-1
Bare rocks	332	-1	-1	-1	-1	-1	-1	-1	-2	-1	-1	-1	1	1	1	1	1	1	2	1	-1	1	1	3	3	3	2	2	2	2	0		1	-3	1	1	1	1	-1	-1	2	2	2	-1	-1
Sparsely vegetated areas	333	-1	-1	-1	-1	-1	-1	-2	-3	-1	-1	-1	-1	-1	-1	-1	-1	-1	2	-1	-1	-1	-1	3	3	3	2	2	2	1	-1	-1		-3	-1	1	1	-1	-2	-1	2	2	2	-1	-1
Burnt areas	334	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	3	0	0	0	0	3	3	3	3	3	3	0	3	3	3		3	3	3	3	0	3	3	3	3	3	3
Glaciers and perpetual snow	335	-1	-1	-1	-1	-1	-1	-1	-2	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	-1	-1	-1	-1	2	2	2	1	1	1	-1	1	-1	1	-3		1	1	1	-1	1	-2	-2	-2	1	1
Inland marshes	411	-2	-2	-2	-2	-2	-2	-3	-3	-2	-1	-2	-2	-2	-2	-2	-2	-2	-1	-2	-2	-2	-2	2	2	2	-1	-1	-1	-2	-1	-1	-1	-3	-1		0	-2	-3	-2	1	1	1	-2	-2
Peat bogs	412	-2	-2	-2	-2	-2	-2	-3	-3	-2	-1	-2	-2	-2	-2	-2	-2	-2	-1	-2	-2	-2	-2	2	2	2	-1	-1	-1	-2	-1	-1	-1	-3	-1	0		-1	-3	-2	1	1	1	-2	-2
Salt marshes	421	-1	-1	-1	-1	-1	-1	-2	-3	-1	-1	-1	1	1	-1	-1	-1	-1	1	-1	-1	-1	-1	3	3	3	1	1	1	-1	1	-1	1	-3	-1	2	1		-2	-1	2	2	2	-1	-1
Salines	422												2	2					2					2	2	2	2	2	2		2	2	2	-3	2	2	2	2		2	2	2	2	2	2
Intertidal flats	423	-1	-1	-1	-1	-1	-1	-2	-3	-1	-1	-1	1	1	-1	-1	-1	-1	1	-1	-1	-1	-1	3	3	3	1	1	1	-1	1	1	1	-3	-1	2	2	1	-2		2	2	2	-1	-1
Water courses	511	-2	-2	-2	-2	-2	-2	-3	-3	-2	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-1	-1	-1	-2	-2	-2	-2	-2	-2	-2	-3	2	-1	-1	-2	-3	-2		2	-1	-1	-1
Water bodies	512	-2	-2	-2	-2	-2	-2	-3	-3	-2	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-1	-1	-1	-2	-2	-2	-2	-2	-2	-2	-3	2	-1	-1	-2	-3	-2	-2		-1	-1	-1
Coastal lagoons	521	-2	-2	-2	-2	-2	-2	-3	-3	-2	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-1	-1	-1	-2	-2	-2	-2	-2	-2	-2	-3	2	-1	-1	-2	-3	-2	0	0		0	-1
Estuaries	522	-2	-2	-2	-2	-2	-2	-3	-3	-2	-1	-2	2	2	-2	-2	-2	-2	2	-2	-2	-2	-2	3	3	3	2	2	-2	2	1	1	1	-3	-1	2	2	1	-3	1	1	1	1		0
Sea and ocean	523	-2	-2	-2	-2	-2	-2	-3	-3	-2	-1	-2	-2	-2	-2	-2	-2	-2	1	-2	-2	-2	-2	2	2	2	1	1	-2	1	1	1	1	-3	-1	2	2	1	-3	1	0	0	0	0	

Figure A3. Land-use change assessment matrix in the environmental aspect.

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