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The evolution in time of the concept of fast growing tree species: is it possible to use a definition applicable to all environmental conditions?

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ABSTRACT Although the expression "fast-growing species" (FGS) referred to tree species has been since long time used, a clear definition has not been adopted for decades. Starting from the Italian historical background, we searched for the definitions of FGS formulated over time at a national and international level. The mean annual increment (MAI) of 10 m^3 ha^{-1}, identified by the FAO, has been the most commonly considered threshold until recently. Subsequently, experimental activities and research efforts have consistently enhanced the productivity of FGS, and other definitions have been proposed accordingly. Hence, FGS should provide annual wood yields of 15-25 m^3 ha^{-1} with rotations of less than 25-30 years. In Europe, the maximum MAI can reach about 20-25 m^3 ha^{-1}, while in fast-growing tropical plantations the MAI frequently exceeds 30-35 m^3 ha^{-1}. However, we deem that the threshold of 10 m^3 ha^{-1} $year^{-1}$ is still reliable for Mediterranean conditions. Since the fast-growing is a relative concept, strongly affected by species' traits, environmental conditions and cultural practices, a future increase in the productivity levels of wood plantations can be expected.

KEYWORDS: wood plantations, mean annual increment, short rotation forestry, wood and timber production.

Foreword and aims

The expression "fast growing species" (FGS), referred to tree species, has been widely and for a long time used in forestry and agroforestry fields, but no clear definition has been formulated before the 1960s. The need to define FGS, and to identify productivity thresholds, appeared to be especially felt after the large-scale establishment of wood plantations in developing countries, pursuing the main aim to provide as much wood as possible in a short time (FAO 1965). Since the 1960s onwards, widespread afforestation and reforestation programs have characterized many countries all around the world, under the essential promoting role played by the Food and Agriculture Organization of the United Nations (FAO) (Cossalter and Pye-Smith 2003, Overbeek et al. 2012). The use of FGS could significantly shorten the rotation cycles, thus allowing to reach the same wood yield with lower production costs (e.g. reducing the needed area), and consequently producing higher income. The possibility of increasing wood production in dedicated plantations has also been considered as a way to reduce the exploitation and pressure exerted on natural forests and hence deforestation, although significant social and environmental implications come into play (Cossalter and Pye-Smith 2003, de Oliveira Garcia et al. 2018). For instance, it should be kept in mind that the widespread use of exotic plants in short rotation systems could represent a serious threat for biodiversity conservation and ecological networks of surrounding native ecosystems, when invasive species are employed (Bianco et al. 2014, Badalamenti et al. 2018 a,b). In the last decades, the use of tree species, clones, and hybrids with fast-growing traits has been strongly tied to the development of intensive production systems, collectively referred to as Short Rotation Forestry (SRF), which have progressively assumed well defined cultural modules, cultivation techniques and productivity levels. Within the scope of the SRF, the earliest experimentations were closely linked to the pulp and paper industry, while the energy crisis of the 1970s pushed towards the search for alternative energy sources (including woody biomass), especially the Northern European countries (Mitchell et al. 1999, Facciotto 2012, Lindegaard et al. 2016). More recently, fast-growing species and plantations have been thought to play an important role among the overall strategies aimed at mitigating climate change, favouring the progressive shift from a fossil fuels economy to a bio-based economy (van Dam et al. 2005, Corona 2014, Bennich and Belyazid 2017). In this perspective, the energy demands should be mostly met by renewable energy sources (RES), among which wood is considered one of the most important and with higher potential for future exploitation (Di Candilo and Facciotto 2012, Bredemeier et al. 2015, Scarlat et al. 2015). Indeed, such cultivation systems (SRF) can be considered in national carbon balances and they could help to accomplish the bioenergy goals in Europe and to fulfill the obligations deriving from international commitments to combat climate change, starting from the Kyoto Protocol (1997) (Ciccarese et al. 2014, Dimitriou and Rutz 2015, Njakou Djomo et al. 2015). As wood is the first source of renewable energy in Europe (FAO and Plan Bleu 2018), forestry and agroforestry systems addressed to biomass production

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may provide a substantial contribution to reach the European 20-20-20 energy targets (European Directive 2009/28/EC) (e.g. RES should account for 20% of energy needs). For the potentiality to fulfill both environmental and socio-economic needs, the area covered by fast-growing plantations (FGPs) has significantly increased in the last decades, reaching 10 million hectares worldwide, and with an estimated average pace of increase of 1 million hectares per year (Cossalter and Pye-Smith 2003). More recently, it is estimated that industrial FGPs could cover about 54.3 million hectares worldwide, accounting for 1.3% of total forest area; furthermore, they are likely to double by 2050 (FSC 2012). Despite the growing interest in this topic, a review of the concept of FGS has not been carried out up to now. After providing a historical overview of the Italian background, we searched for the definitions of FGS adopted over time at a national and international level. Being strictly linked to the definition, we also provided a brief account of the variation in productivity of wood plantations over time, also identifying the main factors affecting fast-growing traits in tree species.

Materials and Methods

Firstly, to assess the use over time of fast growing-related terms, the expressions "fast growing tree/s", "fast growing tree species" and "fast growing plantation/s" were searched within the Scopus database

(https://www.scopus.com/search/form.uri?zone=TopNavBar&origin=resultslist&display=basic),

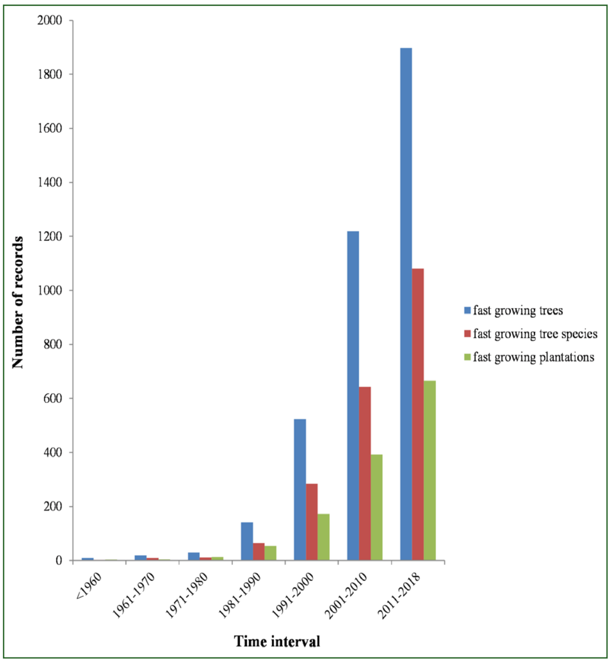
which provides a quite long years coverage (about 100 years) on solid scientific basis. Then, we carried out bibliographic research looking for the definitions of fast-growing tree species adopted by the scientific community over time. For this scope, Italian journals (e.g. Annali della Sperimentazione Agraria, Annali dell'Istituto Sperimentale per la Selvicoltura, Cellulosa, Cellulosa e Carta, l'Alpe, l'Italia Agricola, l'Italia Forestale e Montana, Monti e Boschi), books and reports about forest plantations, as well as international reports published by the FAO and by other international organizations, have been consulted. Most of the national literature uses the phytoclimatic classification by Pavari (1916), which, conversely, is very rarely used at an international level. For ease of understanding, it should be considered that the Lauretum by Pavari basically corresponds to the thermo-Mediterranean bioclimatic belt (Rivas-Martinez 1996), which encompasses all the vegetation aspects dominated by evergreen sclerophyllous woody species, such as the Mediterranean maquis and forests, with *Quercus ilex* L. as dominant tree species (Gianguzzi et al. 2016). Rising in altitude, the Castanetum by Pavari mostly corresponds to the meso-Mediterranean bioclimatic belt (Rivas-Martinez 1996), and it is dominated by deciduous oaks, primarily *Quercus pubescens* Willd s.l., but also including notable hardwood species such as ash trees, chestnuts, and maples. Some Italian sentences coming from literature reported in the manuscript are preceded by the abbreviation o.t., meaning our translation.

Results

The use of terms related to fast-growing concept over time

Within the Scopus database, "fast growing tree/s", "fast growing tree species" and "fast growing plantation/s" were found 3,840, 2,095 and 1,305 times, respectively. Despite this large difference in the total number of records, the three expressions showed a very similar increasing trend (Fig. 1). Considering the effective historical distribution of the surveyed terms, we subdivided the overall time frame (1919-2018) into seven intervals (< 1960, 1961-1970, 1971-1980, and so forth). Overall, only 0.1-0.2% of total records belonged to years before 1960, and less than 1% to the years before 1980. Even in the following decade (1981-1990), the records registered only a small increase, not even reaching 5% of total records. A strong increase was observed in the following two decades (1991-2000 and 2001-2010), which accounted for about 13% and about 30-31% of total records, respectively. Finally, about half (49-51%) of total records dated back to the last 8 years.

Figure 1 - A bar chart showing the progressive use over time of "fast growing trees" (in blue), "fast growing tree species" (in red), and "fast growing plantations" (in green) within the Scopus database (1919-2018).



The concept of fast-growing species: the Italian historical background

In Italy, the expression "fast-growing species" (FGS), referred to tree species, dates back to the beginning of the last century (Pavari 1916), whereas a clear definition was not formulated just as soon. The evolution of the concept of FGS in Italy is strongly linked to the massive experimentation with exotic forest species started about one century ago by the pioneer researcher Aldo Pavari (1916). The first experimental parcels were established in 1922, after the foundation of the "Reale Stazione Sperimentale di Selvicoltura di Firenze" (Royal Experimental Station of Silviculture in Florence). In the following years, hundreds of forest parcels were spread all over the national territory, giving rise to a broad and widespread program for the use of exotic forest species (Ciancio et al. 1981-1982). The main objective of the experimentation was to increase the Italian wood production, by (o.t.) "*greatly increasing in a given climate zone, in a given region, in a given site, the number of species among which the choice can be made, thus preferring those species which, in such conditions, hold the greatest technical, cultural and economic values and therefore represent the best production tool*" (Pavari 1916). It was highly felt the need to increase the economic value of forests and wood products, and the main shortage in the Italian forest heritage was in the fast-growing conifers, especially in the thermophilous phytoclimatic zones of the Lauretum and Castanetum (Pavari 1937, 1940, Giordano 1970). Hence, the fast growth was one of the most important characteristics to be considered for the target species. Indeed, (o.t.) "*To increase the income of our forests it is necessary to increase the wood production in the unit of time, so as to significantly shorten the current rotations, it is necessary to produce timber and therefore replace unprofitable coppices with fast-growing plantations*" (Pavari 1916). The fast growing-traits have maintained a high consideration over time in Italy. During the last century, many subsequent authors emphasized the higher need, for the Italian wood sector, to produce in a shorter time a higher amount of less-valuable timber rather than producing in a much longer time a lower amount of high-quality timber (Pavari 1916, Pavari and de Philippis 1941, Allegri 1962, Giordano 1970).

A problem of definition

The expression "fast-growing species" (FGS) has been used in forestry research at least since the beginning of the last century. For instance, a paper in the form of "Science news", entitled "*Fast-growing trees for paper*", reported early information about promising poplar hybrids with fast-growth in the United States (Anonymous 1927). However, there has not been an explicit definition for decades. Overall, we found only five explicit definitions of FGS (Table 1). The global spread of wood plantations pushed the FAO (1965) to formulate one of the most commonly used definitions: "*Fast-growing species are considered as those capable of a mean annual increment of at least 10 cubic meters per hectare under favorable site conditions and providing appropriate techniques are used for ground preparation and for the establishment, care and tending of the plantations*". It was soon clear the importance of the mean annual increment (MAI) to assess the productivity of tree species. Such definition has likely prompted the Italian forest researchers to debate about the most appropriate definition of FGS, also taking into account the specific conditions of the national forests. According to Morandini (1976), a comparative criterion should have been prevalent, and a FGS is (o.t.): "*...a species which, introduced in a given environment, is capable of providing, in shorter rotation periods, wood productions much higher than those of the pre-existing plantations*". However, recognizing the importance of assessing the potential wood production in a given site, de Philippis (1980) emphasized the need to identify a threshold, whereby (o.t.) "*the significance of fast growth must be considered in a relative sense, i.e. comparing the species that can be cultivated in a given locality, and in an absolute sense, with reference to a minimum threshold of annual increment in the woody biomass*". In the same years, Ciancio et al. (1980) formulated a more precise definition (o.t.): "*the concept of fast growth cannot be rigid, neither so elastic as to be practically emptied of content. Nor can it be confused, as some are often tempted to do, the fast growth with the level of wood production at the end of the rotation period, regardless of the duration of this...it can be considered as fast-growing a species whose mean increment, under conditions of average fertility, may exceed 10 m^3 per hectare per year at the age of 20-25 years... but not if a species reaches such levels of production at the age of 40-50 years*". Other definitions of FGS have been proposed much more recently, following the progressive intensification of cultivation systems of woody species and the related enhancement of productivity of plantations. Such intensive systems, collectively referred to as Short-Rotation Forestry (SRF), are progressively spreading in the last decades (Calfapietra et al. 2010). The SRF is the reversible cultivation of FGS, established on land with potential agricultural use, with high density (from 1,000 to 16,000 individuals ha^{-1}), and very short rotation periods (1-6 years) (Facciotto 2012, Mosiej et al. 2012, Stajić 2016, Rödl 2017). The cultivation techniques are similar to those used for agricultural crops, including the mechanization of most of the cultural operations (Buresti Lattes and Mori 2005, Scarascia-Mugnozza et al. 2007, Bisoffi et al. 2009).

According to other authors, the definition of SRF would be broader, including all the wood plantations with FGS with rotations shorter than 20-30 years (Dallemand et al. 2008). The expression Short Rotation Coppice (SRC), by contrast, would indicate more intensive cultivation systems, mostly targeted to energy production and characterized by very short rotation periods (2-4 years) (Dallemand et al. 2008, Leek 2010, Bianco et al. 2014). The terms Short Rotation Woody Crops (SRWC) and Short Rotation Plantations (SRPs) are also commonly used, generally including both SRF and SRC productive systems (Calfapietra et al. 2010, Stajić 2016). Such cultivation systems have almost doubled their cover in Europe in the last decade, from about 30,000 hectares in 2010 (Leek 2010), to the current estimates of about 50,000-60,000 hectares (Lindegaard et al. 2016, Mola-Yudego et al. 2017). Furthermore, they are likely to spread further in the next decades to meet the growing demand for wood and wood products for energy purposes (Leek 2010, Dimitriou and Rutz 2015). The progressive intensification of the cultivation modu–les, and the considerable activity of genetic improvement, selection, and breeding, to identify the most suitable species, hybrids and clones for productive purposes, have significantly increased the productivity of FGS. For instance, the standing volume of *Pinus radiata* D. Don plantations in New Zealand has increased up to 25% with the sole contribution of genetic improvement (Kimberley et al. 2015). Such research progress has caused the progressive increase of the suggested minimum threshold of wood production to identify FGS. According to Cossalter and Pye-Smith (2003): "*Fast-wood plantations...are intensively managed commercial plantations...which produce industrial round wood at high growth rates (mean annual increment of no less than 15 m^3 per hectare) and which are harvested in less than 20-year rotation*". Subsequently, Christersson and Verma (2006) hypothesized a threshold of 25 m^3 ha^{-1} in less than 30 years rotations, which, however, appears to be high in the European context. For instance, the average annual productivity of SRF, in 1-10 years rotations, in 25 European countries was found to be 17.8 m^3 ha^{-1} (Mola-Yudego et al. 2017). Higher values were reached by intensive systems with hybrid poplars in North Europe, where the maximum annual production may range from 21 m^3 ha^{-1} to 26 m^3 ha^{-1} in rotations of 16 and 23 years, respectively (Tullus et al. 2012). Very high productivity was recorded in some *Pinus radiata* arboriculture plantings in South Italy, with MAI exceeding 20 m^3 ha^{-1} after 20 years (Arcidiaco et al. 2005, Ciancio et al. 2006). An analysis about the most suitable and productive fast-growing tree species for Mediterranean Italy can be found in Badalamenti et al. (2020). Much higher is the productivity of tropical and sub-tropical plantations, where the best ecological conditions for plant growth are found; MAIs of 30-40 m^3 ha^{-1} are usually reached in 5-20 years rotations, mostly by eucalypts and leguminous trees like Acacias (Cossalter and Pye-Smith 2003, Overbeek et al. 2012). Reflecting the increasing role attributed to FGPs in the framework of the mitigation strategies to combat climate change, to exploit wood as energy renewable source, the productivity of wood plantations is increasingly assessed in terms of aboveground dry biomass. One of the most considered reference thresholds is 10 Mg of dry matter per hectare per year, reached by FGPs with rotations less than 30 years (Christersson and Verma 2006), but with generally more intensive productive cycles (1-5 years) (Scarascia-Mugnozza et al. 2007). A notable increase in the productivity of FGPs has been recorded in the last 20-25 years, following intense research efforts and experimental activities, especially for what concerns poplars (*Populus* spp.) and willows (*Salix* spp.) in the Northern hemisphere (Stanton et al. 2002, Larocque et al. 2013, Sabatti et al. 2014). Both genera, including many hybrids and clones with fast-growing traits, have been subject to massive experimentation, both in small field trials and larger commercial stands (Hauk et al. 2015), reaching very high wood yields. The average productivity in SRF plantations from seven countries in the world ranged from 2.2 to 13.5 Mg ha^{-1} year^{-1} at the end of the last century, considering three different tree genera (*Alnus*, *Populus* and *Salix*) in 12 possible cutting cycles (Mitchell 1995). Currently, the estimated range for poplar and willow plantations in 25 European countries, in 1-10 years rotations, is between 2.9 and 17 Mg ha^{-1} year^{-1} (Mola-Yudego et al. 2017). However, in the optimal matches site-poplar clone in Europe, in 2-4 years rotations, the maximum annual yield has also arrived in the range of 30-40 Mg ha^{-1} (Paris et al. 2011, Allwright and Taylor 2016). Italy was by sure a leader country in the experimentation with poplar genotypes and has a long and solid tradition about that (Facciotto 2012). The annual biomass production has increased from 6-10 Mg ha^{-1} in the 1990s with traditional clones in biennial rotations, to 10-15 Mg ha^{-1} with the first selected clones for the market in biennial rotations, up to 15-20 Mg ha^{-1} and beyond with the experimental and commercial plantations established on fertile soils with the last clones in 5-years rotations (Facciotto and Bergante 2011). Under Mediterranean conditions, the eucalypts are probably the tree species potentially reaching the higher growth rates. For instance, *Eucalyptus globulus* Labill. plantations in Spain reached 13 Mg ha^{-1} year^{-1} at 18 years old (Merino et al. 2005). In Southern Italy, a MAI of 12.1 m^3 ha^{-1} was reached in 20 years old eucalypt plantations in optimal cultural conditions (Arcidiaco et al. 2000). In Italy, extensive breeding programs, genetic improvement activities, individual selection and controlled crossings have been implemented in the 1990s to identify new high-yielding hybrids for short rotation coppices (Mughini et al. 2011, La Mantia 2013). Recent investigations provided promising results, with the best hybrid clones being able to reach 22 and 27 Mg ha^{-1} year^{1} with a three-year rotation period (Mughini et al. 2014). In order to show the considerable influence of environmental conditions in determining the maximum growth rate of tree species, we report the emblematic case of eucalypt plantations in Brazil, which may reach significantly higher values than those achieved in temperate or Mediterranean environments. The "Brazil Eucalyptus Potential Productivity" (BEPP) project was launched in 2001 and it was addressed to assess the potential growth rate of eucalypts in the absence of water or nutrient limitations. The BEPP project has found that fast-growing eucalypt plantations, with fully established trees at 1.5–6.0 years, could reach a potential productivity of about 38 Mg ha^{-1} year^{-1}, corresponding to a MAI of 77 m^{3} ha^{-1} (Stape et al. 2010). Furthermore, considering the optimal ecological conditions (only the 6-month wet season), the maximum potential productivity was estimated to even reach 42 Mg ha^{-1} year^{-1}, corresponding to a MAI of 83 m^{3} ha^{-1} (Stape et al. 2010). Although they are potential values, the effective field data are also significant: *Eucalyptus grandis* W. Hill ex Maiden and other eucalypt clones may reach, in 5-6 years rotations, annual yields up to 60-62 m^{3} ha^{-1} (Almeida et al. 2004a, Stape et al. 2010), while values of 40-46 m^{3} ha^{-1} with rotations of 5-7 years are considered ordinary in such intensive production systems (Almeida et al. 2004b, Stape et al. 2010). The production gap compared to the Mediterranean and temperate regions appears to be very marked. According to Gonçalves et al. (2004), the fast growing eucalypt plantations (in 5-7 years rotations) can be classified with "low productivity" if the annual wood production is less than 15 Mg ha^{-1}, with "average productivity" if they reach, on average, 20 Mg ha^{-1} and with "high productivity" if they exceed 30 Mg ha^{-1}. A similar ranking of wood production is considered for the *Eucalyptus globulus* plantings in South-western Australia (O' Connell et al. 2000). A very close link between wood production and soil water availability was found in eucalypt plantations both in Australia (O' Connell et al. 2000) and in Brazil (Stape et al. 2004, Ryan et al. 2010), where higher irrigation regimes ensured increases in productivity as much as 30% (Stape et al. 2010). With this regard, it is worth emphasizing that annual yields over 30 Mg ha^{-1} have been recorded in tropical FGPs since the end of the 1980s (Lugo et al. 1988, Parrotta 1999).

Table 1 - Summary of the definitions fast-growing species over time found in literature.

Year	Definition	Productivity threshold (m^{3} ha^{-1} year^{-1})	Productivity threshold (Mg ha^{-1} year^{-1})	Rotation period (year)	Reference
1965	*"Fast-growing species are considered as those capable of a mean annual increment of at least 10 cubic meters per hectare under favorable site conditions and providing appropriate techniques are used for ground preparation and for the establishment, care and tending of the plantations"*	10	-	-	FAO (1965)
1980	*"…it can be considered as fast-growing a species whose mean increment, under conditions of average fertility, may exceed 10 m^{3} per hectare per year at the age of 20-25 years...but not if a species reaches such levels of production at the age of 40-50 years"*	10	-	20-25	Ciancio et al. (1980)
2003	*"Fast-wood plantations...are intensively managed commercial plantations, set in blocks of a single species, which produce industrial round wood at high growth rates (mean annual increment of no less than 15 m^{3} per hectare) and which are harvested in less than 20-year rotation"*	15	-	< 20	Cossalter and Pye-Smith (2003)
2006	*"Short-rotation forestry is defined...as the silvicultural practice under which high-density, sustainable plantations of fast-growing tree species produce woody biomass on agricultural land or on fertile but degraded forest land. Trees are grown either as single stems or as coppice systems, with a rotation period of less than 30 years and with an annual woody production of at least 10 tonnes of dry matter or 25 m^{3} per hectare"*	25	10	< 30	Christersson and Verma (2006)
2012	*"Short rotation plantations usually have a rotation cycle ranging from 3 to 6 years, in some cases even 1-2 years. They involve fast growing tree species planted at very high density with up to 10,000 trees per hectare.....the annual yield of biomass produced could then be as high as 20 tonnes (Mg) of dry matter per ha per year, if the soil and moisture conditions are optimal, and appropriate fertilisers are used"*	-	20	3-6	Mosiej et al. (2012)

Conclusions

In an attempt to answer the initial question, i.e. when a tree species can be uniquely identified as fast growing, we carried out bibliographic research at a national and international level. We found large differences in the productivity between different biogeographical regions, proving that a univocal definition is neither convenient nor valid. In fact, the thresholds of productivity should be defined by the combination species/bioclimate/management, and it is difficult to find situations worldwide where the environmental homogeneity is such as to extend the forecasts of productivity for large areas. One benchmark value is the MAI of 10 m^3 ha^{-1} identified by the FAO (1965) for FGPs in developing countries. The same threshold was considered by Ciancio et al. (1980), and referred to a maximum age of 20-25 years. More recently, the concept of FGS has been linked to intensive cropping systems of woody species, collectively known as Short Rotation Forestry. The annual productivity is steadily and inexorably increased, up to 20-25 m^3 ha^{-1} in temperate Europe with a rotation period of less than 25 years, and up to 30-40 m^3 ha^{-1} (and beyond) in tropical plantations in 5-20 years rotations. Notwithstanding this, we believe that the "historical" MAI threshold of 10 m^3 ha^{-1} can still be considered valid under Mediterranean conditions. Moreover, in most of nutrient- and water-limited Mediterranean ecosystems, a threshold of 7-8 m^3 ha^{-1} $year^{-1}$ may represent the most likely upper limit for the productivity of the most suitable species. To assess and compare the productivity of wood plantations, we found that the parameter determining the least interpretation problems is the mean annual increment (MAI, expressed as m^3 ha^{-1} $year^{-1}$). Even the most recent data (Ugalde and Pérez 2001, Mead 2013), and numerous communications during international congresses (e.g. Nambiar 2008), confirm the current and wide use of the MAI. However, taking into account the possible role of SRF to mitigate the effects of climate change, being wood a renewable energy source, the aboveground dry biomass is increasingly considered. With this regard, the threshold of 10 Mg ha^{-1} $year^{-1}$ has been identified until recently, taking into account a rotation period of less than 30 years. In intensive cultivation systems (less than 6-years rotations), maximum annual biomass productions of 15-20 Mg ha^{-1} and 30-40 Mg ha^{-1} were reached in Europe and in tropical countries, respectively.

In conclusion, the fast growing has to be considered anything but a fixed or absolute trait for tree species. New taxa, hybrids, clones or genotypes more productive than the previous ones could be found, further enhancing the wood production levels. It could be enhanced the knowledge about the eco-physiological mechanisms underlying the resources use efficiency (Monclus et al. 2006), which affect the gross primary productivity and the resources partitioning towards wood structures, thus affecting wood production (Ryan et al. 2010). Therefore, the fast growing should be considered a relative trait which depends on the dynamic interaction of three main factors:

1. Genetic characteristics; they define the intrinsic potential of a given genotype to sustain high growth rates. Some tree species and genotypes are inherently faster growing than others (Ceulemans and Deraedt 1999, Bonhomme et al. 2008, Verlinden et al. 2015). These traits can be substantially improved through selection, breeding and genetic improvement (Kimberley et al. 2015, Allwright and Taylor 2016);
2. Environmental conditions; they include the total range of abiotic and biotic factors (temperature and rainfall regimes, soil characteristics, fungal symbionts, aspect, slope, ecc.) which significantly affect the availability of resources necessary for growth and hence wood production (Boosma and Hunter 1990, Ryan et al. 2010);
3. Management practices; they include the whole set of cultural practices, starting from the planting, through the tending operations (thinning, pruning, irrigation and fertilization treatments, weeding, ecc.), up to the final harvesting. Such conditions are imposed by man and represent the most adjustable component of the variation of wood production, having a strong influence on the resource use efficiency and availability, on the plant interspecific competition, as well as on the technological characteristics of wood (O'Connell et al. 2000, Diaconu et al. 2015).

Since to some extent these three main factors, both on a short-term and long-term perspective, may be modified by man, a further increase in the productivity levels of fast-growing plantations can be expected.

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