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Benefits, costs and risks related to use of improved poplar clones FRM in alluvial regions of central and southern Europe

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crea Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

MINISTERO DELL'AGRICOLTURA DELLA SOVRANITÀ ALIMENTARE E DELLE FORESTE

B4est

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1. INTRODUCTION

The changing climate is an important driver of change in forests. It can also have positive effects, offering opportunities for growing trees in previously suboptimal regions. The use of new FRM will be able to guarantee wood supplies for the poplar processing industry (wood security) adapting to climate change with sustainable productions (low impact cultivation techniques).

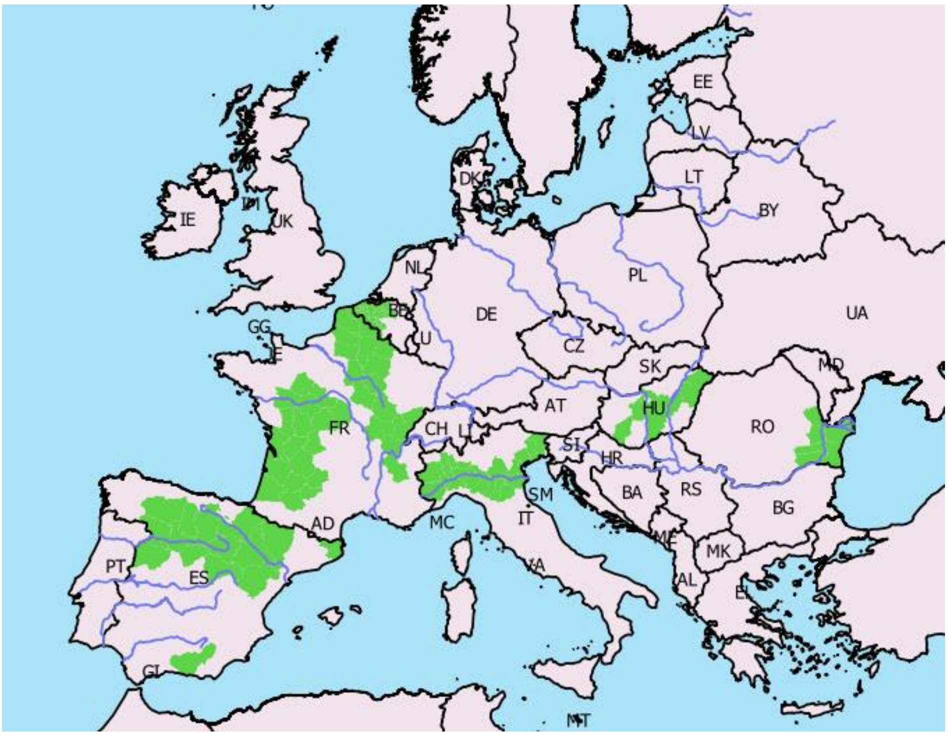

Figure 1 *- Location of intensive poplar cultivation in Europe*

In figure 1 in green are highlighted the main poplar cultivation areas in Europe. The plains of Spain, France, Italy, Hungary and Romany are the most important. Poplars are cultivated in the plains along rivers where they found site conditions favourable with good water availability. Different to other Country, in Italy poplar cultivation is located in the agricultural land, in rotation with crops, mainly cereals.

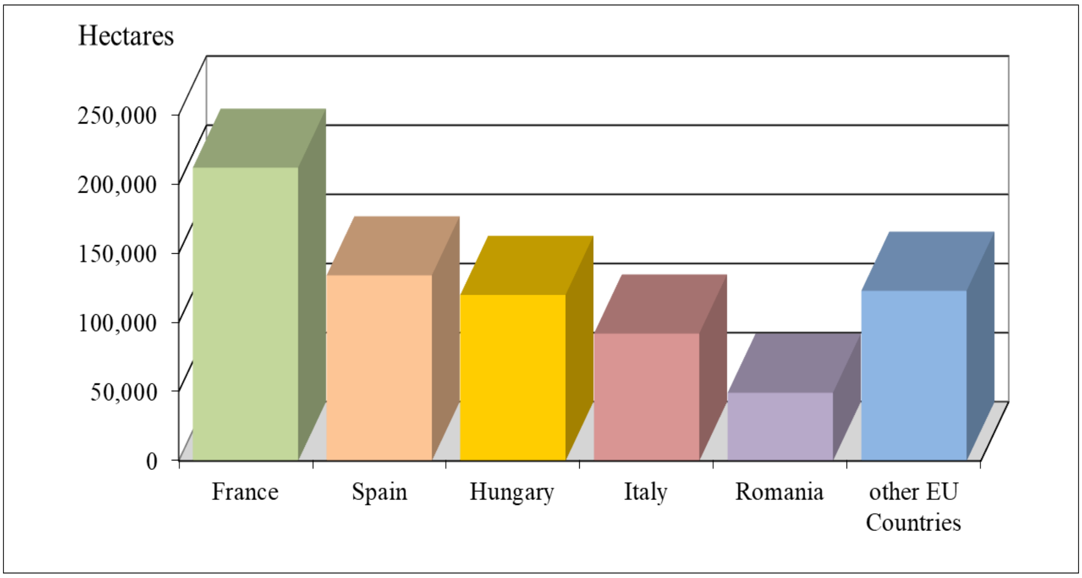

Figure 2 *- Total hectares of poplar plantation in EU.*

Poplar cultivation in EU amount to 900,000 hectares (FAO 2016). France is the most important Country for poplar production with more than 200,000 hectares. Spain and Hungary follow with values above 100,000 hectares and then Italy with about 92,000 hectares. Other Countries (Belgium, Serbia, Germany, Croatia, Switzerland, Sweden, Moldova, Bulgaria, United Kingdom, Slovenia) have an area of 123,500 hectares.

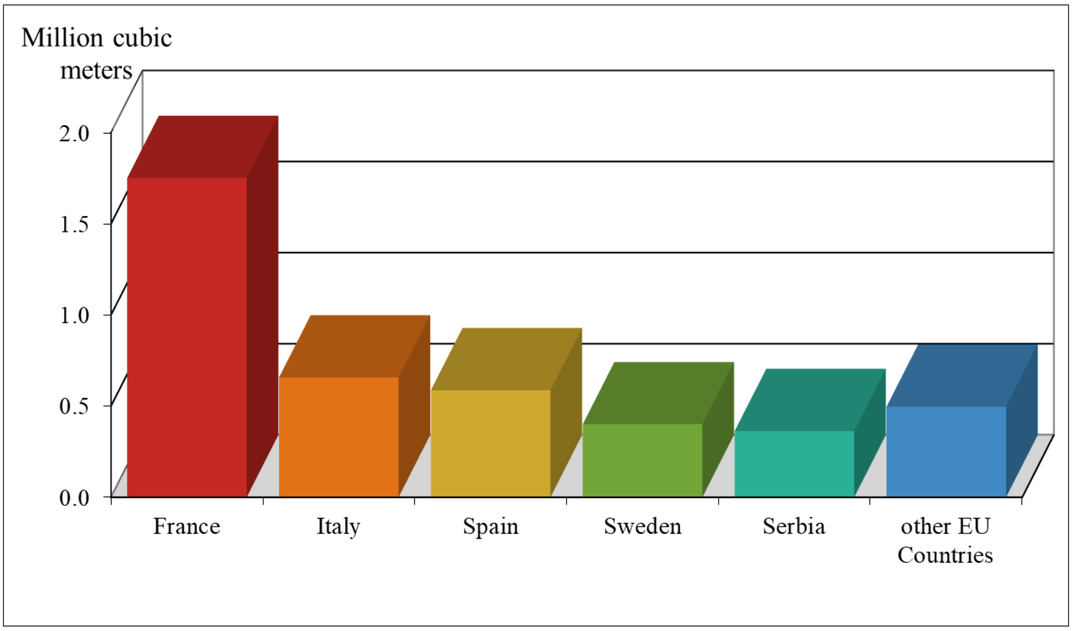

Figure 3 *- Production of poplar wood in cubic meters in EU.*

As far as the production of wood assortments is concerned, France is still the most important Country with approximately 1.7 million cubic metres of round wood equivalent, followed by Italy and Spain with just over 0.5 million cubic metres, Sweden (0.4 million) and Serbia (0.36 million cubic meters). All other EU Countries produce about 5.0 million cubic metres of round wood equivalent.

The strategic goal of B4EST project is to increase forest survival, health, resilience and productivity under climate change. The project results will provide forest tree breeders, forest owners, managers and policy makers better scientific knowledge of adaptation profiles to increase sustainable forest productivity, ad added value of raw materials for economically important tree species. New and flexible adaptive tree breeding strategies and tools have been proposed as well as tree genotypes of high adaptive and economic value. A decision-support tools for the choice and use of Forest Reproductive Material (FRM) for balancing production, resilience and genetic diversity has been implemented.

Particularly the WP5 evaluate impacts of deployment of an extended FRM portfolio on wood and biomass production, supply of benefits (wood, non-wood products, carbon sequestration, biodiversity), and resilience. In alluvial regions of Southern Europe (Italy, France and Spain) where intensive production areas of poplar are located, benefits and risks of improved FRM and new associated management scenarios are evaluated for different objectives (plywood production, biomass for bioenergy, phytoremediation on marginal lands). The effect of using improved FRM on wood and biomass production, cost-efficiency of different forest management systems and ecosystem resilience in poplar plantations are investigated also in WP4 and WP5 of B4EST project.

Figure 4 *- Poplar intensive plantation.*

2. RESULTS

2.1 Importance of poplar ecosystem services

According to the Millennium Ecosystem Assessment (2005), there are four categories of ecosystem services: 1) provisioning, the goods or products obtained from ecosystems, e.g. wood for industry; 2) regulating, the benefits obtained from an ecosystem's control of natural processes, e.g. flood regulation and reduced soil erosion, reduces impact compared to agricultural crops, filtering of contaminants in soil and groundwater nutrients and other pollutants, reduction of greenhouse gases; 3) supporting, the natural processes that maintain other services, e.g. creation of buffer zones between wooded and agricultural lands, constitution of elements of the ecological network; 4) cultural, the nonmaterial benefits obtained from ecosystems, e.g. conservation of the rural landscape, conservation of biodiversity, public use for recreation as walking, cycling, horse riding.

2.1.1 Provisioning

Poplar is a fast-growing tree species, and the plantations produce in about 10 years 150 – 200 cubic meters of wood for the industry (average of 15 to 20 m^3 ha^{-1} $year^{-1}$). Specialized plantations are particularly relevant in the production of wood-based panels, i.e. plywood, veneer, fiber-board and particle-board; only a small amount of wood is used for energy purposes.

Figure 5 *- Pile of poplar logs ready for veneer.*

The high quality and quantity of wood from intensive plantations reduces pressure on natural forests.

2.1.2 Regulating

2.1.2.1 Flooding and soil erosion

Investigations have been carried out to study the effects of natural forests and poplar plantations in floodplain areas to reduce soil erosion and allow water regulation during flood events. After the occurrence of floods in the Po valley (Italy) in 1994 and 2000, poplar plantations and other tree crops contained soil erosion and hydrogeological instability as much as natural forest. (Chiarabaglio et al. 2014a).

Figure 6 *- Poplar root system during flood events allows to reduce soil erosion and to regulate flooding.*

2.1.2.2 Reduces impact compared to agricultural crops

An ecological study of the environmental impact of poplar cultivation as compared to the impact caused by a typical crop (corn) in rotation with poplar was carried out, using as a control the ecological parameters of natural forests present on the same sites. The study was carried out considering two different cultivation models: the “traditional model”, characterized by intensive cultivation and frequent phytosanitary treatments, and a “controlled model” (considering, for poplar, the improved FRM), with little use of phytosanitary products and low-impact cultivation practices. The quantities of nitrogen fertilization for both corn and poplar in the two cultivation models are reported in the table.

Nitrogen units per hectare per year	product	corn		poplar	
		traditional	disciplinated	traditional	Impr. FRM
Fertilization pre-sawn	15-15-15	105	60	-	-
Fertilization	urea	207	140	179	124
Total Nitrogen		**312**	**200**	**179**	**124**
Removal		140	140	163	163
Not used		**172**	**60**	**16**	**-39**

Figure 7 *- Nitrogen units per hectare and per year for corn and for poplar in traditional and innovative (low impact) plantations.*

The "corn traditional model" shows a surplus of 172 units of nitrogen not used by the crop, while the "corn controlled model" has 60 units; on the other hand poplar stands have a very low surplus of nitrogen in the "traditional model" and no surplus with the "Improved FRM" (probably the deficit is covered by the organization of the poplar leaves fallen to the ground at the end of each growing season) (Chiarabaglio et al. 2014 b).

In order to assess the environmental impact of the phytosanitary treatments an index has been applied: the Impact Index by Bonari et al. (1999) is the sum of the ratio between the lethal dose 50 and the treatment dose of the phytosanitary products.

Corn		Poplar	
traditional	disciplinated	traditional	improv. FRM
38160	12970	15258	4437

Figure 8 *- Impact index for phytosanitary treatments in traditional and innovative(low impact) plantations.*

The highest impact index recorded is that of "traditional corn" (Impact index = 38.160) while the lowest is that of "Improved FRM" (Impact index = 4437). The second is that of "traditional poplar" (Impact index = 15258: < 50% traditional corn) and the third is that of "disciplinated corn" (Impact index = 12970) (Chiarabaglio et al. 2014 b).

The Biological Soil Quality Index (BSQI) is based on the evaluation of the community of soil Arthropods present in the first 10 cm of the soil: these invertebrates are particularly sensitive to soil quality and therefore to human activities (Andrews et al. 2002, Parisi et al., 2005).

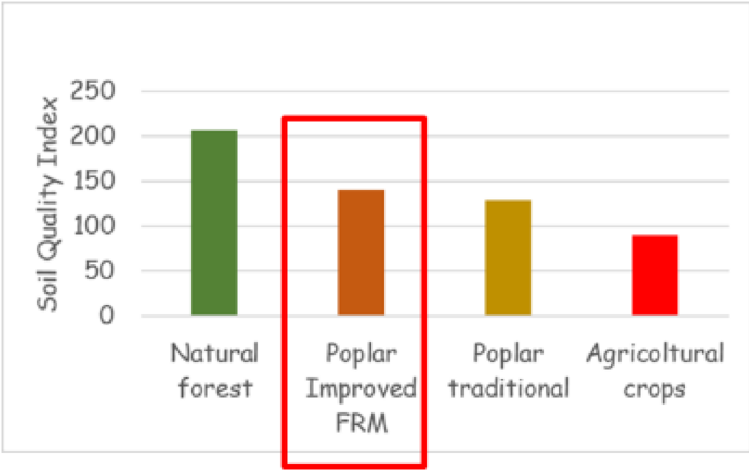

Figure 9 *- Soil Quality Index for poplar traditional and with improved FRM plantation compared with natural forest and agricultural crops.*

The poplar stands with Improved FRM have a higher BSQI than crops (corn and wheat) but lower if compared to natural forest. The lower values of the index are due to both cultivation practices (mechanical operations and chemicals) and to the lack of ground cover in the first months for crops and for young poplars having negative effects on soil fauna (Chiarabaglio et al. 2014 b).

2.1.2.3 Filters the solutions circulating in the soil

Poplar have been recognized as a promising approach for the decontamination of polluted soils because of their rapid growth, extensive root system and above all high-water uptakes. Many experiences have been conducted on different types of contaminants: heavy metal, polycyclic aromatic hydrocarbons, hydrocarbons and nitrogen (Giordano et al. 2021).

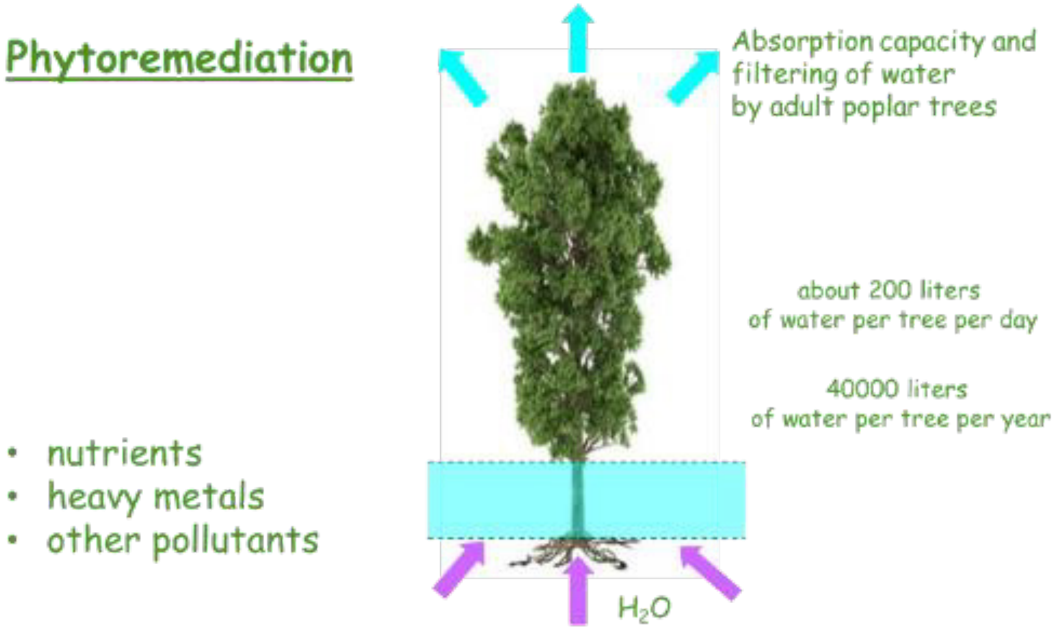

Figure 10 *- Poplar plantations can be used for phytoremediation activities.*

In the frame of the Project “DENDROCLEAN: trees to clean up contaminated soils” (grant number CSTO160891), the response to some major heavy metal contaminants of different poplar (Populus spp.) and willow (Salix spp.) clones cultivated in hydroponic systems was tested by investigating their tolerance, phytoextraction potential and pattern of heavy metal accumulation between green and ligneous organs. Treated clones did not show substantial phytotoxic effects; the phytoextraction efficiency and the accumulation patterns displayed high variability depending on the heavy metal. Although heavy metals can be efficiently sequestered by leaves, some clones achieved good performances in the absorption at stem level.

Figure 11 *- Absence of symptoms related to phytotoxicity associated with treatments with Zn and Pb solutions on poplar (left panel) and willow (right panel) clones.*

2.1.2.4 Fix CO_2 in the wood (and temporary in the soil)

Poplar plantations contribute to remove from the atmosphere some of the carbon (which in the form of carbon dioxide is among the causes of the greenhouses effect) by storing it in long-lived products for furnishing and construction; therefore, can contribute to the pursuit of important objectives for society, such as climate change mitigation and environmental improvement. Acquired knowledge suggests that the carbon footprint of poplar cultivation is more than positive thanks to poplars' high capacity to absorb CO_2 and accumulate it in wood (up to 25 t ha^{-1} $year^{-1}$). Poplar production, including industrial material and biomass for energy, can contribute to reducing emissions of climate-altering greenhouse gases. The long duration of the plantations on agricultural land, with lower soil disturbance, results in an increase of organic content and fertility in comparison with annual agricultural crops. The storage of carbon in poplar wood has a long-life cycle thanks to the use of wood in furniture and other products that can be further recycled (Chiarabaglio et al. 2020).

2.1.3 Supporting

2.1.3.1 Represent transition zones between "natural land" (river, forest) and agricultural areas

Poplar cultivation is carried out mainly along rivers, on highly environmentally sensitive land and the cultivation practices carried out by farmers may constitute elements of negative impact. However, in riparian and protected areas, a sustainable cultivation model it is possible using the new FRM that include clones offering greater environmental sustainability ("Maggiore Sostenibilità Ambientale" in Italian, thus referred to as "MSA" clones) characterized by better resistance to the main biotic adversities (brown spot *Marssonina brunnea* (Ell. Et Ev.) P. Magn., rust *Melampsora* spp., spring leaf and shot blight *Venturia populina* (Vuill.) Fabric. and wooly poplar aphid *Phloeomyzus passerinii* Sign). In this way it is possible to develop semi-extensive cultivation models including those based on agroforestry systems or with mixed plantations that, by minimizing cultural and pest-control treatments, allow more environmentally sustainable poplar culture (Chiarabaglio et al. 2016).

2.1.3.2 Forms parts of the ecological network

Cultivated poplars diversify the agroforestry environment, form part of the ecological network in the often monotonous and relatively low-biodiversity landscape of agricultural areas, create niches with conditions favorable for the survival of animal and plant organisms, and can serve as windbreaks (Corona et al. 2018).

Figure 12 *- Poplar plantations represent an important part of the ecological network especially in intensively cultivated agricultural areas.*

2.1.4 Cultural

2.1.4.1 Maintenance of the rural landscape and conservation of biodiversity

Poplar plantations are characteristic of the rural landscape of many lowland and floodplain areas. The natural affinity of the Salicaceae for riparian and floodplain areas the most recent technical standards and procedures for an environmentally sustainable cultivation of poplar, suggest that poplar cultivation can have a positive impact on biodiversity with respect to other agricultural crops (Corona et al. 2018).

2.1.4.2 The innovation: the new FRM

The improved poplar clones are resistant to main leaf diseases (*Venturia* spp., *Marssonina brunnea*, *Melampsora* spp.) and woolly aphid (*Phloeomyzus passerinii*), generally, grow better than traditional ones, and are generally heavier (higher wood density) respect to several traditional ones as 'I-214'.

The cultivation of improved poplar clones requires lower cultural input, and then lower production costs; this results in a better environmental sustainability, also remarked in Deliverable D 4.3, D 4.6 and D 4.9 and in a good economical sustainability. The higher wood density and the high production give interesting technological characteristics for different uses.

Operation	Irrigated plantations			Not irrigated plantations		
	I-214	Improved FRM	difference	I-214	Improved FRM	difference
	€/ha	€/ha	%	€/ha	€/ha	%
Site preparation	275	275		275	275	
Fertitisation	375	375		375	375	
Mark. dig and planting	615	615		615	615	
Seedings	1,251	1,251		1,251	1,251	
Planting	**2,516**	**2,516**		**2,516**	**2,516**	
Disk harrowing/Weeding	1,085	1,085		1,085	1,085	
Irrigation	2,336	2,336		291	291	
Disease control	1,143	0		1,143	0	
Pest control	797	623		797	623	
Pruning	587	720		587	720	
Fertitisation	447	447		447	447	
Coltural operations	**6,395**	**5,211**	*-19*	**4,350**	**3,166**	*-27*
TOTAL	**8,911**	**7,727**	*-13*	**6,866**	**5,682**	*-17*

Figure 13 *- Cultural costs for the cultivation model of traditional and improved poplar clones.*

The data reported here refer to the cultural costs of two different cultivation models based on the use of only the traditional clone 'I-214' or on the use of new FRM clones, resistant to the main poplar adversities. The greater susceptibility of clone 'I-214' to some pest and diseases (Marssonina, Melampsora and poplar aphid) compared to the new FRM clones requires greater phytosanitary treatments with higher cultivation costs for 'I-214' plantations. On the contrary cost for pruning are higher with the new FRM clones because their crown architecture (Coaloa et al. 2016).

2.1.4.3 Wood good for uses in building sector.

The improved FRM is very interesting for structural application. The high density of the wood represents an opportunity to develop and increasingly employ of poplar wood in engineered products and in buildings. A new structural innovation, eco-sustainability construction was made using poplar wood and plywood obtained from it (Castro et al. 2014).

Figure 14 *– Examples of poplar wood employ in engineered products.*

Figure 15 *– Field meeting with stakeholders in an agroforestry farm.*

3. COOPERATION

3.1 Cooperation between other WP´s of B4EST project

The indications given in this document summarize some of the results achieved in the different WPs of B4EST project, thanks to the network of relationships and knowledge put in place between the researchers, also highlighted in more detail in several deliverables. Starting from the assessment of the main biotic and abiotic problems deriving from climate change, new breeding strategies for poplar have been adopted; phenotyping analysis and the genetic characteristics of the germplasm available for the traits of greatest economic and physiological interest were addressed in WP 1 and WP2. In addition to breeding guidelines, genomic analyses were developed in WP3 using segregating populations of different poplar genotypes, with regard to some important characters related to resistance to pest and diseases such as woolly poplar aphid and rusts. Improved genetic materials (FRM) have been evaluated for adaptability and productivity in different environments by adopting conventional practices or cultural models with greater environmental sustainability, in order to provide correct information to the various stakeholders, as remarked also in D 4.3, D 4.6 and D 4.9.

3.2 Link to the results of the B4EST stakeholder survey DL 5.1

3.2.1 Farmers

Poplar farmers express an interest in improved FRM for the economic aspects (reduction of cultural costs due to lower pest and diseases treatments), faster growing (more wood in less time) and clear environmental benefits (lower cultivation inputs, higher environmental sustainability).

On the other hand, they show some perplexity in the diffusion of improved FRM because of the greater difficulty in selling their wood on the plywood market. To encourage the use of the new FRM clones, technical and information meetings with the main stakeholders were organized as part of B4EST.

Poplar growers are aware of the potential of linking increased production to carbon sequestration and environmental benefits: they would like to receive an economic accreditation for these assets.

3.2.2 Timber industry

The timber industry is in favour of improved FRMs and an increase in poplar cultivation areas in order to have more raw material that can also be certified by sustainable forest management systems. The lack of knowledge about the workability of wood is actually a limitation to spread of new FRM and right remuneration. Evaluation tests and dissemination days on the technological wood characteristics of the different FRM clones compared to the traditional 'I-214' clone was carried out at two different plywood manufacturers, as part of the activities supported by the B4EST project.
The demand for wood-based products has increased in the last period and this has produced an increase in demand that is currently not balanced by supply (poplar wood productions).
The wood industry, as poplar growers, would like to have an economic accreditation for the use of certificated wood (environmental sustainability) and for the storage of Carbon in products (i.e. furniture and other products) with long life cycle and that can be further recycled.

3.2.3 Carbon neutrality

Poplar plantations create opportunities to achieve carbon neutrality for companies that can no longer reduce their emissions and need to offset them.

4. DISSEMINATION

4.1 Regional stakeholder events

The results presented in this Deliverable have been the subject of presentations at Poplar Producer Associations (API and AsProLegno), regional forestry technicians (Piemonte, Lombardia, Veneto and Friuli Venezia Giulia), nursery and wood processing workers at various meetings to update on the results of ongoing research.

4.2 Planned dissemination activities in the future

In the future, dissemination events will be organized among poplar growers and other stakeholders to inform them of the results obtained in the B4EST project.

5. CONCLUSIONS

The results obtained with the B4EST project made it possible to pursue strategic objectives in terms of knowledge and innovation transfer to the European forestry sector. New and flexible adaptive tree breeding strategies and tools have been proposed as well as tree genotypes of high productivity and economic value.

While some new problems of a biotic (new insects and diseases) and abiotic (drought and severe storms) nature lately have affected the growth and production of poplar wood in alluvial regions of central and southern Europe, a renewed interest in wood plantations outside the forest, has been detected and widely perceived with a greater attention towards sustainable management practices also in view of the increase in prices of phytosanitary products, based on the use of new improved poplar clones, more productive and resilient to climate change.

Monoclonal or mixed poplar plantations will be able to guarantee wood security to better respond to the increased need for timber and wood products but also for other ecosystem services they can provide such as carbon sequestration, soils, and water phytodepuration, flood regulation, creation of buffer zones and conservation of the biodiversity and rural landscape for greater social well-being.

Figure 16 *– Poplar mature stand.*

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