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OLD-GROWTH FORESTS IN ITALY: INPUTS FOR FOREST MANAGEMENT AND PLANNING IN AREAS WITH LONG-STANDING HUMAN IMPACT

The paper discusses if and how research results can support forest management and planning in areas where forests have been heavily and pervasively modified during the centuries. Along with the rare tracts of old-growth forests, the reduction in forest utilization which has taken place in Italy starting from the 1960's has favored natural development and an increasing degree of "old-growthness" in many once managed forest stands.

Difficulties in using "old-growth" forests as models for sustainable forest management in this situation arise from many factors: scarcity and limited surface of most old-growth forests; relatively short history of non-management; heavily disturbed surrounding matrix. Further uncertainty is added by the fact that old-growth forests have developed in climatic and environmental conditions which might be very different from the ones that will be faced in the future.

Nevertheless lessons can be learned if the growing scientific knowledge is connected to a dynamic concept of forest ecosystems and forest management, where monitoring and feedback is the basis for adapting silviculture to the reactions of each different stand. In areas with long standing human impact, interdisciplinary research insights into the structural changes and development processes of forests which have been subtracted from direct management and utilization, can provide criteria and indicators for designing monitoring schemes in support of forest management, and for implementing ecological networks which integrate biodiversity conservation with socio-economic opportunities and constraints.

Key words: virgin forests; old-growth forests; old-growthness; adaptive management; complexity.

Parole chiave: foreste vergini; foreste vetuste; vetustà; gestione adattativa; complessità.

1. INTRODUCTION

Scientific interest in virgin forests has developed in time following the search for models of forest ecosystem's "natural" functioning and thus as possible inspiration for "close to nature" silviculture. More recently, virgin and old-growth forests have gained great attention for biodiversity conser-

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vation and literature on this topic is increasing rapidly from the first papers dating from the last decades of the XXth century (e.g. FRANKLIN *et al.*, 1981; FRANKLIN and SPIES, 1991; HANSEN *et al.*, 1991; KEDDY and DRUMMOND, 1996). Research has turned towards identifying indicators of old-growth connected to biodiversity conservation (habitats and species) to be used to assess sustainable forest management practices (LINDENMAYER *et al.*, 2000). Furthermore, the role of virgin and old-growth forests as carbon sinks is today gaining increasing attention (SCHULZE *et al.*, 1999; LUYSSAERT *et al.*, 2008; MOTTA, 2008; PIOVESAN *et al.*, 2010) and there is a growing awareness of their importance also from a cultural point of view (KANOWSKI and WILLIAMS, 2009; OWEN *et al.*, 2008).

The aim of this paper is to discuss if and how research results can support forest management and planning in areas where forests have been heavily and pervasively modified during the centuries, with particular reference to the Italian situation.

2. FROM “VIRGIN” FORESTS TO “OLD-GROWTH” FORESTS

The first writings testifying the interest in “virgin” forests in Europe date from the middle of the XIXth century (SEIDEL, 1848). One of the earliest citations attributing particular value to virgin forests for silviculture is in a paper by RUBNER (1920), who claimed that three things could be learned from virgin forests: whether stands are naturally mixed or mono-specific; whether they are uniform in structure or heterogeneous; and how natural regeneration occurs (BRANG, 2005).

Many other authors reported on virgin forest studies in the period between 1920 and World War II (JONES, 1945). After World War II, the scarcity of virgin forest remnants in Western Europe stimulated cooperation of scientist from western countries to study such forests especially in the Carpathians and the Balkans. This has produced a wide variety of papers and reports concerning structure and composition of virgin forest remnants mostly for these areas (e.g. MARKGRAF and DENGLE, 1931; MAUVE, 1931; LEIBUNDGUT, 1959, 1960; PINTARIĆ, 1959; MLINSEK, 1967)¹. SUSMEL (1956; 1980) referred to many of these studies in his outline of close to nature silviculture for mixed fir-beech forests in the eastern Italian Alps.

In Europe truly “virgin” forests are very rare and often even forests defined as such have been in some way impacted by human activities

¹ See BRANG (2005) for a detailed review and critique of the development of interest in virgin forests as models for close to nature silviculture.

(FALINSKI, 1986; PETERKEN, 1996). Since prehistoric times human pressure has affected forest dynamics especially in central and southern Europe (FARRELL *et al.*, 2000; MOTTA and NOLA, 2001; WINTER *et al.*, 2010).

Starting from North America, the concept of “virgin forest” has been gradually substituted both in the scientific and technical forestry literature by the term “old-growth forest”². Whereas a “virgin forest”, in purely theoretical terms, can be univocally identified in a forest which has *never* been modified by human activity, conceding that such information could be known or that such a state could exist, the term “old-growth forest” has not as yet been univocally defined. “Old-growth” was first used in the North America referring to forests which had not been extensively logged by European settlers, in contrast to “second-growth” forests which originated after logging and/or fire following colonization and exploitation of new territories.

The terminological debate is still going on and it is not difficult to agree with SPIES (2004) that “A consensus on the wording of an ecological definition of old-growth will never be reached and may not be desirable, given the diversity of forests”, and forest histories, I would add. This is particularly true in the Mediterranean region where a classification for old-growth must take into account a number of landscape, historic, biological and social issues (MARCHETTI *et al.*, 2010).

Both in the Italian Alps and all along the Italian Peninsula practically all forests have been affected by humans in some way, either through direct periodic destruction of the forest or by more subtle forms of management and habitat manipulation (MOTTA, 2002).

In Italy the term “foresta vetusta” (from the Latin *vetus*, ancient) has been introduced in the forestry literature to indicate a forest which shows many of the typical traits attributed to old-growth forests, i.e. species composition considered natural for the site, presence of many big, old trees, a high level of deadwood (standing dead trees, snags and woody debris), and a long known history of protection or exclusion from direct human influence (PIOVESAN *et al.*, 2003; DI FILIPPO *et al.*, 2005; PIOVESAN *et al.*, 2005; BLASI *et al.*, 2010).

How old the oldest trees must be and how long the period of non-management must be so that a forest can be considered “vetusta” has not been clearly defined. Although age in relation to «natural longevity» of tree

² WIRTH *et al.* (2009) report that from the period 1940-50 to the period 1995-2005 the number of times the term “virgin forest” is used in scientific papers decreases from over 70% to less than 10% compared to a parallel increase of the term “old-growth forest” from less than 10% to over 60%.

species is usually recalled as a parameter, generally trees at least two centuries old³ and a period of abandonment or protection of at least 50 years are considered the base line for defining a forest as “vetusta” (e.g. PACI and SALBITANO, 1998; DI FILIPPO *et al.*, 2005; CIANCIO *et al.*, 2010). Presence of cut stumps and other signs of previous human impact, such as areas used for charcoal kilns, are usually accepted if the forest complies with the other typical features of “old-growthness”⁴.

Apart from the rare tracts of what could be considered “very old” old-growth forests (e.g. PIOVESAN *et al.*, 2003; 2005; 2010), the increasing reduction in forest utilization which has taken place in Italy starting from the 1960's has favored natural development in many once managed forest stands. Parallel with other countries (BAUHUS *et al.*, 2009), growing attention is being given to the unmanaged parts of previously managed forests on the grounds that the past history, present structures and long-term monitoring of these forest stands are fundamental steps for increasing our knowledge of natural forest stand dynamics (MOTTA, 2002). It has been estimated that all together several thousand hectares of forested landscape in Italy (on a total forest area of 10.5 Mha, INFC, 2007), have reached structural and compositional traits typical of the mature stage of forest dynamics (MOTTA, 2002) and are playing an important role for biodiversity conservation and are increasingly recognized as important carbon sinks (MARCHETTI *et al.*, 2010; PIOVESAN *et al.*, 2010).

The substitution of the concept of “virgin forest” with “old-growth forest” or “foresta vetusta”, has opened up new perspectives in research. The hypothesis is that selecting appropriate indicators of “old-growthness” and research based thresholds for these indicators, it is possible to identify “potentially” old-growth forests and plan appropriate conservation measures.

3. OLD-GROWTH FORESTS: LESSONS FOR FOREST MANAGEMENT AND PLANNING?

While research on old-growth forests in Italy is increasing rapidly, the question arises as to the role of old-growth forests and of the results of this intense scientific activity in supporting management and planning.

The scarcity of truly old-growth forests large enough to enable

³ This is similar to what WIRTH *et al.* (2009) have found analyzing the world literature in old-growth studies for many different types of forests.

⁴ A similar approach has been adopted also for other Mediterranean forests (e.g. PANAIOTIS *et al.*, 1997; ROZAS, 2003).

ecosystem processes to occur undisturbed by human impacts, the relatively short history of non-management which characterizes most of the forests considered as old-growth in Italy and the fact that they are often enmeshed in a landscape of heavily modified forests and anthropogenic communities, create quite a few problems both in planning the protection of these old-growth forest remnants and in using them as possible models for sustainable forest management.

Further uncertainty is added by the fact that old-growth forests, however they might be defined, are a phase of a (more or less) long development history which has taken place in climatic and environmental conditions which might be very different from the ones that will be faced in a probably not so distant future. According to NOSS (2001) a community of long-lived organisms is seldom, if ever, in equilibrium with the prevailing climate (PERRY *et al.*, 1991): vegetational change lags behind climate change, such that the vegetation at any point in time is a legacy of climatic conditions decades or centuries in the past (SPRUGEL 1991; MILLAR and WOOLFENDEN, 1999).

Nevertheless there are very important lessons to be learned if the growing scientific knowledge is placed into the right reference frame. We must be aware that if we are looking for a “natural model” we are in fact looking at a moving target (MITCHELL *et al.*, 2003). Therefore insights into the structure, composition and processes of old-growth forests cannot serve as templates on which to shape our forests, but are fundamental in understanding the complexity of processes and interactions that take place in forest ecosystems under different degrees of human impact. And this is particularly important when dealing with stands which are in fact recovering from past utilization and which will very probably differ in structure and composition from the old-growth forests that we have inherited from the past. Forests develop along complex pathways: old-growth characteristics do not develop instantaneously at some magical age, but rather they accrue over time (HAGAN e WHITMAN, 2005).

Examples of lesson to be learned concern insights on the natural longevity of forest species compared to the classic and often conventionally and uncritically accepted concept of rotation age; on regeneration patterns based on gap dynamics compared to the “regular” silvicultural systems which have been supported by classic forest management for many species, such as, e.g., beech (NOCENTINI, 2009) and Calabrian black pine (CIANCIO *et al.*, 2006; 2010); on the role of structural features (deadwood etc.) in relation to biodiversity.

All these insights must be related to a dynamic concept of forest management, where monitoring and feedback is the basis for adapting

silviculture to the reactions of each different stand. This means that management does not tend towards a predetermined model, but instead acts according to a co-evolutionary continuum between cultivation and reaction of the ecosystem. In this approach, indicators are useful in the monitoring process that must sustain adaptive forest management, but not for predetermining “optimal” levels, e.g. of deadwood or other biodiversity indicators (CIANCIO and NOCENTINI, 2004).

Identification, description and above all monitoring in time of forest areas where direct human impact has been very low or has stopped for a long period of time must continue and is the basis for planning preservation of such areas. Because of the often limited size of these areas there is the need to analyze and protect also buffer areas in connection with the characters of the surrounding matrix.

In this sense, research on biodiversity linked to old-growth forests and old-growth features should be based on a network approach at the different scales. Interdisciplinary studies are fundamental in identifying and integrating different habitat requirements in relation to the whole forest ecosystem.

As a result of the reduction in forest utilization intensity which is characterizing many forest types in Italy, the forest landscape can be viewed as a mosaic of different patches with differing degrees of “old-growthness”. On the other hand, in many areas characterized by coppices, utilization has intensified in the last few decades, following a constant rise in firewood prices and demand. Here planning should provide for the creation of a network of elements with “old-growth” characters at the different scales, going from selecting and releasing one or more trees per unit area to “grow old” (as is already provided for by many regional forest regulations⁵), to leaving a network of unmanaged forest patches and buffer areas. In the creation of such networks, research should provide information for integrating operational needs with biodiversity conservation.

4. CONCLUSIONS

Forests are complex biological systems, they follow development trajectories that cannot be precisely foreseen or modeled. Their boundaries are not impermeable and they are continuously subject to internal and external influences, both from changing environmental and socio-economic

⁵ As an example, according to the Forest regulation of the Tuscany Region (*DPGR Toscana* 8 agosto 2003, n. 48/R), the biggest tree per hectare must be left for undefined ageing in all felled areas of 1 or more hectares.

conditions. Only the passing of time can allow a forest disturbed by human impact to regain a more “natural” functioning. The degree of “old-growthness” is therefore a relative concept, a definition in progress.

In areas with long standing human impact, interdisciplinary research insights into the structural changes and development processes taking place in forests that have been subtracted from direct management and utilization, should be the basis for implementing ecological networks which integrate biodiversity conservation with socio-economic opportunities and constraints.

The history of each forest is dominated by processes that cross multiple space and time scales: lessons learned from old-growth forests must be placed into this context. Management of simplified forest systems, such as the ones that characterize many areas with long standing human impact, cannot be shaped on a supposed “natural” state, based on evidence from old-growth forests, but should instead be based on an adaptive approach with the aim of increasing the system’s diversity and complexity in an ever changing environmental, economic, social and cultural scenario.

RIASSUNTO

Boschi vetusti in Italia: collegamenti con la pianificazione e la gestione forestale in aree da lungo tempo antropizzate

Viene analizzata la possibilità di utilizzare i risultati della ricerca sui boschi vetusti come base per la gestione sostenibile e la pianificazione forestale in aree dove il paesaggio forestale è stato a lungo e fortemente alterato dall’attività umana. Oltre ai pochi tratti di foreste propriamente vetuste ancora presenti nel nostro Paese, la forte riduzione nelle utilizzazioni forestali che ha caratterizzato molte aree boscate a partire dagli anni ’60 dello scorso secolo, ha favorito l’evoluzione naturale e l’aumento del grado di “vetustà” di molti soprassuoli forestali.

In Italia, la scarsità e la limitata superficie della maggior parte dei boschi vetusti, la relativa brevità del periodo in cui sono stati sottratti alle attività antropiche, il fatto di essere immersi in una matrice territoriale fortemente alterata dalle attività umane, sono tutti fattori che rendono difficile proporre di utilizzare i boschi vetusti come modelli per la gestione forestale. A ciò si aggiunge l’incertezza derivante dal fatto che i boschi vetusti si sono sviluppati in condizioni climatiche e ambientali che potrebbero essere anche molto diverse da quelle che si verificheranno in futuro.

Pur tuttavia, importanti lezioni possono essere derivate dalla crescente mole di indagini scientifiche sui boschi vetusti, a patto che i risultati ottenuti vengano connessi a una concezione dinamica degli ecosistemi e della gestione forestale, dove il monitoraggio è la base per adattare la selvicoltura alle reazioni di ogni diverso soprassuolo. Nelle zone dove più lungo è stato l’impatto antropico sul paesaggio forestale, le indicazioni derivanti dalla ricerca interdisciplinare sui cambiamenti strutturali e sui processi evolutivi che si instaurano nei boschi sottratti alle utilizzazioni possono fornire criteri e indicatori per delineare schemi di monitoraggio a supporto della gestione forestale e per disegnare reti ecologiche che integrino la conservazione della biodiversità con le opportunità e i vincoli socio-economici.

REFERENCES

- BAUHUS J., PUETTMANN K., MESSIER C., 2009 – *Silviculture for old-growth attributes*. Forest Ecology and Management, 258: 525-537; doi:10.1016/j.foreco.2009.01.053.
- BLASI C., MARCHETTI M., CHIAVETTA U., ALEFFI M., AUDISIO P., AZZELLA M.M., BRUNIALTI G., CAPOTORTI G., DEL VICO E., LATTANZI E., PERSIANI A.M., RAVERA S., TILIA A., BURRASCANO S., 2010 – *Multi-taxon and forest structure sampling for identification of indicators and monitoring of old-growth forest*. Plant Biosystems, 144 (1): 160-170.
- BRANG P., 2005 – *Virgin forests as a knowledge source for central European silviculture: reality or myth?* Forest Snow and Landscape Research, 79 (1/2): 19-32.
- CIANCIO O., IOVINO F., MENGUZZATO G., NICOLACI A., NOCENTINI S., 2006 – *Structure and growth of a small group selection forest of Calabrian pine in Southern Italy: A hypothesis for continuous cover forestry based on traditional silviculture*. Forest Ecology and Management, 224: 229-234.
- CIANCIO O., IOVINO F., MENGUZZATO G., NICOLACI A., VELTRI A., 2010 – *Stand structure of a Calabrian pine old growth forest: indications for forest management and forest landscape preservation*. L'Italia Forestale e Montana, 65 (5): 529-544.
- CIANCIO O., NOCENTINI S., 2004 – *Biodiversity conservation in Mediterranean forest ecosystems: from theory to operationality*. In: M. Marchetti ed., Monitoring and Indicators of Forest Biodiversity in Europe - From Ideas to Operationality. EFI Proceedings, n. 51: 163-168. Online: http://www.efi.int/files/attachments/publications/proc51_net.pdf.
- DI FILIPPO A., PIOVESAN G., SCHIRONE B., 2005 – *Le foreste vetuste: criteri per l'identificazione e la gestione*. Atti del XIV Congresso Nazionale della Società Italiana di Ecologia (Siena, 4-6 Ottobre 2004). In: C. Gaggi, V. Nicolardi e S. Santoni (editori), Ecologia. Atti del XIV Cong. Naz. SITE: <http://www.xivcongresso.societaitalianaecologia.org/articles/Di-Filippo-61.pdf>
- FALINSKI J.B., 1986 – *Vegetation Dynamics in Temperate Lowland Primeval Forests*. Ecological studies in Białowieża Forest. Geobotany, 8: 1-537.
- FARRELL E.P., FUHRER E., RYAN D., ANDERSSON F., HUTTL R., PIUSSI P., 2000 – *European forest ecosystems, building the future on the legacy of the past*. For. Ecol. Manage., 132 (1): 5-20.
- FRANKLIN J.F., CROMACK K. JR., DENISON W., MCKEE A., MASER C., SEDELL J., SWANSON F., JUDAY G., 1981 – *Ecological characteristics of old-growth Douglas-Fir forests*. USDA For. Serv. Gen. Tech. Rep. PNW-118.
- FRANKLIN J.F., SPIES T.A., 1991 – *Composition, function, and structure of old-growth Douglas-fir forests*. In: Ruggiero L.F., Aubry K.B., Carey A.B., Huff M.H., editors. Wildlife and vegetation of unmanaged Douglas-fir forests. USDA Forest Service General Technical Report PNW-GTR-285, p. 91-110.
- HAGAN J.M., WHITMAN A.A., 2005 – *Biodiversity Significance of Old-growth, Late-*

- successional, and Economically Mature Forest*. In: Bennett K.P. (technical coordinator), 2005. Moving Toward Sustainable Forestry: Lessons from Old Growth Forests. University of New Hampshire Cooperative Extension Natural Resource Network Report, p. 60-61; http://extension.unh.edu/resources/files/Resource000406_Rep428.pdf
- HANSEN A.J., SPIES T.A., SWANSON F.J., OHMANN J.L. 1991 – *Conserving Biodiversity in Managed Forests*. BioScience, 41 (6): 382-392.
- INFC, 2007 – *Le stime di superficie 2005 - Prima parte*. Autori G. Tabacchi, F. De Natale, L. Di Cosmo, A. Floris, C. Gagliano, P. Gasparini, L. Genchi, G. Scrinzi, V. Tosi. Inventario Nazionale delle Foreste e dei Serbatoi Forestali di Carbonio. MiPAF - Corpo Forestale dello Stato - Ispettorato Generale, CRA-ISAFA, Trento; [on line] URL: <http://www.infc.it>.
- JONES E.W., 1945 – *The structure and reproduction of the virgin forest of the North Temperate Zone*. New Phytol., 44: 130-148.
- KANOWSKI P.J., WILLIAMS K., 2009 – *The reality of imagination: Integrating the material and cultural values of old forests*. Forest Ecology and Management, 258: 341-346; doi:10.1016/j.foreco.2009.01.011.
- KEDDY P.A., DRUMMOND C.G., 1996 – *Ecological properties for the evaluation, management and restoration of temperate deciduous forest ecosystems*. Ecol. Appl., 6 (3): 748-762.
- LEIBUNDGUT H., 1959 – *Über Zweck und Methodik der Struktur- und Zuwachsanalyse von Urwäldern*. Schweizerische Zeitschrift für Forstwesen, 110: 111-124.
- LEIBUNDGUT H., 1960 – *Risultati delle ricerche in foreste vergini europee*. L'Italia Forestale e Montana, 15 (6): 213-219.
- LINDENMAYER D.B., MARGULES C.R., BOTKIN D.B., 2000 – *Indicators of biodiversity for ecologically sustainable forest management*. Conservation Biology, 14: 941-950.
- LUYSSAERT S., SCHULZE E.D., BÖRNER A., KNOHL A., HESSENMÖLLER D., LAW B.E., CIAIS P., GRACE J., 2008 – *Old-growth forests as global carbon sinks*. Vol. 455, 11 September 2008, p. 213-215; doi:10.1038/nature07276.
- MARCHETTI M., TOGNETTI R., LOMBARDI F., CHIAVETTA U., PALUMBO G., SELBITTO M., COLOMBO C., IOVIENO P., ALFANI A., BALDANTONI D., BARBATI A., FERRARI B., BONACQUISTI S., CAPOTORTI G., COPIZ R., BLASI C., 2010 – *Ecological portrayal of old-growth forests and persistent woodlands in the Cilento and Vallo di Diano National Park (Southern Italy)*. Plant Biosystems, 144 (1): 130-147; doi: 10.1080/11263500903560470.
- MARKGRAF F., DENGLE A., 1931 – *Aus den Wäldern Albaniens*. Z. Forst- u. Jagdztg., 63: 1-31.
- MAUVE K., 1931 – *Ueber Bestandesaufbau, Zuwachsverhältnisse und Verjüngung im galizischem Karpathen-Urwald*. Mitt. Forstwirt. Forstwiss., 2: 257-311.
- MILLAR C.I., WOOLFENDEN W.B., 1999 – *The role of climatic change in interpreting historical variability*. Ecological Applications, 9: 1207-1216.
- MITCHELL R.J., SCHULTE L.A., HUNTER M.L. JR., FRANKLIN J.F., MCINTYRE R.K., PALIK B.J., 2003 – *Conservation theory and forest management: foundation,*

- utility, and research needs. Final Report NCSSF Research Project B2. On-line: <http://ncseonline.org/ewebeditpro/items/O62F5611.pdf>
- MLINSEK D., 1967 – *Verjüngung und Entwicklung der Dickungen im Tannen-Buchen-Urwald "Rog"*. Slowenien: Proceedings, IUFRO World Congress, XIV/4: 436-442.
- MOTTA R., 2002 – *Old-growth forests and silviculture in the Italian Alps: the case-study of the strict reserve of Paneveggio (TN)*. Plant biosystems, 136: 223-232.
- MOTTA R., 2008 – *Il ciclo del carbonio nelle foreste vetuste*. Forest@, 5: 302-305 [online: 2008-12-12]; URL: <http://www.sisef.it/forest@/>
- MOTTA R., NOLA P., 2001 – *Growth trends and dynamics in sub-alpine forest stands in the Varaita Valley (Piedmont, Italy) and their relationships with human activities and global change*. J. Veg. Sci., 12 (2), 219-230.
- NOCENTINI S., 2009 – *Structure and management of beech (Fagus sylvatica L.) forests in Italy*. iForest, 2: 105-113 [online 2009-06-10]; URL: <http://www.sisef.it/iforest/show.php?id=499>; doi 10.3832/ifor0499-002.
- NOSS R.F., 2001 – *Beyond Kyoto: Forest Management in a Time of Rapid Climate Change*. Conservation Biology, 15 (3).
- OWEN R.J., DUINKER P.N., BECKLEY T.M., 2008 – *Capturing old-growth values for use in forest decision-making*. Environ. Manage., 43: 237-248.
- PACI M., SALBITANO F., 1998 – *The role of studies on vegetation dynamics in undisturbed natural reserves towards the need of knowledge for close-to-nature silvicultural treatments: the case study of Natural Reserve of Sasso Fratino (Foreste Casentinesi, Northern-Central Apennines)*. AISF-EFI International Conference on "Forest Management in Designated Conservation & Recreation Areas" (Morandini R., Merlo M. and Paivinnen R. eds.), 7-11 october 1998, Florence, Italy. University of Padua Press, p. 145-156.
- PANAÏOTIS C., CARCAILLET C., M'HAMED M., 1997 – *Determination of the natural mortality age of an holm oak (Quercus ilex L.) stand in Corsica (Mediterranean Island)*. Acta OEcologica, 18: 519-530.
- PERRY D.A., BORCHERS J.G., TURNER D.P., GREGORY S.V., PERRY C.R., DIXON R.K., HART S.C., KAUFFMAN B., NEILSON R.P., SOLLINS P., 1991 – *Biological feedbacks to climate change: terrestrial ecosystems as sinks and sources of carbon and nitrogen*. Northwest Environmental Journal, 7: 203-232.
- PETERKEN G.F., 1996 – *Natural woodland: ecology and conservation in Northern temperate regions*. Cambridge University Press, Cambridge, 522 p.
- PINTARIČ K., 1959 – *Urwald in Jugoslawien*. Schweiz. Z. Forstwes., 110: 163-168.
- PIOVESAN G., ALESSANDRINI A., BALIVA M., CHITI T., D'ANDREA E., DE CINTI B., DI FILIPPO A., HERMANIN L., LAUTERI M., SCARASCIA MUGNOZZA G., SCHIRONE B., ZIACO E., MATTEUCCI G., 2010 – *Structural patterns, growth processes, carbon stocks in an italian network of old-growth beech forests*. L'Italia Forestale e Montana, 65 (5): 557-590.
- PIOVESAN G., DI FILIPPO A., ALESSANDRINI A., BIONDI F., SCHIRONE B., 2005 – *Structure, dynamics, and dendroecology of an Apennine old-growth beech forest*. Journal of Vegetation Science, 16: 13-28.

- PIOVESAN, G., BERNABEI M., DI FILIPPO, A., ROMAGNOLI, M. & SCHIRONE, B. 2003 – *A long-term tree ring beech chronology from a high-elevation old-growth forest of central Italy*. *Dendrochronologia*, 21: 1-10.
- ROZAS V., 2003 – *Regeneration patterns, dendroecology, and forest-use history in an old-growth beech-oak lowland forest in Northern Spain*. *Forest Ecology and Management*, 182: 175-194; doi:10.1016/S0378-1127(03)00070-7.
- RUBNER K., 1920 – *Die waldbaulichen Folgerungen des Urwaldes*. *Naturwiss. Z. Forst- Landwirtschaft*, 18: 201-214.
- SCHULZE E.-D., LLOYD J., KELLIHER F.M., WIRTH C., REBMANN C., LÜHKER B., MUND M., KNOHL A., MILYUKOVA I.M., SCHULZE W., ZIEGLER W., VARLAGIN A.B., SOGACHEV A.F., VALENTINI R., DORE S., GRIGORIEV S., KOLLE O., PANFYOROV M.I., TCHEBAKOVA N., VYGODSKAYA N., 1999 – *Productivity of forests in the Eurosiberian boreal region and their potential to act as a carbon sink - a synthesis*. *Global Change Biology*, 5: 703-722; doi: 10.1046/j.1365-2486.1999.00266.x
- SEIDEL A., 1848 – *Beiträge zur Kenntnis des Urwaldes*. *Tharandter Forstliches Jahrbuch*, 5: 158-181.
- SPIES T.A., 2004 – *Ecological concepts and diversity of old-growth forests*. *Journal of Forestry*, 102: 14-20.
- SPRUGEL D.G., 1991 – *Disturbance, equilibrium, and environmental variability: what is "natural" vegetation in a changing environment?* *Biological Conservation*, 58: 1-18.
- SUSMEL L., 1956 – *Leggi di variazione dei parametri della foresta disetanea normale*. *L'Italia Forestale e Montana*, 11 (3): 105-116.
- SUSMEL L., 1980 – *Normalizzazione delle foreste alpine. Basi ecosistemiche, equilibrio, modelli colturali, produttività*. Liviana Editrice, Padova, 437 p.
- WINTER S., FISCHER H.S., FISCHER A., 2010 – *Relative quantitative reference approach for naturalness assessments of forests*. *For. Ecol. Manag.*, 259: 1624-1632.
- WIRTH C., MESSIER C., BERGERON Y., FRANK D., FANKHÄNEL A., 2009 – *Old-growth forest definitions: a pragmatic view*. In: Wirth C., Heimann M., Gleixner G. (eds.) *Old-growth forests: function, fate and values*. Ecological studies. Springer, New York.