Tandem Forest Value project

FutureGenes: Resilient future forests via genomics of adaptation to climate in natural forests and breeding populations

Consortium:

Luke: Katri Kärkkäinen

UOulu: Tanja Pyhäjärvi, Outi Savolainen

SLU, Umeå: Harry Wu

Skogforsk: Mats Berlin

I Description of the research:

The objective of Tandem Forest Value call was to combine basic and applied research to contribute to new methods of forest management that meet both existing and new needs and goals of forest owners and society. That is needed to understand the role of the forest in efforts to tackle climate change, and for sustainable use and maintenance of forests in Nordic countries.

In FutureGenes, we combined genomic and quantitative approaches and compared genetics of two major species in Nordic forests, Scots pine and Norway spruce to 1) reveal local genomic adaptations in natural populations and compare adaptations between the two species. Genomics work was done in collaboration with other projects. Breeding for growth may have an influence on growth phenology, and we aimed to compare 2) the effects of breeding on adaptive variation at the phenotypic and genic level. The use of improved genetic material in future deployment populations was studied in EU projects. In the project FutureGenes, we aimed to 3) add genomic understanding into the analyses of optimal deployment. And finally, we planned to 4) study the effects of breeding and deployment on genetic diversity. Results of the project was planned to be utilized by breeding programmes and national recommendations and project has dissemination and communication plan for interaction with researchers, stakeholders, and general audience.

In 2019, we announced open a postdoctoral researcher position, focus on research on genetics and genomics of local adaptation to climate change in populations of Scots pine and Norway spruce. She/he was expected to take part in e.g., in sequence analysis

(comparisons of genes and networks involved in growth rhythm in Scots pine and Norway spruce), analyses of genetic variation, differentiation and genomic prediction (e.g., quantitative genetic analyses, GS; methods, and in defining optimal deployment models for future climates. The position was based on collaborative research between Luke, UOulu, SLU and Skogforsk, and as a requirement of funding party (KSLA), will share working time between two countries, in practice, between Oulu and Uppsala (host: Skogforsk).

During year 2019, we hired a post doc, Haleh Hayatgheibi, to work on the project. She has allocated her time equally between countries, her main office being Luke Oulu, but she had a desk also in Skogforsk, Uppsala. Furthermore, she visited regularly Harry Wu's group in SLU Umeå. In 2019, she divided her time between countries equally, and the plan (weeks in Oulu/Uppsala) is made for each month depending on the stage of each research activities.

During the first year, she analyzed large quantitative genetic study of Scots pine conducted by Luke. The data will be used to answer the questions 1 and 2, and further analyses will be done when genotyping activities are completed for these progenies during year 2020. Furthermore, she has participated in analyzing similar datasets on Norway spruce in Harry Wus laboratory. For the questions 3 and 4, Haleh has analyzed large dataset consisting Swedish breeding trials with the guidance of Dr Mats Berlin to assess how progressing tree breeding affects optimal deployment of regeneration material. These sensitivity analyses continued during 2020. She has also been analyzing the amount of genetic variation in drought tolerance in Norway spruce breeding material in both countries.

In addition to national projects, Haleh has been strengthening our international collaboration in H2020 project B4EST by participating in discussions on methodology on genomic prediction, and being a coauthor in a review in prep. on trade-offs of adaptive traits and financially important characteristics and their role in changing climate.

Several joint manuscripts are in preparation. Furthermore, Haleh participated in courses on genomic selection and maintenance of genetic variation in breeding programmes during year 2019. She has also been actively participating the Oulu plant genetics group discussions and UOulu statistical genomics group meetings.

In 2019, the project was progressing as planned. The only delay has been caused by genotyping platform, the international agreements with EU project B4EST, partners and the company Thermo Fisher are causing some delay in obtaining the genotypic SNP-data for analyses.

In 2020, the progress of the project suffered substantially due to covi-19 pandemics. From March onwards, travelling between countries became difficult – and it was not accepted by Lukes covid-19 regulations. While collaborative meetings, analyzing data and writing MSs was feasible, the SNP analyses were severely delayed due to Covid-19 problems in EU coalition (B4EST project, especially British collaborators) and in commercial supplier Thermo Fisher. The genotypic data was finalized in late autumn thus the final analyses are presently being completed.

Haleh was offered a position from Skogforsk, and she ended her Tandem Forest Value post doc in October 2020. We contacted KSLA Eva Ronquist, MSc Agriculture, Secretary of the General Section, on the matter and agreed with KSLA secretary that no new post doc was hired for such short period, but the project was finished by work contributions of Lukes researchers.

During the FutureGenes project, Haleh produced two first-author publications, in collaboration between Luke and Skogforsk which was mainly about climatic adaptation, including 1. Application of seed transfer effect models in Scots pine 2. Impact of drought stress on Norway spruce. She also participated in producing a poster to a scientific meeting and writing a collaborative research proposal. Furthermore, data she has analyzed will produce several other publications, e.g. SNP chip development, comparison of genetic variation in natural vs breeding populations, GWAS and GS analyses of Scots pine (Luke lead data), and intensive quantitative genetic analysis on about 50 clonal progeny trials of Skogforsk that will be published in the future. Furthermore, she was involved in writing a part about wood quality in a review paper on trade-offs together with a large European coalition. Due to delays in SNP chip work, the comparative studies on the genomic adaptation in Scots pine and Norway spruce will be conducted in 2021-2022, thus after the Tandem project.

II Publications:

Hayatgheibi, H., Berlin, M., Haapanen, M., Kärkkäinen, K. and Persson, T., 2020. Application of Transfer Effect Models for Predicting Growth and Survival of Genetically Selected Scots Pine Seed Sources in Sweden. Forests, 11(12), p.1337.

Hayatgheibi, H.; Haapanen, M.; Lundströmer, J.; Berlin, M.; Kärkkäinen, K.; Helmersson, A. The Impact of Drought Stress on the Height Growth of Young Norway Spruce Full-Sib and Half-Sib Clonal Trials in Sweden and Finland. Forests 2021, 12, 498. https://doi.org/10.3390/f12040498.

Poster in scientific meeting:

The effects of natural and artificial selection on seedling traits in Scots pine (Pinus sylvestris). Sonja T Kujala, Timo Kumpula, Haleh Hayatgheibi, Komlan Avia, Tino Knurr, Katri Kärkkäinen, Outi Savolainen 2020/1/28 Conference: Genetics to the rescue: Managing forests sustainably in a changing world. University of Avignon, France.

Manuscripts in preparation (to be submitted in 2021, more papers emerging later):

Kastelly et al. PiSy50k, a genotyping array for Scots pine (Pinus sylvestris)

Kastelly et al. Comparison of genomic and quantitative genetic variation in natural population and breeding population of Scots pine.

Kujala, Hayatgheibi et al. Genome wide associations in natural population of Scots pine

Kujala, Hayatgheibi et al. Possibilities of genomic selection in breeding of Scots pine

Climent et al. Trade-offs in trees

III Impact of FutureGenes to competence building that will facilitate and strengthen long term collaboration between Finland and Sweden.

FutureGenes has increased collaboration between Nordic countries. While some degree of collaborative efforts existed before this project, the collaboration has intensified.

The genomic tools that have been developed during the time of FutureGenes, and the expertise needed to use them will be highly important for the future. The research teams involved in this project have been involved in developing SNP chip platforms: the development of Scots pine SNP chip where main responsibility was in Finland (UOulu, Luke), and the development of SNP chip of Norway spruce where the main responsibility was in Sweden (SLU, Umeå Plant Science). These tools that will be possible to utilize in the future via commercial company (Thermo Fisher) will be jointly utilized by Luke and Skogforsk for breeding work, and by other institutes for research purposes. Furthermore, during the process, partners have been sharing expertise in bioinformatics (sequence analyses), and in genotype-phenotype statistics (GWAS, GS).

Collaboration in tree breeding has been discussed with Luke and Skogforsk (led by breeding programme leaders Matti Haapanen, Thomas Kraft) during 2020 and 2021, and collaboration has been seen highly important in themes studied in this project: assessment methods of optimal deployment of forest regeneration material, evaluation of novel genomic methods in tree breeding, and possibilities to include novel traits increasing resilience and wood quality in breeding programmes. In addition to conifers studied in this project, collaborative interests have been identified to cover broad-leaved trees (especially silver birch).

IV Description of research areas being started or strengthened at the departments in Finland and Sweden

Genetic basis of adaptive variation in traits important to climate change is a theme that will be jointly studied, as well as impact of selection in tree breeding on traits that are not under selection (e.g. how selection on growth influence growth rhythm or wood quality). Studies on forest management practices (e.g., advancing breeding, deployment methods) on genetic diversity have also been identified as joint interest.

While FutureGenes ended, new collaborative efforts have been planned and proposed, e.g., Horizon Europe call in prep (call yet not open), and ERANET Forest Value (consortium Assess4Manage submitted, SLU and Luke as partners, Katri Kärkkäinen as a coordinator).

V FutureGenes and strengthening the forest sector in Finland and in Sweden

Forest sector needs wood, and sustainable wood production is essential for economy of these countries. Results and methods tested in FutureGenes will help national breeding programmes conducted by partners Luke and Skogforsk. Furthermore, the analyses conducted by the FutureGenes on optimal deployment of advanced generation seed orchard material will affect the deployment recommendation in both countries – and thus has impact on growth and resilience of managed forests.

VI Description of communication with relevant stakeholders and end users

During the project lively discussion has been conducted between partners, stakeholders and end users. Discussions have been conducted via established channels (e.g. informing the advisory board of Tree Breeding and seed supply hosted by ministry of agriculture and forestry in Finland, in meetings (e.g. Metsätieteen päivät), and together with other international projects (e.g. H2020 B4EST). While covid-19 situation has radically decreased meetings and discussions in person, virtual meetings have exploded and provided numerous possibilities for interaction between stakeholders. During the project, one key person of the group, Tanja Pyhäjärvi, got a tenure track professorship in forest genomics and tree breeding in University of Helsinki, and has used our results in teaching. Furthermore, discussion with stakeholders is seen highly important also in the future, and partners of the project, in different coalitions will continue that work, and is seeking more resources for that (e.g., in Finland funding was applied from MMM Catch the carbon call to build an information platform on possibilities of tree breeding and regeneration methods on mitigating the effects of climate change and helping sustainable forestry). New collaborative

efforts are presently being discussed with partners and stakeholders, e.g. on the role of broad-leaved trees in Nordic forests and in forestry.

VII Financial accounting

Most of the costs covered salary of post doc:

- Haleh, 2019- 10/2020; salary with obligatory additional costs = 114.167,64€ / 1.187.343,45 SEK (corresponding to 80,5% of working costs)

Other working costs include supervision by Katri Kärkkäinen, small working contributions of staff of Luke in helping out with study and cost of researcher of Luke (Dr. Sonja Kujala) that helped to finish the project after Haleh left (See Appendix 2)

salary costs with obligatory costs = 27.511.36€ / 286,118,14 SEK

Other costs include mainly travelling and accommodation. The detailed information on costs is included in attachments.

The realized costs follow quite carefully planned ones, as shown by Table 1.

Table 1. Planned costs vs. realized cost in the project FutureGenes. Details on realized costs can be found in Appendix 1 and 2.

	Budget	Realized costs
Salaries	1 418 249	1 473 462
Overheads	1 347 336	1 296 646
Other coststst	494 880	528 386
Total	**3 260 465**	**3 298 494**

In behalf of the FutureGenes consortium,

15th April 2021

Katri Kärkkäinen