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# RECENT TRENDS IN FOREST COVER CHANGES: ONLY POSITIVE IMPLICATIONS?

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*During the last 50 years, the Italian landscape has been subjected by different land use and land cover changes (LULCC). The IUTI inventory (*Inventario dell'Uso delle Terre d'Italia*) is proved to be a cheaper, fast and statistically accurate method for LULCC monitoring. The aim of this study is to summarize the LULCC trends at national level, in Italy, focusing on natural reforestation processes at macro-regions level. Some of the LULCC effects on ecosystem services provisioning (carbon storage and sequestration, and biodiversity conservation) have been also analysed. Although on one side the forest re-growth represents a positive opportunity in terms of mitigation strategies due to the enhancement of potential carbon sinks, on the other side, the abandonment of agro-pastoral practices, has several potential negative impacts from an environmental, economic and social perspective.*

*Key words:* Land Use Change; natural reforestation; land abandonment; carbon storage; biodiversity; Invasive Alien Species.
*Parole chiave*: cambiamento dell'uso del suolo, ricolonizzazione, abbandono colturale, sequestro di carbonio, biodiversità, specie invasive.

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## 1. INTRODUCTION

Human activities radically modify biogeochemical cycles and influence land use and land cover changes (LULCC), altering composition and abundance of vegetal and animal species (Vitousek, 1994). Nowadays, only 22% of the emerged lands are free from human alterations and related land uses, following the concept of



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"Anthropocene" (Ellis and Ramankutty, 2008). The increasing debate around the Anthropocene and LULCC, which are seen as major signals of alteration of ecosystem structures and processes, derives from the need to maintain the capacity of the territory to provide goods and services over the time (MA, 2005; Marchetti *et al.*, 2014a; Ametrano *et al.*, 2015), as well as requires to deeper focus on small-scale dependent knowledge and local socio-economic transformations.

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 (Conti and Fagarazzi, 2004; Falcucci *et al.*, 2007; Marchetti and Sallustio, 2012).

In Italy, as well as in the rest of Europe, the most critical LULCC phenomenon is represented by the urban growth, because of its irreversibility (Sallustio *et al.*, 2015). This process, conventionally known as "urban sprawl" (EEA, 2006; Marchetti *et al.*, 2014a), is characterized by different shapes and dynamics, depending on the socio-economic and geographical features of the national territories (ISPRA, 2014). Furthermore, during the past 50 years, the urban growth in Italy was characterized by fragmentation and diffusion of the urban texture, leading to the systematic lack of town planning (Romano and Zullo, 2012). In quantitative terms, the most important phenomenon is represented by the decline of arable lands, with a net loss of about 1.3 million ha from 1990 to 2008 across the national territory, combined with a relevant decrease in meadows and pastures, especially in mountain areas (Marchetti *et al.*, 2014b).

Worldwide, land abandonment is strictly connected to agriculture globalization and demographic trends. In European mountain areas, the rural exodus follows a hypothetical circle of decline, in which a low population density limits business creation, causing the reduction in job opportunities and the increase of out-migration that, in turn, emphasizes the decrease in population density (Navarro and Pereira, 2012; Sallustio *et al.*, *in press*). Accordingly, the abandoned lands suffer a rewilding process, but, in spite of the several benefits provided by forests, their growth at the expense of croplands, meadows and pastures, especially in mountain areas, represents a critical issue, being at the same time a new challenge and opportunity in terms of land use planning and politics (e.g., Conti and Fagarazzi; 2004; Huston, 2005; Sitzia *et al.*, 2010; Navarro and Pereira, 2012). On one hand, the natural revegetation represents a positive opportunity in terms of mitigation strategies [(see Kyoto Protocol (KP), UNFCCC, 1997], due to the enhancement of potential carbon sinks (Corona *et al.*, 2005; Salvadori *et al.*, 2006; Lamedica *et al.*, 2007). On the other hand, the depopulation of rural areas and the abandonment of agro-pastoral practices, seem to have several potential negative impacts from environmental, economic and social perspectives (Conti and Fagarazzi, 2004; Marchetti and Barbati, 2005; Sitzia *et al.*, 2010; Agnoletti, 2014; Sallustio *et al.*, *in press*).

Furthermore, forests expansion affects the decrease of landscape variability and transformation, promoting the landscape homogenization, as a "whole green sea" (Paci *et al.*, 2006), and creating a subsequent loss of cultural heritage and biodiversity (Brandymar, 2002; Höchtl *et al.*, 2005; Garbarino and Pividori, 2006; Agnoletti, 2014). Moreover, the land abandonment and rewilding process are particularly critical for the Italian landscape, as they increase the overall vulnerability of terrestrial ecosystems to several extreme phenomena such as destructive fires, floods and landslides (see e.g. Agnoletti, 2010; Marchetti *et al.*, 2013; Corongiu *et al.*, 2015).

Since the Convention on Biological Diversity (CBD, UNEP, 1992), biodiversity and ES in general were placed at the base of the most important global, European and national processes, according to the main purposes of enhancing and preserving natural capital and related benefits for people. These objectives are realized through implementing specific policies and strategies, such as the European Biodiversity Strategy to 2020 (EP 2011/2307(INI)), and the correlated Italian Biodiversity Strategy (MATTM, Decree 6th June 2011). In such a context, a further threat is represented by the spread of Invasive Alien Species (IAS) (Benesperi *et al.*, 2012), which is considered as the second most relevant threat to biodiversity worldwide, second only to habitat loss and fragmentation (MA, 2005), and the third at European level (Genovesi *et al.*, 2015), even affecting ES provisioning (Vilà *et al.*, 2010). IAS such as *Robinia pseudoacacia* L. and *Ailanthus altissima* Mill., often take advantage from the characteristic open structure of new forest stands during the early ecological succession stages (Arévalo *et al.*, 2005, Radtke *et al.*, 2013). This is possible because of their high spread ability due to their quick and great seeds production combined with their characteristic lightness enabling them to cover long distances from the original seeds source (Celesti-Grapow *et al.*, 2010). Moreover, IAS-LULCC relationship is also explained by the expansion of roads and railways, which represent habitat and corridors facilitating the seed dispersal (Krìzsik e Körmöczi, 2000; Arévalo *et al.*, 2005; von der Lippe and Kowarik, 2006; Arteaga *et al.*, 2009; Mortensen *et al.*, 2009).

The aim of this study is to analyse and describe the main LULCC trends in Italy occurred during the last decades, mainly focusing on the natural reforestation process and its temporal and spatial dynamics, from an ecological prospective. In particular, the major impacts of natural reforestation process on ES, both in positive and negative terms, are also assessed. The analyses were carried out by using different inventory approaches, in order to: (i) assess LULCC in Italy from 1990 to 2013; (ii) estimate the amount of C stored by secondary forests; and (c) offer a preliminary evaluation of the IAS spreading rate and the related impact on biodiversity. The analyses were conducted across the whole national territory for the first point, and in study areas within the Molise region for the others.

## 2. Recent LULCC trends in Italy

### 2.1. *Urban growth, land abandonment and forest re-growth*

Starting from the national LULCC trends (see also Marchetti *et al.*, 2012), we used the IUTI (*Inventario dell'Uso delle Terre in Italia*; Corona *et al.*, 2012) database to investigate changes occurred in the forest area. Specifically, we analysed the LULCC trends at macro-regional scale (North, Centre, South and Islands), focusing on forest types and implications for C storage and biodiversity. IUTI classification system is reported in Tab. 1.

*Table 1* - IUTI land use classification system.

| GPG-LULUCF class<br>I level | IUTI category<br>II level | IUTI subcategory<br>III level | Code |
|---|---|---|---|
| 1. *Forest Land* | Wooded land | | 1.1 |
| | Wooded areas temporarily without coverage | | 1.2 |
| 2. *Cropland* | Arable land | | 2.1 |
| | Permanent crops | Orchards, vineyards and nurseries | 2.2.1 |
| | | Forest plantations | 2.2.2 |
| 3. *Grassland* | Natural grassland and pastures | | 3.1 |
| | Other wooded land | | 3.2 |
| 4. *Wetlands* | - | | 4 |
| 5. *Settlements* | - | | 5 |
| 6. *Other Land* | Bare rock and sparsely vegetated areas | | 6 |

The most important LULCC process in Italy, between 1990 and 2008, has been the decrease in arable lands, equal to 1,260,000 ha (-4.18%), partially offset by an increase in arboriculture, especially orchards, vineyards and nurseries for about 440,00 ha (+1.43%) (Marchetti *et al.*, 2012). Nevertheless, during the same period, forests have gained about 500,000 ha (+1.70%). The losses due to deforestation have not been negligible (around 127,000 ha; Corona *et al.*, 2012). These results demonstrate that the new forest lands have derived from the following processes: the natural forest expansion, after the abandonment of arable lands (especially in hills and plains) or natural grassland and pastures (in mountain areas), and the succession processes at the expense of other wooded lands, *per se* representing a transitional state towards forest. Another important landscape change has been the 500,000 ha of new settlements (+1.65%) (Tab. 2), principally at the expense of croplands (see Marchetti *et al.*, 2014b).

*Table 2* - IUTI estimates for each land use class, and its changes between 1990 and 2008. Values expressed in % for the total considered surface (macro-regions or national territory).

| IUTI code | North | | | Centre | | | South | | | Italy | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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) |
| *1* | 33.4 | 34.8 | +1.43 | 38.8 | 41.0 | +2.24 | 23.3 | 25.0 | +1.70 | 30.3 | 32 | +1.7 |
| *2.1* | 36.9 | 33.6 | -3.30 | 38.4 | 34.1 | -4.29 | 37.7 | 32.7 | -4.97 | 37.5 | 33.4 | -4.1 |
| *2.2.1* | 4.2 | 4.6 | +0.43 | 8.2 | 9.0 | +0.79 | 13.8 | 16.6 | +2.72 | 8.9 | 10.5 | +1.6 |
| *2.2.2* | 1.0 | 0.8 | -0.11 | 0.1 | 0.3 | +0.12 | 0.1 | 0.2 | +0.14 | 0.4 | 0.5 | +0.1 |
| *3.1* | 7.0 | 6.4 | -0.65 | 3.8 | 3.1 | -0.76 | 9.2 | 7.6 | -1.61 | 7.3 | 6.2 | -1.1 |
| *3.2* | 3.2 | 3.4 | +0.21 | 3.5 | 3.5 | +0.02 | 10.4 | 11.2 | +0.79 | 6.2 | 6.6 | +0.4 |
| *4* | 2.7 | 2.7 | +0.01 | 1.1 | 1.1 | +0.01 | 1.0 | 1.0 | +0.06 | 1.7 | 1.7 | +0.0 |
| *5* | 7.0 | 9.0 | +2.01 | 5.7 | 7.6 | +1.87 | 3.8 | 5.0 | +1.18 | 5.5 | 7.1 | +1.6 |
| *6* | 4.7 | 4.7 | -0.02 | 0.2 | 0.2 | -0.01 | 0.7 | 0.7 | -0.01 | 2.2 | 2.2 | +0.0 |

Recently, the IUTI database has been updated using a 1% subsample within the whole national territory (about 13,000 sample points), thus obtaining an estimate of the LULCC trends at 2013. These new estimates present standard errors below 5%, except for categories as *forest plantations* and *other lands,* due to their paucity. The results of this updating process show a decrease in the rate of annual variation from the first detection period (1990-2008) (Tab. 3) (Munafò *et al.*, 2015). On one hand, the annual rate of loss in arable lands is significantly reduced (from -0.2% to -0.08% year$^{-1}$), as well as the one referred to natural grassland and pastures. On the other hand, the annual rate of forest increase is still high, although slightly smaller in comparison with the first detection period (from 0.07% to 0.06% year$^{-1}$), while soil sealing due to urban growth has a more significant reduction (from 0.08% to 0.06% year$^{-1}$).

We performed a further analysis on forest dynamics by dividing the Italian territory (30,148,676 ha) into three macro-regions, according to the ISTAT classification (http://www.tuttitalia.it/statistiche/nord-centro-mezzogiorno-italia/): North (11,993,630 ha), Centre (5,839,718 ha) and South (including Sardinia and Sicily) (12,315,327 ha). The results show that the largest increase in forest area occurred in central and southern Italy, with +2.24% and +1.70%, respectively (Fig. 1). Instead, the northern Italy was the most affected by urban growth (+2.01%, about 241,353 ha), thus higher than the increase in forest area (+171,032 ha), in absolute terms (Tab. 4). Accordingly, the North shows an increase in forest area lower than the national average (+1.43% against 1.7%). The highest deforestation rate was found in southern Italy, with a total loss of 76,418 ha (about 60% of the total deforested area in the Country) (Tab. 4).

*Table 3* - Annual relative variation with respect to the baseline (1990).

| IUTI code | 1990-2008 | 2008-2013 |
|---|---|---|
| 1 | 0.07% | 0.06% |
| 2.1 | -0.20% | -0.08% |
| 2.2.1 | 0.06% | 0.01% |
| 2.2.2 | 0.01% | -0.01% |
| 3.1 | -0.07% | -0.03% |
| 3.2 | 0.02% | -0.02% |
| 4 | 0.00% | 0.00% |
| 5 | 0.08% | 0.06% |
| 6 | 0.02% | -0.01% |

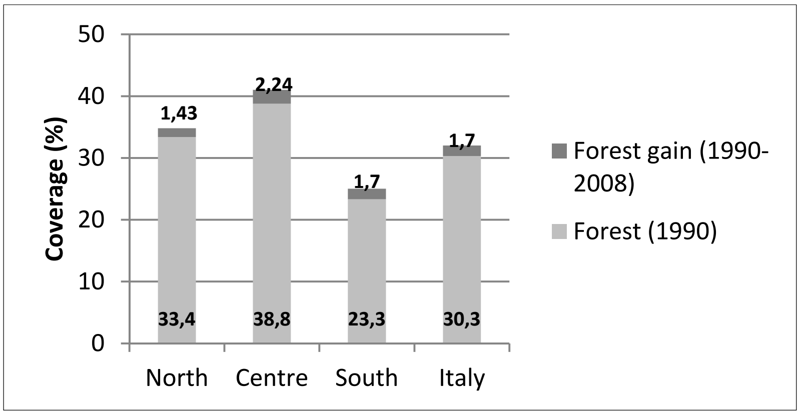


*Figure 1* - Forests coverage in 1990, and its expansion between 1990 and 2008 for the three macro-regions and the whole Italian territory.

Through crossing IUTI dataset with the Digital Terrain Model (DTM), it was possible to identify the altitudinal and slope ranges, i.e. areas where the increase in forest cover was more relevant. To facilitate the analysis, the data were grouped into three elevation classes (plain, hill and mountain), according to ISTAT (2009).

Although forest area largely dominates mountain areas in northern Italy, where it represents about 70% of the land use, its increase is more relevant in plain and hilly areas (Fig. 2), where approximately 50% of new forests since 1990 have been established. Similarly, forests are principally found in mountain areas in southern Italy (46%), despite their presence is mostly attributable to hilly areas in central Italy (44%). It is worthy to note that forest expansion during last three decades has been principally located in hills, both in southern (42%) and central Italy (46%), and that their gain has been just attributable for about 32% and 24% to their respective mountain areas.

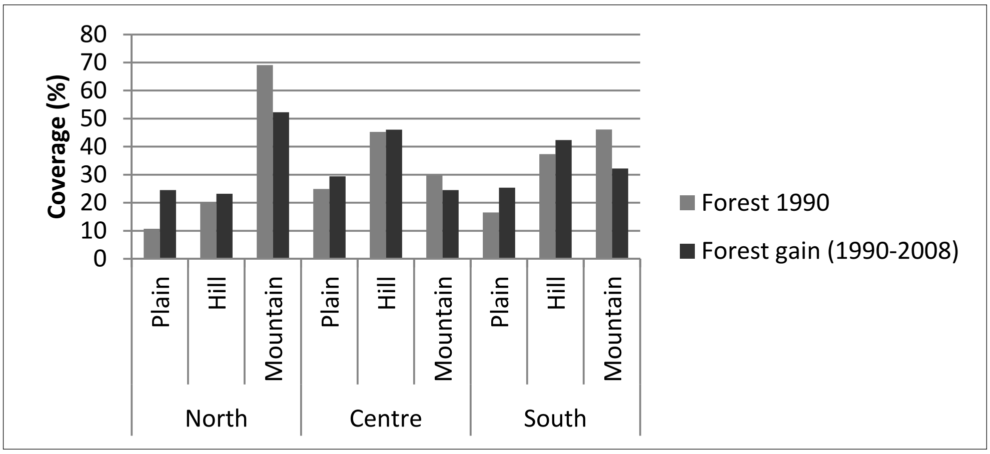


*Figure 2* - Forests in 1990 and forest expansion between 1990 and 2008, distinguished by altitudinal classes.

*Table 4* - 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.

| | North | | Centre | | South | |
|---|---|---|---|---|---|---|
| | (ha) | (%) | (ha) | (%) | (ha) | (%) |
| Forest land 1990 (ha) | 4,003,104 | 33.38 | 2,264,689 | 38.78 | 2,872,786 | 23.33 |
| Afforestation/reforestation (ha) | 221,778 | 1.85 | 162,929 | 2.79 | 286,266 | 2.32 |
| Deforestation (ha) | -50,746 | -0.42 | -31,948 | -0.55 | -76,418 | -0.62 |
| Forest land 2008 (ha) | 4,174,136 | 34.80 | 2,395,670 | 41.02 | 3,082,634 | 25.03 |
| Afforestation/reforestation (ha $year^{-1}$) | 12,321 | 0.10 | 9,052 | 0.16 | 15,904 | 0.13 |
| Deforestation (ha $year^{-1}$) | -2,819 | -0.02 | -1,775 | -0.03 | -4,245 | -0.03 |
| Net progress (ha $year^{-1}$) | 9,502 | 0.02 | 7,277 | 0.12 | 11,658 | 0.09 |

## 2.2. *Natural reforestation vs. deforestation: studying the trends in forest categories*

Combining the IUTI data with the CLC (Corine Land Cover) map allowed us to identify forest types affected by afforestation or deforestation. In this context, we used different terminologies to identify the same phenomenon, such as: "forest re-growth", "forest gain", "forest expansion", "natural reforestation" and "afforestation". However, it is important to underline that natural reforestation starts when disturbance factors, as mowing and grazing, are lacking (e.g., disused agricultural lands, meadows and pastures), and as a consequence create a way to forest stands (where forest is the potential natural vegetation) for their expansion (Conti and Fagarazzi, 2004; Sitzia *et al.*, 2010).

Because of the differences in classification systems, definitions, and spatial resolution of the two sources, we performed a proximity analysis using ARC

GIS 10.1 to classify IUTI points not classified as forest by the CLC map. We assigned to each IUTI point the forest category of the nearest CLC forest polygon. We used the 4th level of classification provided by the CLC 2006. Results (Tab. 5) show that the net forest increase at national level mainly occurred on *Mixed forest of conifers and broadleaved species, dominated by exotic conifers (e.g., Douglas fir, Monterey pine, Weymouth pine* - 31325) CLC class with 20.5% of the total net surface, followed by *Mixed forest of conifers and broadleaved species, dominated by larch and/or Swiss pine* (31324 - 14.5%). Conversely, deforestation was significant in all the macro-regions *for Forest dominated by hygrophytes, pure or mixed with conifers* (3116-31316) and *for pure or mixed (with broadleaves) Forest dominated by Mediterranean pines and cypresses* (3121-31321).

Specifically in northern Italy, forest re-growth also showed high values for *pure or mixed Forests and plantations dominated by exotic conifers* (3125-31325) classes, which had a net increase of 23.5% and 18.8%, respectively. On the contrary, in the same area, *Forest dominated by hygrophytes* (3116) and *Forest and/or ex-plantations dominated by self-sown exotic broadleaved species* (3117) showed a net decrease (-4.8% and -1.5%). Instead, in central Italy, *Forest dominated by beech* (31315) and *Forest dominated by hygrophytes* (31316) had an increase equal or even higher than 50%, followed by *Mixed forest of conifers and broadleaves, dominated by silver fir and/or spruce* (31323) *and Forests dominated by other site-native broadleaves (mesophilous and meso-thermophilous broadleaves as maple-ash, hop-hornbeam and flowering ash)* - 31313. The latter class had a net increase of 77.2% in southern Italy, followed by the *Forests dominated by silver fir and/or spruce* (3123) with 35.3%.

## 3. The effects of forest expansion on ecosystem services

### 3.1. *The contribution of secondary forests for improving carbon storage and sequestration*

Land abandonment and natural forest re-growth has both positive and negative influences on ES (see e.g. Navarro and Pereira, 2012). This has encouraged the debate on land use planning and agricultural policies in many European countries, including Italy.

Among the others, natural forest recovery processes lead to the increase of carbon (C) stored by trees and shrubs, contributing to mitigation policies and strategies, such as KP. More specifically, the increase in C storage by LULCC (art. 3.3; KP) and forest management activities (art. 3.4, KP) can be included into the national budget of greenhouse gases (GHGs), only if they are accounted following the methodologies provided from Good Practice Guidance for Land Use, Land Use Change and Forestry (GPG-LULUCF) of the Intergovernmental Panel on Climate Change (IPCC 2003). However, according to KP, the opportunity to include these activities, and the related C amounts, is still strongly related to the possibility of proving that such processes and activities are really "directly human-induced". Even overlooking these political restrictions and recommendations, the technical issue related to the lack of data, estimates and

*Table 5* - Afforestation (Aff.), Deforestation (Def.) and Net change for different forest types (CLC2006). Values expressed in % with respect to the surface of the category in 1990.

| CLC Code | North | | | Centre | | | South | | | Italy | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aff. | Def. | Net change | Aff. | Def. | Net change | Aff. | Def. | Net change | Aff. | Def. | Net change |
| *Forests dominated by oaks and other evergreen broadleaved species (holm oak and cork oak)* - 3111 | 11.4% | 3.2% | 8.3% | 2.0% | 0.8% | 1.2% | 4.3% | 1.8% | 2.4% | 3.8% | 1.6% | 2.2% |
| *Forests dominated by other deciduous oaks (Turkey oak and/or downy oak and/or Hungarian oak and/or sessile oak)* - 3112 | 4.2% | 1.3% | 2.9% | 4.8% | 1.1% | 3.7% | 9.2% | 1.9% | 7.2% | 6.4% | 1.4% | 5.0% |
| *Forests dominated by other site-native broadleaves (mesophilous and meso-thermophilous broadleaves as maple-ash, hop-horn-beam and flowering ash)* - 3113 | 3.9% | 1.1% | 2.9% | 6.3% | 0.5% | 5.8% | 16.4% | 1.1% | 15.3% | 6.3% | 1.0% | 5.3% |
| *Forests dominated by chestnut* - 3114 | 2.2% | 1.0% | 1.2% | 4.8% | 0.7% | 4.2% | 9.4% | 1.5% | 7.9% | 4.3% | 1.0% | 3.3% |
| *Forests dominated by beech* - 3115 | 3.7% | 0.3% | 3.4% | 3.2% | 0.3% | 2.9% | 2.8% | 0.3% | 2.5% | 3.3% | 0.3% | 3.0% |
| *Forests dominated by hygrophytes* - 3116 | 4.6% | 9.4% | -4.8% | 14.6% | 5.2% | 9.4% | 20.3% | 7.1% | 13.2% | 12.9% | 7.3% | 5.5% |
| *Forests and/or ex-plantations dominated by self-sown exotic broadleaved species* - 3117 | 2.7% | 4.2% | -1.5% | 11.4% | 1.3% | 10.2% | 18.8% | 3.4% | 15.5% | 7.4% | 3.8% | 3.7% |
| *Forests dominated by Mediterranean pines and cypresses* - 3121 | 10.5% | 5.5% | 4.9% | 14.5% | 1.7% | 12.8% | 8.0% | 3.8% | 4.2% | 9.2% | 3.6% | 5.6% |
| *Forests dominated by oro-Mediterranean and Mountainous pines* - 3122 | 10.3% | 1.4% | 8.9% | 24.5% | 1.1% | 23.4% | 9.4% | 1.4% | 8.0% | 11.5% | 1.4% | 10.1% |
| *Forests dominated by silver fir and/or spruce* - 3123 | 3.5% | 0.6% | 2.9% | 34.9% | 1.1% | 33.7% | 35.3% | 0.0% | 35.3% | 3.9% | 0.6% | 3.3% |
| *Forests dominated by larch and/or Swiss pine* - 3124 | 6.2% | 0.5% | 5.8% | - | - | - | - | - | - | 8.1% | 0.5% | 7.6% |
| *Forests and plantations dominated by exotic conifers* - 3125 | 25.0% | 6.3% | 18.8% | 27.6% | 0.0% | 27.6% | 6.2% | 3.1% | 3.1% | 11.3% | 2.7% | 8.6% |

*(Continued)*

*(Tab. 5 - continued)*

| CLC Code | North | | | Centre | | | South | | | Italy | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aff. | Def. | Net change | Aff. | Def. | Net change | Aff. | Def. | Net change | Aff. | Def. | Net change |
| *Mixed forests of conifers and broadleaves dominated by oaks and other evergreen broadleaved species (holm oak and cork oak)* - 31311 | 7.1% | 1.1% | 6.0% | 18.3% | 1.8% | 16.5% | 6.9% | 2.2% | 4.7% | 9.1% | 2.0% | 7.1% |
| *Mixed forest of conifers and broadleaves dominated by other deciduous oaks (Turkey oak and/or downy oak and/or Hungarian oak and/or sessile oak)* - 31312 | 9.2% | 2.1% | 7.1% | 17.4% | 1.1% | 16.4% | 18.6% | 2.0% | 16.6% | 15.3% | 1.7% | 13.5% |
| *Mixed forest of conifers and broadleaves dominated by other site-native broadleaves (mesophilous and meso-thermophilous broadleaves as maple-ash, hop-hornbeam and flowering ash)* - 31313 | 8.9% | 1.5% | 7.5% | 37.1% | 0.4% | 36.7% | 79.0% | 1.8% | 77.2% | 11.8% | 1.4% | 10.3% |
| *Mixed forest by conifers and broadleaves dominated by chestnut* - 31314 | 6.6% | 1.7% | 4.9% | 25.1% | 0.7% | 24.4% | 18.2% | 1.8% | 16.5% | 11.7% | 1.5% | 10.2% |
| *Mixed forests by conifers and broadleaves dominated by beech* - 31315 | 8.8% | 0.6% | 8.3% | 56.1% | 0.3% | 55.7% | 10.8% | 0.6% | 10.2% | 10.9% | 0.5% | 10.4% |
| *Mixed forest by conifers and broadleaves dominated by hygrophytes* - 31316 | 10.5% | 8.1% | 2.4% | 50.0% | 0.0% | 50.0% | - | - | - | 17.2% | 7.5% | 9.7% |
| *Mixed forests by conifers and broadleaves and/or ex-plantations dominated by self-sown exotic broadleaved species* - 31317 | 14.6% | 7.6% | 7.0% | 2.4% | 1.0% | 1.4% | - | - | - | 11.5% | 4.1% | 7.4% |
| *Mixed forests by conifers and broadleaves dominated by Mediterranean pines and cypresses* - 31321 | 22.4% | 4.6% | 17.8% | 11.0% | 1.0% | 10.0% | 10.7% | 3.1% | 7.5% | 11.9% | 2.2% | 9.6% |
| *Mixed forests by conifers and broadleaves dominated by oro-Mediterranean and Mountainous pines* - 31322 | 8.7% | 1.2% | 7.5% | 22.8% | 1.1% | 21.6% | 13.7% | 1.6% | 12.1% | 12.1% | 1.3% | 10.9% |
| *Mixed forests by conifers and broadleaves dominated by silver fir and/or spruce* - 31323 | 8.9% | 0.6% | 8.3% | 41.2% | 0.0% | 41.2% | 18.7% | 0.5% | 18.2% | 9.7% | 0.6% | 9.1% |
| *Mixed forest of conifers and broadleaved species, dominated by larch and/or Swiss pine* - 31324 | 10.0% | 0.6% | 9.4% | - | - | - | - | - | - | 15.1% | 0.6% | 14.5% |
| *Forests and plantations mixed by conifers and broadleaves dominated by exotic conifers* - 31325 | 23.5% | 0.0% | 23.5% | 26.1% | 2.2% | 23.9% | 11.9% | 0.0% | 11.9% | 21.9% | 1.3% | 20.5% |
| Total | 5.3% | 1.2% | 4.1% | 6.4% | 0.9% | 5.5% | 8.6% | 1.9% | 6.7% | 6.6% | 1.3% | 5.3% |

methodologies for C accounting in secondary forests still remains (Pompei *et al.*, 2008). Although there are several methodologies for assessing LULCC and estimating the extension of the secondary forests (Corona *et al.*, 2005; Salvadori *et al.*, 2006; De Natale *et al.*, 2007), few studies evaluating their C storage capacity are available, especially at local scale (see Tab. 6). For example, Lamedica *et al.* (2007) estimated the increase of forest areas in Veneto region through photointerpretation processes and following the methodologies previously proposed by Salvadori *et al.* (2005). Afterwards, Lamedica *et al.* (2007) estimated the C stored at the baseline year (1990) and after recent spontaneous reforestation (2006), thorough biometric field surveys performed in 2006. The suggested methodology was based on the application of allometric equations referring to the WBE functional model proposed by West *et al.* (1999) and adapted according to the use of stand parameters, such as DBH (diameter at breast height) and height. Nevertheless, only the tree aboveground biomass was considered, thus excluding shrub, herbaceous, litter, and soil C pools. The estimated average C stored by the aboveground biomass in secondary forests of Veneto was 10.98 Mg C ha$^{-1}$.

*Table 6* - Studies on C storage in secondary forests and respective values *per* each C pool.

| Reference | Study area | Time period | Above ground C (Mg ha-1) | Belowground C ( Mg ha-1) | SOC C ( Mg ha-1) | Deadwood ( Mg ha-1) | Shrubs and herbs C ( Mg ha-1) | Litter C ( Mg ha-1) |
|---|---|---|---|---|---|---|---|---|
| Lamedica *et al.* (2007) | Northern Italy | 1990-2006 | 10.98 | - | - | - | - | - |
| La Mantia *et al.* (2007) | Southern Italy | 30 years | - | - | from 13 to 85 | - | - | from <1 to 7 |
| DiBT Forestry Lab work (unpublished data) | Central-southern Italy | 1990-2012 | 10.24 | 1.72 | 15.15 | 0.02 | 1.46 | 0.04 |

More recently, we conducted a similar study in the Molise region. The aim was to assess the amount of C stored by secondary forests within the "Collemeluccio-Montedimezzo Alto Molise" UNESCO Man and Biosphere (MaB) Reserve, covering 25,268 ha. At first, the re-growth processes were assessed by using the IUTI database at 1990 and 2012, and the relative transition matrix created as proposed by several studies (e.g., Pontius *et al.*, 2004; Riitano *et al.*, 2015). Through field surveys, the biometric data were collected in order to estimate growing stock and consequently C stored by different C pools. The estimates of C stored by secondary forests were realized by applying the For-Est model (Federici *et al.*, 2008). Then, using this methodology, it was possible to assess the C stored by the aboveground biomass and by the other pools as well: belowground biomass, soil (Soil Organic Content - SOC), deadwood and litter (the last two combined into Dead Organic Matter - DOM). Finally, by applying the methodology proposed by Chirici *et al.* (2009), and using the Volumetric Index, we also assessed C stored by the understory layer (shrubs, small trees under the minimum DBH threshold, and herbs). The total C amount in secondary forests was defined as follows:

$$C_{Tot} = \Sigma\, C_{aboveground} + C_{belowground} + C_{soil} + C_{deadwood} + C_{litter} + C_{shrubs} + C_{herbs}$$

Among the main results, we found that forest area increased by 2,494 ha (+9.9%) from 1990 to 2012, which is higher than the average regional (4.2%) and national (1.7%) values. This is explained by the fact that the study area is entirely located in a mountain area in Central Apennines, where land abandonment represents the prevalent socio-economic phenomena. The mean total C amount stored by the considered secondary forests is 28.63 Mg $ha^{-1}$ (RSD= 66%). The high value of RSD could be easily explained by the variability characterizing stands with different age and forest type, among other ecological and management factors. Although the RSD value is not negligible, this estimate represents one of the first attempts to assess the whole amount of C stored by secondary forests and not only the one referred to aboveground biomass. Moreover, the C stored in aboveground biomass (10.24 Mg ha-1) is close to the one reported by Lamedica et al. (2007; 10.98 Mg C ha-1). The calculated C stored could be largely attributed to SOC (53%) and aboveground (41%) pools. The remaining 6% is due to the understory layer (5%), while less than 1% is related to DOM. In particular, the results obtained for the soil C pool fall within the range indicated by La Mantia et al. (2007) in Pantelleria (South Italy) (from 13 to 85 Mg C ha-1), who studied the evolution of SOC in re-growing forests after 30 years of land abandonment. The relevance of secondary forests in the MaB Reserve and their C storage capacity result into about 71,000 Mg C stored by these stands. This is not a negligible value, considering possible future opportunities of C accounting for mitigation strategies and policies to face the ongoing Climate Change challenges.

### 3.2. *Forest expansion, IAS invasion and implications for biodiversity*

Biodiversity loss is related to several drivers, including LULCC and the introduction and spread of IAS (Sala *et al.*, 2000). Urban growth in Italy, often with a chaotic and metastatic organization (Romano and Zullo, 2012), represents a serious risk in terms of biodiversity loss, causing habitat fragmentation and isolation, and facilitating the spread of IAS (Marchetti and Sallustio, 2012; Trentanovi *et al.*, 2013).

The ecological simplification at landscape scale coincides with a great reduction of ecotones (Garbarino and Pividori, 2006), as well as plant and animal biodiversity in general (Conti and Fagarazzi, 2004). Although in the early stages of secondary succession, floristic diversity could increase (Höchtl *et al.*, 2005), as the landscape becomes more uniform, plant diversity decreases because the loss of species typical of semi-natural habitats and open spaces, i.e., grassland species (e.g., Gellrich *et al.*, 2008; Sitzia *et al.*, 2010). The same trend has been demonstrated for animal species (Bolliger *et al.*, 2007). Moreover, secondary forests often have lower levels of biodiversity than primary ones (Gerhardt and Foster, 2002).

Another issue regarding natural reforestation processes is the risk of entry and spread of IAS. The spread of IAS results to be a very important issue, especially in the Mediterranean biome (e.g., Sala *et al.*, 2000; Crosti and Forconi, 2007), considered as one of the biodiversity "hotspot" worldwide (Myers *et al.*, 2000).

Abandoned agricultural systems and semi-natural areas have a low self-regulation capacity, in a way that they are more vulnerable to exogenous factors, such as e.g., erosion, pest attacks, fires and IAS spread (Conti and Fagarazzi, 2004; Bertacchi and Onnis, 2004). On the contrary, the maintenance of agro-pastoral practices, especially close to invasive stands, arrests the spread of IAS because they do not allow their lasting establishment (Arnaboldi *et al.*, 2002). For example, Sitzia *et al.* (2012) demonstrated that during natural reforestation on abandoned lands, many native species suffer the competition from IAS.

Although Italy has about 230,000 ha of forests dominated by IAS (Tabacchi *et al.*, 2007), studies on their spread, behaviour, management implications, and effects on biodiversity are still uncommon (Sitzia, 2014), especially in the central and southern part of the Country. For this reason, we started a long-term experiment in the "Collemeluccio-Montedimezzo Alto Molise" UNESCO MaB Reserve to analyse the characteristics of IAS spread in a typical Mediterranean mountain ecosystem. The aim of this study was to analyse the presence and behaviour of the black locust (*Robinia pseudoacacia* L.), with particular regard to roads and railways proximity (von der Lippe and Kowarik, 2008; Penone *et al.*, 2012).

Preliminary results showed that the presence of black locust decreases with increasing altitude and slope, and preferring Southwest facing slopes, according to Brown (1962) and Converse (1984). Moreover, the impact of human disturbances was quite evident. In fact, the invasion of the black locust trees were strictly dependent on the proximity to major roads and railways. Among the different forest management systems, natural evolution forests, new forest stands and coppice forests were the most affected ones by the black locust invasion. During the first stages of secondary succession processes, the invasion was strictly related to the proximity to seed sources, both individual trees and stands. In fact, IAS take advantage of structural and ecological features typical of these young forest formations, which are rich in open spaces, where more light availability and less competition with other trees exist. Moreover, our preliminary results on black locust demonstrate that preserving meadows, pastures and arable lands at the border to black locust stands, can reduce their spread, because the regular practices of mowing, grazing or soil movement can avoid the rooting and growth of new individuals of this species, as also demonstrated by Arnaboldi *et al.* (2002) for tree of heaven stands. However, the study of successional dynamics proves that with increasing age and canopy cover of forest stands and without any disturbance, black locust slowly regresses in favour of native species (see Pividori e Grieco, 2003; Addario, 2007; Nola *et al.*, 2008; Motta *et al.*, 2009).

## 4. Discussion and conclusions

Urban growth is one of the most worrying LULCC in Italy, and occurs especially at the expense of arable lands and croplands in general (about 75%, Marchetti *et al.*, 2012). In particular, land take occurs especially in lowlands and gentle slope territories, more attractive for brick and mortar investments (Marchetti *et al.*, 2014b). It is interesting to note that, despite their negative demographic balance, some Regions (e.g., Basilicata, Calabria, Liguria and Molise) continue to consume arable and semi-natural lands increasing their per capita built-up area (Sallustio *et al.*, 2013). Land take in lowlands is often related to the loss of valuable *oro-Mediterranean pines and cypress forests* in southern Italy. This is a worrying issue, considering that the settlements coverage in coastal areas is much higher than in the rest of the Country and it is still rising (Sallustio *et al.*, 2013; Romano and Zullo, 2013).

On the contrary, agro-pastoral areas of mountain landscapes are affected by natural reforestation after their abandonment (Palombo *et al.*, 2013, 2014). Our results show that LULCC in Italy are following a latitudinal gradient. For example, the decrease in arable lands, meadows and pastures is emphasized when descending from North to South. This phenomenon is related to a sort of chronological trend in land abandonment. In fact, the abandonment of mountain areas in northern Italy, e.g., the Alps, began long time before than in the rest of the Country, starting during the end of XIX century with the powerful industrial revolution. The faster was the economic and industrial development, the faster was the abandonment of mountain areas and agro-pastoral activities. On the contrary, in many areas of central-southern Italy, the sharecropping organization assured, till after the World War II, a substantial stability in rural population and its economy (Massimi and Tubito, 1998). Moreover, land abandonment is likely to be more marked where soils are shallow, slopes are steep and road infrastructure is less developed (Gellrich and Zimmermann, 2007a,b). Land abandonment is a consequence of socio-economic changes connected to the globalization of the agriculture and related demographic processes that move rural population to town and cities (Sallustio *et al.*, 2013). According to the European Action Plan, woodlands are increasing approximately 400,000-500,000 ha $year^{-1}$ in rural areas all over the Europe (Agnoletti, 2014). Natural reforestation leads to the decrease of open spaces, thus reducing landscape heterogeneity, and represents a serious risk for cultural landscapes (Sitzia *et al.*, 2010), despite this needs to be complemented with a dynamic perspective. The same definition of "landscape", identifies it as "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors" (Council of Europe, 2000). The environmental mosaic is typical of the Italian Peninsula, and it is strictly correlated to the conservation of key species and habitats (Marchetti *et al.*, 2013). For this reason, many historical and rural landscapes in Italy are often included in protected areas, as well as the Natura 2000 network sites. In addition to a loss of biodiversity, this often generates conflicts between policy makers and local populations (Agnoletti, 2014).

The increase of exotic conifers in the northern Italy results from reforestation practices for productive purposes and represents the forest category with the most increasing percentage in these areas (23.5% of their total surface). Forest re-growth is mostly related to the expansion of beech forests (mixed with conifers) in central Italy, where they are recolonizing ancient grasslands and pastures in hills and mountains. The same phenomena occur in the South, where forest dominated by maple-ash, hop-hornbeam and flowering ash considerably increased. At the same time, the decline in forests dominated by hygrophytes can be attributed to human impact especially in lowlands. This sounds like an important issue because of their key role in maintaining local biodiversity, acting as corridors, shelter and dispersal sources for many species (Naiman *et al.*, 1993). Finally, a noticeable process is also the increase of forests dominated by IAS, especially in central and southern Italy, which is equal to 10.2% and 15.5%, respectively. This is mainly due to the increase of degraded ecosystems in hills and plains and to the disseminating role played by new road networks and urban growth in general (von der Lippe and Kowarik, 2008; Mortensen *et al.*, 2009; Marchetti and Sallustio, 2012).

Considering the negative effects of LULCC on ES, we demonstrated that more attention should be paid by the scientific community and policy makers on land abandonment and natural reforestation, which nowadays are often underestimated or totally ignored (Conti and Fagarazzi, 2004) in spite of their environmental, socio-economic and cultural impacts. In fact, it is clear that the positive aspect of this phenomenon is attributable to the C stored by the new secondary forests, which should be considered as one of the most important factor responsible for the increase in C stocks in the Italian peninsula (Corona *et al.*, 2005). The GPG-LULUCF requires a careful estimate of the extension and C stock capacity of new forest stands in order to be eligible for the KP purposes. In this way, our findings represent a first estimation of C storage and sequestration in new forest stands, which have of course to be further tested, validated, and replicated in different contexts. Besides, the adopted methodologies are limited, because based on studies concerning mature forests (Federici *et al.*, 2008). Accordingly, an adaptation of these approaches to young secondary forest would be necessary.

Forest re-growth occurs especially in mountain areas, where "cultural landscapes" are losing their peculiarity related to centuries of agro-pastoral activities. Many authors agree that in order to promote high biodiversity levels (at different scales), a high diversity of land use types is recommended, because of the higher species richness associated to complex ecosystems (Fischer *et al.*, 2008; Sitzia *et al.*, 2010; Agnoletti, 2014). From a management perspective, there are two main ongoing approaches related to the conservation of rural and cultural landscapes (see e.g. Sitzia *et al.*, 2010; Agnoletti, 2014) and to the "rewilding" practices (see e.g. Gillson *et al.*, 2011; Navarro and Pereira, 2012). The rewilding of abandoned lands is considered as assisting natural regeneration of forests and other natural habitats through passive management approaches, although intervention may be required in the early successional stages, because of their vulnerability. In land use planning, the choice between rewilding and active management should depend on the goals and the local context. Active management seems to be desired where the aim is to preserve species or habitats related to cultural landscapes (Navarro and Pereira, 2012). The choice depends on economic sustainability of the management practice and on the targets locally set in policy and planning. As a consequence, policy makers should identify the possible targets and the best solutions related to the specific needs of the territory (Sallustio *et al.*, *in press*). In local governance, a fundamental role is played by the local communities, which ultimately determine the success or failure of certain policies. In this way, it is important to create consensus and common objectives among the different actors involved (Pisanelli *et al.*, 2012).

Moreover, this paper shows how many aspects of the biodiversity should be investigated during the study of natural reforestation processes, and taken into account contextually to the formulation of policy and management decisions. Among the others, for example, the challenge of stopping the IAS spread. Despite this scenario, there is an absence of a scientific approach to the forestry of IAS across Europe, apart from rare scientific works as reported by Sitzia (2014). In the same study, he highlighted the necessity to disseminate a series of scientific researches about the behaviour of IAS, their capacity of invade adjacent native woodlands or semi-natural and natural non wooded ecosystems and their impact on ES, with the purpose of finding new forestry management systems able to control their spread.

Concluding, this paper shows that LULCC and related effects require a more holistic view, and should be considered by the scientists during their research, and by the decision-makers during their decision-making processes. Monitoring LULCC, and assessing and simulating the related impacts on ES, play an important role in supporting land use planning and policy makers decisions. At the same time, it is also necessary to control and analyse the real effects and consequences of different management systems on ES (Nagendra *et al.*, 2013; Vizzarri *et al.*, 2015; Marchetti *et al.*, 2014a).

Much more efforts should be made to investigate the faint border between human activities having only negative impacts on landscape and biodiversity and that practices which are so deeply rooted and integrated into ecosystems, as they have created a semi-natural environment now commonly perceived as the typical landscape. In fact, for the latter, the active management became an essential factor to ensure their stability, resilience and ability to provide ES (in this case potentially definable as "acquired biodiversity"?).

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## RIASSUNTO

*Le recenti evoluzioni dei cambiamenti nella copertura forestale in Italia: solo conseguenze positive?*

Negli ultimi 50 anni, il paesaggio italiano ha subito diversi cambiamenti di uso e copertura del suolo. L'Inventario dell'Uso delle Terre d'Italia (IUTI) rappresenta un metodo economico, veloce e statisticamente accurato per il monitoraggio di questi cambiamenti. L'obiettivo di questo studio è di riassumere i principali andamenti della copertura del suolo a scala nazionale in Italia, portando l'attenzione sui processi di ricolonizzazione naturale da parte dei sistemi forestali e preforestali a scala di macro-regioni. Inoltre, vengono analizzati alcuni degli effetti di questi cambiamenti sull'approvvigionamento di alcuni servizi ecosistemici, quali la fissazione del carbonio e la conservazione della biodiversità. Sebbene da un lato la riconquista degli spazi rurali abbandonati possa rappresentare un'opportunità positiva per le strategie di mitigazione, considerando la valorizzazione dei serbatoi potenziali di carbonio, dall'altro l'abbandono delle pratiche agro-pastorali può avere impatti negativi da un punto di vista ambientale, economico e sociale.


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