ENHANCEMENT OF TIMBER PRODUCTION

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Summary

Considering the wide distribution of chestnut trees throughout Europe (including outside EU countries, from Portugal to Georgia and Azerbaijan), and the high density of forest (France and Italy count together up to 14.000 km² of chestnut forests), chestnut timber production proves to be a very good opportunity for all the Countries where it grows naturally.

The use of the wood of sweet chestnut tree is potentially unlimited: from the smallest objects (hedges, "ganivelles" - boards for wind barrier -, barrels, ...) up to biggest (public buildings, structural beams, …). The content and high quality of the tannin allows outdoor and indoor uses. The chestnut wood can be used in very modern applications: part of modern furniture, laminated wood frames, solid wood panels, jewels, shingle, "bardage" (exterior wall cladding), houses of the future...

The sweet chestnut is a sustainable tree and a very interesting species for the social-environmental change in the future. Its strong growth (until 24 m³/ha/year the strongest after the poplar), allows it to store more CO2 than numerous indigenous species as e.g. the oak and the beech.

But all this potential is strongly limited by the lack of silviculture, the risks of climatic changes, the absence of high quality genetic material resistant to diseases, and insufficient efforts in development and innovation.

Although it is no possible to summarize in a few lines the work and results of the different chestnut working groups (e.g.: the French working group on chestnut from the "Institut pour le Développement Forestier" totalized more than seventy articles and some fundamental texts as e.g. Bourgeois et al., 1992-2004, VV.AA., 2008, Cousseau and Lemaire, 2008 and 2009), in these brief notes the main current silvicultural and technological aspects have been presented to intercept the priority of the research and the need of improvement for the technology.

Keywords: climate change vulnerability maps**,** new silviculture in connection with climate change, sawn-wood, round-wood, quality, grading, wood products, environment- friendly harvesting.

1. Silviculture and climate change

The chestnut is sensitive to drought and to high summer temperatures (Lemaire, 2008 d). Risks of decay linked to climate changes will increase in forests and orchards. The risk of diseases (ink and blight) can be aggravated by the lack of new silvicultures (Lemaire, 2005 a,b,c,d).

It is very important to specify the autecology of this species and to delimit the future distribution area (GIS MAPS) of the sweet chestnut tree in Europe in link to climate changes. One of the major objectives of this project is to define European regions, sites (key of determination) and stands where it is possible to produce high wood quality. The objectives of this study is to determinate the relationships between the potential of productivity (site index, annual increments, reactivity to thinnings, risks of ring shake…) and ecological factors. One study of this importance is possible thanks to the availability of climatic databases (like http://eca.knmi.nl, wordclim, ...). An European database, with silvicultural and ecological data, will be created. This database will contain numerous data (diseases, stands and ecological data) of chestnut forests in Europe.

Global Climate models will be included in the statistical analysis to define the sites able top produce high quality wood. Several studies (Lemaire 2008 d, Bergès et al. 2005) demonstrate that is better to study a large ecological region to define the ecological exigencies of a species than a little one. A similar protocol is used today to determine the risks due to the climatic changes in France (Project: *Climate Change: The risks for the oak stands in the Atlantic region* - Lemaire "en cours"-).

The studies conducted in Corsica (Pavie et al. 2008) demonstrate that it is possible to distinguish chestnuts able to surmounting a stress (tree in the reversible sanitary state) from those which are not capable (tree in the irreversible sanitary state). The validation of such a protocol turns out indispensable to help the forester to select the most resistant trees in the context of the climate change. This method is already validated for the *Quercus* (Drénou and Lemaire 2011, not yet published).

The dynamic silviculture allows to produce high quality wood by limiting the ring shake (Lemaire 2008 a). The development of this silviculture can be slowed down in the zones more sensitive to climate change. It is important to test and develop new lower-cost and environment-friendly silvicultures : irregular silviculture, thinnings, regenerations, plantations.

In general, characteristics of resistance to stress have not been much taken into consideration in the application of genetic improvement programmes due to the difficulty of defining premature qualitative and quantitative criteria in adaptation (Zhu, 2002). However, this is not the case with the chestnut as its widespread distribution throughout south-east Europe means it has been exposed to different environments. In fact, it is widely distributed and it is an element of many forest ecosystems in temperate areas. On the other hand it has been, and still is, under strong selection pressure due to: i) intensive cultivation for fruit and timber production; ii) parasitic attacks which are the cause of widespread diseases like blight and ink diseases, iii) climate changes cause several diebacks. This capacity for dynamic colonization has been attributed to its great adaptability (Eriksson et al., 1993), due to common adaptive mechanisms to drought, concerning genetic and physiological determinants (Lauteri et al., 2004). These mechanisms are especially important in those areas with expected climate changes during the present century (Ramírez-Valiente et al. 2009).

In the South-West of the France, the diseases due to the climatic changes are more frequent today. It is very important to select new varieties of chestnut trees, more tolerant to climatic change and diseases (Cynips, ink and blight) and to develop biological tests (blight tests, ink tests, ...) allowing the trees selection in European plantations or coppices.

The survival and growth of juvenile progenies of C. sativa Mill. grafted cultivars coming from Northern and Southern Spanish areas were compared to an applied drought stress, which modified significantly their water potential, growth, morphology and several allometric relationships. The findings suggest that the adaptation of F1 half-sib progenies of Spanish chestnut cultivars to the two geographical areas was due to genetic differentiation, though important phenotypic plasticity was found in both origins of variability. Adapted genotypes for conservation purposes and genetic improvement programmes for wood quality could be selected, taking into account that some cultivars were selected both for fruit and timber production, such as 'Parede' (Ciordia, 2009, doctoral thesis).

Also research on other chestnut cultivars (‘Cardaccio’, ‘Mozza’, ‘Politora’, ‘Perticaccio’ and ‘Mondistollo’, ‘Marsol’, ‘Marigoule’,…), traditionally cultivated in Central Italy and in France for the high quality of their timber has been recently done (Tani et al., 2009) and, due to genetic reasons, seem to have interesting properties that could be very useful for the production of timber for joinery and structures; further researches on cultivars about these topics have to be done.

In the end, the forester will have a lot of elements for an optimal silviculture. He will know the risks (autecology, climate change vulnerability maps) and will have solutions against them :

- **protocol to detect tree capable of surmounting a stress and development of new silvicultures = short-term solution;**
- **selection of new chestnut varieties more tolerant to climate changes and diseases = long-term solution;**
- **Training sessions (with audiovisual slideshow) and a book will help in realizing the principles of theses new silvicultures.**

2. Mountuain logging operations

Chestnut mountain forests are valuable resources providing wood, water, wildlife habitat and scenic quality. Meeting society’s demands for wood and wood products while maintaining and enhancing those scenic, protective and productive values requires skillful application of forest engineering operations and management knowledge. Now, we have to meet the challenge of increasing productivity while at the same time not increasing global environmental impact. It is not a wild guess that high productivity and low costs will continue to be an important research area, but more and more focus will probably be on high profitability and global environmental impact. Automation seems to be one way of increasing productivity (Sessions and Havill, 2007).

Moreover, there is a need to recognise that forest harvesting is intrinsically dangerous irrespective of the amount of training given to operators and personal protective equipment they are provided with. Accordingly, every opportunity must be sought to reduce hazards by investigating and implementing new operational methods for chestnuts logging. In this sense, there is a great deal of potential for future research and development with mountain loggers in order to develop more robust models for logging.

The mechanization of wood harvesting operations has intensified since the 1990s, driven by the reduction in workforce required, improvements in working conditions, the need to reduce production costs and the desire to increase yield (Bramucci and Seixas, 2002). Whilst felling operations and timber transport represent over 50 percent of the total final cost of wood delivered to the factory (Moreira et al., 2004), the improvement of forest operations is becoming increasingly necessary (Minette et al., 2004). This implies the need for improved performance of forestry operations; increasing the level of productivity and contributing to increased competitiveness in the forestry companies (Bramucci and Seixas, 2002; Silva et al., 2007).

Traditionally, steel cable has been used for all types of timber harvesting, owing to its strength, durability and longevity (Hartter et al., 2006). However, there are difficulties associated with its use because of its weight and lack of flexibility, which causes operator fatigue, contributing to the occurrence of occupational health risks and/or accidents (Pilkerton et al., 2001; Hartter et al., 2006). Furthermore, its use increases the likelihood and degree of puncture damage to operators, especially on hands and arms (Spong, 2007).

The potential of new technologies, i.e. fibre rope, produced from high density polyethylene, allows replace the steel cable in timber applications, how has been demonstrated recently in various coppice chestnuts studies (Canga et al., submitted). This synthetic rope is much easier to work with in difficult terrain and on steep slopes, reducing health and safety risks i.e. the potential for, and severity of, slips and falls and more importantly reducing the physical demands on the operator (Pilkerton et al., 2001, Spong, 2007). Moreover, in all types of work carried out in the countryside there are associated negative effects on the natural environment. As synthetic rope is much lighter and makes the extraction of timber easier, there is less resistance at the time of drag, thereby reducing environmental impact on the stand (Spong, 2007).

3. Timber quality, wood products and wood based products

The main aim of the part of work to be done must be the abatement of all limitations, to a prompt valorisation of the wood products, pointing out the principal strength points on the characteristics of the timber and on processes but also the criticality.

3.1 Timber quality and wood quality

Chestnut wood has some particular properties, so that many different uses are possible. From the point of view of the aspect, the light brown colour and the veining meet the interest of the user; it has good strength properties and an excellent material efficiency due to the very high ratio between strength-stiffness and density; moreover the light weight (average density is lower than 600 kg/m³) gives it a good dimensional stability. It has a high natural durability (class 2 in EN 350-2), the processes forming the heartwood are very precocious, so heartwood is abounding also inside young plants (Pividori *et al.*, 2002; Zanuttini and Cielo, 1996a). Furthermore large annual rings characterise the species so that it can be placed just below the species with a very fast rate of growth (increase in circumference until 6 cm/year).
The critical aspects about wood quality can be attributed to the variability of durability, physical and mechanical properties, in connection to the geographical sources and the trees growth pattern (Fioravanti *et al.*, 1995a, Fioravanti, 1999, Militz *et al.*, 2003, Romagnoli *et al.*, 2009a, Romagnoli *et al.*, 2009b; Sarlatto *et al.*, 2006). Many defects as irregular shape of trunks, knots, reaction wood and stains have a strong effect on final quality of sawn timber and particularly on the processing yields. Furthermore the ring shake and diameters of logs at the end of coppice turnover are severely influencing the utilise of this timber and the woodworking processes; exactly ring shake is the more frequent technological defect but also the most investigated (Fioravanti *et al.*, 1995b; Fioravanti 1997; Fonti *et al.*, 2002; Spina *et al.*, 2008; Romagnoli *et al.*, 2009c; Lemaire 2008 a, Cousseau et Lemaire 2009 a,b,c,d, Spina *et al.*, 2009a, 2009b).
If silvicultural treatments are timely executed (Fioravanti *et al.*, 2002; Fioravanti and Galotta, 1998, Lemaire, 2008 e) chestnut can realise trunks with dimension and technological properties appropriate to the need of markets, due to a high growth dynamism, also for aged trees of the species (over the typical coppice turnover). On the contrary, lengthening of rotation by itself, without a proper silviculture and cure of the forest, can reduce the quality (Romagnoli *et al.*, 2009b, Spina *et al.*, 2009a): small dimension of boles, increasing of shape anomalies and high frequency of ring shake (Lemaire, 2008 a).
Generally it can be stated that in the best condition of growth, the chestnut should be considered like a fast growing species, which could be correctly included in arboriculture plans for production of timber, to be realised through schemes for modular management, voted to the production of different kinds of assortment. The technological characteristics of chestnut wood make it good for many kind of different uses, from poles to structural timber, and also for a variety of industrial processing (sawing, slicing, rotary slicing, panels and so on).
The very wide diffusion of the species, sometimes also out of its climate zones, the basic work conducted until now on selecting cultivars for wood (very low in comparison to what done about chestnut fruit! ... the need of genetic improvement for better qualities of wood was well asserted by VV.AA. [1995]) and the lack of adequate silvicultural conduct systems, are the main factors

determining the strong variability of the properties and quality. As a consequence, in Italy this situation involves a very low yield in processing and the need of timber imported from other Countries (first France) for the use of high quality (joinery, large beams etc.).

3.2 Wood products and wood based products

The chestnut timber has various usages in every kind of timber sector. Particularly the uses here listed have to be taken in consideration for the economic relevance.

3.2.1 Round wood

For this product typology it is possible to use logs with different diameters, but thanks to the early maturation of heartwood, also small diameters assure a good durability; the eventual ring shake do not compromise this kind of use.

So chestnut poles are absolutely recommended because they represent a production of high environmental sustainability, in comparison with softwood poles which need chemical preserving treatments.

Service buildings for agriculture and other similar constructions (e.g. buildings cited in Barbari *et al.*, 2003) could be profitably realised with round wood, too. They are some niche realisations which in agriculture and particularly in provisional constructions (devoted to specified factory farming and agricultural farms) could find interesting future developments (VV.AA., 2009).

The diffusion of round wood for soil bioengineering construction, attests the very good durability and duration of chestnut and also the versatility of this product.

While, in Italy, poles for electric lines seem to be critical because they need large dimension and good shape of logs (quoted in Bonamini, Uzielli, 1997) which are not so easy to obtain without problems, particularly in this Country.

The lack of standards at European level, for grading sawnwood by defects, must be reminded (Casini and De Meo, 2001, Nosenzo 2007, Togni 2008 b), because this gap brings severely disadvantage to forestry companies.

3.2.2 Sawn wood

The structural use of chestnut sawnwood is one of the most interesting applications for the next future. In Italy, due to the recent law for the constructions (Construction Technical Regulations, D.M. 14-01-2008), to the availability of the necessary standards and thanks to the research results from over ten years (much more than other hardwoods), suitable timber for structural use from chestnut can be produced (Bonamini and Togni, 1999). This possibility is going to be realized thanks to the wide distribution of small and medium enterprises over all Italy and to the perspective to gain the mark CE in a very short period. In fact the next release of the standard EN 1912, at present in public inquiry, will already include the combination of species/origin/grade for this timber, corresponding to *"chestnut"*, *"grown in Italy"*, graded in *"S grade"* through Italian visual grading rule UNI 11035, and assigned to Strength Class D24 (EN 338:2009, strength = $f_{m,k}$ 24 N/mm², stiffness = $E_{0,mean}$ 10 kN/mm², Characteristic Density 485 kg/m³, Brunetti *et al.*, 2009). Now it is necessary to extend sampling, testing and the data collection to other Regions of Europe and to other more timber sizes, to enlarge the possibilities for using in constructions and increase the volume of trade.

Another structural use regards the large waned beams called in Italian *"Uso Fiume"*, (*"obtained by squaring a log, continuous and parallel from the butt to the top on the four faces, with regular thickness, with wane and boxed heart"*, from standard UNI 11035-3): at the present some researches for the determination of characteristic values for chestnut are going on. For this kind of timber the long path to get the CE marking (soon, compulsory for every kind of structural timber)

has been started. In this direction it could be very important to extend researches to other European Countries interested on chestnut for structures.
Sawn timber for non structural use, to be used in joinery, for quality and dimensional reasons, can be produced mainly from logs produced in France and Countries of the East Europe. The defects influencing the aspect (knots, stain, etc.) are strongly excluding and only large plank with no defects or only partially defective may be used.
In Europe there is a lack of standard devoted to chestnut. Presently there are no European rules to select chestnut sawn wood by aspect (Togni, 2008 a). A standard over the rules of the Nations, which can favour the sector, facilitate the commercial exchange of timber and sustain people involved in grading this kind of material, is necessary.

3.2.3 Wood based products: glue laminated timber

Different levels of technology and various woodworking processes pertain to this group of products. From glulam (non structural) for door and window frames (Negri and Uzielli, 1997), to other kind of glued laminated timber as solid wood panel (SWP), laminated veneer lumber (non structural LVL) (Cielo *et al.*, 1995 a,b, 1996 a,b, Bargelli *et al.* 1995, Berti 1995) to goods made by coupling wood with other materials (e.g. roadway acoustical-barrier [Berti *et al.*, 2004; Moschi *et al.*, 2003]).
Generally the actual possibility to solve the strong limitations of rough materials for dimensions and original defects seems the glulam production, but over a certain threshold the high number of defects gives a so low yield to make uneconomic the processes (economic and energetic costs for the transformation are higher than the cost of rough material, VV.AA.,1995). The sector for doors and windows frame is the most mature and technologically the most advanced.

3.2.4 Indoor wood based products

Many other products are relevant in the group of secondary processes like furniture and wood floor (Cielo *et al.*, 1996a, Zanuttini *et al.*, 2001; Fonti and Giudici, 2002). The strengths for these kinds of production have to be found in a certain aesthetic appreciation by consumers and in the possibility of using wood from coppice (small diameters), thereby providing a product with higher added value compared to the simple process for poles. There are still some weaknesses: a lack of knowledge in relation to the study of the most appropriate schedules for drying, the classification of sawn timber, the drawbacks due to the tannins in wood, and, depending on the type of finished product, it can be difficult finding material suitable for size and quality.

3.2.5 Other products

Many other products can be obtained from wood of chestnut: we can remember the shingle, timber for barrel, sliced wood for veneered panels etc.
From the chemical point of view also the tannins are very important and they may be used for tanning heavy leather, to improve the stability of wines, in cosmetics to reduce ageing, with antioxidant effects in the diet of farm animals (Wei Liu *et al*. 2009) and many other uses.
The tannins can be added to fibre panels to improve bonding (Trosa and Pizzi, 2001; Widsten *et al.*, 2009). The residues of the processing of chestnut find frequently use for energy purposes (as biomass, or wood chips and also as pellets, after removal of tannins, Gotti *et al.*, 2009).
Among innovative processes of wood also the heat treatments have to be remembered (in particular: heat oil bath for chestnut). The wood is treated and warmed at precise temperatures, conditions and noted time; in this way tannins could be blocked into the wood. The main advantage deriving by this wood treatment has to be the reduction of the movement of tannins due to the rain-wash, so that the use of wood, particularly outdoor (terraces, windows, cladding,

etc.), is improved, the colour is more stable, the durability is increased (more than 25 years) and generally it can be "more sustainable".
The wood rests coming from industrial processes, including extraction of tannins, supplies rough material also for panel production (MDF, HDF – Medium/High Density Fibreboard), with the possibility to integrate the production together with other industrial manufacture. But these productions are associated to specific industrial condition and they need high quantity of rough material, constantly. The short chain of production is not favourable to this option.

4.Conclusions

The research works carried out so far on the chestnut wood products and derived products, allow us to highlight the flexibility of this species and its potentiality for many different uses. But a lot of work has still to be done.
In particular it is necessary to work on projects for a genetic improvement of chestnut with the aim to better the wood quality and to reduce the incidence of defects (particularly ring shake and blight) and to slow down importance of climate change.
It is very important to define the risks due to the climate change and to propose solution against these problems (new silvicultural approaches, protocol to select trees able to surmounting a stress, to delimit risks area for chestnut in Europe, …).
Then there is a need to develop systems for verifying, early in the chain of production, the quality of the wood (already on standing trees and on young plants). It is very important to validate the use of survey instruments during nondestructive testing and classification of roundwood or semi-finished products, in order to identify defects as soon as possible, especially the presence of ring shake.
At the same time it is important to identify and promote the knowledge of criteria and guidelines for the selection and grade of the different timber assortments of chestnut. As already gained by many important hardwoods (beech, oak, ash etc.), an European standard, supranational rule for grading by defects roundwood and sawnwood, is a strong requirement.
About structural timber, it is essential collecting data on mechanical properties of roundwood, to enable the implementation of the use of this assortment in construction; EU needs to adopt an adequate regulation for structural roundwood (the standard prEN14544 about basic requirements for structural roundwood was been stopped).
To increase the use of structural chestnut in all the Countries interested in this kind of use (from Portugal to Georgia) new samplings of sawn timber and the related mechanical tests are necessary.
The innovative products based on chestnut wood and derived products should be encouraged and supported by studying and testing the optimal conditions of some important processes (e.g. drying, gluing, heat treatments), paying particular attention to environmental compatibility and sustainability of production processes.
The developing of new outdoor products based on chestnut wood, which could be competitive with other durable species, would allow an impulse to the market and to exploit the biological properties of durability. To complete it would be useful a starting action to promote awareness and promotion of the chestnut wood in the field of industrial design.
In conclusion, due to their high natural durability, chestnut wood products are an efficient way of extending the storage of the forest carbon sink. To increase their efficiency and have them play a greater role in the mitigation of Climate Change, we need to increase the market share of wood products through promotion and technical innovation and increase the extend, the life of wood products and their quality through of silvicultural treatments timely and precisely executed.

Objectives and results

Climate Change :

- Climate change vulnerability maps. Key of determination of stands more sensible to climate changes.
- Protocol to select best trees able to surmounting a stress due to climate changes.
- New silvicultures to product high wood quality without ring shake and to slow down the risk due to climatic changes**.**
- Training sessions (with audiovisual slideshow) and a book will help in realizing the principles of theses new silvicultures against the climate changes.

Harvesting:

- Upgrade the quality of the harvest in coppices (environmental and economic problematics in mountain).
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Quality of the wood:

- Genetic selection of the best chestnut trees for wood quality and more tolerant to diseases and climate changes.
- Validation of standards at European level to grade on quality chestnut round-wood and saw-wood.

Wood and wood products:

- Studying and testing the characteristics of wood from cultivars traditionally devoted to the wood production, improving the possibilities to promote plantations of chestnut for wood.
- Studying and implementation of processes regarding innovative products: heat treatment, green wood gluing, low impact drying etc., to enhance technologies.

Structural timber:

- Sampling and testing sawn-timber to determine characteristic values of chestnut in the Countries interested to promote its structural use.
- Studying, analysing and solving the technological aspects about the production of KVH (structural beam made by solid wood) and glulam by using of graded structural boards (finger joints, gluing, testing), to promote new structural products.
- Studying, sampling and testing round-wood to implement the use of structural not processed timber.

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