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Concept note

# Forest-food nexus: a topical opportunity for human well-being and silviculture

P. Corona[1], A. Cutini[1], Ugo Chiavetta[1], Elena Paoletti[2*]

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**Abstract** - As population will reach over 9 billion by 2050, interest in the forest-food nexus is rising. Forests play an important role in food production and nutrition. Forests can provide nutritionally-balanced diets, woodfuel for cooking and a broad set of ecosystem services. A large body of evidence recommends multi-functional and integrated landscape approaches to reimagine forestry and agriculture systems. Here, after an in-depth commented discussion of the literature produced in the last decade about the role for forests with respect to the food security global emergency, we summarize the state of the art in Italy as a country-case-study. This commentary aims to increase awareness about the potential of silviculture in Italy for combining ecological resilience with economic resilience, and for reasonably increasing non-wood products supply by means of a sustainable intensification of forest management at national level. Chain-supply fragmentation, landowner inertia, and lack of governance and cooperation may hamper an effective exploitation of non-wood products. The strategies to guarantee an effective supply of non-wood products require appropriate business skills and the presence of a structured business service. A transparent market is also essential; therefore, the introduction of standards (e.g. grading rules and forest certification schemes) is important since they can add value to products and services, and emphasize the importance and complexity of the forest sector. However, the implementation of sustainable forest management for an effective supply of non-wood products is affected by the availability of appropriate planning tools, and the public officers need a new mindset to stimulate and support the business capacity of forest owners.

**Keywords** - Forest, Food, Silviculture, Security, Safety

## Introduction

Up to 805 million people are undernourished worldwide (FAO, 2014) and malnutrition affects nearly every country on a global scale (IFPRI, 2014). As the world population was 7.2 billion in 2013 and is projected to reach over 9 billion by 2050 (Roberts, 2011), the demand for food, feed, fibre and energy will increase, while per-capita land availability will decline. Therefore, the issues of food security and nutrition are now strategical in policy debates. In 2012, the UN Secretary General proposed to eliminate global hunger by 2025 – the so-called "Zero Hunger Challenge". In parallel, interest in the role of forests and tree-based systems in complementing agricultural production has been rising (Vira et al. 2015).

Forests provide food for one billion people, e.g. by providing ≈20% of proteins in the diet in 62 countries (FAO, 2013). However, the forest-food nexus is complex with many and strong connections. Forests produce carbohydrates, proteins, fats, vitamins, fuels, medicinals, wood for construction, fencing and furniture, as well as essential ecosystem services such as water control and protection of biodiversity, soil, and quality of water and air. The intensity by which forests are managed affects forest structure (Vilén et al., 2012), soils (Jandl et al., 2007), biogeochemical cycles (Luyssaert et al., 2007), biodiversity (Paillet et al., 2010), and other ecosystem services provisioning (Gamfeldt et al., 2013). Growing demand for food, energy and land is increasing the pressure over forests. Loss and degradation of forests worsen food insecurity both directly – by affecting the availability of fruits, wildlife, mushrooms and other products of use in the food industry (tannins, cork, truffles, aromatic herbs, honey, etc.) – and indirectly – by modifying the factors that are important for crop and livestock production (van Noordwijk et al., 2014).

A recent Global Assessment Report prepared by the International Union of Forest Research Organizations (Vira et al. 2015) highlights that the complex processes linking tree products and services to food security and nutrition are currently not adequately incorporated into global and national strategies. Although the focus is mostly on those parts of the world that are characterized by extensive hunger

[1] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Forestry Research Centre (CREA-SEL, Arezzo, Italy)
[2] Consiglio Nazionale delle Ricerche, Institute for Sustainable Plant Protection (CNR-IPSP, Sesto Fiorentino, Italy)
*elena.paoletti@cnr.it

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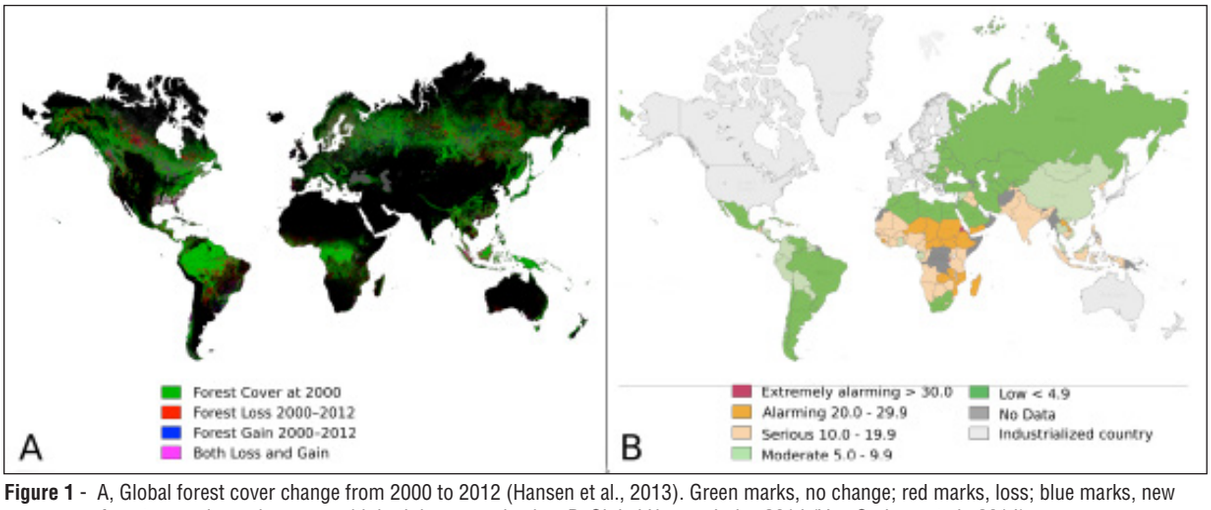


**Figure 1** - A, Global forest cover change from 2000 to 2012 (Hansen et al., 2013). Green marks, no change; red marks, loss; blue marks, new forests; purple marks, areas with both losses and gains. B, Global Hunger Index 2014 (Von Grebner et al., 2014).

and malnutrition, primarily in poorer nations and in the tropics (Figure 1), also the most industrialized countries can contribute to a sustainable use of their own forests for improving global food security.

After an in-depth commented discussion of recent scientific literature about forest contribution to food production and the main drivers of forest systems for food nutrition, this commentary addresses the state of the art in Italy as a country-case-study, that is representative of the situation in developed countries. The aim is to increase awareness about the potential of silviculture in Italy by means of a sustainable intensification of forest management for combining ecological resilience with economic resilience.

## How forests contribute to food production and nutrition

Non-wood and non-timber products (NWFP and NTFP) are defined as products of biological origin other than wood derived from forests, other wooded land and trees outside forests" (FAO 1999) and as "all biological materials other than timber which are extracted from forest for human use" (De Beer and McDermott 1989), respectively. Therefore NWFPs include animal products (bush meat, trophy, skin, fish, insects), soil (litter, clay, chalk, sand), fungi (mushroom, truffle, spawn), and plants (trees, shrubs, herbs, grasses), which are further subdivided into flowers and fruits (food, oil, spices, honey), leaves (forage, fodder), stem and bark (latex, gum, resin, fibre, dye, sap, cork, bark pieces), while NTFPs include also wood in forms of fuelwood, poles, derivatives (Vidale et al., 2015). All these products may have either a direct or an indirect use in the food industry.

Natural forests, agroforestry systems, single-species tree crop systems and orchards support food production and contribute to dietary diversity and quality. They are a vital source of food to millions of people on the planet, although this service is not well recognized yet. Around one out of every six persons in the world directly depends on forests, with food being one essential aspect of this dependence (Agrawal et al., 2013; Vira et al. 2015).

Much attention is nowadays on agroforestry systems that involve the cultivation and management of trees and/or shrubs for food and/or non-food values (such as soil conservation or providing shelter for crops), generally in combination with agricultural crops. A geospatial analysis by Zomer et al. (2014) estimated extent and recent changes in agroforestry practices at a global scale, based on remote sensing-derived global datasets of land use, tree cover and population: agroforestry systems (defined in this study as agricultural lands with > 10 % tree cover) were 43 % (over 1 billion ha) of global agricultural land in 2010. Globally, the amount of tree cover on agricultural land increased substantially between 2000 and 2010, with the agroforestry area increasing by 3 % (+82.8 million ha). The proportions of agroforestry lands and of people living in these landscapes in Europe were 45 and 46 %, respectively, that basically correspond to the averages at world level.

All forest-based systems represent a steady supply of fruits, vegetables, seeds, nuts, oils, roots, fungi, herbs and animal protein. For instance, around 50 % of the fruit consumed globally comes from trees (Powell et al., 2013): most of these fruits are from fully-domesticated, cultivated sources, but native forests are important genetic resources for the improvement of planted stock (Dawson et al., 2014). A limited number of plant species (20-30) is nowadays used in conventional agriculture all over the world (Ducci et al., 2015), while natural forests and agroforestry systems often harbour high biodiversity and can deliver a wide array of tree foods. As

an example, Mediterranean forests include 25,000 plant species (Myers et al., 2000).

Wild meat, fish and insects are other important food sources from forest systems. In Europe, wild ungulate populations of roe deer, red deer, wild boar and alpine chamois have been expanding in recent years (Ramanzin et al., 2010). At present, there are 20 ungulate species in Europe, with an estimated total number of 18 millions heads and a total biomass of about 770 000 tons (Apollonio et al., 2010). The growth of ungulates in many areas has turned into overabundance, originating conflicts with human activities and biodiversity. Marketing of meat from hunted wild ungulates is already a practice in various European countries (Winkelmayer and Paulsen, 2008), and has been proposed as a way of counteracting overabundance (Thogmartin, 2006). Game meat production as alone was estimated over 23,000 tons in EU-28, corresponding to a total value of above 321 M € (FOREST EUROPE 2015). Safety requirements of game meats have been addressed by Regulations (EC) No. 853/2004, 854/2004 and 178/2002. The value of fish as a nutritious food is well established (Kawarazuka and Béné, 2011). In many tropical forests, wild fish represents the main source of animal protein in the diet (daSilva and Begossi, 2009). The importance of insects as a source of food and livestock feed has recently gained momentum (FAO, 2013). Insects are a cheap, available source of proteins, fats, and, to a lesser degree, carbohydrates. Some species are also considered good sources of vitamins and minerals (FAO, 2013; Schabel, 2010).

Trees also provide fodder, green fertiliser and fuel that are essential to food production. Animal fodder enables communities to keep livestock that provides them with nutritionally important products, such as milk and meat. Trees also provide green manure that replenishes soil fertility and supports crop production (Jamnadass et al., 2013). Many forest products are also used in ethnoveterinary treatments that support animal health and hence human food production (Dharani et al., 2014).

In developing countries, 2.4 billion households still use conventional biofuels for cooking and heating. Firewood is the most important rural domestic biofuel in the world, and is expected to further increase (IEA, 2006).

Forest products are also an important source of revenue, which can contribute to food supply. A multitude of NTFPs harvested from natural and cultivated forests and woodlands provide a range of resources that are used directly, or are sold for income that can be used to purchase a variety of products, including food. As NWFP consumption is rarely reported by the national statistical agencies, an estimation of their economic value is complex.

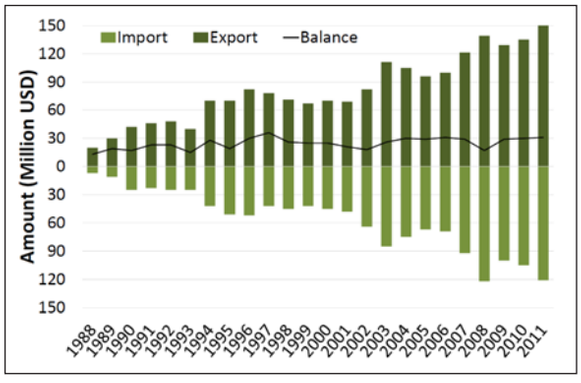


**Figure 2 -** EU-World trade balance for non-wood forest products (Vidale et al., 2015).

According to UN (2000) and FAO (2010), however, the market in Europe is rising, as it totaled 1.10 billion € in 1995 and 4.53 billion € in 2005. Both import and export of European NWFPs have been considerably increasing in the last 25 years, with a net balance of more than 30 million USD in 2011 (Figure 2). When there is availability but relatively low NTFP food use in areas of dietary need, reasons can include high labour costs, low yields, high phenotypic variability (with large proportions of non-preferred products), and lack of knowledge on appropriate tree management (Jamnadass et al., 2011).

Apart from these direct roles, forests provide ecosystem services which underpin the agricultural production and support the diversification of livelihoods. Forests, agroforests and, within certain conditions, plantations provide important ecosystem services, including water provision, soil protection, nutrient cycling, climate regulation, clean air and water, biodiversity conservation, and pollination, all of which are essential for crop production and ultimately affect food and nutritional security (Figure 3). Here below, we summarize the major links between food security and these forest ecosystem services.

Forests, woodlands and trees play a vital role in controlling water flows and in supplying farmers with water (Malmer et al., 2010). If rainfall does not provide sufficient water supply, households depend on sources of groundwater that are often found in or near the forest. Moreover, forests play a basic role in the quality of groundwater since they act as filters and remove pollution from water and air, with benefits for human and crop health. Trees also prevent soil erosion and nutrient leaching, both of which are critical functions for food production systems. At the same time, green manures and forest litter maintain and enhance soil fertility, supporting crop yields when external fertiliser inputs are not available (Garrity et al., 2010). Nitrogen-fixing trees have received considerable attention for their ability

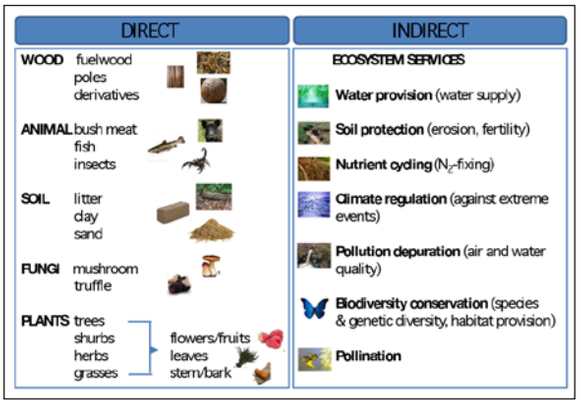


**Figure 3** - Effects of forest-based systems to support agricultural production.

to cycle atmospheric nitrogen in cropping systems (Sileshi et al., 2012). Climate regulation by trees can promote more resilient and productive food-cropping systems, such as through the provision of a canopy that protects crops from direct exposure to the sun, extreme rainfall events and high temperatures (Pramova et al., 2012). Forests are centres of plant and animal biodiversity, protecting species and their genetic variation, which may be essential for human food security (Dawson et al., 2014). Pollination is one of the most studied ecosystem services (Klein et al. 2007). A diversity of trees can support populations of pollinator species such as insects and birds (Garibaldi et al., 2013). In addition, forests provide important habitat for a range of other fauna that include the natural predators of crop pests, although forests may also host the crop pests themselves.

## Drivers of forests and tree-based systems for food security and nutrition

Interconnected environmental, social, economic and governance factors affecting forests and tree-based systems for food security and nutrition have been classified into the following major drivers: population growth, urbanisation, governance shifts, climate change, commercialization of agriculture, industrialisation of forest resources, gender imbalances, conflicts, formalisation of tenure rights, rising food prices and increasing per capita income (Kleinschmit et al. 2015).

The shift from forests and tree-based systems towards agriculture is among the many inter-related factors that continue to drive deforestation and forest degradation. Deforestation and forest degradation interact with food security and nutrition by affecting both the direct and indirect provision of goods and services. During the past decade, deforestation rates have decreased globally, while some countries are showing increasing rates of reforestation (Meyfroidt and Lambin, 2011). However, deforestation continues unabated in many parts of the world, and is in large part the result of agricultural expansion, cattle ranching (FAO, 2010), urbanization, and globalization of agricultural trade (De Fries et al., 2010). Recent trends show that agriculture is the biggest driver accounting for 73 % of deforestation worldwide, while mining accounts for 7 %, infrastructure for 10 % and urban expansion for 10 % (Hosonuma et al., 2012). Agri-businesses such as cattle ranching, soybean farming and oil palm plantations are now the most important drivers of forest loss globally (Boucher et al., 2011).

Further, an increasing proportion of the world forests have been degraded both structurally and functionally. Forest degradation is the long-term decline in forest ecosystem function and productivity caused by disturbances from which land cannot recover without human intervention. Land degradation currently affects hundreds of millions of hectares of agricultural lands and forests, and an estimated 1.5 billion people who live in these landscapes (Zomer et al., 2009). Land degradation is the long-term result primarily of poor agricultural management, associated with the expansion of extensive and intensive agricultural production practices into lands that are only marginally suitable for such activities. Without adequate organic or fossil fuel-derived fertilisers or other agricultural inputs (e.g. irrigation, pesticides, etc.), agricultural productivity typically declines in such areas. The drivers of forest degradation include unsustainable forest management for timber, fuelwood, wildlife and other NTFPs, air pollution, and human-induced fires, exacerbated in many regions by a number of factors, including climate change (Chazdon, 2014) and changing rural demographics (Uriarte et al., 2012).

As already stressed, deforestation and forest degradation interact with food security and nutrition. For instance, they affect forest carbon stocks and have implications for the governance and local use of forests (Phelps et al., 2010). Studies have shown that there is a direct relationship between tree cover, tree species diversity and food security especially of vulnerable groups (van Noordwijk et al., 2014). Changes in the extent and type of forests have implications for food provisioning, and for food security and nutrition of local and distant human populations (Sunderland et al., 2015). Habitat loss, largely driven by agricultural expansion, has been identified as the single largest threat to biodiversity worldwide (Newbold et al., 2014). Agricultural activities are intensifying, particularly in the tropics (Shackelford et al., 2015). The tropics host the majority of biodiversity-rich areas on the planet.

Consequently tropical land is increasingly subject to competing claims (Giller et al., 2008). A range of concepts and frameworks for implementation are now being discussed which aim to consider land-use change in forested landscapes in such a way that competing demands for food, commodities and forest services may be, hopefully, reconciled (Pirard and Treyer, 2010).

In a world characterized by increasing resource and land scarcity, the traditional conflicts between farming and foresting are aggravated by the increased demands for land to allow for the expansion of urban settlements, industrial development and resource extraction. Under such increasing pressures, hard choices have to be made about land and forest management. Sustainable multi-functional integrated landscape approaches aim at balancing livelihood security and nutritional needs of people with other land management goals (Vira et al. 2015). The contribution of forests to these approaches is of high significance for the implementation of existing international commitments. Forests and tree-based systems are embedded within a mosaic of food production systems and other land uses. An integrated governance is thus needed for securing these multi-functional landscapes.

Present pressures on forests, including climate change, population growth, urbanisation, deforestation, are often interrelated. Thus, designing appropriate responses requires multiple, nested-scales approaches. Managing resilient and climate-smart landscapes on a multi-functional basis that combines food production, biodiversity conservation, other land uses and the overall maintenance of ecosystem services should be at the forefront of efforts to achieve global food security (Vira et al. 2015). Applying an integrated landscape approach provides a unique opportunity for forestry and agriculture to coordinate efforts. Not all tree commodities are, however, amenable to production in diversified systems; for example, oil palm is not well suited (Donald, 2004).

Greater attention from the scientific and policy communities is required for reimagining forests for food security. In particular, a supportive policy framework needs to be developed that considers both the forestry and agriculture sectors in tandem. A better quantification of the benefits received by rural communities from different tree production categories is required (de Foresta et al., 2013): in many tropical countries, laws for timber extraction were largely designed around large-scale export-oriented forestry operations rather than to sustain healthy small-scale domestic markets (Cerutti et al., 2013).

## Non-wood forest products in Italy

FOREST EUROPE (2015) estimated that a marketed value of around 2.3 billion €/year is provided by plant (73%) and animal (27%) products from European forests, but the statistics may be incomplete. With respect to the total, 1.7 billion €/year is from plant products (73%), with the main part represented by decorative and ornamental plants (47%), while the value of animal products is around 0.6 billion €/year, mainly due to wild meat (51%) and wild honey (45%). Overall, NWFPs trade is increasing in Europe (Figure 4), where raw NWFPs account for ~20% of timber trade (Vidale et al., 2015). Italy is first in Europe as ratio of annual NWFP value to annual value of industrial roundwood (Figure 4).

Recent results from the COST Action StarTree (Vidale et al., 2015) show that Italy is among the four top European exporters of cork stoppers, is one of the three top countries for chestnut seed processing, and is among the leading exporters of wild mushroom, while it is the only European country among the top five global importers of tannins.

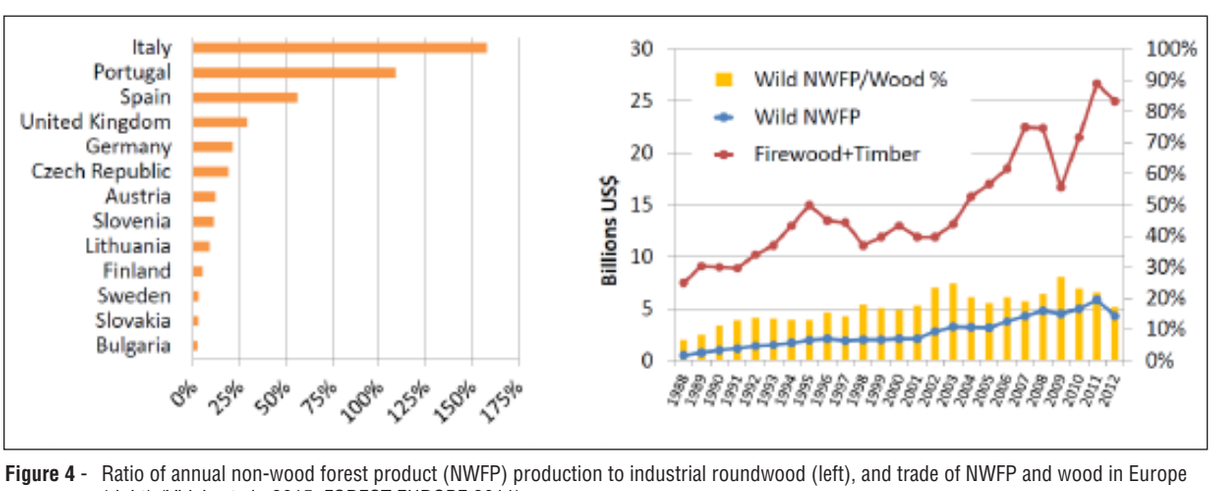


**Figure 4** - Ratio of annual non-wood forest product (NWFP) production to industrial roundwood (left), and trade of NWFP and wood in Europe (right) (Vidale et al., 2015; FOREST EUROPE 2011).

The annual value of marketed NWFP in Italy is estimated around 100 M €, but the statistics may be largely incomplete (FOREST EUROPE, 2015). Among NWFPs, food products are also relatively relevant. For instance, Italy is the second largest European chestnut (*Castanea sativa*) producer for fresh and dry products and flour; walnut (*Juglans regia*) production is 10,500 tons per year (Ducci et al. 2015). The market for pine (*Pinus pinea* and *Pinus cembra*) fruits in shell represents over 208,000 tons per year, 80 % absorbed by the industry. Collecting mushrooms and truffles has considerable importance in the economy of rural mountainous and hilly areas: reliable statistics are not available for mushrooms while Italy is the 3rd European producer of truffles, with a turnover of over 19 M €/year (Ducci et al., 2015).

Game meat market trend observed at European level is similar even in Italy, where the increase of total forest coverage and a cautious approach in forest harvesting have enhanced the expansion of ungulates. This trend involved mainly roe deer (*Capreolus capreolus* L.), wild boar (*Sus scrofa* L.) and red deer (*Cervus elaphus* L.), whose populations are estimated to be over 400,000, 1,000,000 and 65,000 heads, respectively, with increasing pressure on agricultural crops and forests in many areas (Chianucci et al., 2013). Roe deer, wild boar and red deer represents over 80% of total ungulates biomass and contribute to the market of wild meat with important economic revenues, which are estimated around 25 M €/year just for Tuscany, a region in Central Italy (Cutini et al., 2015).

The Italian trade of honey is estimated in 38 M €: transhumance of hives to the woods affects honey quality and organoleptic traits determined by the forest species that provide pollen and nectar. Another important example of high value production at local level is that of *manna*, a natural product, at high content of mannithol harvested by the incision of the bark from two species of Ash (*Fraxinus* spp) trees: Italy is the first world producer of manna, with 3200 kg per year (Ducci et al., 2015).

## Grounds for intensifying silviculture and food products from forests in Italy

Albeit trade-offs between wood and NWFPs cannot be excluded as it is often the case in developing countries (Chakravarty et al., 2015), in Italy an effective joint impulse for exploitation of wood and NWFPs may come from a sustainable intensification of forest management, with a reasonable increase of the marketed NWFPs too: currently these products are, in many cases, excluded from the market and fostering payments for them would encourage landowners to sustainably manage their forests on the whole (Prokofieva et al., 2012).

Chain-supply fragmentation, ownership fragmentation (Paletto et al., 2013), landowner inertia, and lack of governance and cooperation may hamper an effective exploitation of food products from Italian forests. However, these issues impact all the product chains from forestry in Italy. Generally, the increase of forest service demand and the gradual abandonment of mountainous land have caused a decrease of forestry and significant changes in land management. Only in the case of coppice, wood production has remained relatively high. The wood harvesting rate of Italian forests is ~14 $Mm^3$/yr, i.e. 1.5 $m^3$/ha yr (Gasparini and Tabacchi, 2011) and is among the lowest rates in Europe. As a consequence, also the mean value of marketed roundwood (74 €/ha) is much lower than in the neighbouring countries (FOREST EUROPE, 2015). In contrast, the current increment of wood volume is around 36 $Mm^3$/yr (Gasparini and Tabacchi, 2011), and thus the harvesting rate (≈40 %) is largely lower than in the EU-28 and Europe (71 % and 66 %, respectively, FOREST EUROPE, 2015).

To develop Italy's forest sustainability and resilience and favour forest bioeconomy, an intensification of forest management is the possible solution to the conundrum that increasing demand for conservation areas and increasing pressure for good production have created, similarly to what is happening in Europe (Carnus et al., 2012) and other world areas (e.g. Canada, Mathey et al., 2008). An improved awareness of policy makers and the general public may translate these unexploited Italian forest assets into employment (e.g. a gradual and sustainable increase of the wood harvesting rate up to a sustainable threshold of 20-21 $Mm^3$/y would translate into ~35,000 new jobs) and gross domestic product.

Developing measures targeted at increasing wood and non-wood supply from forests requires policy decisions and expert knowledge. A forest management map of European forests has been recently developed (Hengeveld et al., 2012): approaches of this kind may greatly help in selecting the areas suitable for intensification. Moreover, the implementation of sustainable forest management for an effective supply of wood and non-wood products is conditioned by an appropriate use of planning tools, and the public officers need to develop a new mindset for stimulating and supporting the business capacity of forest owners.

As concerns distinctively the NWFPs, it should be stressed that they can be effectively exploited under the broader perspective of territorial marketing (Pettenella and Secco, 2006): well known

success cases are those of the Road of Porcino mushroom (http://www.stradadelfungo.it) and the Road of Truffle and Chestnut (http://www.tartufoecastagna.it). Under such a perspective, the strategies to guarantee an effective supply of NWFPs require appropriate business skills and the presence of structured business services. A transparent market is also essential: the introduction of standards (such as grading rules and forest certification schemes) is important since they can also add value to products and services, and emphasize the importance and complexity of the forest sector.

## Conclusions

Policy processes towards a bio-based economy should seek to produce decisions that are evidence-based (Corona, 2014). Contextually, the use of scientific knowledge to support evidence-based decisions requires suitable communication of figures and key findings: this paper has been targeted to contribute to this end.

The adoption of large-scale industrial agriculture has resulted in negative impacts on the environment (Cassman, 2012), public health (Bandara et al., 2010) and even nutrition (Ellis et al., 2015), suggesting the paradigm itself needs to be challenged (Tilman and Clark, 2014). This approach was appropriate to the context of the 1960s and 1970s, when water and nutrients were abundant, energy was cheap, and ecosystems were able to detoxify pollutants. The global context today is very different with growing scarcity of cheap energy (Day et al., 2009), water (Wallace, 2000) and nutrients (e.g. phosphorus, Cordell et al., 2009).

The development of crop agriculture and animal husbandry over the past few centuries, and particularly since the early 20th century, has diminished dependence on forests for food security and nutrition in many societies. Nonetheless, forests continue to play a very important role, often complementing other food production systems, and, on a global level, can contribute to the "Zero Hunger Challenge" (Vira et al. 2015). While forests are not a solution for global hunger in themselves, in many circumstances they play a vital supplementary role, especially during periods of unpredictability (such as long drought spells), as they complement conventional staple diets derived from agricultural production systems. To do this efficiently, an improved knowledge of the most effective management of landscapes and the role of forests in the provision of nutritious diets is required.

Evolving strategies to respond to the "Zero Hunger Challenge" primarily focus on achieving a sustainable intensification, by improving the productivity of agricultural and forest systems without causing ecological harm or compromising biodiversity and other ecosystem services (FAO, 2011; Garnett et al., 2013). Paradigms for forest and tree management have evolved considerably in the last 50 years, away from a state-controlled, production-centric approach to more collaborative systems which prioritise the needs of local people, and value the provision of ecosystem services (Mace, 2014). Landscapes are now managed for a much more diverse (often non-local) set of purposes (Ribot et al., 2006). It is time to develop a vision where economic resilience is joint with ecological resilience towards actual sustainability.

Managing landscapes on a multi-functional basis that combines local and global scales, food production, forest conservation and the maintenance of ecosystem services will help to achieve food security (Godfray, 2011). This provides a unique opportunity for silviculture and agriculture to coordinate efforts at the conceptual and implementation levels and achieve more sustainable systems.

Italian forests are well suited for a sustainable intensification of forest management, i.e. for suitably increasing the intensity of forest harvesting while maximizing the provision of forest ecosystem services and products. Ultimately, national production of wood and non-wood goods, including food products, may reduce the pressure on global forests, in particular in the areas at higher risk of deforestation and hunger.

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