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Urbanisation and Land Take of High Quality Agricultural Soils - Exploring Long-term Land Use Changes and Land Capability in Northern Italy

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ABSTRACT: Urban expansion and agriculture intensification are relevant drivers in Land Degradation (LD) processes in Europe due to net loss of land, soil sealing, landscape fragmentation and other negative effects on the environment. This paper explores changes (or "trajectories" of change) in land use and cover (LULC) and their relationship with the consumption of soils in Emilia-Romagna (northern Italy) over a 55-years period from 1954 to 2008, and separately over three time periods (1954-1976, 1976-1994 and 1994-2008) characterized by distinctive processes of urban and agricultural development. Four high-resolution LULC maps for 1954, 1976, 1994, and 2008 were analysed together with a 1:50,000 scale land capability map used as an indicator of soil quality. Out of an investigated area of around 12.000 km^2, 34% underwent changes in LULC over the entire study period. "Agriculture internal conversions" accounted for 46% of the changes and "urban expansion" for as much as 35%. The first period was characterized by "agriculture internal conversions" associated with intensification processes. In the second period internal agricultural conversions became even more important. In the third period the most relevant conversion process was agricultural extensivation, with urban expansion also becoming relevant. During the entire period, the area consumed by urban expansion took around 41 % of the high-quality soils. Other trajectories consumed soils of lower quality, with the exception of internal agricultural conversions (accounting for another 46%). The suggested approach can provide valuable indications for assessing quantity and quality of soils taken by urban expansion, thus orienting sustainable land management.

Key words: Degradation, Capability, Trajectories, Agriculture, Urban

INTRODUCTION

Land is one of the most valuable natural resource, and it needs to be harnessed according to its potential. Due to over exploitation and mismanagement of natural resources coupled with socio-economic factors, the problem of land degradation (LD) is on the rise (Panhalkar, 2011). Nowadays lands and soils, especially of high-quality, are threatened by land-use mismanagement and unfitting land cover changes such as urban expansion and unsustainable agricultural intensification. Urban expansion has both direct and indirect negative effects. The direct effect consists in a physical loss of agricultural land as well as of natural or cultural landscapes, while indirect effects are related to surface sealing (responsible for instance for the alteration of the hydrological cycle, increased run-off and soil erosion, point contamination), landscape fragmentation, as well as biodiversity decline. It is interesting to note that, in the long-term, this process may have an impact on landscape resilience and ecosystem stability (Antrop, 2005). This is especially true in regions undergoing climate changes and subject to increasing human pressure, as in the case of Emilia-Romagna, in north-eastern Italy, where a remarkable increase in climate aridity was observed in the last twenty years (Salvati, 2012).

Population growth and rapid urbanization determined, after World War II, important landscape transformations reflected in soil, water, and land degradation in Europe (Antrop 2000). A pan-European study showed the rapid increase of the urbanisation pace, particularly in the form of dispersed urban expansion, recently occurred in the EU, considering this as an "ignored challenge" (European Environment Agency, 2006). The most visible impacts are in areas with high density of population and economic

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activities, as in the case of the north-western part of Italy. A further proof of the relevance of this process is that the same European Commission has very recently published guidelines for monitoring and containing soil sealing in the continent (EC, 2012). While the impact of urban growth on landscape structures is relatively well known, limited information is available on the effect of urban expansion on soil resources depletion (Herrick, 2000; Karlen *et al.*, 2003; Schloter *et al.*, 2003; McGregor *et al.*, 2006; Kong *et al.*, 2009; Podmanicky *et al.*, 2011; Xia *et al.*, 2011).

Also agricultural intensification plays a key role in LD dynamics and impacts, in the form of soil degradation and extinction of species and habitat (Benton *et al.*, 2003). Agriculture intensification is a key feature of arable systems throughout Western and especially Northern Europe (Stoate *et al.*, 2011), the main characteristics being heavy mechanization, the use of artificial fertilizers and pesticides, soil mismanagement, irrigation and loss of spatial heterogeneity (Goulart *et al.*, 2009). Arable intensification has resulted in loss of non-crop habitats and simplification of plant and animal communities within crops, with consequent disruption to food chains and declines in many farmland species (Stoate *et al.*, 2001). Soils have deteriorated as a result of erosion, compaction, loss of organic matter and contamination with pesticides, and in some areas, heavy metals. Impacts on water are closely related to those on soils as its contamination by pesticides and excessive content of nutrients originates from surface runoff and subsurface flow. Nitrates and some pesticides also enter groundwater following leaching from arable land. The highest impacts are associated with simplified, high inputs arable systems. Intensification of arable farming has been associated with pollution of air by pesticides, especially NO_2 and CO_2, while the loss of soil organic matter has reduced the system's capacity for carbon sequestration (Stoate *et al.*, 2001). On-farm impacts of changes in arable management include a local simplification of landscape and biodiversity, and deterioration in soil characteristics. These consequences however, together with many others, are more evident as off-farm impacts on biodiversity, landscape, water and air (Meeus, 1993).

A loss of biodiversity in both natural and agricultural systems also causes a loss of other ecosystem services. Any given area of land can have a multitude of potential uses and all may need to be considered in planning and the management of a land resource. Uses of the land to humankind are multi-faceted. As a source for primary production system, it serves as a store of water and nutrients required for plants and other living organisms. Land resource is one of the limited resources. The use of land and its cover are not only determined by the user but also by the land capability (Panhalkar, 2011). To get the maximum benefit out of the land, a proper use through time is unavoidable. Land use/land cover (LULC) change is a major issue of global environment change and constitutes an important feature in shaping the physical and human environment.

The European Topic Centre on Terrestrial Environment of the European Environment Agency (EEA) has developed the Land and Ecosystem Accounts (LEAC) system (Gómez and Ferran Páramo, 2005), where LULC changes are categorized into meaningful flows or "trajectories" of change. Within this framework of LULC trajectories, the present study aims to investigate the land transformations occurred in northern Italy over more than 50 years. It also aims at analyzing the associated impacts and their implications in terms of losses of soils of high-to-medium quality, based on a diachronic, high-resolution analysis of LULC and land capability. The objectives of the study are hence to investigate: (i) which trajectories occurred from 1954 to 2008 and in three time phases (1954-1976, 1976-1994 and 1994-2008) within this period, and (ii), if such trajectories consumed high-quality soils.

The study area is part of the Emilia-Romagna Nuts-2 region located in north-eastern Italy and includes more than 300 local municipalities (Fig. 1). The region as such covers nearly 22.120 km^2 with varied morphology going from 0 m.a.s.l. along the Adriatic coast, to 2,165 m in Apennines (Monte Cimone). The study area consists of the lower portions (in orographic terms) of the region, represented mainly by the Po River valley: altogether 12.000 km^2 which is around 54% of the total surface of the region. Emilia-Romagna is one of the critical areas in respect to urban expansion as well as to agricultural development in Europe (Fig. 2). The economic structure of the region, one of the most affluent in Italy, is mainly based on manufacturing industry, high-tech services, tourism, and high-income agriculture.

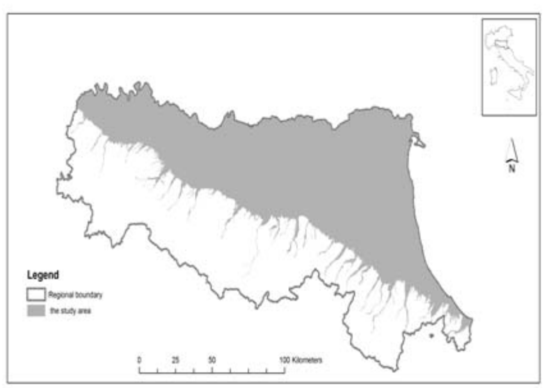

Fig. 1. The boundaries of the Emilia-Romagna administrative region and of the investigated area

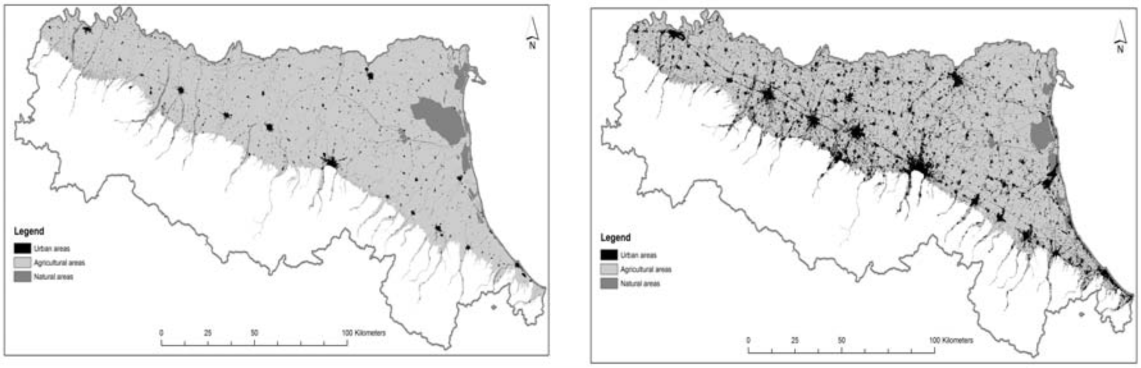

Fig. 2. Main distribution of LULC (I classification level) in 1954 (left) and 2008 (right)

MATERIALS & METHODS

The LULC datasets were generated over the years 1954, 1976, 1994 and 2008 by the Regional Cartographic and Geographic Information System Service of Emilia-Romagna. An overview of the datasets is given in Table 1. The datasets have a nominal scale of 1:25.000. A great effort was placed by the same Service in order to make comparable the same datasets both in terms of geometric resolution and thematic content. Additional elaborations were performed in the context of this research in order to harmonize the minimum mapping units of the datasets and solve a limited number of inconsistencies in the nomenclature. The classification schemes vary according to the years, but the harmonization exercise allowed a comparison, with some adaptations, to the third hierarchical level of the CORINE (COoRdination of INformation on the Environment or CLC) Land Cover nomenclature (EEA, 1994). Table 2 provides a list with the description of the harmonized nomenclature at the third (19 classes starting from the original 44 CLC classes) and the first, aggregated CLC level (five classes). In this case, class 1 corresponds to urban areas, class 2 to agricultural areas, class 3 to forest and semi-natural areas, class 4 to wetlands and, finally, class 5 to water bodies.

The LULC datasets were analysed with the help of the IDRISI TAIGA (Eastman, 2009) Land Change Modeler (LCM) over four time horizons: 1954-2008 (the whole study period), 1954-1976, 1976-1994, and 1994-2008. The 1976 and 1994 mid-points in the 55-year time series allowed analyzing separately three horizons of comparable length. This choice was also made based on the observation that in the late 1970s and then in the early 1990s changes in the modalities of the urban expansion as well as distinctive agricultural processes occurred in Emilia-Romagna. Matrices of LULC change were generated by the LCM and presented for instance in the form of graphs of net changes for all LULC classes, or of contributions to the change for a given class, and finally in the form of change maps. Change matrices and maps contain all the LULC change transactions.

LULC changes were further analysed and classified following the criteria in the LEAC system (and first of all at its 2nd level of aggregation) with a few simplifications. From the initial 119, six trajectories were identified which are described in more details in Table 5:

1. urbanisation,
2. internal transformation of urban areas,
3. extension of agriculture,
4. agriculture internal conversions,
5. farmland abandonment and afforestation,
6. conversion to forests, natural areas and water bodies.

Table 1. LULC datasets used in the analysis

Year	Nominal Scale	Minimum mapping unit (ha)	Original classification scheme	Number of classes
1954	1:25.000	2.25	ad-hoc, but made comparable with 2008	19 classes
1976	1:25.000	0.38	ad-hoc , but made comparable with 2008	29 classes
1994	1:25.000	2.25	ad-hoc , but made comparable with 2008	31 classes
2008	1:25.000	1.56	CLC up to the third level and based on ad-hoc specifications for a fourth level	83 classes

Table 2. LULC classes after the harmonization: description and coding at the third and first level

Description	Third level	First level
Urban areas (urban fabric, commercial units), major roads, railways	1	1
Mine, dump and construction sites	2	1
Industrial and port areas	3	1
Airports and associated infrastructures	4	1
Artificial, non-agricultural vegetated areas (green urban areas, sports and leisure facilities)	5	1
Arable land also in association with permanent crops	6	2
Rice fields	7	2
Vineyards	8	2
Olive groves and fruit trees plantations	9	2
Mixed specialized crops, orchards, greenhouses, and nurseries	10	2
Poplars and other tree plantations	11	2
Meadows also in association with permanent crops	12	2
Complex cultivation patterns (crop mosaics)	13	2
Forests and chestnut plantations	14	3
Scrubland and recent reforestation	15	3
Natural grasslands and moors	16	3
Areas with dominant bare rocks	17	3
Wetlands	18	4
Water bodies	19	5

Each LULC change was reclassified based on the 6 trajectories above. On this basis the total area of each trajectory was computed as well as for the different land capability classes and for the three study periods.

A more in-depth analysis was performed as regards to the trajectory "Agriculture internal conversions" at the 3rd level of aggregation in LEAC. An "intensification direction" was then associated with each flow in this trajectory ranging from 0 ("neutral"), to 1 ("intensification"), to 2, ("extensivation", i.e. the opposite process to intensification). This was done on the basis of expert judgement taking into account the level of capital investment, land development, chemical inputs, irrigation requirements, mechanisation, usually associated with each agricultural LULC. Details on the 3rd level LEAC flows and the respective "intensification directions" are given in Table 6. Each type of LULC change inside this trajectory was reclassified based on the "intensification direction". The total area of each flow was finally computed for the three time periods analysed.

Land capability is one of the approaches that have been used since the 1960s to classify soil and land according to requirements and constraints of specific land uses (Klingebiel and Montgomery, 1961). A land capability classification can be therefore used to rank land on the basis of its potential productivity and flexibility for supporting specific agricultural utilizations. This is determined by the extent to which the physical characteristics of the land impose long term restrictions on its use. Such agricultural capability maps can be used at the regional scale for making decisions on land improvement and farm consolidation, for developing land use plans, and for preparing equitable land assessments.

As for the land capability map of the study area, the territory was evaluated by the Emilia-Romagna Regional Geological, Seismic and Soil Service according to the land capability classification system of the United States Department of Agriculture (USDA). The classification, discussed for instance in Klingebiel and Montgomery (1961), results in eight classes having increasing limitations in their use for agricultural purposes (Fig. 3). The order of suitability ranges from suitable (that characterizes a land were a sustainable agricultural use can take place) to not suitable (Panhalkar, 2011). Table 3 gives more details on the definition of the classes which, when read inversely, provide an indicator of soil quality. The variables considered in the classification include soil depth, workability, fertility, salinity, aeration, as well as surface stoniness and rock outcrops, slope, risk of flooding, risk of erosion and land instability, as well as the influence of climate. Pedological variables were obtained for each soil type from the regional soil database, while others (e.g. slope, erosion risk, influence of climate) were obtained from additional regional GIS datasets (RER, 2010a). The classification, which initially refers to a single soil type, is further related to soil delineations (i.e. soil mapping units where more soil types may be associated) in the soil map at the scale 1:50,000 realized by the same regional Service (RER, 2010a). The result is a land capability map (RER, 2010b), with an investigated area of approximately 12.000 km^2 (see study area), where a final, compound capability class is assigned to each delineation, regardless of the number of soil types and of their respective capability classes. The following seven classes are identified: (1) soils suitable for agriculture with very few limitations, (2) with moderate limitations, (3) intermediate limitations, (4) severe limitations, (5) very severe limitations, (6) not suitable for agricultural use, (7) not determined (water bodies and waterways). Table 4 provides more details on the aggregation criteria applied for deriving the compound capability classes.

For the purpose of this analysis we regarded as "high to medium quality soils" those belonging to the classes 1, 2 and 3 of the land capability map.

The LULC change map was overlaid on the land capability map in order to obtain information on which LULC trajectories have consumed high-to-medium quality soils during the study periods. Through a simple cross-tabulation performed by means of the tabulate area tool in ArcGIS 9.3-Spatial Analyst Extension® (ESRI), the area of each class of land capability within each occurrence of LULC change was computed and analyzed.

RESULTS & DISCUSSION

Analyzing the LULC data over the whole study period, out of an investigated area of around 12.000 km^2, as much as 4.100 km2 (34%) underwent changes. As summarized in Table 7, the trajectory named "agriculture internal conversions" accounted for 46% of these changes, and "urban expansion" for as much as 35%. "Extension to agriculture" was limited to 8%, the same percentage as in the case of "conversion to forests and natural areas". Interestingly, the trajectory "Farmland abandonment and afforestation" which implies a change from agricultural uses to forest land and other natural areas, was marginal (2%). Although withdrawal of farming, especially in the form of abandonment of agricultural land, is known to be an important, on-going process especially in hilly and mountain areas of the region, this did not seem to be relevant in the Emilia-Romagna Lowlands.

The net changes (difference between gains and losses) for all LULC classes over the period 1954-2008 are shown in Fig. 4. The gains reported for all urban classes are the clear expression of the process of urban expansion occurred over the study period. In the case of the urban areas alone (including the residential urban fabric, and commercial uses), this mainly happened at the expenses of arable land, as also shown in Fig. 4. When considering the break down in the three sub-periods (see Table 7 for details), different patterns can be observed. The period 1954-1976 (the first to be analyzed in the aftermath of the Second World War) was characterized mostly by "agriculture internal conversions" (61% of the changes). Urban expansion (which, as discussed, occurred mainly in the form of compact and dense urban growth) and urban internal conversions accounted for 19% of the changes (Fig. 5). Also agriculture expansion was of importance (13%) in a phase which, as mentioned earlier, was characterized by a strong process of intensification. When looking at the details of internal conversions in agriculture (Table 8), this trend towards intensification is confirmed by the fact that 57% of the internal flows were associated with a shift between arable land and perennials (implying higher capital and labor investments per surface unit). During the second period (1976-1994) "Agricultural conversions" was also the most relevant trajectory (66%), although urban expansion (in the form of low-density, dispersed expansion) was also important, accounting for 16% of the changes. "Extension of agriculture" was still relevant (12%) while "conversion to forests and natural areas", amounted to just 6%. "Farmland abandonment and afforestation" was marginal (1%). When considering flows within the agricultural transformations, 64% can be associated with intensification processes. In this case, together with the already observed conversion from arable land to permanent crops, a change to specialized crops was especially relevant.

Finally the third period (1994-2008) was characterized by a major increase in "urban expansion" and "internal transformation of urban areas", accounting for 28% of the changes. "Agriculture internal conversions" were again the most important ones (50%), although less than in the previous phases. "Expansion" of agriculture was limited to 5%, while "conversion to forests and natural areas", which most likely included managed interventions of re-naturalization, accounted for 11%. "Farmland abandonment and afforestation", was again marginal

Table 3. Capability classes for specific soil types (USDA classification)

Class	Description
1	soils have slight limitations that restrict their use.
2	soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.
3	soils have severe limitations that reduce the choice of plants or require special conservation practices, or both.
4	soils have very severe limitations that restrict the choice of plants or require very careful management, or both.
5	soils have little or no hazard of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
6	soils have severe limitations that make them generally unsuited to cultivation and that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
7	soils have very severe limitations that make them unsuited to cultivation and that restrict their use mainly to grazing, forestland, or wildlife.
8	soils and miscellaneous areas have limitations that preclude their use for commercial plant production and limit their use to recreation, wildlife, or water supply or for esthetic purposes.

Table 4. Compound capability classes for soil units (delineations)

Class	Suitability	compound soil unit capability	corresponding soil type capability classes
1	suitable for agricultural use	few limitations	I
2		moderate limitations	II, I/II, II/I
3		severe limitations	II/III, III/II, or I/III, I/II/III, III/I, II/I/III
4		very severe limitations	III
5	not suitable for agricultural use, only for grazing and forestation	severe limitations	III/IV, IV, IV/III, or IV/II, II/IV, II/III/IV, III/II/IV
6		very severe limitations	V,VIII, or V/II, IV/VI, III/II/VI, III/VI, VI/IV
7	not assessed (water bodies and rivers)		

Table 5. LULC trajectories and correspondence with the LEAC flows (2nd level)

Number	Name of the trajectory	Correspondence with LEAC flows
1.	Urbanisation	"Urban residential sprawl", and "Sprawl of economic sites and infrastructures"
2.	Internal transformation of urban areas	"Urban land management"
3.	Extension of agriculture	"Conversion from forested & natural land to agriculture", "Conversion from semi-natural land to agriculture", "Conversion from wetlands to agriculture", "Conversion from developed areas to agriculture"
4.	Agriculture internal conversions	"Agriculture internal conversions"
5.	Farmland abandonment & afforestation	"Withdrawal of farming: farmland abandonment and other type of withdrawal of agriculture activity in favour of forests or natural land"
6.	Conversion to forests and other natural areas	"Forests creation and management", Semi-natural cover types creation and rotation; also included is "Water bodies creation and management"

Table 6. LULC in the "Agriculture internal conversions" trajectories and their correspondence with the LEAC flows (3rd level) and intensification direction (0 = neutral; 1 = intensification; 2 = extensivation)

LEAC code, 2nd level	Description of the flow	Intensification direction
41	Extension of set aside fallow land and pasture	2
42	Internal conversions between annual crops	0
43	Internal conversions between permanent/specialized crops	0
44	Conversion from permanent/specialized to arable land	2
45	Conversion from arable land to permanent/specialized crops	1
46	Conversion from pasture to arable and permanent/specialized crops	1

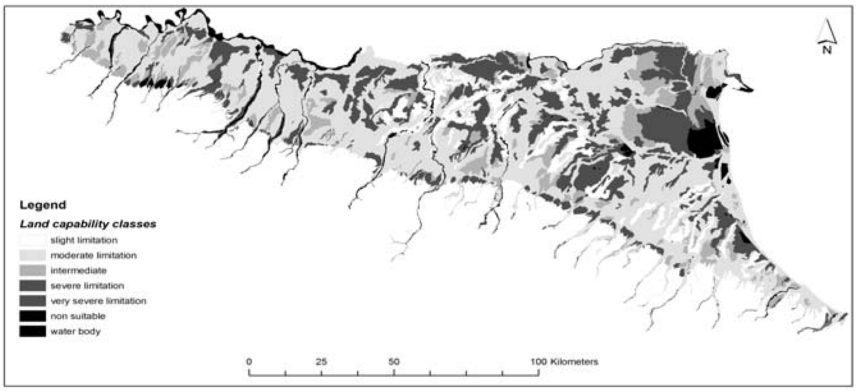

Fig. 3. The Land Capability map of Emilia-Romagna

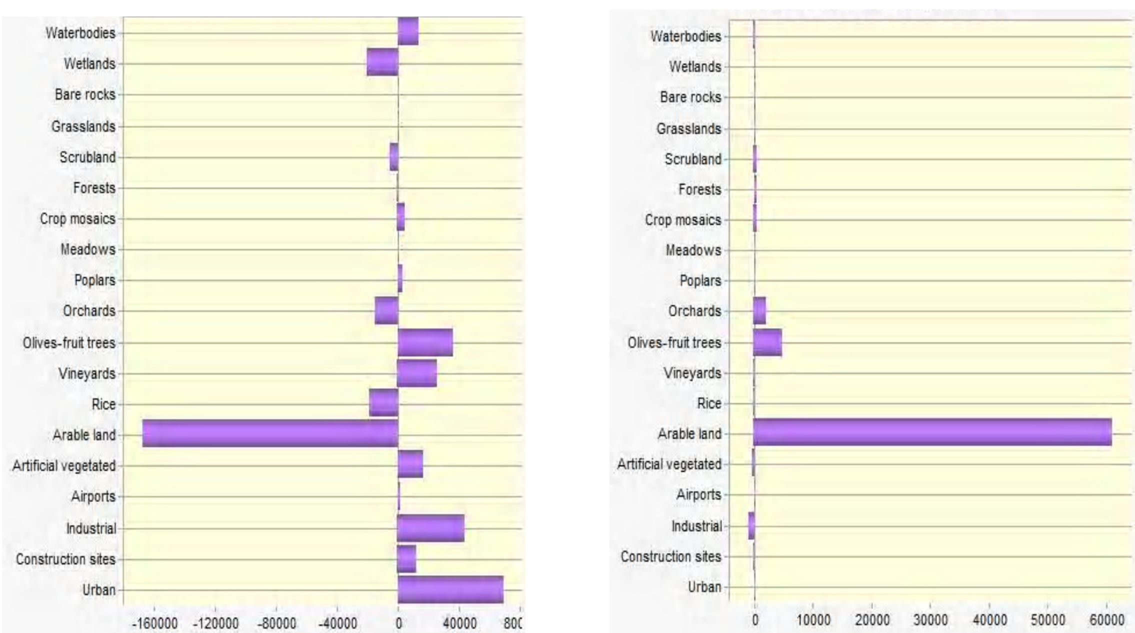

Fig. 4. Net changes in all LULC classes (left) and contributions to the change for the urban areas (right) for the period 1954-2008, in ha

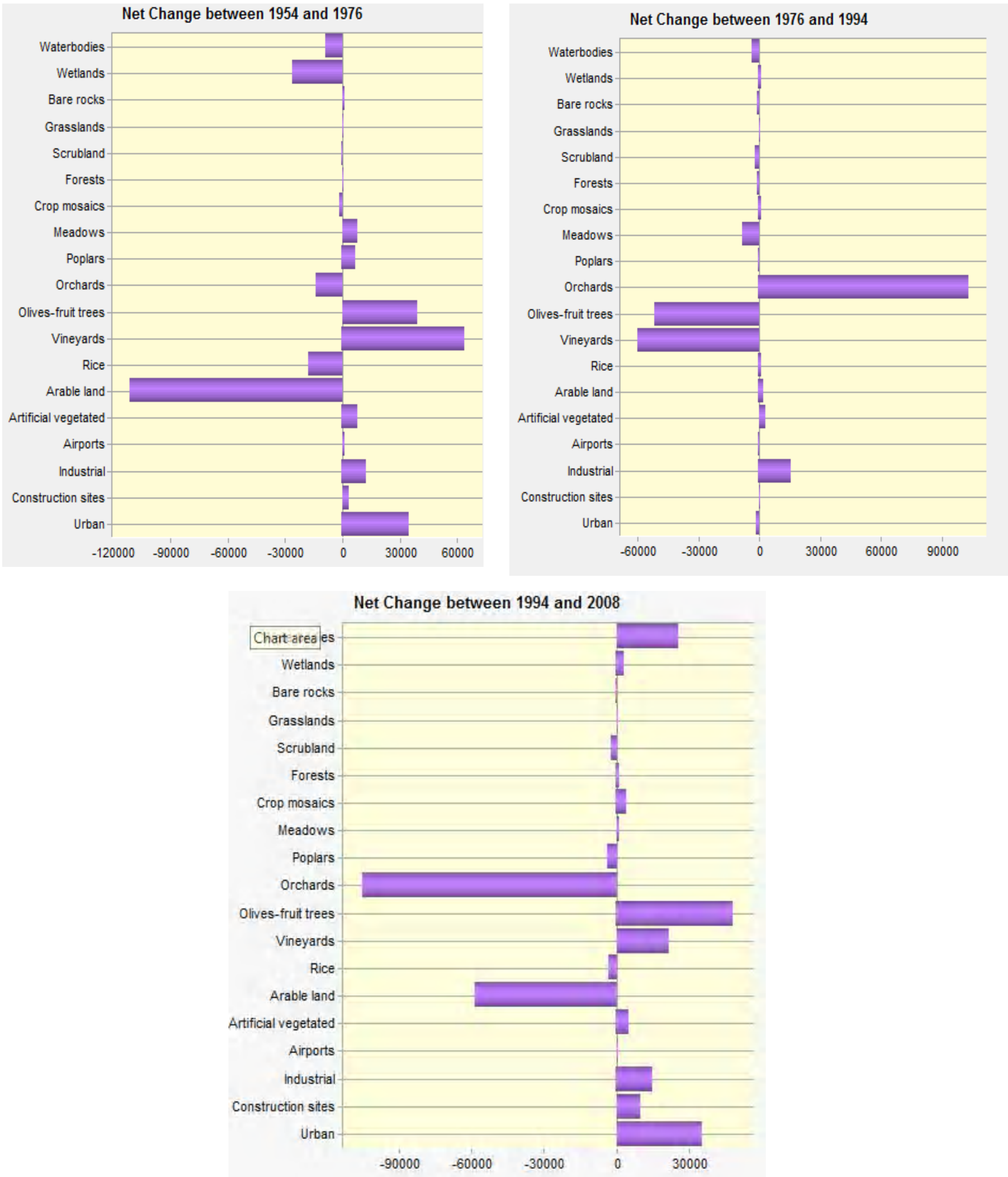

Fig. 5. Net changes in all LULC classes for the periods 1954-1976 (left) 1976-1994 (middle) and 1994-2008 (right), in ha

(2%). A breakdown inside the "agriculture internal conversions" showed that flows towards extensivation were more relevant than those associated with intensification.

Table 7 shows how much of the best quality soils (classes 1, 2 and 3 of the land capability) was taken by the different land-use change trajectories. During the entire study period the area consumed by urban expansion, which, as seen previously, took place mostly at the expenses of agricultural land, consumed around 41% of the high-quality soils. Conversions among different agricultural classes accounted for another 46%, although these refer to internal, reversible transformations (Fig. 6). When considering the break down into the three separate phases, urban expansion and transformations took around the same percentages

Table 7. LULC trajectories: area changed and best land capability classes for the whole study period and the three phases

	whole period (1954-2008)				first phase (1954-1976)				second phase (1976-1994)				third phase (1994-2008)			
	tot.area changed		land cap. class 1,2,3		tot.area changed		land cap. class 1,2,3		tot.area changed		land cap. class 1,2,3		tot.area changed		land cap. class 1,2,3	
Trajectory	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Urban expansion	144,349	35%	122,032	41%	64,411	18%	4,951	21%	39,191	11%	32,855	12%	73,375	23%	60,470	24%
Internal transformation of urban areas	5,433	1%	4,683	2%	3,398	1%	3,075	1%	15,618	5%	13,671	5%	15,155	5%	13,289	5%
Extension of agriculture																
Agriculture internal conversions																
Farmland abandonment & afforestation	7,845	2%	3,882	1%	7,475	2%	4,322	2%	3,840	1%	1,879	1%	7,449	2%	3,383	1%
Conversion to forests and natural areas	31,798	8%	12,202	4%	18,490	5%	6,874	3%	19,224	6%	6,073	2%	36,787	11%	15,271	6%
Total	409,658	100%	297,312	100%	358,464	100%	260,053	73%	346,781	100%	271,160	78%	323,724	100%	247,350	76%
Tot. investigated area (ha)1203263	% area changed %34				% area changed 30%				% area changed 29%				% area changed 27%			

Table 8. In depth analysis of the LULC flows inside the "Agriculture internal conversions" trajectory

	whole period (1954-2008)		first phase (1954-1976)		second phase (1976-1994)		third phase (1994-2008)	
	Ha	%	Ha	%	Ha	%	Ha	%
0= neutral	30117	16%	37302	17%	70378	31%	90407	49%
1= intensification	105864	57%	137698	64%	74817	33%	21540	12%
2= extensivation	50498	27%	41744	19%	82764	36%	71989	39%
total	186479	100%	216744	100%	227959	100%	183936	100%

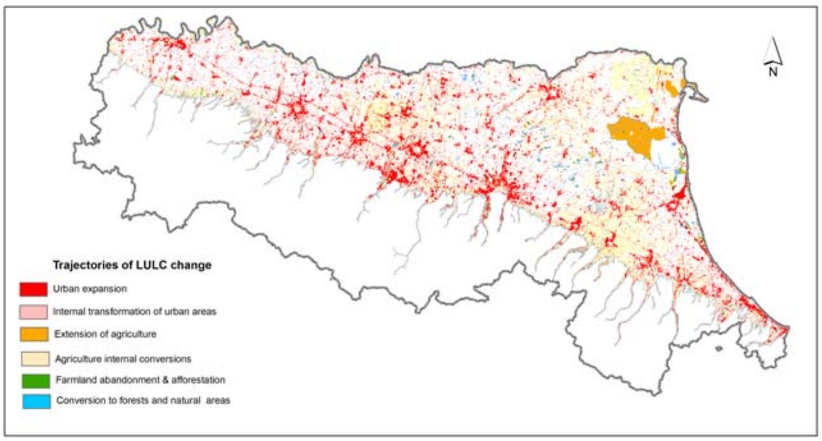

Fig. 6. Map of the LULC trajectories 1954-2008

of the best quality soils in 1954-1976 (22%) and 1976-1994 (17%), with a considerable increase (29%) in last phase (1994-2008), also due to the increase in the pace of urban expansion. Internal agricultural transformations consumed respectively 66% and 69% of the same soils in the first two phases, and decreased in the last phase (53%).

Although limited in their extent, the newly cultivated agricultural areas consumed, over the whole period, only 3% of the best soils. Inversely, the remaining 97% had severe to very severe limitations, or were not suitable for agriculture. Always with reference to agricultural land expansion, a decrease can be observed over the three phases: from 7% (over the period 1954-1976) to 11% (1976-1994) and finally 9% (1994-2008). Similarly, low percentages of good quality soils were consumed by the conversion to forests and natural areas. This finding appears to be justified since specific interventions of re-naturalization would be geared towards soils of lower agricultural quality.

This study investigated how LULC changes, especially urban expansion and agricultural development, have consumed soils of different quality. It evaluated long term trajectories of change in respect to land capability with reference to an European region in Italy.Emilia-Romagna experienced urban growth associated with high-input, intensive agriculture development in the decades immediately after the World War II, then shifting to a dispersed urban expansion and more extensive agricultural development towards the 2000s. This spatial configuration is in common with several other regions in Western Europe and may represent a paradigmatic example, even for non-European countries, in evaluating the consumption of soils by urban growth and agricultural development not only in absolute terms but also in respect to its relative quality.

Results showed a first phase (1954-1976) which can be altogether associated with urban growth and agricultural intensification. It is what some authors referred to a as the "great transformation" phase which has seen a rapid shift from the traditional rural setup established in Emilia-Romagna since the second half of the nineteen century to an urban-industrial one (di Gennaro *et al.*, 2010), coupled with the appearance of a modern agricultural sector. Agricultural intensification occurred especially in terms of "agriculture internal conversions" in the form of transformations from annual crops to perennials and specialized crops. Also of relative importance in this period was the net increase in the agricultural land, which has been progressively decreasing over the rest of the study period. In this period the total population grew of around 8% (di Gennaro *et al.*, 2010) as opposed to the 18% increase in urban areas, a first example of the well-known paradox of 'decoupled land take' highlighted for instance in the guidelines on soil sealing (EC, 2012). In the second phase (1976-1994) agricultural conversions became even more important, although without a clear prevalence between intensification and extensivation. Urban expansion was less relevant than in the previous phase. Altogether we could consider this as a transition phase, where the processed already seen in the previous phase have been consolidating, including the gap between population and urban growth. In the third and last phase (1994-2008) the most relevant trajectory was, once more, "agricultural internal conversions" with LULC flows this time mainly oriented towards extensivation or "neutral". The percentage of increase in the urban expansion and internal conversions almost doubled in respect to the previous phase. This period can be seen as a step in the of further 'decoupling' between urban growth and demographic dynamics. A decreasing economic profitability of agriculture in respect to increasing values of areas of potential urban development, most likely facilitated the 'taking' of farmland by the urbanization processes. This mostly occurred in terms of low-density, dispersed expansion, exacerbating processes of land degradation as described in the introductory section.

Results also proved that urban expansion consumed soils with the highest available quality. With reference to the entire period, apart from the internal agricultural conversions which took 46% of the soils in land capability classes 1, 2 and 3, urban expansion consumed around 41% of these soils, mostly at the expenses of agricultural land. The other trajectories consumed soils of lower quality. This occurred for instance in the case of the trajectory "Conversion to forests and other natural areas", and is possibly in relation to specific interventions of re-naturalization targeting soils of lower agricultural value. The importance of this specific LULC change increased progressively over the three phases.

CONCLUSION

Land-use/land cover data are among the most important and universally used terrestrial datasets and represent key environmental information for a variety of science and policy applications (Cihlar, 2000; DeFries and Belward, 2000). Accelerated transformations in the earth system are raising increasing awareness (Millenium Ecosystem Assessment, 2005), and there is compelling evidence that global environmental change is largely due to human activities, resulting in the alteration of almost all terrestrial ecosystems (Steffen *et al*., 2004; Vitousek *et al*., 1997).

A specific concern has recently emerged in Europe in relation to land take and land degradation processes associated to urbanization (EC, 2012), leading to the ambitious objective of achieving a "zero net land take" by 2050 (EC, 2011). A special emphasis is placed on the cases of polycentric, affluent areas in the EU where, in more recent years, soil consumption by urban uses has progressed almost independently from demographic growth. In this light, the questions of which soils (of which quality) have been consumed in the past urbanisation and would be in future urban developments, takes a special meaning, hopefully orienting land use planning and management at both regional and local levels.

These problems can be described using different methodologies focusing on structural composition, or considering the concepts of productivity, quality of a landscape, and soil capability in relations to LULC changes. The approach illustrated in this paper was implemented on the basis of high-resolution, long term series of LULC and land capability maps using Geographic Information Systems and land change models.

According to the evidences of this study, through time comparisons of LULC data it is possible to quantify specific change trajectories providing crucial information on the effect of current transformations (such as urbanization, intensification of agriculture, deforestation and afforestation, and land abandonment). For instance a relation can be established between the urbanization trajectory and specific land degradation processes such as land taking and soil sealing.

Moreover, it is possible to relate change trajectories to soil quality data informing decision makers on land consumption dynamics and hopefully orienting sustainable land use planning and management.

A more refined analysis, aiming for instance at identifying different degrees of soil sealing, implies the combined use of the cartographic datasets used in this study and higher resolution data as illustrated in Corticelli et al. (2008), as well as in-situ information.

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