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ADAPTIVE FOREST GOVERNANCE TO FACE LAND USE CHANGE IMPACTS IN ITALY: A REVIEW

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Land use change is one of the most important drivers for the reduction of ecosystem resilience, and the loss of biodiversity and services provision. This is a peculiar challenge, especially in Mediterranean mountain environments, where abandonment and forest transition phenomena increasingly threaten the forest capacity to provide benefits for local communities. Under these conditions, forest governance is called to balance the land use change impacts and the health and stability of forest ecosystems, in order to ensure the long-term sustainability of such marginal environments. This paper aims at deeper understanding the impacts of land use change on forest ecosystem on mountain environments in Italy. At first, a downscaled review on the concepts of land use change and ecosystem services provision is carried out. Then, according to the review results, the relationships between adaptive capacity of forest management and planning, and land use change is deeply described. Finally, future-oriented strategies of adaptive governance to face land use change are proposed. In the context of land use change, adaptive governance can improve forest resilience through filling the research gaps between the national and the global contexts, adopting monitoring and assessment tools to simulate external changes and disturbances, and effectively implement consistent policy measures and strategies at local scale.

Key words: adaptive forest governance; land use change; forest ecosystem services; forest resilience; Mediterranean forest landscape.
Parole chiave: *Governance* forestale adattiva; cambiamento dell'uso del suolo; servizi ecosistemici forestali; resilienza forestale; paesaggio forestale mediterraneo.

Citation: Vizzarri M., Sallustio L., Tognetti R., Paganini E., Garfì V., La Mela Veca D.S., Munafò M., Santopuoli G., Marchetti M., 2015 - *Adaptive forest governance to face land use change impacts in Italy: a review*. L'Italia Forestale e Montana, 70 (4): 237-256. http://dx.doi.org/10.4129/ifm.2015.4.01

doi: 10.4129/ifm.2015.4.01

1. LAND USE CHANGE IMPACTS ON FOREST ECOSYSTEMS: A DOWNSCALED REVIEW

1.1. *A background on land use change trends and effects on forest ecosystems*

During the last centuries, land use change (LUC)[1] has strongly altered the asset of ecosystems at global scale. The human population growth, combined with other socio-economic drivers (e.g., the technology development), caused a land use intensification, and subsequently global changes in land use (i.e., from natural to Anthropogenic systems; Ellis 2015). Several authors described this generalized trend in LUC by different angles, such as geological, ecological, and economic ones, as well as the related causes and effects (e.g., Corlett 2015).

In this context, forest ecosystems were increasingly altered by the combination of climate and LUC. The reduction of ecosystem resilience (i.e., the capacity of an ecosystem to withstand perturbations without losing any of its functional properties; Walker *et al.*, 2004) and the correlated loss of biodiversity and erosion of ecosystem services (ES), are considered as the major effects of LUC (Foley *et al.*, 2005). Recently, Newbold *et al.* (2015) highlighted that LUC-related effects strongly reduce local terrestrial biodiversity (13.6% in species richness; 10.7% in total abundance; and 8.1% in rarefaction-based species richness). Other studies demonstrated that for some European Countries (including Italy), the Human Appropriation of Net Primary Production (HANPP) is exceptionally higher in comparison with the global trend (Gingrich *et al.*, 2015). These trends also explain the 'forest transition' phenomenon, which describes the shift from net deforestation to net reforestation in Europe, as occurred since the 19th and early 20th centuries (Lambin and Meyfroidt, 2011). Especially in mountain landscapes of Southern Europe, a generalized forest expansion during the last decades, in turn originated by land abandonment phenomena, led to a reduction of grasslands and croplands at higher elevations, as well as the expansion of fragmented settlements at lower elevations (urban sprawl phenomenon; Marchetti *et al.*, 2014). These changes in forest cover caused the modification of species and habitat distribution, landscape fragmentation, as well as an increasing vulnerability of not only forest ecosystems to threats and diseases (e.g., Metzger *et al.*, 2006). On one hand, forest fragmentation (i.e., reduced fragmented area, increased isolation, and increased edge) is found to have degrading effects on core ecosystem functions, such as e.g., carbon and nitrogen retention, productivity, and pollination (Haddad *et al.*, 2015). On the other hand, the rewilding phenomena are found to have positive consequences on the delivery of some forest ES in European mountain landscapes (Navarro and Pereira, 2015).

At Mediterranean scale, several studies demonstrated the effects of LUC on e.g., water quality in a forest watershed in Slovenia (Glavan *et al.*, 2013), carbon

[1] We use "land use change" instead of the extended "land use and land-cover change" (LULCC) term, because the purposes of this paper are mainly oriented to assess and discuss the effects of changing human activities (e.g., forestry) on forest ecosystem functions and processes (see e.g., Ellis 2007), and subsequently on the capacity of forest ecosystems to deliver important services to people. Accordingly, the "land cover change" is used here as a descriptive feature to e.g., report the change in the extent of physical and biological coverage (e.g., forest ecosystems), without any further speculation.

sequestration in an agro-forestry system in Spain (Padilla *et al.*, 2010), habitat vulnerability in Southern France (Fonderflick *et al.*, 2010), carbon storage due to urban growth in Central Italy (Sallustio *et al.*, 2015), and biodiversity conservation on Italian Alps (Scolozzi *et al.*, 2014). Under these changing conditions, forest governance (i.e., forest planning and management) is called to balance ecosystem productivity (in terms of ES delivered) with land use allocation and transformation. Especially considering the forest ecosystems on Mediterranean mountains, where socio-economic barriers and drivers continuously modify the landscape pattern, forest governance needs to be more adaptive (Gunderson and Holling, 2002), and resilience-based (e.g., Rist and Moen, 2013). Resilience equates to the maintenance of key components and relationships and the continuity of these through time. If resilience is low, identity may be lost (including the provision of ES). For example, the identity of a shepherd-pasture resource system may depend heavily on the presence of shepherds, a persistent population of sheep, and an environment in which sheep-farming by traditional means can occur. If the shepherds become workers, or other, the relationship of people to their landscape will be interrupted and the system can be considered to have lost its identity. Particularly in the case of Italian forest ecosystems, the recent progresses in LUC monitoring (Corona *et al.*, 2012; Marchetti *et al.,* 2012a), as well as those concerning the analysis of LUC impacts on carbon sequestration (Marchetti *et al.*, 2012b), highlight the importance to further understand how forest governance can be effectively implemented to improve resilience, stability, and adaptive capacity of forest ecosystems. According to these emerging challenges, the aim of this paper is threefold: (i) to analyze the mechanisms of LUC, and their impacts on forest ES provision, through a downscaled review from global to national scale, in Italy; (ii) to unravel the linkages between LUC and forest governance, with a particular focus on mountain forest landscapes in Italy; and (iii) to provide future-oriented forest governance guide-lines to face LUC impacts on forest ecosystems in Italy.

1.2. *Review exercise*

The review exercise consists of a by-keyword based search through using SCOPUS (www.scopus.com) and ISI-Web of Knowledge (ISI-WoK; apps.webofknowledge.com) as search tools. The reference period was chosen between 2000 and 2014. Search strengths and keywords used are reported in Table 1. Search strengths have been prepared in order to consider both the LUC phenomenon in general, as well as some associated mechanisms, particularly related to forest ecosystem dynamics, both at global and Italian scale. Moreover, search strengths are associated with "title, abstract, and keywords" in the case of SCOPUS, and with "topic" in the case of ISI-WoK. The main evaluation parameters are (i) the number of publications per year, and (ii) the analysis of the main contents per publication (top 10 publications per search step).

The main results concerning the number of publications are hereinafter reported and discussed, accordingly. Figure 1 shows the main results concerning the number of publications for each research field-scale combination.

Table 1 - Summary table reporting the main characteristics of the review exercise, such as the search steps, the research fields, and the keywords used for both global and national scale analysis.

Search step	Research Field	Global scale (A)	National scale (B)
1	Land use change	"land use change" AND "ecosystem services"	"land use change" AND "ecosystem services" AND "Italy"
2	Land use change and forest ecosystems	"land use change" AND "forest" AND "ecosystem services"	"land use change" AND "forest" AND "ecosystem services" AND "Italy"

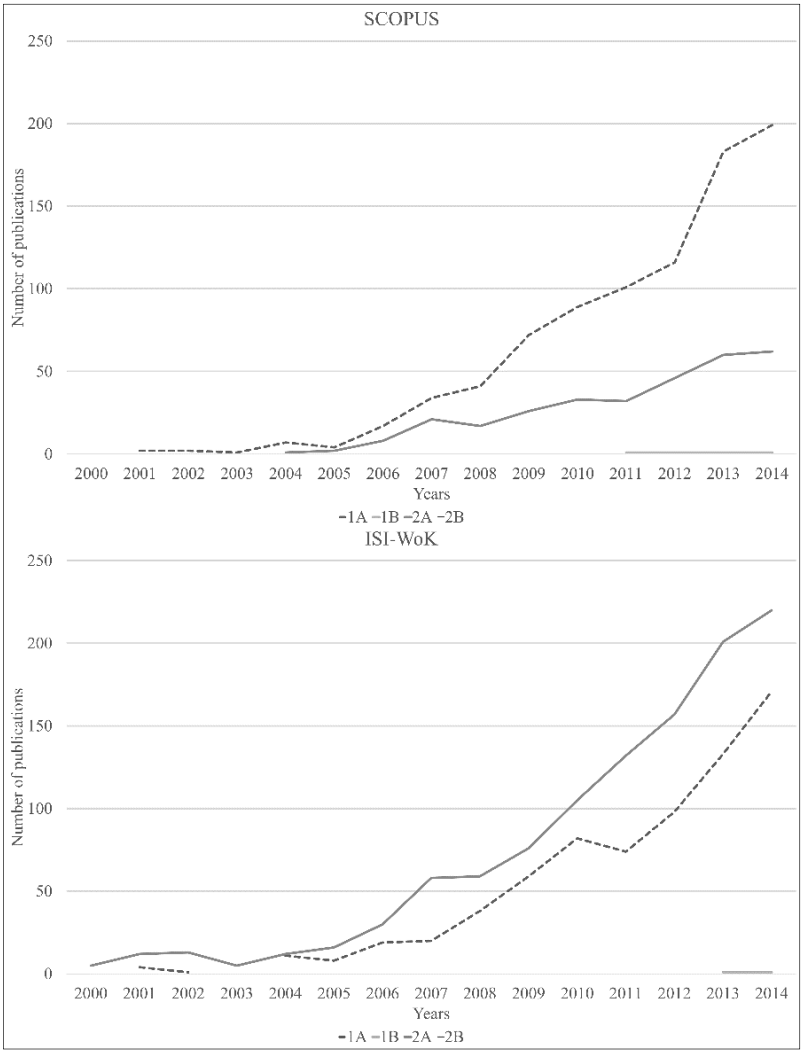

Figure 1 - Total number of publications for each research field (from 1 to 5)-spatial scale (A or B) combination, as found by using SCOPUS (at top) and ISI-WoK (at bottom) search engines in the 2000-2014 period. For further details, the reader is referred to Table 1.

The number of publications concerning the relationships between LUC and ES (search step 1) passed from two in 2001 to 199 in 2014 at global scale (A) in the case of SCOPUS, and from four to 141 publications in the period 2000-2014 in the case of ISI-WoK. However, this trend is not the same at national scale (B): eight publications in the case of SCOPUS, and four publications in the case of ISI-WoK for the entire considered time-span. When LUC is combined with forest ES (search step 2) at global scale (A), publications increased by 61 units from 2004 to 2014 (one publication registered in 2002) in the case of SCOPUS, and by 215 units from 2003 to 2014 (five, 12, and 13 publications in 2000, 2001, and 2003, respectively) in the case of ISI-WoK. At national scale (B), very few publications concerning the linkage between LUC and forest ES were found in the 2000-2014 period, both in the case of SCOPUS (no publication), and ISI-WoK (one publication in 2013).

According to the above-reported results, the main insights are following detailed. At first, results demonstrate that the number of publications generally increased from 2000 to 2014 (Figure 1). This is partly due to the fact that the challenging debate around the anthropogenic impact on Earth systems on late 80s facilitated the sharing of knowledge on both climate and LUC topic from global to local scale, and subsequently the increasing release of related publications (Figure 1). For example, the Intergovernmental Panel on Climate Change (IPCC) was established in 1988 to assess the impact of human activities on the global climate (mainly atmospheric emissions and soil contaminants), through monitoring the land use, land use change and forestry (LULUCF) activities, and providing a related good practice guidance (e.g., Penman *et al.*, 2003). Since then, key scientific contributions fostered the discussion about the implications of LUC on the ecosystem functioning at various scales (e.g., Foley *et al.*, 2005). Furthermore, the correlation between LUC and ES, in both ecological and socio-economic terms, gained much more attention within the scientific community since the release of the Millennium Ecosystem Assessment in 2005 (MEA 2005). Contextually, the concept of LUC was thus explored in terms of its consequences on the human wellbeing, seen as the whole benefits from the ES delivered (e.g., Schröter *et al.*, 2005, concerning forest ecosystems), as also demonstrated for the recent evolution of the approach to biodiversity conservation (Tallis and Lubchenco, 2014).

Then, results show that forest ecosystems are often associated with LUC processes (e.g., Hansen *et al.*, 2013). This is demonstrated by the increasing number of publications in the 2000-2014 period (see Figure 1). In particular, when considering the LUC-forest ES as a unique topic at global scale (see ISI-WoK-related results in search step 2; Figure 1), the number of publications is higher than that obtained without using the term "forest" among the keywords in the search strength (see ISI-WoK-related results in search step 1; Figure 1). This proves that, although forest ecosystems are considered one of the main sources for human benefits, they are particularly threatened by human-induced effects, such as LUC (e.g., Metzger *et al.*, 2006). On the other hand, research

contributions have clarified the role of monitoring forest resources to better understand the consequences of LUC impacts worldwide (see Fang *et al.*, 2001 for China).

Results also revealed that the contribution from the Italian research to the topic of LUC is very scarce, as follow: 0.8 and 0.5% (search step 1), and 0.3 and 0.2% (search step 2), for SCOPUS and ISI-WoK, respectively. Research productivity in Italy is generally lower in comparison with that from other Countries, despite the ratio between research outcomes and investments is positive at national scale (Elsevier 2013). In particular, the LUC-related research is relatively new in Italy (first publication found in 2009; Figure 1), and often limited to the national context (e.g., Munafò and Marchetti, 2015). Even considering the LUC-forest ecosystem relationship, Italian research contributions are focused on specific topics (e.g., soil carbon sequestration; Tognetti and Marchetti, 2006) or on large-scale assessments (e.g., national land use inventory; Marchetti *et al.*, 2012a). Furthermore, to our knowledge, no publication addressing the linkage between LUC and forest governance (i.e., management and planning) is currently available in Italy.

2. ADAPTATION OF FOREST LANDSCAPES TO LAND USE CHANGE

2.1. *Vulnerability of forest landscapes to land use change: the case of mountain environment in Italy*

The Mediterranean region is characterized by high spatial heterogeneity, diversified traditions and cultures, and biological variability, in terms of species and habitats distribution. These are the consequences of the human-nature interactions over the history (Blondel, 2006). During the last decades, the abandonment of traditional activities profoundly transformed the Mediterranean landscapes, especially in mountain areas (e.g., Poyatos *et al.*, 2003). Land abandonment derives from socio-economic changes linked to the globalization of agriculture and related demographic processes, and regards the movement of rural populations from those landscapes that are less devoted to the industrial-scale farming (Agnoletti 2014). In Italy, Geri *et al.* (2010) confirmed two major trends of LUC, such as the forest expansion in mountain and hilly areas, and fragmentation of agricultural areas in lowland zones, with parallels between social and ecological fragmentation processes. In Mediterranean mountain areas, the expansion of other wooded lands and forests is considered one of the most influencing LUC effects (Palombo *et al.*, 2013). On the other hand, the LUC-associated landscape degradation effects generally caused a loss of biodiversity and ES for communities living in such marginal areas (Agnoletti, 2007).

Recent analyses of LUC processes during the 1990-2008 period in mountain areas in Italy mainly describe (i) the forest (and other wooded lands) expansion over grasslands and pastures (390,000 ha) (Sallustio *et al.*, 2013), and (ii) the reduction of arable lands, particularly due to the forest expansion in mountain

areas (118,000 ha) (Sallustio *et al.*, *in press*) and urban growth in lowlands (382,000 ha) (Marchetti *et al.*, 2014). Similar trends are registered for the Protected Areas Network, where the large presence of forest ecosystems requires the best balance between alternative land uses (Marchetti *et al.*, 2013). General LUC trends in Italy during the period 1990-2008 are reported in figure 2.

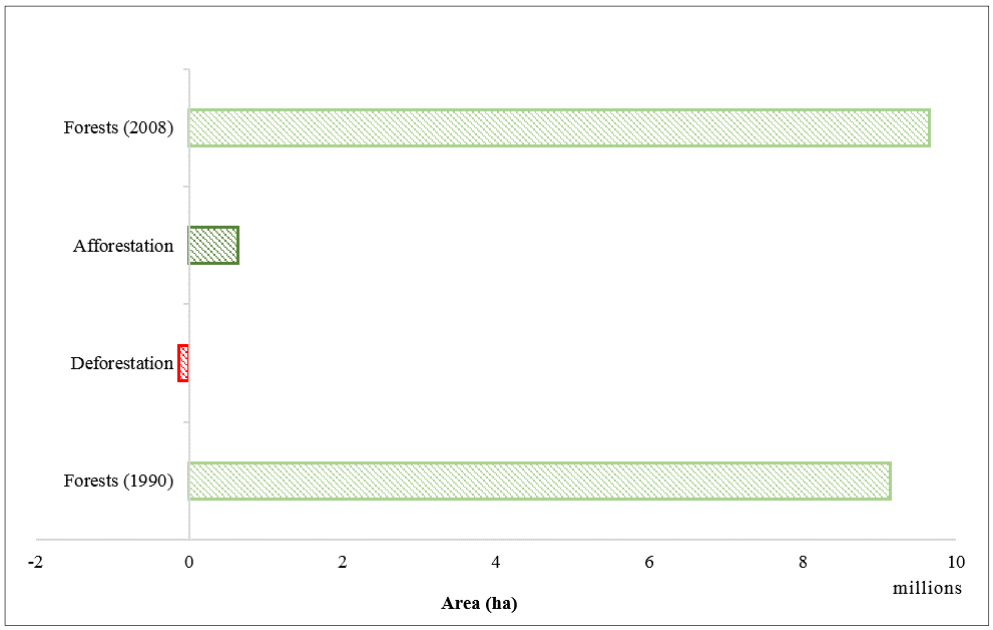

Figure 2 - Forest transitions in Italy from 1990 to 2008 (Marchetti *et al.*, 2012a, modified).

Forest re-growth limits the landscape diversification, threatens the preservation of traditional activities, and reduces the ecological and economic values of pastures (e.g., Ceballos *et al.*, 2010).

The abandonment in mountain landscapes, and the consequent rapid spread of the forest through natural succession processes, have led to situations generally characterized by low biodiversity, corresponding to an oversimplification of the landscape mosaic (Geri *et al.*, 2008). For example, Agnoletti (2007) demonstrated that the increasing in forest cover was accompanied by a marked reduction of forest utilizations in a mountain landscape in Tuscany during the period 1832-2002. In particular, landscape changes have been characterized by the loss of landscape biodiversity, in terms of a reduction of the number of patches, and a large increase of their average size (see also Sitzia *et al.*, 2010). In the same way, land abandonment and post-fire afforestation processes are correlated with an increased vulnerability to land degradation (see Bajocco *et al.*, 2012, for the Sardinian coastal area).

These profound transformations strongly undermined the capacity of forest ecosystems to cope with external changes and disturbances, such as e.g., wildfires, extreme atmospheric events, and insect outbreaks (e.g., Acácio and

Holmgren, 2015). In degraded stands, less intensive forestry practices, in conjunction with low yields and ageing processes, facilitate the abandonment of traditional activities intimately linked with forest resources in rural areas (e.g., grazing, non-wood forest products picking, fuelwood harvesting, etc.). In particular, ES provision and biodiversity conservation in mountain areas need to be preserved through reducing the landscape vulnerability to external perturbations. Considering these challenging conditions, forest governance is called to implement effective tools to assess and monitor LUC especially in mountain environments, where the balance between resilience and local (socio-economic) development is increasingly demanded. In this context, the governance of interactions between regions and the analysis of long-term drivers are key priorities to understand the dynamics of societal and environmental changes. The regional scale is useful because it can connect tangible problems relevant to local actors, and relates to a specific cultural context, though regions cannot be treated as separate units. For example, forest re-growth in one region can result in forest exploitation being displaced to other regions. To address the challenges of biodiversity conservation and wood production, trade-off analyses could help distinguishing between the integration and separation of conservation and production. In this sense, resilience/complexity-oriented management strategies may be able to maximize both short- and long-term benefits. Again, the recent renewable energy strategy of the European Union is expected to result in a much greater demand for biomass for bio-energy, which in Mediterranean countries is mostly available in mountain systems, can exert disproportionate control on the long-term trajectory of social-ecological systems in those areas.

2.2. *Adaptive capacity of forest management and planning in Italy*

According to the above-mentioned issues and taking into account the historical relationships between humans and forest landscapes (Scarascia-Mugnozza *et al.*, 2000), the Mediterranean basin (and its diversification in space and time) can be treated as a complex adaptive system (Nocentini and Coll, 2013). In Mediterranean forests, feedback loops of biotic and abiotic interactions across hierarchical scales create persistent structures and scale-specific patterns (Allen and Holling, 2010). In particular, forest management, which traditionally provided a great diversity of products, has slowly focused towards the almost exclusive wood production, thus resulting in a repeated over-simplification of forest stands (e.g., extensive coppice forests or even-aged pure stands; Ciancio and Nocentini, 2000). In Italy, forests that have not been directly affected by human uses so long, even known as old growth forests, are found in unique conditions, such as remote areas or areas for protection purposes (i.e., against avalanches and landslides) (e.g., Burrascano *et al.*, 2008). Because of the absence of human disturbances, the old growth forests show particular stand structures and dendrometric characteristics (Chiavetta *et al.*, 2012), desirable for biodiversity conservation issues (Lombardi *et al.*, 2008; 2013). However, from larger to smaller scale, Mediterranean landscapes and related forest stands have

become simplified, due to either intensification of production systems (both agricultural crops and woods) or as a consequence of land abandonment, encroachment and desertification (e.g., Alberti *et al.*, 2011). As a consequence, the remaining challenges for Mediterranean forests refer to (i) maintaining diverse traditional forest landscapes, mainly because they offer more options to face future changes, and (ii) increasing heterogeneity and adaptability of simplified forest systems under changing conditions. In addition, recovering biodiversity loss, as well as the health and stability of forest ecosystems, requires a fundamental change in traditional forest management approaches and silvicultural practices, in order to improve the resilience and adaptability of degraded forests to increasing external changes. Accordingly, the 'resilience thinking' embraces a collection of ideas and theories that have become widely applied to individual case studies, such as e.g., regime shifts, thresholds, transformation, adaptive cycles and socio-ecological systems (Rist and Moen, 2013). In this way, the adaptive capacity of forest management and planning reflects a 'learning by doing' approach, as well as an ability to experiment and foster innovative solutions in complex socio-ecological systems (Vizzarri, 2015).

Over the past, classical forest management approaches treated population and ecosystem dynamics as if they were acting in a stable environment and according to predictable trajectories (i.e., a top-down control of natural processes). Therefore, classical silvicultural schemes aiming at maintaining specific forest structures and optimizing timber yields were criticized as inappropriate for the complex non-linearity of forest ecosystems. Thinking of forests as complex systems is a relatively recent development in the fields of ecology and forest management (Campbell *et al.*, 2009). Managing forests as complex systems requires (i) a stronger emphasis on multiple temporal, spatial and hierarchical scales, (ii) more explicitly considering interactions among multiple biotic and abiotic components of forests, (iii) understanding and expecting non-linear responses, and (iv) planning for greater uncertainty in future conditions (Puettmann *et al.*, 2013).

Since 90*s*, the concept of systemic silviculture has been increasingly recognized as a set of methods and operational procedures that are consistent with many attributes of complex systems and complexity science (Ciancio and Nocentini, 1997, 2000; Ciancio, 2011; Ciancio *et al.*, 2003). Systemic silviculture is defined as "an experimental science based on the study, cultivation and use of the forest, [that is] an extremely complex system […] capable of self-perpetuation and of accomplishing of multiple functions" (Ciancio, 2011). In other words, the systemic silviculture orients forest management towards the re-naturalization of simplified forests to foster rehabilitation of natural processes: natural self-regulating and self-perpetuating mechanisms that increase a system's resistance, resilience and adaptability (Ciancio, 2011; Ciancio and Nocentini, 1997; Ciancio *et al.*, 2003). Hence, forest management moves from approaches based on forecasting and anticipating (i.e., the basis of anticipatory management) to approaches based on monitoring interventions effects on stand growth and development over the time (Ciancio and Nocentini, 2004).

At landscape scale, forest ecosystems have to be treated as integrated parts of the whole environment. In this way, the adaptive capacity of forest management and planning serves as a basis to orient decisions towards improving ecosystem resilience, and subsequently the balance of final ES delivered to communities, especially living in rural and marginal areas. De Groot *et al.* (2010) pointed out that an important remaining challenge in landscape planning and management is to investigate the relationship between ecosystem management and the provision of the total bundle of ES and analyze the impact of changes in management state on ES and possible (critical) thresholds. A recent analysis of the impact of alternative future-oriented planning strategies on forest ES (i.e., timber production, carbon sequestration, biodiversity conservation, and tourism and recreational opportunities) in three different landscapes in Italy (i.e., Asiago plateau, 'Alto Molise' Biosphere Reserve, and North-western area of the Etna Volcano) demonstrated that the adaptive forest governance strategies, in terms of promoting local cooperation, enhancing investments in rural areas, and improving landscape diversification, can maximize the balance of ES delivered (Vizzarri *et al.*, 2014a; Vizzarri *et al.*, 2014b; and Vizzarri *et al.*, 2014c). In all cases, the landscape diversification, in terms of changing in ownership structure (i.e., land use), was found to be linearly correlated with the ES trade-offs. At a wider scale, Biber *et al.* (2015) underlined that most forest ES in European landscapes are sensitive to the increase of management intensity.

3. FUTURE-ORIENTED ADAPTIVE GOVERNANCE STRATEGIES FACING LAND USE CHANGE IMPACTS

There is no unique definition of governance. Here we use the concept of forest governance to include both the legislation and regulatory systems (forest policy and planning) and their implementation (forest management). In other terms, forest governance concerns how different stakeholders (public and private forestry sectors, Non-Governmental Organizations, other partners) influence the use of forest resources. 'Good' forest governance is intimately linked to the concept of sustainable development, as it should improve the capacity of forests to deliver goods and services to people (ecosystem functionality), and guarantee the wellbeing of communities living closely to (and benefitting from) natural resources (e.g., Collier 2010). Particularly in the context of LUC, adaptive forest governance should generally be oriented to both further understand the related ecological, socio-economic, and political implications, and promote more effective strategies to limit the impact of LUC drivers/barriers on landscape functionality and resilience (see Vizzarri *et al.*, 2015 for National Parks). Accordingly, we here identify and discuss three governance strategies facing the LUC impact on forest ecosystem resilience, such as: (i) the adoption of the 'resilience-thinking' in practice, through adaptation measures; (ii) the use of monitoring and assessment tools; and (iii) the effective implementation of policy measures for reducing LUC impacts on ecosystem resilience at local scale.

3.1. *Put the ecosystem resilience in practice*

Increasing resilience of forest ecosystems to LUC and other anthropogenic disturbances generally requires assessing and managing inherent tradeoffs between meeting immediate human needs, and maintaining the capacity of ecosystems to provide goods and services in the future (DeFries *et al.*, 2004). Landscape resilience heavily depends on finding an appropriate match between the scales of demands on ecosystems by human societies and the scales at which ecosystems are capable to meet these demands (Cumming *et al.*, 2006). The most effective way to move towards sustainable landscapes appears to be to deliberately encourage local and regional social-ecological experiments that allow social learning to occur within the context of finding long-term solutions to chronic, broad-scale problems (Cumming *et al.*, 2013). Both long-term monitoring and the creation and implementation of diversity in problem-solving approaches rely on adaptive governance and management approaches that: (i) stimulate social learning by involving actors at multiple levels, from local to global; (ii) support the translation and diffusion of new knowledge and practices, creating a continuous feedback between research and implementation and potentially transforming societal attitudes and motivations; and (iii) offer "safety nets" to communities that are willing to engage in potentially risky experimentation (Cumming *et al.*, 2013).

The conservation of traditional practices, cultures, and significant places for local communities is extremely important to maintain a proper landscape diversification, as well as to limit the negative consequences of both land take and abandonment (Agnoletti, 2014; Sitzia *et al.*, 2010). The 'cultural landscape' framework seems to be a challenging opportunity to effectively implement adaptive governance strategies that promote ecosystem resilience (e.g., Schultz *et al.*, 2015). Preserving cultural landscapes is also fundamental to further develop fragile rural economies, mainly encouraging the delivery of particular goods and services linked to a given traditional landscape (e.g., Gobattoni *et al.*, 2015). As also highlighted by Kelly *et al.* (2015) in Southern Italy, an improved resilience of human-natural systems, as well as their increased adaptive capacity, is related to social memory, which is often threatened by outmigration of young people, land abandonment, land degradation in forests, and the loss of traditional knowledge. In this way, the integration between social, economic, and ecological aspects assumes relevant significance while managing forest resources at landscape scale. On the other hand, adaptive governance may be oriented to reduce human pressures on landscapes, through e.g., facilitating the processes of rewilding (Navarro and Pereira, 2015). Of course, this approach implies that forest governance has to consider the formation of the so-called 'novel ecosystems' (Morse *et al.*, 2014), as consequences of the initial LUC-related processes, and the subsequent creation of new lands with a different ecological significance (e.g., new formation forests; Barbati *et al.*, 2013).

3.2. *Adopt monitoring and assessment tools in changing landscapes*

Monitoring LUC and predicting related impacts on resilience and ES is crucial to support adaptive governance, as well as to evaluate the effects of the currently implemented actions on sustainability (e.g., Sallustio *et al.*, 2015). To date, several land use and cover inventories are available, both at national and EU level, such as e.g., Corine Land Cover (CLC), Land Use/Cover Area frame Statistical Survey (LUCAS), Global Monitoring for Environment and Security (GMES), and Copernicus High Resolution Layers (HRLs). However, the 7th FP 'Harmonised European Land Monitoring' (HELM) project highlighted the following main challenges in monitoring LUC (Ben-Asher, 2013): (i) overcoming differences and filling gaps in data and approaches in national systems; (ii) resolving incompatibility of nomenclatures and databases; (iii) improving the inadequate or absent data synchronization; and (iv) reducing the lack of compliance between previous European-level land use and land cover inventories and new bottom-up-created databases at national and local scales. In Italy, the Land Use Inventory (IUTI - *Inventario dell'Uso delle Terre d'Italia*; Corona *et al.*, 2012), firstly developed as a framework for national accounting of greenhouse gases (GHGs) emissions, was proven to be an effective tool to assess stocks and flows of land use at national level. Other experiences for harmonizing land use and cover databases took place in Italy, such as e.g., the Integration of Territorial And Land Information (ITALI) project (Pulighe *et al.*, 2013).

In particular, the change of the contribution of forest ecosystems to the overall carbon budget, the regulation of hydrological regimes, and the biodiversity conservation can be easily detected by adopting LUC monitoring tools. This is the case of e.g., mapping the Natura2000 Network sites for the protection of endangered species and habitats. Other examples concern the network of Protected Areas, where traditional land uses face conservation actions (Marchetti *et al.*, 2012b). In all these cases, mapping and monitoring forest ecosystems largely contribute to assess the ES flow and evaluate the benefits for local communities. This aspect is particularly amplified at landscape scale, where adaptive governance can be achieved through (Spears *et al.*, 2015): (i) delineating ecological and governance scales; (ii) identifying critical slow variables; (iii) identifying scale-dependent ecological thresholds; and (iv) linking ecological and legal thresholds. Furthermore, adaptive governance may be supported by the implementation of spatially-explicit models, as useful tools to assess and map changes in forest extent and the related implications for ES availability. For example, the 'Multi-scale monitoring of ES indicators in Mediterranean forests' (MiMOSE) approach offers a strong contribution to map and assess forest ES at regional scale (see Bottalico *et al.*, 2015 for Molise region), with the main purpose of supporting the 'resilience thinking' in adaptive forest governance.

3.3. *Implement effective policy measures at local scale*

At global scale, adaptation measures concerning LUC mainly refer to the climate change mitigation, and are based on the strategies to reduce the GHGs

emissions through LULUCF (Penman *et al.*, 2003). Other mitigation options are found within the 'Reducing Emissions from Deforestation and Forest Degradation' (REDD) initiatives, especially for developing Countries. In Europe, at least three relevant policy measures concern the LUC-ES topic, as follows: (i) the European Commission's Roadmap to a Resource Efficient Europe (COM(2011)571); (ii) the 2020 - Biodiversity Strategy (COM(2011)244); and (iii) the EU-wide strategy on Green Infrastructure (COM(2013)249). All these measures are part of the wider 7th Environment Action Program (Decision No. 1386/2013/EU). In the first case, Member States are asked to (i) better integrate direct and indirect land use and its environmental impacts in their decision making and limit land take and soil sealing to the extent possible; (ii) implement the actions needed for reducing erosion and increasing soil organic matter; and (iii) set up an inventory of contaminated sites, and a schedule for remedial work by 2050. In the second case, the main targets are: (i) to maximize areas under agriculture across grasslands, arable lands and permanent crops that are covered by biodiversity-related measures, in order to enhance sustainable practices; (ii) to further encourage the collaboration among stakeholders involved in land use management and planning, in order to implement biodiversity strategies at all levels; and (iii) to integrate species and habitat protection (as well as the delivery of other important services) into key land use and water policies. In the third case, one of the most important objectives is to include specific "green" initiatives in planning and decision-making processes in order to help reduce the loss of ES associated with future land take and help improve soil restoration and related functions. Particularly related to LUC, the Common Agricultural Policy (CAP; Regulation No. 1305/2013) aims at preventing land abandonment and fragmentation, through adopting non-productive investments and agro-environmental measures. If properly implemented at national (and landscape) scale, the above-mentioned policy measures can support adaptive governance. Specifically for forest ecosystems, the new EU Forest Strategy (COM(2013) 659) promotes forest resilience at all levels, enhances the forest-based economic sector (especially in marginal areas), and sustains rural communities and complex human-natural systems. Accordingly, Member States are called to implement specific Action Plans aimed at balancing the forest ES provision with the socio-economic development in forested landscapes. On the same line, the 'Mapping and Assessment of Ecosystems and their Services' (MAES) project started from the consciousness to provide to European Countries suitable instruments for ES mapping and assessment at continental scale by combining land use and cover change strata with people perception values (Maes *et al.*, 2012).

FINAL REMARKS

This paper tried to address the linkages between LUC and forest governance at various scales, with a particular focus on adaptation measures in mountain environments in Italy. The main outcomes are hereinafter described. At first, research contributions to the LUC-ES topic in Italy are still few in comparison

with those available in other developed Countries. Much more research efforts are necessary to stimulate the scientific debate at national scale, as well as to increase the local communities awareness on the negative consequences of some LUC processes on ecosystem resilience and landscape asset. Moreover, research activities should be based on effectively linking socio-economic barriers and drivers with LUC and its ecological implications. Secondly, forest management and planning at landscape scale may have a key role in reducing the impact of LUC on forest resilience. This can be achieved by both adopting suitable simulation and modelling tools to assess and predict LUC processes, and creating persistent monitoring framework to make adaptation measures more effective. Finally, national policies about LUC and consequent in ES provision should be oriented to enforce the role of the forestry sector, thus improving resilience of mountain landscapes, and mitigate the impacts of external socio-economic transformations. Furthermore, biodiversity hotspots, cultural landscapes, and areas for nature conservation should be maintained and promoted, even in a broader sense (i.e. tourism and recreational opportunities). Forest governance in marginal areas in Italy, where clear management and planning directions are often absent, should adopt the above-mentioned measures in order to be considered adaptive.

In the view of a proper landscape development, the integration between planning instruments, as well as the harmonization of operative processes, are needful to find a positive balance between natural resources use and conservation, and the local socio-economic development (see also Acutis, 2012). In particular, the 'mountain' is one of the most important policy trajectories, as it regards fast ecological changing processes and unexpected economic consequences. In this way, bridging the gap between communities and mountain environment still represents one of the major challenges for adaptive forest governance. Whereas global change mitigation is primarily a task for national and international level agreements and processes, the responsibility for implementing proactive management strategies will fall more to regional governments and local communities, and the private sector.

ACKNOWLEDGEMENTS

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration, under grant agreement No 282887 (INTEGRAL).

RIASSUNTO

Una governance *forestale adattiva per affrontare gli impatti del cambiamento dell'uso del suolo in Italia*

Il cambiamento dell'uso del suolo è uno dei *driver* principali della riduzione della resilienza ecosistemica, così come della perdita di biodiversità e approvvigionamento di servizi. Rappresenta una sfida peculiare, specialmente negli ambienti mediterranei, dove i fenomeni di abbandono e ricolonizzazione naturale stanno minacciando in modo sempre più crescente la

capacità delle foreste di fornire benefici alle comunità locali. In queste condizioni, il sistema di *governance* forestale è chiamato a bilanciare gli impatti del cambiamento dell'uso del suolo con l'assicurazione della salute e della stabilità degli ecosistemi forestali, al fine di garantire la sostenibilità a lungo termine degli ambienti, soprattutto di quelli marginali. Questo lavoro si propone di analizzare in modo più approfondito gli impatti del cambiamento dell'uso del suolo sugli ecosistemi forestali negli ambienti montani italiani. In primo luogo, esegue un'analisi bibliografica dei concetti legati al cambiamento dell'uso del suolo e all'approvvigionamento dei servizi ecosistemici, dalla scala globale a quella locale. In seguito, indaga le relazioni fra le potenzialità adattive di gestione e pianificazione forestali e il cambiamento dell'uso del suolo. Infine, vengono proposte alcune strategie future di possibili strumenti di *governance* adattiva per affrontare i cambiamenti dell'uso del suolo. Questa infatti può migliorare la resilienza degli ecosistemi forestali riducendo il *gap* nel campo della ricerca tra il contesto nazionale e quello globale, utilizzando strumenti di valutazione e monitoraggio per simulare cambiamenti e disturbi esterni, e adottando strategie e misure politiche coerenti a scala locale.

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