The Italian Land Use Inventory for assessing land use changes in Italy during last decades

Marco Marchetti[a*], Piermaria Corona[b], Lorenzo Fattorini[c], Maria Chiara Pagliarella[a], Michele Munafò[d], Gherardo Chirici[e], Fabio Lombardi[f], Marco Ottaviano[a], Matteo Vizzarri[a], Lorenzo Sallustio[a]

[a]Dipartimento di Bioscienze e Territorio, University of Molise, Contrada Fonte Lappone, 86090 Pesche (IS), Italy. lorenzo.sallustio@unimol.it; matteo.vizzarri@unimol.it; ottaviano@unimol.it; mariachiara.pagliarella@unisi.it; marchettimarco@unimol.it
[b]Consiglio per la Ricerca in agricoltura e l'analisi dell'Economia Agraria, Forestry Research Centre (CREA SEL), Viale S. Margherita 80, 52100 Arezzo, Italy. piermaria.corona@entecra.it
[c]Dipartimento di Economia e Statistica, University of Siena, Piazza San Francesco 8, 53100 Siena, Italy. lorenzo.fattorini@unisi.it;
[d]Italian National Institute for Environmental Protection and Research (ISPRA), Via V. Brancati 48, I-00144 Rome, Italy; michele.munafo@isprambiente.it
[e] Dipartimento di Gestione dei Sistemi Agrari, Alimentari e Forestali, University of Florence, via San Bonaventura 13, 50145 Firenze, Italy. gherardo.chirici@unifi.it
[f] Dipartimento di Agraria, Mediterranean University of Reggio Calabria, Località Feo di Vito - 89122 Reggio Calabria (RC), Italy. fabio.lombardi@unirc.it
*Corresponding author:: *Marco Marchetti, Dipartimento di Bioscienze e Territorio, University of Molise, Contrada Fonte Lappone, 860*
90 Pesche (IS), Italy. Phone: (+39)0874404228, e-mail address: *marchettimarco@unimol.it*
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ABSTRACT

The aim of this paper was to collect research regarding the analysis of land use and land cover changes (LULCC) made with the different approaches and methodologies in the last few years on the Italian territory. The LULCC can be analysed using both cartographic and inventory approaches. The latter, in particular, provide estimates of the accuracy of the sampling strategy adopted , allowing objective and scientifically sound comparisons of the estimates at different times. The possibility to assess the statistical accuracy and the possibility of frequent updates, suggest the inventory approach as a valid and reliable instrument for the LULCC assessment. The evaluation of LULCC and the selection of a reliable and accurate approach usable as a standard for

a large series of experiences, plays a primary role as a support for future land use planning. In this perspective, the Italian Inventory of Land Use has been further implemented during last years to better understand LULCC, their causes and possible effects on ecosystem services, thus offering a valuable support for future land use planning.

Keywords: Land Use, Land Cover, Multitemporal analysis, Inventory, monitoring

1. Introduction

Since the Industrial Revolution, and particularly after the World War II, the socio-economic dynamics have strongly exacerbated the land use and land cover changes (LULCC), particularly in Developed Countries, such as e.g., Italy. LULCC alter the ecosystems' structure, functionality, as well as their capacity to provide goods and services supporting human wellbeing (e.g., Foley et al., 2005). Furthermore, it is now evident that rapid changes in ecosystems, especially if driven by human activities, significantly affect the ecological resilience (Vizzarri et al., 2015). Monitoring LULCC and assessing the related impacts on resilience and Ecosystem Services (ES) are crucial to support adaptive governance, as well as to evaluate the effects of the currently implemented actions on sustainability. Consequently, the development and implementation of new methodologies and approaches to face these needing represent active and stimulating fields of research (e.g. Vizzarri et al. 2015).

Cartographic and inventory approaches are used for LULCC analysis, through applying different methodologies and nomenclatures strictly according to their aims and scopes (Corona, 2010). For example, land use inventories aim to provide statistically sound estimators of land-use proportions and related changes for a given time-span in a study area. This need is satisfied by applying different sampling strategies aimed at maximizing statistical accuracy and data reliability, while minimizing sampling costs and duration. Otherwise, for mapping, the demand is for a graphical depiction of attributes location within a study area, which is useful for the spatially-explicit investigation of certain phenomena. The choice of the most appropriate approach is not then an easy task, since it is related to different aspects, such as time, costs, objectives and data reliability. In this context, the aim of this contribution is to briefly present some recent outcomes and methodological remarks obtained by testing, improving and implementing the Italian Land Use Inventory (IUTI from the Italian acronym of *Inventario dell'Uso delle Terre d'Italia*) at national or regional scale in Italy. The manuscript is divided into four main sessions describing *i*) the characteristics and main aspects of IUTI; *ii*) the LULCC affecting the Italian landscape during the last 20 years; *iii*) the maximisation of the informative power of IUTI through integrating inventory and cartographic approaches, as well as LU and LC meanings; and *iv*) some final comments and remarks.

2. The Italian Land Use Inventory (IUTI)

IUTI has been promoted and implemented by The Italian Ministry of Environment and Protection of Land and Sea in the framework of the Extraordinary Plan of Environmental Remote Sensing as a key instrument of the National Registry for forest carbon sinks (Marchetti et al., 2012). The Italian territory was covered by a network of 1,217,032 quadrats of 25 ha, in a way that each quadrat contained at least a portion of this territory. Hence, in accordance with the protocol of tessellation stratified sampling (TSS), a point was randomly selected in each quadrat (Fattorini, 2014). The large sample size adopted in IUTI was due to the need for estimating LULCC with adequate statistical accuracy, even estimating small changes that are likely to occur during brief temporal intervals (Corona et al. 2012a). The sample points were photo-interpreted on high resolution imagery available for the years 1990, 2000 and 2008 to estimate LULCC over the time. Those points that fell outside the Italian territory were classified in an additional class (i.e. "outside area"), while the others were classified in 9 LU classes divided into 3 hierarchical levels. The analysis of LU and LC changes is based on the construction of a transition matrix, also known as a cross-tabulation matrix (Pontius et al. 2004) (e.g., Table 1 shows the Italian transition matrix from 1990 to 2008).

		2008									
		Forest land	Arable land	Orchards, vineyards and nurseries	Forest plantations	Natural grassland and pastures	Other wooded land	Wetlands	Settlements	Other land	Total
1990	Forest land	9,014,117	30,192	13,573	975	13,446	37,213	9,497	21,118	1,225	9,141,355
	Arable land	184,398	9,586,594	789,148	69,470	154,166	128,526	15,374	387,391	150	11,315,217
	Orchards, vineyards and nurseries	35,547	272,931	2,269,752	775	21,650	16,571	575	64,962	0	2,682,761
	Forest plantations	3,847	51,692	1,249	67,659	2,773	2,349	1,249	3,273	0	134,091
	Natural grassland and pastures	138,121	60,692	22,573	4,224	1,662,343	276,904	5,349	24,998	550	2,195,754
	Other wooded land	256,716	48,566	17,072	750	9,449	1,513,565	7,399	13,097	525	1,867,138
	Wetlands	14,696	1,225	425	400	2,999	11,224	476,768	1,500	825	510,061
	Settlements	5,023	4,174	950	125	5,250	3,724	1,250	1,623,439	75	1,644,010
	Other land	750	75	25	0	2,373	1,125	1,125	1,125	651,691	658,288
	Total	9,653,216	10,056,141	3,114,765	144,376	1,874,449	1,991,200	518,586	2,140,903	655,040	30,148,676

Table 1: *Transition matrix of the changes which occurred in LU from 1990 to 2008 in Italy.(Source: Marchetti el al., 2014a).*

Additionally, during 2013, the IUTI database was updated using a 1% subsample within the whole national territory (about 13,000 sample points), thus obtaining an estimation of the LULCC trends for that year. For reducing the sampling efforts, the one-per-stratum stratified sampling (OPSS) has been adopted. The results from Fattorini et al. (2015) showed that in front of a reduction of the on-screen classification effort of 100 times, the RSE estimates increased by approximately 10 times. In absolute terms, these results are then rather encouraging, because the largest LU classes show RSE estimates invariably smaller than 3%, while the smallest ones show RSE estimates always below 9% (Pagliarella et al., *in press*).

3. LULCC in Italy during last decades

IUTI allows to identify and quantify in a quick way and at low cost the key dynamics characterizing the landscape changes, including their impact in ecological and functional terms. At national scale, several studies have shown that, during the last 50 years, the Italian landscape has been deeply marked by industrialization, urbanization, agricultural and livestock intensification, mostly in downhill and plains. On the contrary, mountain areas are currently affected by land abandonment and spontaneous forest revegetation. Summarizing, the most important LULCC in Italy, during the last decades, were: (i) urban growth and soil sealing; (ii) loss of arable lands, meadows and pastures; and (iii) natural reforestation (e.g., Falcucci et al., 2007). In particular, forest regrowth (+1.7% of the Italian territory), primarily occurred at the expense of croplands in the hills, pastures and grasslands in the mountains; the shrinkage of arable lands (-4.2% of the Italian territory) is due to urban growth in lowlands, conversions to permanent crops in hills (mainly orchards and vineyards) and natural reforestation in mountain areas; urban area increased by 1.6% with a total coverage of settlements reaching 7.1% of the whole Italian territory in 2008. Preliminary results of the updating process in 2013, show a decreased rate of annual variation, if compared with that from the first monitoring period (1990-2008) (Sallustio et al., 2015a). Considering the first two changes (natural reforestation and land abandonment), IUTI showed that in Italy they are following a latitudinal gradient as shown in table 2. In fact, the decreases in arable lands, meadows and pastures are more marked descending from North to South (Sallustio et al., 2015a). Moreover, it is worthy to note that the loss of arable lands primarily occurs on agricultural land uses marginal in economic terms, despite it is very important from an ecological perspective (see e.g., biodiversity and cultural landscapes conservation) (Marchetti et al., 2014a). Furthermore, Marchetti et al. 2013 showed that the trends registered at national scale in Italy are not very different from those observed within the National Parks. These findings are particularly important to deeper understand to what extent the policy instruments and regulations are currently used and implemented in these areas to address conservation issues.

	North			*Centre*			*South*			*Italy*		
IUTI class	**1990**	**2008**	**Variation 1990-2008 (% of North land area)**	**1990**	**2008**	**Variation 1990-2008 (% of Centre land area)**	**1990**	**2008**	**Variation 1990-2008 (% of South land area)**	**1990**	**2008**	**Variation 1990-2008 (% of national land area)**
Forest land	33.4	34.8	+1.43	38.8	41.0	+2.24	23.3	25.0	+1.70	30.3	32	+1.7
Arable land	36.9	33.6	-3.30	38.4	34.1	-4.29	37.7	32.7	-4.97	37.5	33.4	-4.1
Orchards, vineyards and nurseries	4.2	4.6	+0.43	8.2	9.0	+0.79	13.8	16.6	+2.72	8.9	10.5	+1.6
Forest plantations	1.0	0.8	-0.11	0.1	0.3	+0.12	0.1	0.2	+0.14	0.4	0.5	+0.1
Natural grassland and pastures	7.0	6.4	-0.65	3.8	3.1	-0.76	9.2	7.6	-1.61	7.3	6.2	-1.1
Other wooded land	3.2	3.4	+0.21	3.5	3.5	+0.02	10.4	11.2	+0.79	6.2	6.6	+0.4
Wetlands	2.7	2.7	+0.01	1.1	1.1	+0.01	1.0	1.0	+0.06	1.7	1.7	+0.0
Settlements	7.0	9.0	+2.01	5.7	7.6	+1.87	3.8	5.0	+1.18	5.5	7.1	+1.6
Other land	4.7	4.7	-0.02	0.2	0.2	-0.01	0.7	0.7	-0.01	2.2	2.2	+0.0

Table 2: *Forest dynamics occurred in Italy and in the three macro-regions between 1990 and 2008. Values are expressed as surface (ha) and relative values (%) with respect to the total surface of each macro-region. (Source: Sallustio et al. 2015a).*

The urban growth is one of the most worrying LULCC in Italy, and occurs especially at the expense of arable lands and croplands in general (approximately 75%, Marchetti et al., 2012). In particular, land take occurs in lowlands and gentle slope territories, which are usually attractive for brick and mortar investments (Marchetti et al., 2014a). Moreover, this phenomenon is still also affecting regions with negative demographic balance (e.g., Basilicata, Calabria, Liguria and Molise), with a subsequent increase of their per-capita built-up area (Sallustio et al., 2013).

Using two different definitions of mountain (statistical and juridical) and comparing the LULCC occurred during the same time-span even on the entire national territory and within the National Parks, Sallustio et al., (2015b) highlighted the importance of using a clear and unambiguous definition of the study area to obtain reliable results able to effectively support a certain policy, strategy or plan (the one related to mountain areas in the specific case). In particular, they found that LULCC are very similar (for type and magnitude) both in the statistical mountain and Protected Areas case, despite they appear quite different according to the "statistical mountain" definition, and the whole national territory. This finding turned out to be an essential need also for future policies and management strategies, such as those related to the oncoming Common Agricultural Policy.

4. Beyond IUTI: how to maximize the informative power at low costs?

The lack of data and funding sources limits the research activities, and encourages researchers to optimize the freely available data, as well as maximize their informative power. This section shows the results of the two works carried out by using IUTI data to integrate inventory with cartographic approach, as well as LU with LC meaning.

4.1 The integration of inventory and cartographic approaches

Sallustio el al. (2015c) proposed and tested a method to quantify land take dynamics associated with urban growth, and estimate their effects in terms of carbon stock loss. Specifically, a method used for urban forest coverage assessment over Italy (Corona et al., 2012b) was implemented in order to estimate urban patch abundance and average size. This approach is based on integration between the inventory and cartographic approaches to estimate not only the extension of a given LU or LC class, but also the number and average size of the patches. The sampled urban patches were then used as inputs for the assessment of change in carbon loss, both in biophysical and economic terms, through using the InVEST model (Tallis et al., 2013). Analyses were performed in two very different study areas in central Italy, such as the province of Rome, the most populated and urbanized area in Italy, and the Molise region, the least dense and urbanized area in Italy. The main results are reported in Table 3, in which it is possible to appreciate the satisfactory level of accuracy of the estimates.

Study area	Year	$\hat{N}$	$se_{\hat{N}}$ (%)	$\hat{A}$ (ha)	$se_{\hat{A}}$ (%)	$\hat{\bar{a}}$ (ha)	$se_{\hat{\bar{a}}}$ (%)
Molise Region	1990	2449	10.1	9000	5.2	3.68	7.6
	2008	3455	8.5	12,850	4.3	3.72	6.2
Province of Rome	1990	10,763	4.9	81,037	1.7	7.53	4.4
	2008	13,989	4.2	109,026	1.4	7.79	3.8

Table 3: *Estimates of number of urban patches (N), urban coverage (A) and urban patch average area (a), and their estimated relative standard errors (expressed in percent).(Source: Sallustio et al., 2015c).*

Despite the low realization and updating costs, the integration of inventory and cartographic approaches is demonstrated to be a reliable estimate, enhancing their information power. Moreover, the possibility to couple such estimates with spatially-explicit tools allows the identification of ES or functions loss due to a certain LULCC of ecosystems' modification, and provides useful information for land use planning.

4.2 The integration of LU and LC inventories

There are both semantic and technical differences between LU and LC measurements. The most common definitions of LU and LC are those adopted in the Land Cover Classification System by FAO (2000), in which the former is referred to the socio-economic function of a given piece of territory, while the latter is usually related to its biophysical cover that can be directly observed in the field and registered by orthophotos. The confusion between the two concepts has existed in the literature for at least forty years (Anderson et al. 1976), leading to the spread of hybrid classification systems. However, the ability to distinguish or integrate use and cover concepts can represent a challenging opportunity for researchers.

Recently, Sallustio et al. (2016) presented an example of LU and LC inventories integration applied to the Molise region. Changes in LU and LC were evaluated from 2000 to 2012 using the IUTI sample points. The analysis was performed using both the original LU classification and through a new classification system addressing the LC. The sampling points were classified through a visual interpretation of aerial photographs for both LU and LC in order to estimate their surface and changes over time. The results demonstrated that a comparison between the two classification schemes provides an understanding of the causes of their misalignment. In fact, the aggregation proposed in table 4 indicates a good correspondence between the LU and LC estimates only for *Arable lands and Orchards, vineyards and nurseries*, whose differences are not significant. In the other cases (e.g., *Forest lands and forest plantations*, *Settlements and artificial lands*, and *Other lands*), the differences between the LU and LC estimates are highly significant. In the case of *Forest lands*, for example, such difference is 2.16%, mainly due to the LU parameters of classification used, such as the height of mature trees, the crown coverage, the extension and the minimum width of the woods (FAO, 2000), which are neglected by the LC classification.

	LU classes	LC classes	LU (%)	LC (%)	LU (ha)	LC (ha)	absolute differences (%)	absolute differences (ha)	significance
Forest lands and forest plantations	1.1- 1.2- 2.2.2	33	35.23	33.06	161,525	151,600	2.16	9,925	0.00001(*)
Arable lands	2.1	34- 43	43.33	42.66	198,675	195,625	0.67	3,050	0.19821
Orchards, vineyards and nurseries	2.2.1	32	5.82	5.89	26,700	27,025	0.07	325	0.77257
Grasslands and other wooded lands	3.1- 3.2	35- 44	8.85	9.50	40,600	43,575	0.65	2,975	0.03140(*)
Wetlands	4	36- 37- 38	0.50	0.68	2,300	3,125	0.18	825	0.02464(*)
Settlements and artificial lands	5	From 11 to 24	3.03	3.71	13,875	17,025	0.69	3,150	0.00027(*)
Other lands	6	39- 40- 41- 42	0.07	1.16	325	5,325	1.09	5,000	0.00000(*)

Table 4: *Comparison of the estimates achieved for LU and LC aggregated categories in 2012, their differences and their corresponding significance. (Source: Sallustio el al., 2016).*

The combined use and interpretation of the LU and LC estimates are helpful for deeper analysing and understanding the processes and dynamics occurring within a certain study area. For example, from the repartitioning of the sampling points classified as *Settlements* among the LC classes for the Molise region, Sallustio et al. (2016) found that 31.9% of them fall in unsealed (permeable) classes. This value gives insights on the density and compactness of urban areas. In fact, the higher is the degree of the unsealed surface, the higher its degree of permeability, corresponding to more scattered and fragmented urban areas. The extension of this permeable surface in urban areas offers a great potential to enhance and implement urban green spaces to improve the people wellbeing (Haase et al. 2014). The comparison of the estimates from the two classification systems may constitute a quick and effective instrument able to provide essential information to support land use planning.

5. Final remarks

The evaluation of LULCC and the selection of a reliable and accurate approach usable as a standard for a large series of experiences, plays a primary role as a support for future land use planning. This turns to be extremely important to make the future-oriented management guidelines coherent with the bioeconomy bases and to frame other key questions for sustainable development policies, like the set-up of environmental-economic accounting systems (Marchetti et al., 2014b).

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