The German forest tree breeding concept – the base for new seed orchards

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Abstract

Climate change is one of the key challenges of the 21st century. The environmentally friendly, CO2-saving and resource-saving raw material wood is of particular importance in efforts to counteract the undesirable consequences of this development. With the search for CO2-neutral energy resources and rising energy prices, the demand for wood is steadily increasing. However, the demand for wood is increasing not only in the energy sector (heating sector, power generation, biofuels), but also in the material-mechanical and chemical sectors, high growth rates are forecast. Forest tree breeding can contribute to the solution.

Key words: forest tree breeding, seed orchard, Douglas-fir, Scots pine

Current forest situation in Germany

Germany is covered by 10.9 Mio ha of forests. The percentage is 32 %. About half of the forest area is public owned (4 % Federal Government, 29 % state, and 19 % municipal). The remaining 48 % are private owned.

The last German federal forest inventory 2012 (BMEL 2016) showed that 43.4 % of the forest area are covered by broadleaves and 54.2 % are occupied by conifers. Since the previous inventory (BMELV 2005) the area of broadleaves has increased (+2.8 %) and the percentage of conifers has decreased (-2.8 %) (BMEL 2016). The highest losses are observed for Norway spruce followed by Scots pine. The area of silver fir and Douglas-fir increased during the last 10 years.

Regarding the age pyramid of forests there is a lack in the age classes 1 (age up to 20) and 2 (21-40 years for the conifers between the two inventories. The reason is the change in manner of forest regeneration. Since the 1980th the percentage of planting and seeding on one hand to natural regeneration on the other site has changed to the opposite. The percentage of natural regeneration was 80 % in 2002 and 85 % in 2012.

Planting is restricted nowadays on afforestation, if natural regeneration is missing, when a change in tree species is planned, to introduce additional species, after external events (e.g. storm, fire), and in some cases to change the provenance to increase growth / quality.

Due to implement the National Strategy of Biodiversity (BMU 2007) natural forest development without any use is planned on 5 % of the forest area in Germany until 2020, and 10 % of the public forests, respectively. By 2020, an increase in raw wood demand for material and energy use of up to 20 million m^3 is expected (MANTAU 2012). For these reasons, it is necessary to develop a precautionary strategy to meet future challenges. An important starting point is forest tree breeding with the provision of high quality, high performance and resistant seed and seedlings.

Potential of forest tree breeding

The potential of forest tree breeding is demonstrated by conservative model calculations. The models are based on the following fix assumptions:

For afforestation on one third of the area the current choice of the provenance is right. On one third of the area the present stand will be substituted by a better growing provenance of the category "selected" and an increase in yield of 5 % is supposed. On the remaining third of the afforestation area the present stand will be replaced by a forest reproductive material of the category "tested" with an assumption of an increase in yield of 10 %. For conifers a mean increase of 14.24 m^3/ha*year was assumed, and for broadleaves of 9.70 m^3/ha*year.

In 4 scenarios three variable assumptions were used (Table 1):

(1) The annual regeneration area is (1.a) calculated as the mean of the last 20 years or (1.b) 1 % of the forest area. These are 64,000 ha/year and 103,200 ha/year, respectively.

(2) The proportion of the planting area in comparison to the natural regeneration is (2.a) 50 % and (2.b) 70 %. This means that on 50 % and 30 %, respectively, the forests will still be regenerated naturally.

(3) The species proportion of broadleaves to conifers is (3.a) 50:50 and (3.b) 40:60.

Table 1: Combination of variable assumption in the four calculated scenarios

Scenario	Regeneration area	Planting proportion of the regeneration area	Species proportion: broadleaves : conifers
Scenario 1	mean of last 20 years (64,000 ha/year)	50 %	50 : 50
Scenario 2	mean of last 20 years (64,000 ha/year)	70 %	40 : 60
Scenario 3	1 % of forest area (103,200 ha/year)	50 %	40 : 60
Scenario 4	1 % of forest area (103,200 ha/year)	70 %	40 : 60

The models show that after 40 years between 0.77 million m^3 (scenario I) and 1.78 million m^3 (scenario IV) wood can be available annually. This sustainable wood supply is only (mid- to) long-term possible when the process has started once.

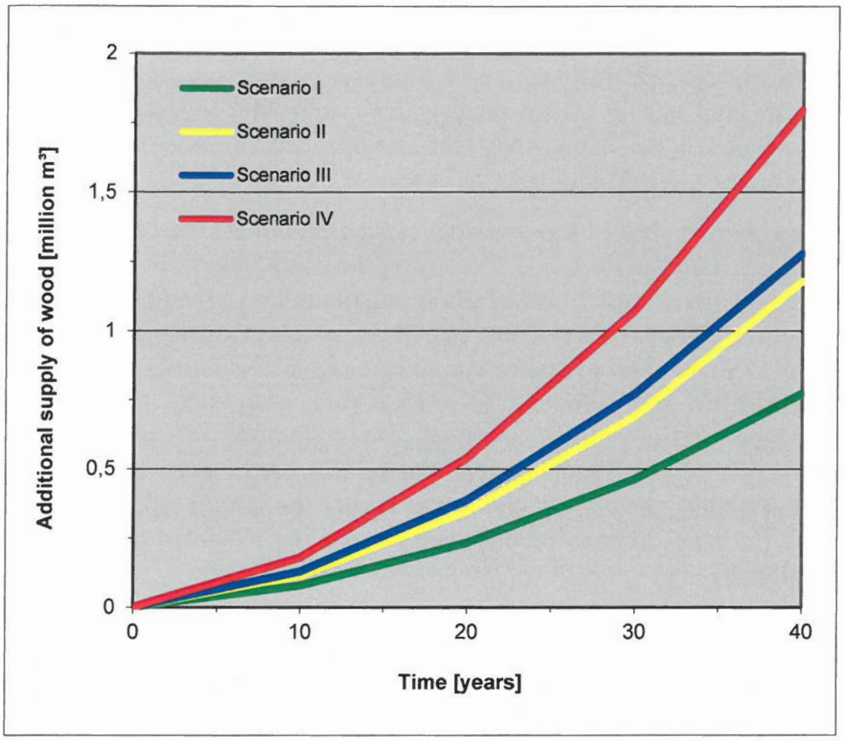

Figure 1: Addition mean annual wood supply in the 4 scenarios after 40 years.

Political development

Since the beginning of this decade there are new activities by the federal government to promote the need of forest tree breeding.

In the ***Forest Strategy 2020*** ("Waldstrategie 2020" [BMELV 2011]) contains in the chapter silviculture solutions which are connected with forest tree breeding. The following approaches are suitable ways of achieving a close to nature and environmentally compatible increase in forest productivity:

- Creation of diverse, stable and high yield mixed forests
- Planting of site-adapted species of trees with a high level of resistance and growth rate
- Use of high quality, site-adapted, resistant and high yield forest plants

As a milestone to achieve the "Climate protection plan 2050" the ***Charter for Wood 2.0*** ("Charta für Holz 2.0" [BMEL 2017]) was adopted. The Charta puts its focus on a sustainable wood supply, which is addressed for forest tree breeding in the chapter forests and wood as resources within the field of actions. Important statements are:

- Cultivating productive tree species
- Securing the supply of softwood
- Forest tree selection/forest genetics
- Alternative sources of raw materials (e.g. short-rotation-coppices [SRC], agro-forestry)

Forest tree breeding strategy

In Berlin the 3rd meeting on the Forest Strategy 2020 of the BMELV in April 2010 and the BMELV workshop on forest tree breeding organized by the Thünen Institute of Forest Genetics and the Agency for Renewable Resources (FNR) in November 2011 gave a good overview on the current state of work, the enormous potential, but also to the clear need for Germany to catch up in this area compared to other countries (report in LIESEBACH 2011). An important objective of breeding is to provide reproductive material that is adaptable and powerful enough to meet the expected changes in the performance of all forest functions. The workshop has clearly clarified that forest tree breeding in Germany can only meet these great requirements of the future and deliver visible results, if all remaining federal and state breeding facilities cooperate even more closely by sharing the tasks and financing not only in the short term but also in the medium to long term for a period of at least 15 years.

Based on comparable strategies abroad and in view of the available capacities, forest tree breeding will have to focus on a few tree species in the future in Germany. Therefore, the more important is the right selection of these species. Due to the long generation times of the trees, forest tree breeding programs are only successful after decades. However, because it is possible to build on already existing results, clear successes can be expected after about 15 years. New programs would take significantly longer periods of time. Experience has shown that within this approximately 15-years period, a significantly increased growth and value performance can be expected through breeding. When choosing the tree species, different aspects are important. On the one hand, it should be tree species that can be expected to show significant breeding progress in the planned period, on the other hand, the future orientation of silviculture in view of climate change must be taken into consideration and the expected demand for products and services of the forest included.

Finally this process leads to a „Breeding strategy" for 6 tree species or species groups (Table 2), which was published in November 2013 (LIESEBACH et al. 2013). There are much more species of interest in breeding. The 6 species were chosen as model species because for each a different approach is followed.

The intensity of breeding will vary depending on the species (Table 2). The range extends from the testing of progenies of stands (e.g. oak) to the installation of new high-performance seed plantations (e.g. sycamore maple) up to controlled crossings (e.g. larch). The achievable improvement in volume yield after 15 years of breeding work averages of 10 %. In the longer term, a value increase of at least 20 % is to be expected.

Table 2: Future breeding priorities the 6 focus tree species or tree species groups (LIESEBACH et al. 2013)

Species	Reason	Breeding priorities			
		Stands	Seed orchards	Parents of families	Clones
Douglas-fir	growth potential	x	x	(x)	-
Larches	breeding experience, growth potential	(x)	x	x	(x)
Sycamore maple	expected growth potential	(x)	x	-	-
Norway spruce	main species, breeding experience	-	x	-	(x)
Scots pine	main species, breeding experience	-	x	-	-
Oaks	valuable main broadleaves	x	(x)	-	-

The **Douglas-fir** (*Pseudotsuga menziesii* [Mirb.] Franco.) is particularly important due to its growth performance and its ability to replace Norway spruce in some locations. Breeding focuses on the testing of progenies and the establishment of seed orchards. Furthermore, family crossings are conceivable.

Larches (*Larix decidua* Mill., *L.×eurolepis* Henri) are promising because of their growth performance and the extensive breeding advance. Here, the establishment of seed plantations and the approval of parents of families of promising hybrids are in the foreground.

The **sycamore maple** (*Acer pseudoplatanus* L.), which has not yet undergone breeding, is of particular importance both in the mountains and in the lowlands and as a tree in mixed stands. In the foreground are seed orchards, whereby also increases can be expected due to the testing of progenies.

Norway spruce (*Picea abies* [L.] Karst.) and **Scots pine** (*Pinus sylvestris* L.) are the most common tree species in German forestry and are expected to remain so for the foreseeable future. Here, among other things, the establishment of seed orchards is in the foreground.

In the case of **oaks** (*Quercus petraea* [Matt.] Liebl., *Q. robur* L.), breeding activities will focus mainly on the testing of progenies with the aim of the approval of forest reproductive material of the category "tested".

Beside these six species breeding within the Genus *Populus* was financed in the FastWOOD projects by the BMEL through the FNR with the focus on SRC. These projects started in 2008 and will end between 2017 and 2019 (e.g. BORSCHEL et al. 2012; LIESEBACH 2015). During that time more than 1,000 new crosses were done, over 60 progeny trials were established and new material in the category "tested" was approved by analysing existing trials (LIESEBACH 2013). BMEL and BMUB are funding a project within the Waldklimafonds (2014-2017) to develop a management concept for seed stand with beech to increase the quality of the seed (EUSEMANN et al. 2017a, b). Recently a project on ash breeding started on the background of ash die back.

Implementation of the breeding strategy

In 2014 the implementation of the breeding strategy started with the joint project FitForClim (2014-2018) (MEIßNER et al. 2015, JANßEN et al. 2017). Within this joint project all breeding organizations work together. The bigger ones coordinate the work within the six species: Norway spruce and oaks (Northwest German Forest Research Institute [NW-FVA]), sycamore maple (Bavarian office for Forest Seeding and Planting [ASP]), larches (Public Enterprise Sachsenforst [SBS]), and Douglas-fir and Scots pine (Thünen Institute of Forest Genetics).

The aims of the project FitForClim are to delineate deployment zones (approx. 3 per species), to select plus trees (between 500 and 800 per species), vegetative propagation of the plus trees, growing plants to establish progeny trials, genetic characterisation of the plus trees, analyses of mating system of Douglas-fir, approval of forest reproductive material in the categories *"qualified"* and *"tested"*, and investigation on frost hardiness. The delineation of deployment zones takes future climate scenarios into consideration. The majority of the plus trees are selected in progeny trails where a direct comparison with other progenies is given.

The vegetative propagated plus trees will be saved in archives. An archive (*"breeding population"*) contains the approx. 200-300 genotypes of a deployment zone. This is done in the joint project AdaptForClim (2017-2019) (WOLF et al. 2017). Further work packages in this project are the development of a concept for the structure of seed orchards to maintain genetic sufficient diversity, and of a concept on additional provenance trials to realize the breeding strategy, the reorganization of clonal trials with Norway spruce into stands to harvest seeds, physiological investigation on the grafts of the plus trees, and the establishment of several progeny test (e.g. with Douglas-fir progenies from seed orchards, with oak progenies and single tree progenies of Scots pine). The clone archives are the base to compile new seed orchards (*"production population"*) in a further step. Both projects FitForCLim and AdaptForClim are funded by BMEL and BMUB within the Waldklimafonds.

The breeding strategy for Douglas fir is shown in Figure 2 and for Scots pine in Figure 3 which are coordinated by the Thünen Institute of Forest Genetics.

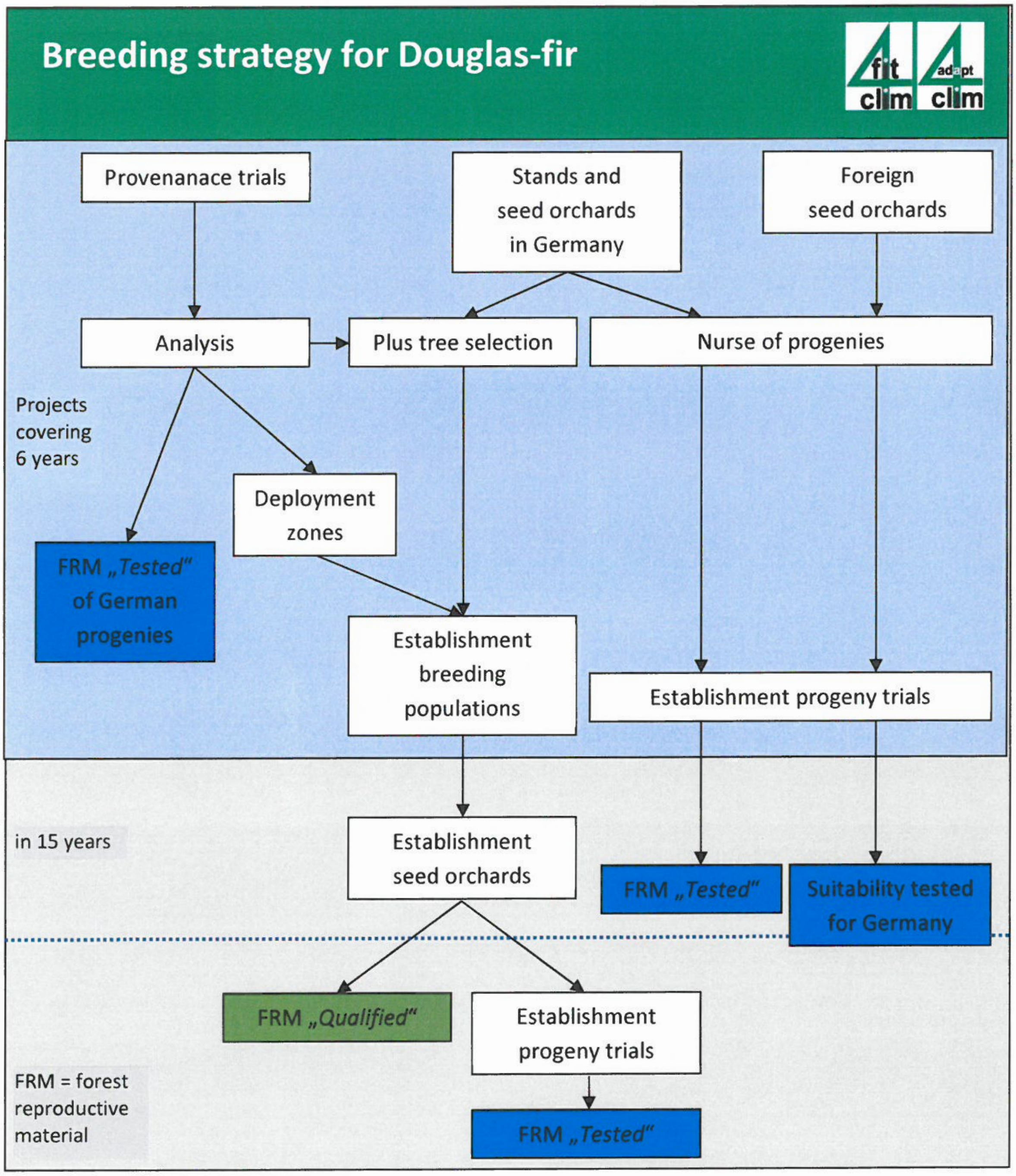

Figure 2: Breeding strategy for Douglas-fir. The blue shaded part is financed by the projects FitForClim and AdaptForClim.

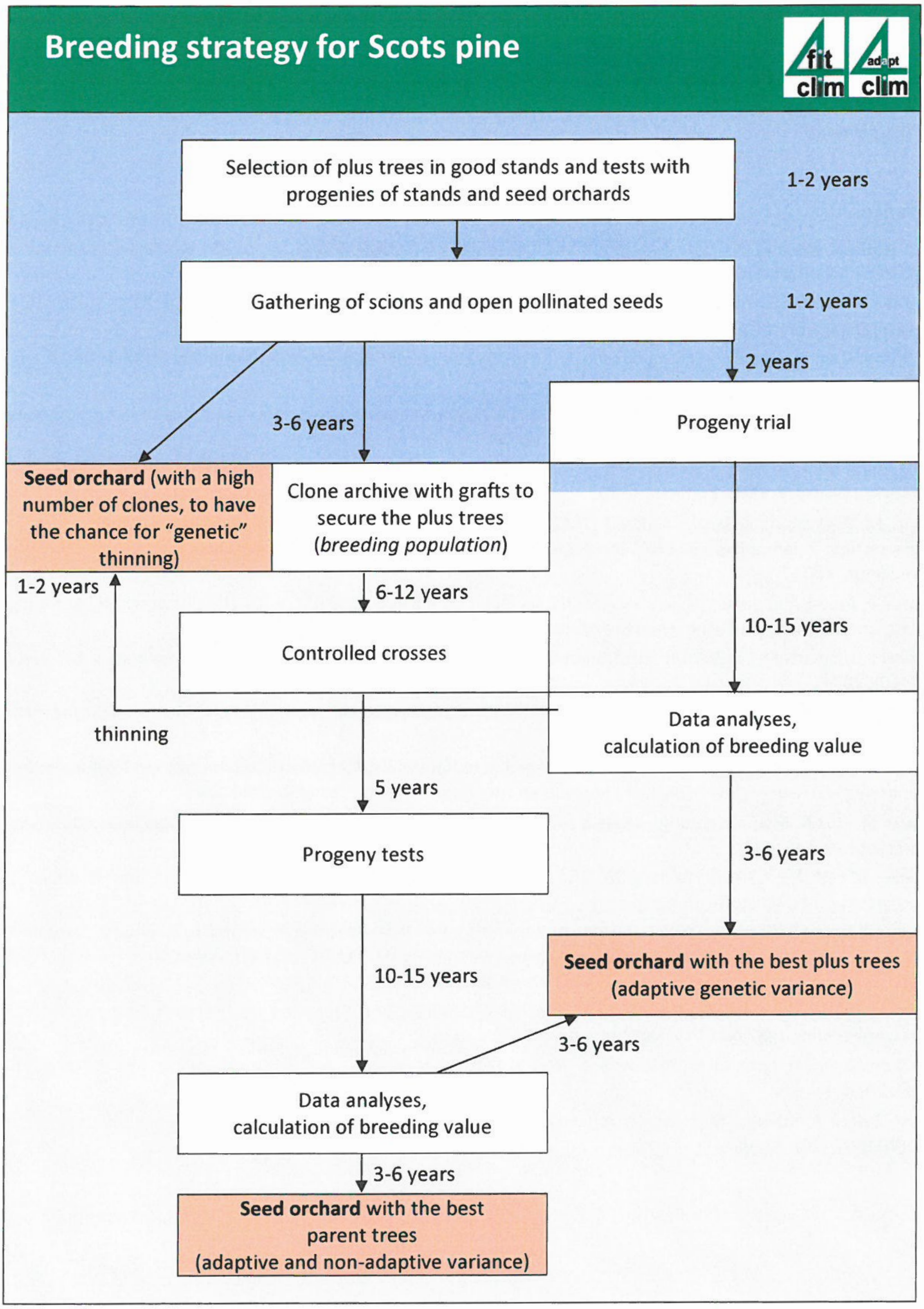

Figure 3: Breeding strategy (positive selection of individuals with progeny tests) for Scots pine. The blue shaded part is financed by the projects FitForClim and AdaptForClim.

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