EIP-AGRI Focus Group
Forest Practices & Climate Change

MINIPAPER4: Climate smart silviculture & genetic resources
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1. INTRODUCTION

Forests across Europe are dealing with challenges related to climate change. Droughts and forest fires in the Mediterranean countries, extreme events like floods and ice storms in the northern countries and new plagues and diseases are examples of those challenges. According to EUROSTAT today forests cover 41% of Europe's land area and play an important role in environmental functions crucial for our wellbeing: conserving biological diversity, protecting soils, preserving water resources and providing significant socio-economic benefits (Forest Europe, 2015). At the same time, forests have great potential to mitigate climate change. Improving the resilience of forests to the future climate and supporting the adaptation of forestry practices should have top priority in forest policy development and implementation. So how can we prepare our forests to adapt to climate change and continue their critical role in society? Are there improvement opportunities in silvicultural practice and genetic resources which could make our forests more fit for the future?

There are already several evidence-based practices that have been implemented in European forests to address climate change, but whose dissemination is insufficient to ensure their greater implementation and/ or adaptation to other forest types. Knowledge, options and adaptation measures are available, but practical implementation lags behind.

In Portugal, the National Forest Strategy (DGRF, 2006) identifies climate change as one of the most relevant context changes for the forestry sector, highlighting the increase in biotic and abiotic risks, impacts on the potential distribution of major species and impacts on wood production potential. Many other countries in Europe share this perspective. Drought mitigation strategies, forest fire risk reduction and prevention and increased resistance to pests and diseases are some of the key topics that can and must be pursued to help our forests adapt to climate change. It is highly likely that innovations in silvicultural practice and genetic resources are needed to address these key topics; a 'Climate Smart Silviculture' is critical to the future of our forests.

The concept of Climate-Smart Silviculture is based on a similar concept adopted by FAO in relation to agriculture (CSA – climate smart agriculture). The aim is to incentivise the adoption of silvicultural practice and genetic resources that allow forests to better adapt to climate change. A COST project, CLIMO ('Climate-Smart Forestry in Mountain Regions'), is already working on translating the CSA concept to a Climate-Smart Forestry (CSF) concept for mountain forests in Europe (COST Action, 2016).

This minipaper explores the need for and potential of a Climate Smart Silviculture.

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2. DISSERTATION

The practice of even-aged, mono-species “plantation” or regular silviculture has dominated much of European production forestry, particularly softwoods, since the early decades of the 20thCentury. Those forests were planted, often on abandoned agricultural land or other land unsuitable for agriculture, to address the loss of productive forests owing over-exploitation over the preceding centuries. However, increasing social pressure against clear felling of plantations, higher susceptibility to pest and diseases and reduced resilience against climate change has stimulated debate on the acceptability of this widespread practice for the future. Interest in alternatives to even-aged, mono-species forests, typically harvested by clear-fell, has been growing in continental Europe (Brang et al, 2013) and the UK (Helliwell& Wilson, 2012) among other areas of the world. The 7thIUFRO International Conference on Uneven-aged Silviculture (IUFRO, 2010; Diaci et al, 2011), featured 60 presentations on different aspects of changing silvicultural practice. These demonstrate the thought being given to, in many cases, the implications of changing climate for the world’s forests (Boxes 1, 2).

Box 1. Recent publications in England confirm wide public and policy recognition that the dominant UK even-aged forestry practices of the 20th Century must adapt to changing conditions and social values. The ‘Climate Change Accord: a call for resilient forests, woods and trees’ of July, 2015 (Forestry Commission England, 2015) published a list of principles and statements from public, private, commercial and charity organisations setting out their intended actions to achieve more resilient forests in England. Many of those actions called for a move toward greater species and structural diversity, less even-aged silviculture and bringing forest land back into active management. Eves et al (2014), in research conducted for the United Kingdom Department for Environment, Food & Rural Affairs, sought to understand the drivers and constraints impacting on forest owners such that policy might be designed to encourage more owners into action in line with principles of the ‘Climate Change Accord’. And, in the 2015 British Woodlands Survey (Hemery et al, 2015) 52% of participants believed climate change will impact forests, while 90% reported they believed impacts were already being seen.

Regular silviculture continues as a normal practice in the Nordic countries, partly in response to over-harvesting in the post-World War 2 period, but according to National Forest Inventory (NFI) in Finland, removals were more than growth only at the time of the 4th NFI in 1960’s. Since 1970’s it has been the opposite, as removals have been less than the growth. As result of intensive management and sustainable use the amount of stout timber and the growing stock has increased since 1960’s (28).

However, silvicultural practice around the world have adapted to changing circumstances over time and the typical silviculture of boreal regions of the world is being analysed in depth with science and monetary based arguments demonstrating opportunity under some circumstances to modify the current general silvicultural model (Bose et al, 2014; Pukkala et al, 2010, 2011; Tahvonen, 2007, 2011).

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Box 2. Adaptation to climate change -- as any other change -- is an inherent part of sustainable forest management. Forest management practices provide options which can be deployed for supporting adaptation, helping natural processes and speeding up the formation of new types of forests, more resilient and suitable for changing climate patterns. The practices may vary to a reflect local situations, but generally consist of a range of silvicultural management tools including forest protection, control of pests and diseases, forest operations and forest regeneration including the planting of new species or better-suited seed sources.

An approach which many believe to be effective in adapting forests to climate change is close-to-nature silviculture (CNS), (Brang et al, 2014: O'Hara, 2014). CNS is comprised of the following broad principles:

- promotion of natural and/or site-adapted tree species, often based on the assumed potential natural vegetation;
- promotion of mixed forests;
- promotion of diverse vertical and horizontal stand structures;
- promotion of natural regeneration;
- silvicultural practices that focus on individual trees;
- avoidance of clear cuts.

BOX 3.

The Nordic model, from excessive harvesting (1800's)to sustainable management

When netgrowth is retained in the forest, there is long-term carbon storage, and the forest acts as a carbon sink. This annual climate benefit remains as long as the carbon stock increases, but there is an upper limit to how many trees a forest can contain. One cubic metre of stem wood contains a carbon equivalent to approximately 750 kg CO_2. One average forest hectare in the Nordic region, growing at a rate of 5 cubic meters per year,therefore annually stores the equivalent of about 4 tonnes of carbon dioxide in its stemwood.

There exist detailed felling and growth data for the Nordic forests from the national forest inventories since the 1920s. When an average tree is harvested and used, it creates a substitution effect of about 500 kg of carbon dioxide that otherwise would be derived from fossil sources.The sum of the stored and utilized wood represents thetotal climate benefit. The annual climate benefit increases overtime with proper management. Over all three Nordic countries, it is almost twice as high today as it was fifty years ago, about 150 million tonnes compared with 83 million tonnes in 1965. Forest growth has continuously increased during this period, and so have both substitution and carbon storage in the forests. In Sweden and Finland, substitution accounts for the bulk of the climate benefit, while Norway's climate advantage mainly consists of an increase in living wood stock (29).

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But even-aged silviculture also has its place so both management types are sustainable, and have their role to play. In boreal regions with large forest areas that would be naturally affected by forest fire and pest outbreaks as part of their regeneration cycle, even-aged management is actually close to nature. Results of the 11th National Forest Inventory (field work carried out in 2009–13) in Finland show that more than four out of five Finnish trees are the result of natural regeneration. When the share of naturally regenerated trees is calculated according to the total volume of trees on productive and poorly productive forest lands, the inventory shows that 84 percent are naturally regenerated and 16 percent cultivated (4). Clearcuts may look ugly but with proper design and size regulation the ugly phase is like 5 years. Continuous cover has its place (i.e. recreation forest) but it is not the only method in whole Europe.

It's also climate smart to select fast growing species if we want to fix carbon. But these stands should be placed in the right sites, with proper thinning and management, and possibly mixed with other species.

But should we also regard other strategies to face the climate change challenge?

Protected area networks of natural habitats decrease the negative effects of climate change and provide resilience in preserving declining species of conservation concern. Intensive land use, such as forestry, strengthens the influence of climate change on biodiversity, because many species of natural habitats, such as mires and old-growth forests are negatively affected both by climate change and forestry.

However, climate change also affects protected areas, which calls for consideration and anticipation of changes in conservation planning. By appropriate and gradual adaption of forest management practices and sustainable use of forest resources, it will be possible to gain from the positive effects and decrease the negative effects of climate change. In terms of forest regeneration, the site-specific selection of species and regeneration methods should be applied. Timely and proper management of young stands is needed to maintain the vitality, resistance and health of forests and the resistance of trees to wind and snow-induced damage (30).

Future forest stands may survive and fulfil their multiple functions only if there is enough adaptive potential to cope with gradual changes and extreme events. Their adaptive potential is based on sufficiently large species diversity and within-species diversity (i.e. genetic diversity). Relying exclusively on the capacity of natural selection is appropriate if regeneration is abundant and has sufficient adaptive potential. Current knowledge does not allow us to determine whether a close-to-nature approach (which relies on spontaneous, natural processes including natural regeneration), or more proactive interventions specifically in enhancing forest regeneration will be required in future.

Selection of genetic resources for trees has, in the past, been most often focussed on selection and breeding for better quality (and faster grown) timber. Genetic resources are now, though, of significant interest and importance in the quest for species and genetic pools within species that show better potential for adaptation to climate change or subsidiary aspects of climate change, e.g. more disease pressure. As an example, in the UK the search for ash (*Fraxinus excelsior*) trees which show a resistance to 'ash die-back' may be the best hope we have of saving that important ecological and timber species. The same goal is pursued on cork oak (*Quercus suber*) and holm oak (*Quercus ilex*), in Portugal and Spain trying to find the provenances that are more resistant to drought stresses and plagues associated with the climate change.

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a. State of the art of research/ practice

According to Millar (2007) (7), managers will need to address the effects of climate change on forests through adaptation and mitigation strategies. Within adaptive strategies, silvicultural practices can be subdivided into 3 types of measures with complementary goals: (a) promoting resistance (to impacts and targeting high-value forest areas, in environmental, social or economic terms); (b) promoting resilience (ensuring that the ecosystem is able to recover to a given situation after a disturbance); (c) promotion of response (aimed at facilitating the ecosystem's transition from the actual situation to the future scenario).

- Resistance practices seek to improve forest defenses against direct and indirect effects of rapid environmental changes (7). That's the case of forest fire prevention/ defense (see minipaper 8 of this series);

- Promoting resilience is the most commonly suggested adaptive option discussed in a climate-change context (Dale et al. 2001, Price and Neville 2003, Spittlehouse and Stewart 2003 cited in (7)). For example, intensive management at reforestations during the early years (watering and controlling competition, plagues and diseases) may allow the establishment of certain species even when the conditions have deteriorated at the site;

- Promotion of response options intentionally accommodates change rather than resists it, enabling or facilitating forest ecosystems to respond adaptively as environmental changes accrue. Treatments implemented would mimic, assist, or enable ongoing natural adaptive processes such as species dispersal and migration, population mortality and colonization, changes in species' dominances and community composition, and changing disturbance regimes (7).

In the case of the European temperate forests six principles were referred by Brang (2014) for enhancing their adaptative capacity: (a) increase tree species richness, (b) increase structural diversity, (c) maintain and increase genetic variation within tree species, (d) increase resistance of individual trees to biotic and abiotic stress, (e) replace high-risk stands and (f) keep average growing stocks low (8).

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Several investigation projects are researching about adaptative silviculture with different approaches:

PROJECTS NAME	MAIN ISSUE ADRESSED	WEBPAGE FOR FURTHER INFO
CLIMO	Translating the CSA – Climate smart agriculture concept to a Climate-Smart Forestry (CSF) concept	www.cost.eu/COST_Actions/ca/CA15226
ASCC – adaptative silviculture for climate change	Establishment of experimental silvicultural trials	https://forestadaptation.org/ascc
Life MixForChange		http://www.mixforchange.eu/en/
Life +Suber		http://lifesuber.eu/en/
AdapteCCa.es	Networking platforms	http://www.adaptecca.es
Models for adaptative forest management – MOTIVE	Decision support systems (DSS)	https://www.wsl.ch/lud/motive/
ClimAdaPT.pt	Policy	http://climadapt-local.pt/en/project/
ProSilva	Advancing "close to nature" silvicultural systems	http://www.prosilva.org
Continuous Cover Forest Forestry Group		http://www.ccfg.org.uk/
FORGEN	Genetic resources research	www.apforgen.org
GENTree		www.gentree-h2020.eu
NordGen		www.nordgen.org/en/

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The adaptation of species to climate change or genetic improvement may change the potential distribution limits as we know them. Many studies indicate that climate change may be so fast that natural migration speed cannot keep up with the rate of change so it is likely that in the case of trees, natural migration must be accompanied by assisted migration (Linder, 2008; Kremer, 2007).Assisted migration actions, i.e. introduction of species where it is envisaged that future climatic conditions will be unacceptable, carries a high risk, not only associated with climate change but also because the installation of the species in new conditions would have an associated high failure risk.(5)

Some authors also defend the implementation of genetically oriented practices to accelerate adaptation, by increasing the chance of emergence of new genotypes and facilitating the spread of best adapted types (limiting random drift and consanguinity; increasing the diversity of mating pairs; avoiding counter selection and maintaining selection pressure) (9) (Box 4 and 5 for examples).

BOX 4: Results from provenance trials of 3 main species in Portugal

a) The influence of the origin of the adaptive characteristics such as survival, height and sprouting, which is an indication that natural selection gave rise to genetically differentiated populations of cork oak (*Quercus suber*). Drought tolerance is one of the distinguishing characteristics of Iberian cork oak. (Almeida et al., 2005; Facade, 2011);

b) In the case of maritime pine (*Pinus pinaster*), the similarity of observed behavior among provenances seems to be indicate the genetic proximity between populations of maritime pine at the national level (Cerasoli et al. , 2005; Ribeiro, 2001) although there is a high intra-population genetic variability (Correia et al. , 2004, Ribeiro, 2001). Studies of pine tree provenances conducted in France revealed morphological and adaptive characteristics (resistance to drought, frost and biotic agents) (related?) to the species' geographical distribution (Correia et al., 2004);

c) The umbrella pine (*Pinus pinea*) shows a low genetic variability along its distribution area which, however, did not prevent its wide geographical distribution (Vandramin et al). The low genetic variability is, from the outset, a weak point in the face of climate change, which is to some extent compensated by its high phenotypic plasticity, which explains, among other factors, the success of its dispersion (Fady et al., 2004). (5)

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BOX 5: Provenance research helps guide adaptive forest management (from Matyas, Cs. and Kramer, K. 2016. FORGER Policy Brief).

Superior or equal performance of non-autochthonous populations has been frequently observed in provenance tests of various tree species. This may be explained by the simultaneous action of genetic adaptation, gene flow and other genetic effects. It indicates the availability of a wider range of options in the choice of appropriate forest reproductive material (FRM), including use of FRM introduced through assisted migration. It is, however, always important to track the origin of the FRM.

Based on the analysis of the performance of tree populations in provenance trials, FORGER developed projections of future responses of trees. It also determined the species-specific extreme climatic conditions beyond which adaptive management would not be effective. The analysis of field studies allowed the assessment of optimal environmental conditions at species level and also for different populations within the same species, by identifying sites where maximum growth and vitality were recorded.

The following general patterns, common to all four tree species analyzed in FORGER (*Picea abies, Pinus sylvestris, Fagus sylvatica* and *Quercus petraea*), were observed:

• A significant part of the differentiation between provenances of a species is linked to climatic conditions at origin and is likely the result of climatic selection.

• The asymmetric shape of transfer functions (i.e. maxima of performance shifted away from local origins) indicates that local genetic resources are not necessarily superior.

• Limits of tolerance to climatic extremes are genetically determined.

• When exposed to extreme droughts, vitality of populations declines, particularly at the xeric limit (the low-elevation, low latitude limit of distribution where moisture supply is the main constraining factor) and may lead to mass mortality. Populations at the lower, xeric limits of the species' distribution are thus more exposed to climate change impacts.

Provenance trials provide a unique insight to guide adaptive forest management. However, existing provenance trials were not designed to study the effects of climate change. Therefore, new trials need to be established, especially designed to further investigate the effects of climate change on tree species and the use of genetic resources to increase their adaptation.

Forest management decisions on use artificial regeneration and choice of suitable forest reproductive material need to be based on information about the expected climate (change) patterns for a particular region. If the projections indicate that the local conditions will change drastically during rotation period, causing a significant decline in vitality of the stand, then use of alternative provenances may be considered. Provenance research trials and complementary information from silvicultural practice provide the basis for such decisions. One policy implication of the research findings obtained to date is that current national seed zone regulations may need to be reviewed in future.

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b. Existing best practices, tools, etc.

Below are listed some of the climate-smart silvicultural practices mentioned in the bibliography and also some examples from the practitioners' side.

Even-aged silviculture	Sustainable management and use of intensively managed indigenous forests practiced especially in the Boreal zone (Finland and Sweden), including both tree planting and natural regeneration. Local softwoods *Pinus sylvestris* and *Pice aabies* (Silvicultural guidelines 2014, revised. TAPIO [Finland]. Long experience with data from National Forest Inventories. (https://image.slidesharecdn.com/2017-bestpracticesforsustainableforestmanagement-170209113431/95/best-practices-for-sustainable-forest-management-in-finland-1-638.jpg?cb=149000895)
Selective thinning	A form of free thinning linked to close to nature forestry. Promotes structural diversity; decreases the water competition; increases individual tree resistance to biotic and abiotic factors. Can reduce genetic variability if just one selection criterion is chosen (e.g. stem straightness). The general idea is to create the conditions for the establishment of natural regeneration of the same or different species by opening clearings through selective thinning (in close to nature forestry).
CNS – Close to Nature Silviculture (Continuous Cover Forestry)	System based on mixed forests with heterogeneous structures and natural regeneration. Management may include proactive steering of natural successions instead of passive waiting for natural processes to occur. Relies on seven principles (with different expressions according to the site): Promotion of natural and/or site-adapted tree species (often based on the assumed potential natural vegetation); promotion of mixed forests; promotion of diverse vertical and horizontal stand structures; promotion of natural regeneration; silvicultural practice that focus on individual trees; avoidance of clear cuts.
Irregular silviculture for carbon sink enhancement	There are discrepancies in the way carbon sink rates are consideredin uneven-aged stands, being generally assumed that irregular silviculture usually has lower carbon sink rates. On the other hand carbon sink enhancement does not consider long term sequestration in the products (for example in non timber forest products like cork) or that uneven-aged forests with large old trees can reach large increments on suitable sites. Some carbon code promotes non-management of forest for highest rewards on carbon payments (UK carbon code).
Promotion of NWFP – Non wood forest products	Forest species producing NWFP are a niche of forestry that simultaneously increases adaptation (carbon sequestration) and mitigation (carbon sequestration on product). The introduction of these species in regular timber focused stands, would contribute to climate adaptation and may also be a form of proactive steering of natural successions; for instance, cork oak (*Quercus suber*) commonly appears naturally under planted stands of maritime pine (*Pinus pinaster*) and eucalyptus (Eucalyptus sp.), in the Mediterranean climate. The creation of canopy openings with different sizes within regular and monospecific stands to promote the regeneration of NWFP species is a practice to increase the species richness. EIP-AGRI workshop 'a New value chain from multifunctional forests' addresses the economic, environmental and social relevance of these species. (https://ec.europa.eu/eip/agriculture/en/event/eip-agri-workshop-%E2%80%98new-value-chains)

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	The reduction of the rotation length is another climate change friendly suggested practice. For example, that was achieved using grafting techniques on umbrella pine (*Pinus pinea*) young stands, allowing speeding up the first production (from 20 to 8 years) and decreasing the cone production fluctuation between years (that can be influenced by the climate change). (http://www.iniav.pt/fotos/gca/manual_ilustrado_enxertia_do_pinheiro_manso_1369127188.pdf**)**
Understory vegetation management to increase carbon sink in the soil	Special attention should be given to the direct effects of climatic changes on soils in particular on organic matter, particularly important for the performance of environmental and ecological functions of soils, such as fertility and hydrological regulation. The increase in temperature associated with dryer conditions will reduce the inputs of organic matter, which results from the lower production of biomass, which, in already vulnerable soils, will increase erosion and desertification processes. Fuel management practices without soil disturbance minimize impacts on the soil and increase their carbon content. (5) As example, changes in the way the understory vegetation was managed on cork oak forests occurred since 2007, being the plough replaced by a mechanical shrub shredder. This change benefits the forest adaptation/ mitigation of climate change as it increases the carbon sequestration in the soil and reduces the organic matter mineralization, along with the preservation of the integrity of the trees root systems. (http://www.terraprima.pt/en)
Different forest species rotations – a process to prevent soil diseases and improve natural regeneration conditions	The forest cover in areas of higher aridity, through their (re) forestation using species and appropriate installation techniques, could contribute significantly to soil recovery degraded or in the process of degradation. (5) Similar to agricultural practices where culture rotation is required, we've been observing that when changing the forest specie at a given site, for example from eucalyptus to cork oak plantation, higher rates of survival in the cork oak plants occur when compared to similar areas within cork oak forest. Also natural regeneration of cork oak appears in the understory of eucalyptus stands. Forest species rotations can be a process to prevent soil diseases and improve natural regeneration conditions for more demanding species?
Use of adequate reproductive forest resources	In Finland, as well as in other European countries, provenance regions (also called seed zones) have been established for different species with defined areas within which sufficiently similar ecological and climatic characteristics can be found. Within these areas, forest stands are sufficiently similar in terms of phenotype or genetic characteristics and can be used as preferential in reforestation projects. (https://www.evira.fi/en/plants/cultivation-and-production/forestry/notification-of-seed-collection/regions-of-provenance/). These provenance regions have recently been revised in Finland (Finnish Forest Tree Breeding Programme 2050, 2008. The use of high quality seed, suitable for different climatic conditions, is promoted by establishment of new grafted seed orchards. New deployment area maps that consider climate warming predictions were released in 2017 for improved seeds and seedlings of Scots pine (*Pinus sylvestris*) and are under preparation for Norway spruce (*Picea abies*). In addition, an establishment program for a network of gene reserve forests has been set up (30).

	In France, files for different forest species are available for the forest owners with advices on the use of forest reproductive materials, explaining the characteristics and needs of each species and the existing provenances (including international provenances) (http://agriculture.gouv.fr/graines-et-plants-forestiers-conseils-dutilisation-des-provenances-et-varietes-forestieres)

3. CONCLUSIONS

Summary: lessons learnt on the key issues

From the review realised it's clear that there isn't a perfect system/ solution that will allow the maximization of all the variables included in climate change adaptation – resilience, resistance, carbon sequestration, etc.

Complementary strategies must be implemented, fitted for local conditions, probably at a broader scale than the private farm. It's necessary to adapt/change practices, considering local circumstances, supported by more research (because of uncertainty), but also supported by practical demonstration sites with accompanied long-term monitoring.

Areas of even aged silviculture will still be needed in the future to maintain high rates of carbon sequestration, and for those, genetic improvement is mostly important for the selection of the most resistant and tolerant provenances in the future scenarios. But mixed and irregular patterns of forests are better adapted to climate change in terms of resistance and resilience against disturbance. How much do we need of each other? Should there be small patches of these different approaches (local scale) or biggest areas at a regional scale are good enough?

In the short term, we should rethink the new (re)forestations and their rotation period to decide about the species, the seed provenance, etc. If a species is currently at the dry end of their suitable range, it should not be planted again, if drought stress will be higher in the future (6).

If climate adaptation strategies change the forest areas, as we know them, to more naturalized areas, how can we motivate the forest owners for those changes in countries where most of the forest is private? For example in Finland, methods advocated by the researchers are only used by a few per cent of forest owners, even if they can freely choose between even-aged and uneven-aged management (see minipaper 1 on communication to raise awareness and minipaper 2 about economic incentives and minipaper 10 on small-scale forest management and family forestry). The issue is not only an ecological challenge, it's mainly a societal one and therefore policy issue, because nowadays the best forest to achieve climate change adaptation, may not be the most interesting from the economic perspective.

The need to encourage adaptation to the effects of climate change in European forestry is one of three climate change related key actions in the EU Forest Action Plan. The plan calls for targeted research, training and studies on the impacts of an adaptation to climate change.

For instance, present EU regulations on the use of forest reproductive material do not mention assisted migration as a measure to sustain future genetic adaptation. Considering that climate change will be a continued and perhaps increasing challenge also in future and that it will affect next generations of forests, the proper selection of forest reproductive material is crucial.

The Ministerial Conferences on the Protection of Forests in Europe, held within the pan-European process for policy debate and cooperation called Forest Europe, recognized the essential role of Europe's forests in tackling climate change challenges, and highlighted the need for an enabling policy framework.

4. RESEARCH NEEDS

Knowledge gaps to be covered by research

- **Future local/ regional guidelines for the implementation of innovative silvicultural practices towards adaptation (<u>TOP PRIORITY according to the Focus Group</u>)**

  a) What to do and where?
  b) Demonstration plots network of silvicultural practices (with intense monitoring and data analysis to produce information for landowners forest management)
  c) DSS at the local scale (farm) (how is the forest today and what will be expected in the future in the farm with a risk assessment tool regarding changing species, practices and economics)

- **Silvicultural Techniques to be tested under different conditions**

  a) Selective Thinning and higher thinningintervals
  b) Low-impactharvesting techniques
  c) Mixed stands management(research based, silvicultural guidelines for indigenous broadleaved species need to be developed)

- **Nursery practices and genetic improvement**

  a) Integrated pest management (IPM) and biological control in seedling production
  b) Threats of pests (risk assessment and responsibilities of importer, producer, trader; effective control measures; training of nursery people, both for ornamentals and forestry)
  c) Genetic diversityin clonal standsfor the definition of minimum requirements for the number of clones in different forest species, to maintain genetic diversity and decrease stands susceptibility to pest and diseases
  d) Genetic improvement on cork oak (*Quercus suber*) and holm oak (*Quercus ilex*) to select drought resistant provenances
  e) More species and provenance trials (For instance in Finland to try out different seed sources of *Quercus robur*)
  f) Breeding for resistance to pests/ insects

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Research needs from practice

- Local and regional adaptation of innovative silvicultural practices (different silvicultural methods implemented at the stand and management unit level, on landscape scale)
- Threats of pests (trade with ornamental species; should import of some species be banned in some countries)
- Resilience of stands, requirements of genetic variation
- Arboretums as living genepools and climate experiments
- Situation of proper seed sources for species mainly used for other goals than economics
- Testing different provenances of seeds obtained in regions where the climate conditions are the ones expected in the future in higher latitudes
- Development and homologation of plant protection products
- Densities optimization for NWFP
- How can one forest species favour the next one in the succession? Can exotic species help in the establishment of more demanding autochthonous species?

5. IDEAS FOR INNOVATIONS

Ideas for innovative projects/ solutions

- Horizontal integration, pest threat management together with horticultural people (parks, ornamental plants)
- Risk assessment and early warning (see minipaper3)
- Recommendations on mixed stands, pure *Picea abies*, mixed with broadleaves (*Betula, Alnus, Fraxinus*, etc.)
- Game management, how to protect seedlings from animal interaction (repellents and coating treatments of seeds and seedlings)
- Economic incentives to include broadleaved species on suitable sites
- Seed transfer programmes

Potential EIP operational groups

Operational Group about “Effects of climate smart silviculture on carbon stores and forest resilience in Europe”

Further research needs coming from practice, ideas for EIP AGRI operational groups and other proposals for innovation can be found at the final report of the focus group, available at the FG webpage https://ec.europa.eu/eip/agriculture/en/content/focus-groups/new-forest-practices-and-tools-adaptation-and

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