Resilient Future Forests Pilot Project in Uzbekistan and Kyrgyzstan

Progress 2022 report

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Prepared for the International Union of Forest Research Organizations (IUFRO) by

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Executive summary

This report describes our progress in 2022, with the following main achievements in both Kyrgyzstan and Uzbekistan. We installed pilot experiments on the ground to do the first tests of innovative treatments we consider for the planned RFFL locations, and first results are reported.

One of our main efforts was designing and compiling 3 Micro-nurseries in Denmark based on more than 25 years of nursery- experience in practice. The Jiffy-7 plant types we focus on here are expected to provide significant opportunities for RFFL locations to demonstrate innovative solutions for forest restoration and afforestation that are both cost- and water-efficient and as such capable of supporting successful establishment at lower cost, and at more challenging sites than Business As Usual (BAU) treatments. The Micro-nurseries are now delivered in both countries and are being prepared for producing the first innovative plants for pilot experiments to be installed in 2023. There is a brief User's Manual available as an appendix to this report, and the team will provide consultations and advice for this first production of such nursery plants.

Additionally, we developed further upcoming research proposals for the future RFFL projects including more detailed discussions and considerations for the practical installations, site and species selection, treatment description, plant production and associated budgets.

Finally, the climate and hydrologic modeling continued aiming at documentation of the effects of forest cover in the mountains to regional hydrology and how climate change may alter this. The efforts have, however, been challenged by technical problems and reduced access to computing power this past year but we are positive that the work on the Aktash watershed (Uzbekistan) will succeed in covering all the Tien Shan basin in the years to come.

Introduction

This report summarizes the project achievements in 2022, which are resting on our collaboration since 2020, and described in the status report by Stanturf et al. “Resilient Future Forests Pilot Project in Uzbekistan and Kyrgyzstan - End of 2021 status report” dated 14. Feb. 2022.

The main approach of our collaboration is to provide solutions for Forest Landscape Restoration (FLR) on the ground. We therefore need to address the complexity and challenges for successful forest restoration both taking the interests and perspectives. This needs to be done in tandem with concern for the multiple stakeholders and their present needs and preferences as well as the long-term interests of society in expanding the cover of resilient future forests that provide multiple ecosystem services as they need to adapt and overcome stressors of changing climate. To do this our aim is to design and use the Resilient Future Forest Labs (RFFL) in a fruitful international cooperation and partnership where local knowledge and experience can meet and foster synergies with the international networks of practice-oriented forestry science.

Figure 1. The landscapes in Central Asia – here Kyrgyzstan Nov. 2021. Free ranging herds of domestic grazers is a major challenge for FLR to succeed and provide erosion control and other ecosystem services. Solutions need to address not only the grazing pressure but also the summer drought while remaining cost-effective and provide services and be acceptable for the stakeholders and their daily needs.
Left: Grazed fields after harvest as well as grazed hillsides in the background.
Right: The mountain lake Issyk Kul at 1,600 m.a.s.l. in the background of croplands and grazed fields.

FLR objectives and challenges addressed by the RFFL

To have the FLR objectives and challenges present here we list here prime management objectives for the mosaic landscape and forests in both Central Asian countries (from our past status report):

- Restoring forests to protect and enhance quality water supply while avoiding down-stream erosion or flooding caused by deforestation.
- Establish trees shelterbelts, agroforestry, or wood pastoral systems to increase both agricultural and wood production.

The challenges for tree planting in the degraded landscapes are many and substantial:

- Free ranging domestic stock grazing: Abundant herds of domestic grazers graze across the entire landscape except the herders keep the animals out of farm fields when crops are there. In the areas controlled and managed by the state forest services or the forest research institutes grazing may be limited depending on local agreements with staff and presence of fences and their condition.
- Drought: Summer drought or drought in all the growing season is common, which has made irrigation a common practice in afforestation projects close to urban areas an infrastructure and with much and important attention on the success.
- Limited infrastructure and steep slopes: Access to large parts of the landscapes is limited, which favor practices that need little materials for transport across terrain.

The "Innovative" and "BAU" treatments forms together with the "Do nothing" treatments the basic structure of the RFFL experimental approach to develop, document, and demonstrate potential solutions for FLR.

Figure 2. The landscape in and around the Taldy-Bulak RFFL location in Kyrgyzstan, Nov. 2022.
Left: A typical view of the Central Asian landscapes with excessive grazing in need for increased forest or tree cover to provide erosion control and multiple other ecosystem services.
Right: Part of the RFFL team inspecting walnuts planted as wildlings, which are naturally regenerated walnuts (barerooted) transplanted in the 2022 spring from walnuts in a central region of Kyrgyzstan.

Micro-nurseries for better plant material – airpruned containerized plants versus bareroot and plastic bag grown plants

Our online collaboration in 2020-21 was finally expanded and rewarded by our first opportunities to meet in Kyrgyzstan and Uzbekistan in November 2021. We had then the opportunities to inspect potential RFFL locations and initially discuss what we see as the most promising and needed targets for improvements for FLR. We concluded that testing new nursery planting materiel would be one of such targets.

Airpruned containerized plants have shown convincing results and improvements in practice. There is scientific documentation available from Europe and North America, but to our knowledge similar investigations have not been conducted under drier climatic conditions like in Central Asia.

Based on our experiences and the available evidence, we address the challenges of drought, needs for irrigation and reducing the weight of plant material to be carried up into poorly accessible planting sites by testing airpruned plant types as the innovative treatments against BAU and "Do nothing" treatments including traditionally used plant types (bare rooted or seedlings grown in plastic bags with mineral soil growth medium).

We hypothesize that the airpruned container plants will:

- rapidly establish and capture a large root volume at the site shortly after planting and early in the first growing season
- reduce or eliminate the need for irrigation the first years after planting
- provide smaller, lighter, and easier planted plants to considerably improve cost- and labor efficiency of the restoration efforts in the landscapes
- hopefully reduce the need or the size of terraces needed for improving soil moisture on the hill sides.

The containerized plants (seedlings) can be transplanted both when actively growing and when dormant because they keep all their roots undamaged including the fine root during the process of transport from the nursery to the planting site. However, it is crucial that their needs for water and light are observed during transport and storage. Large plants left for just some hours under the sun on a hot day and with no proper irrigation may easily be killed. Likewise, wrapping them in closed containers with high temperature and moisture may kill them as well. <u>They are not difficult to handle – those responsible for the operation just need to remember that they are handling active and sensitive plant material.</u>

The potential avoidance of the transplanting chock to obtain uninterrupted growth immediately after transplanting and initial fast growth of the roots into the soil of the planting spot are the most obvious advantages we pursue. However, the faster initial growth in the green house as well as other long-term advantages can be expected, too. This includes better anchoring, stability, and straighter stems for timber species due to better root symmetry and tap root development (see Appendix 1).

Figure 3. Examples of Jiffy-7 grown seedlings in scientific field experiments, Denmark, illustrating how the initial root development of small airpruned containerized seedlings appear. Above: Fine roots in the bottom of the Jiffy-7 at a 1-year Alnus seedling upon planting while actively growing in June. Below, left: Tilia transplanted to the field in August of the 1st growing season and lifted 1 month later in Sept. for inspection of root growth. Below, right: Fagus, like the Tilia to the left.

Particularly in boreal forestry of Scandinavia, North America and in larger forest industries elsewhere in the world, the containerized plants with various types and quality of airpruning are the commonly used plant (stock) type. Usually, it requires larger initial investments in green houses and their infrastructure as well as more well-developed distribution systems, which seem to be the main disadvantages. However, our approach with initial tests using Micro-nurseries offer an opportunity to start in small scale and become familiar with the system and the plant types but avoid high initial investments and thereby high economic risk. The bareroot plants and plants grown in plastic bags are the commonly used (BAU) in many regions of the world and in Kyrgyzstan and Uzbekistan as well, Figure 4.

Figure 4. Examples of ongoing afforestation in the watershed of the Charvak Reservoir, Uzbekistan, where afforestation has been pursued for decades now to reduce erosion and sedimentation.
Above, left: Afforestation along some of the main roads in the area including extensive technical installations of water tanks and supply systems to facilitate the irrigation of the plants the first years after planting.
Above, right: Planted but failed walnuts in the same area. We expect innovative plant types such as the Jiffy-7 containerized plants can increase success and reduce costs considerably.
Below, left: We inspected other recently planted afforestation sites in the area and found more evidence of the value that improved methods and technology potentially can provide.
Below, right: 1-year old Pistachios grown in plastic bags and in mainly mineral soil, Forestry Research Institute of Uzbekistan.

Bareroot plants need to be dormant to reduce loss of water between they are lifted out of the soil in the nursery and planted at the site. They lose some or many of their fine roots as well athe contact with soil and access to water uptake during this process.

Many tree planting projects often fail to monitor the outcome following planting. Insufficient monitoring and reporting of successes or failures may lead to overall large-scale failures because insufficient approaches and management are not corrected and improved but repeated.

RFFL achievements in 2022

Micro-nurseries – design, compilation, and shipment

After our first visit and meeting in Central Asia in November 2021, we designed and compiled the components March-April 2022 for the Micro-nurseries in Denmark. Initially, we intended to ship them early to mid-April aiming for the first plants to be produced in 2022, but the pandemic caused delays in supply chains of these components. Further, the customs regulations for such shipments turned out to be far more complicated than expected. However, in late July – early August joint efforts in both ends of our supply chain including negotiations with local logistic companies, customs, and other collaborators paved the way for the shipment of all three Micro-nurseries to first Bishkek, Kyrgyzstan and then one of them was forwarded to Tashkent, Uzbekistan.

In November 2022 we met within our team in Kyrgyzstan and later Uzbekistan to have the Danish nursery owner, specialist, and forester Peter Benfeldt, to lead the guidance in assembling the Micro-nurseries and provide the initial guidance in operating them for the first year starting late January or February 2023, Figure 5. Peter Benfeldt has more than 25 years of experience in operating and managing a private forest tree nursery producing more than 50 woody species (tree and shrub species) grown in Jiffy-7 containers.

The primary advantages of this nursery system for the plant quality are described above. However, for the purposes of RFFL in Central Asia we expect are a number of additional advantages:

- The system is designed for primarily ebb-flow irrigation, which is considerably more water use efficient in the nursery than sprinkler or mist irrigation from above. Additionally, it ensures that all Jiffy-7 pellets in the airtrays are equally and sufficiently watered at each irrigation. The alternative use of irrigation from above on well-developed crops of trees forming a uniform closed canopy together, leads to uncertain water supply to the individual pellets in the trays.
- The system is suitable for starting in small scale in an initial learning- and test period for the personnel responsible for its operation and function. Therefore, larger investments in equipment can wait for later expansion until the first experiences have been gained and the personnel is familiar with it.

Disadvantages relative to bareroot plant production may include:

- Higher costs per produced plant in the nursery even in larger and operational scale. It is important to stress that our goal with the innovative treatments of the RFFL is to provide lower cost than BAU per surviving plant in the field when the trees can be considered well-established and free to grow. Inexpensive BAU plants from the nurseries may not provide inexpensive restoration success if survival of these trees is lower.
- The plants growing in the Jiffy-7 airtrays are depending on sufficient and constant supply of WATER. Unlike bareroot plants grown in the field of the nursery, the containerized plants only have the water buffer of the pellets, which is rather limited on a hot or windy day and with large plants. Therefore, the system is critically depending on daily and careful monitoring and management by the personnel in charge. Consult the Grower's

Manual (APPENDIX 1) for further details on the management of Micro-nurseries.

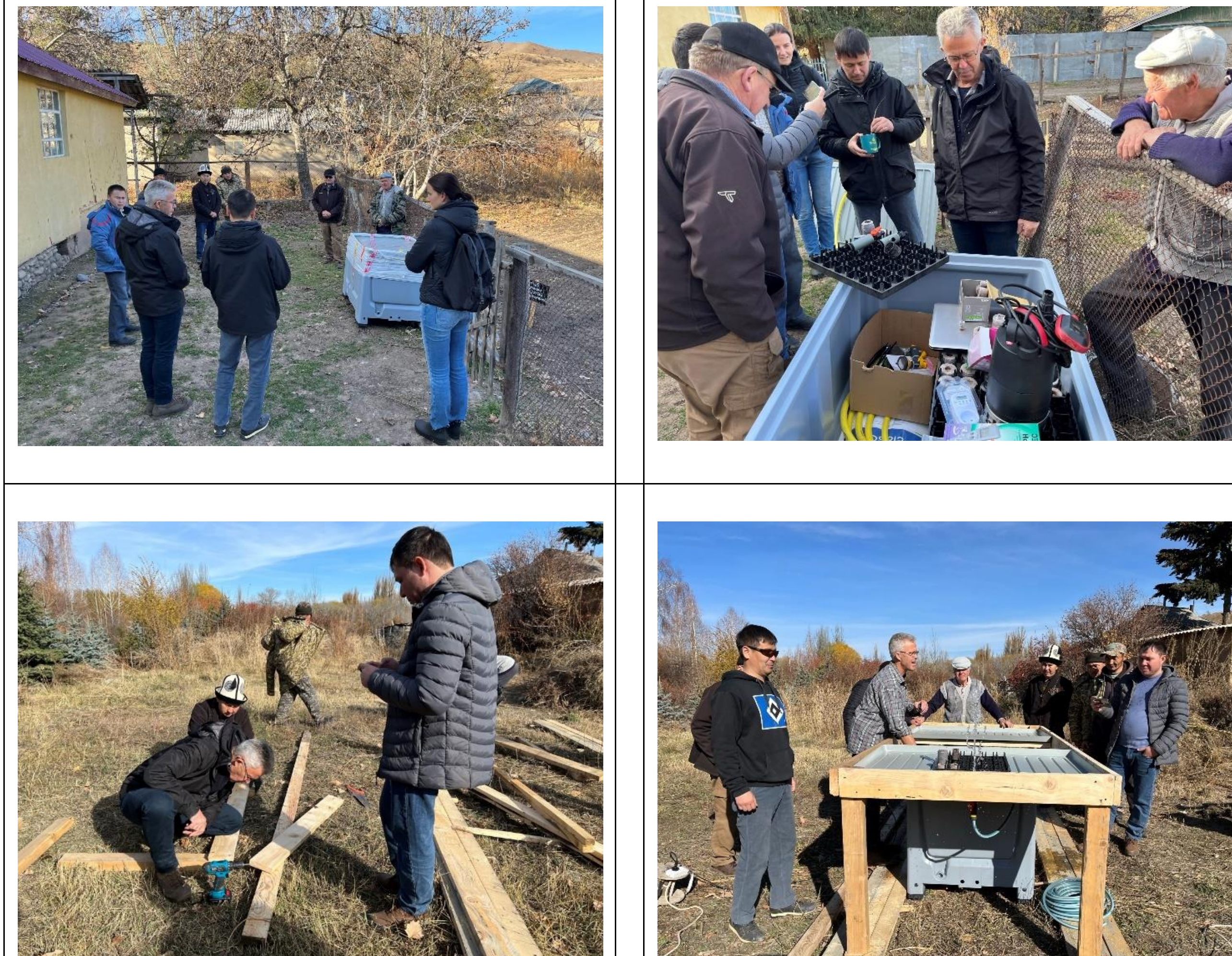


Figure 5. Unpacking and installing a Micro-nursery in Ak-Suu, Kyrgyzstan, 2. Nov. 2022. Peter Benfeldt described the components, the assemblance and functionality of a Micro-nursery, and gave further instructions for the future operation. Senior Researcher Timur Tulyaganov, Forestry Research Institute for Uzbekistan, participated to gain first-hand experience from Peter Benfeld's instructions and experience, since Peter could not later join us for Uzbekistan. The Micro-nursery capacity is 648 plants distributed to 3 ebb-flow trays each with 6 airtrays each holding 36 plants. Additional pellets may be sown on the side to be certain all of the available capacity is utilized.
Below, right: The table with the ebb-flow trays and an airtray, the water tank with the submersible water pump inside, and the hoses, valves and fittings to allow water from the tank to flood the ebb-flow trays with the plants and then a return valve to allow the water returns to the tank. A green house is needed to cover the Micro-nursery for the first month(s) to protect and secure the initial phases of plant development during seed germination and early seedling growth establishment. Later the plants need outdoor conditions to be exposed to wind-movements and develop robustness.

Figure 6. Peter Benfeldt describing potentials for plant and tree quality by the nursery using Jiffy-7 airpruned containerized seedlings as well as providing instructions for the operation of the system including opportunities for using a range of pellet sizes and types as well as warnings for the critical factors such as irrigation and proper control of fertilizer, pH, EC (electrical conductivity). For further information see APPENDIX 1.

Pilot field experiments established in 2022

Kyrgyzstan

So far there are 2 or 3 RFFL locations selected for the further progress and proposals of our project in Kyrgyzstan:

- **Ak-Suu Forest Experimental Station,** 400 km east of Bishkek and high elevation (> 2,000 m.a.s.l., focus on conifer species, figure 7.
- **Taldy-Bulak,** 90 km west of Bishkek, 1,300 m.a.s.l., focus on broadleaved species, figure 7.
- **Sary-Bulak / Jaiyl Leshoz,** 90 km west of Bishkek, 1,300 m.a.s.l., focus on broadleaved species.

Figure 7. Two of the RFFL locations in Kyrgyzstan upon inspection in Nov. 2022.
Left: Ak-Suu Forest Experimental Station, elevation 2,200 m.a.s.l.
Right: One of the walnuts planted in April 2022 in the pilot experiment of Taldu-Bulak. Please observe the already established (decades ago) large and continuous terraces and the mulching of the planting spots to reduce competition and improve soil moisture for the plants.

Only BAU plant types were available for these first Pilot experiments. The innovative plant types from the Micro-nurseries will be available for the next step of pilot experiments in 2023.

Taldy-Bulak: These first pilot plantings of walnut (Juglans regia) were established 15. April 2022 on a north-east facing hill side (Figure 8) at elevation 1,330 m.a.s.l., and with large (3-4 m wide) continuous terraces established decades ago, figure 8.

The area is fenced against livestock, but there were damages and many signs of their presence inside the fence (droppings). The fence provides some but not total protection against the livestock.

A quick inspection of the soil indicated a deep brown soil with high clay and silt content – apparently a rich soil with a good water holding capacity.

The Kyrgyz team have reported on this effort, which is here briefly summarized:

- The walnuts planted were wildings (naturally regenerated) from Zhazy-Kechuu, Jalal-Abad Region, Kyrgyzstan. Estimated 2 years of age by planting for these wildings.
- Stock density: 6 m in rows, 7 m between rows. First row 4,5 m between plants (Figure 8).
- 107 plants planted.
- Inventory 2. Sept. 2022 (selected results):
    - Survival – 93 trees, 87% (most of the "dead" trees were missing)
    - 33% of the surviving trees were damaged by livestock (*missing trees may have been pulled up by that livestock?*)
    - Average height on the individual terraces ranged from 51 to 95 cm with the tallest trees on the lowest terraces and the shortest at the highest.
    - Within each terrace there were a large variation as well – shortest trees by terrace ranged from 7 to 68 cm and tallest from 72 to 112 cm.
    - We plan to interplant sacrificial nurse crop species to increase stock density to 2x2 m or 3x3 m to better pursue the objectives of erosion control. The walnuts are planted in a very wide spacing for that purpose.
    - The hay-harvest on the plot is further reported as 30 bales of hay per hectare, which is Illustrating the importance for of grazing or hay-harvest for the stakeholders.

The plan for pilot experiments in 2023 includes 8 treatments and 3 blocks (replications) to be installed spring 2023. Treatments are alternative sacrificial nurse species as well as different densities of theses. Treatments are 2 or 3 sacrificial nurse trees per crop tree (walnut) and a control-treatment (no sacrificial nurse trees).

The potential woody species we expect to include in the RFFL locations and associated pilot, and small-scale experiments are shown in Table 1.

Table 1. Species preliminary considered as crop species and sacrificial nurse or filler species. The allocation of species to functions and the 3 locations is expected to be revised as the project develops. Sacrificial nurse plants are in the same spots as crop species for protection against grazers, whereas filler plants are planted in between the crop species to increase stock density and thereby improve erosion control.

Crop species	Candidate sacrificial nurse or filler species All locations
1. Ak-Suu Forest Experimental Station *(so far only challenging site identified), south-east facing*	
Pinus sylvestris (Scots pine)	*1. Rosa canina (undesired by farmers)*
Pinus sibirica (Siberian pine)	*2. Sorbus tianshanica*
Pinus nigra var. pallasiana (Crimean pine)	3. *Lonicera tatarica* (Honeysuckle)
Picea schrenkiana (Tien Shan or Schrenk spruce)	*4. Berberis racemose (undesired by farmers)*
Pseudotsuga menziesii (Douglas fir)	5. *Hippophae rhamnoides* (Sea buckthorn)
	6. *Prunus armeniaca* (Apricot, sacrif. nurse. Ak-Suu)
2. Taldy-Bulak (gentle), north-facing	*7. Ziziphus jujuba (Jujuba)*
3. Sary-Bulak / Jaiyl Leshoz *(gentle – partly sheltered*)	*8. Malus sieversii* (Wild apple) https://ucentralasia.org/news/2022/march/preserving-wild-apple-species-in-western-tian-shan
Juglans regia (Walnut)	9. *Elaeagnus angustifolia* (Russian olive)
Prunus armeniaca (Apricot)	*10. Prunus cerasifera* (Alycha - Cherry plum)
Pistacia vera (Pistachio)	
Prunus sp. (Almond)	

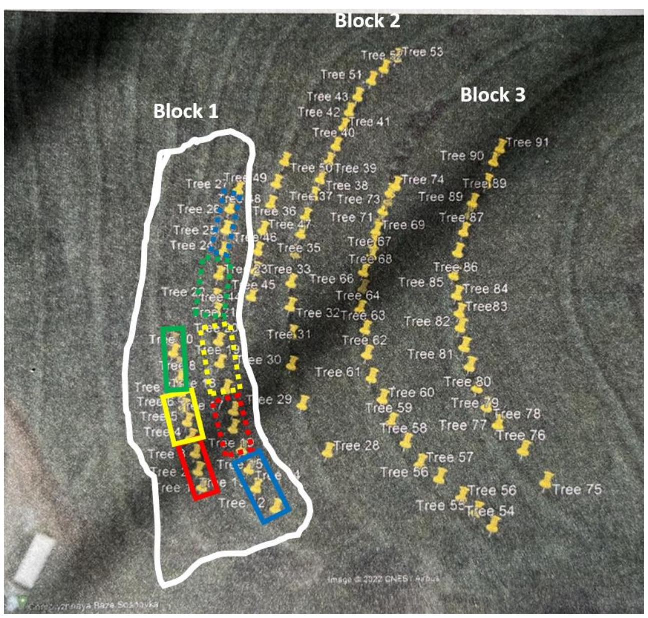


Figure 8. The pilot planting of walnut April 2022 in Taldy Bulak.
Above: Location of the plot on the north-east facing hill side.
Below: Map of the location of the individually planted and recorded walnuts on the 6 terraces including a first draft experimental pilot experiment to be installed in spring 2023 with 8 treatments and 3 blocks (replicates).

Uzbekistan

There are 2 planned experimental sites delineated and measured for pilot experiments testing BAU plant types the innovative plants produced by the Micro-nursery in 2023. They are in the area around the **Charvak Reservoir, Burchmullo Forestry Enterprise,** 100 km north-east of Tashkent and at elevation approximately 950 m.a.s.l.

The identification and establishment of the plots are reported in a separately by E. Botman et al. (11. Dec. 2022) and is briefly summarized here and in figure 9:

- 2 sites of each 0.5 ha
- The steeper slope, the denser stocking is used and prepared by terracing.
- Site no. 1 is on the steepest terrain, so the crop species (almond and pistachio) are planted at 4 x 4 m stocking but in separate rows. To further increase the stocking dog rose (*Rosa canina*) is planned for interplanting as a filler species in both the rows with almond and pistachio as well as in between these rows, so the total stock density including all 3 species will be 2 x 2 m corresponding to 2,500 plants / ha. 12.5 % almond; 12.5 % pistachio; 75 % dog rose.
- Site no. 2 is on less steep terrain, so a 5 x 5 m stocking is selected and the crop species and design with filler species are the same as for Site no. 1. The total stock density including all 3 species will be 2.5 x 2.5 m corresponding to 2,000 plants / ha. 12.5 % almond; 12.5 % pistachio; 75 % dog rose.
- According to the forest manager of the Burchmollo Forestry Enterprise new regulation of livestock is adopted now. In future only free ranging horses are allowed, which is unlike the common regulations in most of the country. Therefore, the grazing pressure in the areas around the Charvak Reservoir is expected to considerably decrease in the future. Further, the Site no. 2 is fenced, too.

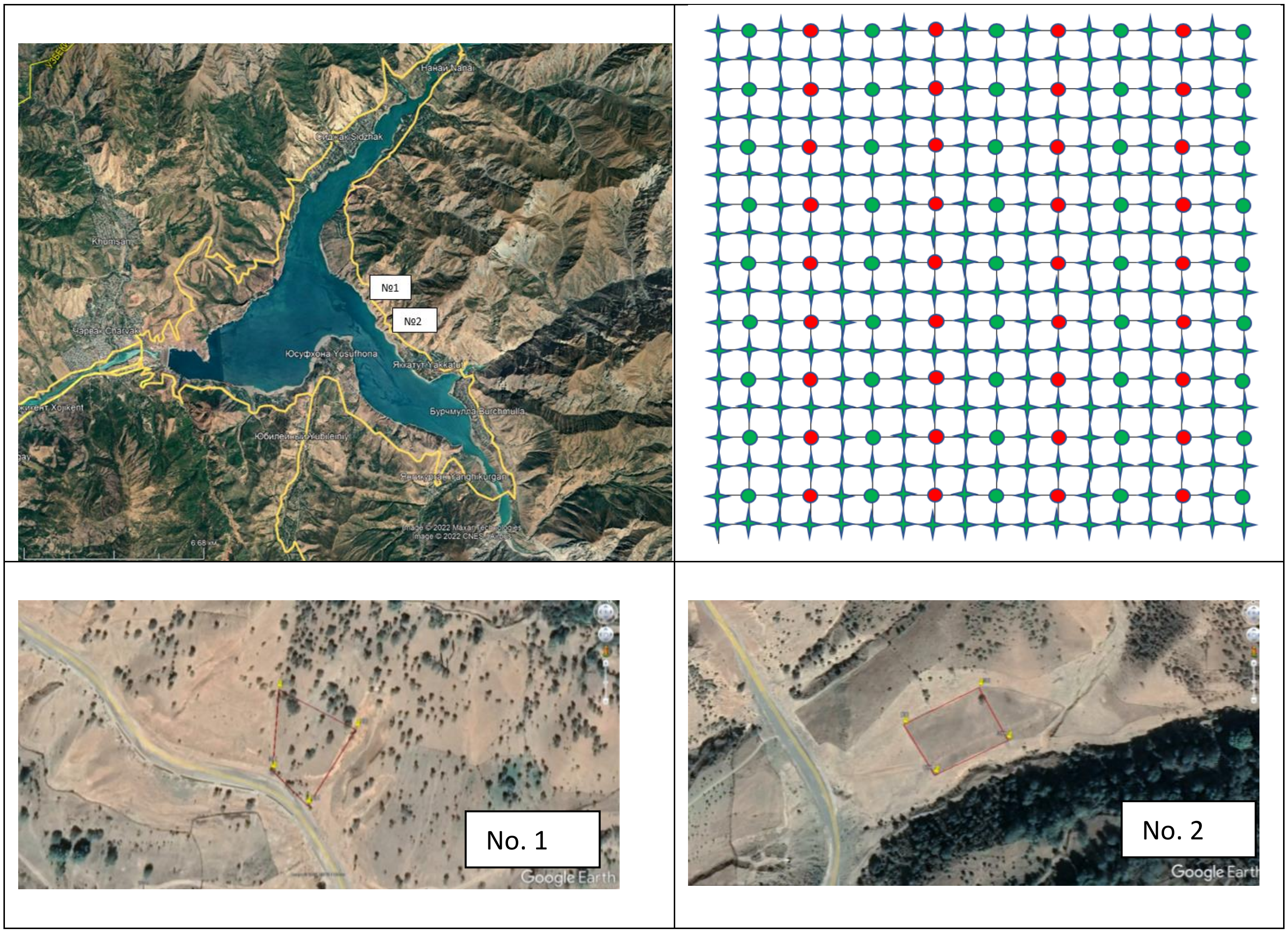


Figure 9. The pilot experiments at the Charvak Resevoir planned for planting in 2023.
<u>Above, left:</u> Location of the two pilot experimental sites.
<u>Above, right:</u> The planting pattern at the two sites with a 2 x 2 m and 2.5 x 2,5 m stock density at site no. 1 and no. 2, respectively. = Almond; = Pistachio; = Dog rose (filler species).
<u>Below, left and right:</u> The two sites showed in higher resolution.

Table 2. Species preliminary considered as crop species and sacrificial nurse or filler species in the area of Chervak Reservoir. The allocation of species to functions and the 3 locations is expected to be revised as the project develops. Sacrificial nurse plants are in the same spots as crop species for protection against grazers, whereas filler plants are planted in between the crop species to increase stock density and erosion control.

Challenging Site, Elevation Range 1000 to 1500 m, south aspect: ***Crop species*** *Prunus mahaleb* (Mahaleb cherry) *Prunus armeniaca* (Apricot) *Crataegus turkestanica* (Turkestan hawthorn) *Crataegus pontica* (hawthorn) *Celtis glabrata* (hackberry?)	**Challenging Site, Elevation Range 1000 to 1500 m, south aspect:** ***Filler species*** *Lonicera tatarica*(honeysuckle) *Berberis racemosa* (barberry) *Rosa canina* (dog rose) ***Sacrificial nurse species*** *Berberis racemosa* (barberry) *Rosa canina* (dog rose) *Prunus armeniaca* (Apricot)
Gentle Site, Elevation Range 800 to 1200 m, north aspect: ***Crop species*** *Juglans regia* (walnut) *Prunus mahaleb* (Mahaleb cherry) *Juniperus seravschanica* (Pashtun juniper) *Juniperus virginiana* (Eastern red cedar, Not local) *Prunus armeniaca* (Apricot) *Pinus sylvestris* (Scots pine, not local) *Pinus nigra var. pallasiana* (Crimean pine, not local)	**Gentle Site, Elevation Range 800 to 1200 m, north aspect:** ***Filler species*** *Lonicera tatarica* (Tatarian honeysuckle) *Berberis racemosa* (barberry) *Rosa canina* (dog rose) ***Sacrificial nurse species*** *Berberis racemosa* (barberry) *Rosa canina* (dog rose) *Prunus armeniaca* (Apricot)

Preparing for RFFL proposal to be submitted in 2023

Here we summarize the plans and content of the upcoming RFFL locations following the pilot experiments and the pilot production of innovative Jiffy-7 containerized plants in the Micro-nurseries.

The research proposals for the future RFFL projects will need more discussions and development in the first 6 month of 2023. Particularly, budgeting of the greenhouse and nursery capacity as well as developing competences are key issues. Here the management of the Micro-nurseries in 2023 will provide valuable experiences for the implementation on the ground.

The discussions of the project plans, content, and proposal during our meetings in November 2022, materialized roughly into the treatments across the RFFL locations as follows:

Content of the 3 main groups of treatments

1. Do nothing
2. BAU – Business As Usual
3. Innovative treatments:
    - Air pruned Jiffy-7 container seedlings.
    - Sacrificial nurse trees – planted or sown in the same spot as crop trees to provide a growing physical protection or cover of the crop species – will need future management and timely removal or reduction (Figure X).
    - Temporary (inexpensive) fences.

8 treatments in greater detail – 3 x 3 m spacing of crop trees if nothing else is mentioned

1. Do nothing - leave plots to natural regeneration/colonization
2. BAU – bareroot plants at 1x1 m terraces,

Innovative: Jiffy only planted at 1x1 m terraces

3. Protection of crop trees by sacrificial nurse trees/shrubs
4. Temporary fence - supported by small experimental fences in other treatments, too

Stock density treatments:

5. 400 trees / ha (5 x 5 m)
6. 400 crop trees + 1,200 filler trees or shrubs / ha (2,5 x 2,5 m)
7. 1.100 trees / ha
8. 2.500 trees / ha trees (2 x 2 m)

Area required per RFFL location:

2 replicates of each treatment
16 plots each 0.5 – 1.0 ha
Total: 8-16 ha – practically 10-20 ha each RFFL location
Plants required per RFFL-location: Roughly 25,000.

Guidelines for initial site registration, monitoring, data handling, and management are in progress for RFFL locations.

Climate and Hydrologic Modeling: Assessing Mountain Forests Impact

Summary

The climate and hydrologic modeling are concentrating on demonstrating the effect of forest cover in the mountains to regional hydrology and exploring the effects of climate change on the relationship. Hydrologic modeling by Ying Ouyang (USFS) was initiated in 2021 and a site-specific SWAT (Soil and Water Assessment Tool) model developed to characterize the mountain forest hydrological processes in the Aktash River basin, Uzbekistan. Evapotranspiration (ET) has been simulated ETs and compared to ET estimated from remote sensing (MODIS ET data from MOD16A2 with an 8-day interval and a 500m resolution for a period from 2000 to 2014). The SWAT model will be used to project hydrological processes under future climate, with and without forested vegetation. Progress on the climate modeling has been slowed due to technical problems and limited access to needed computer resources. Work in the Aktash watershed in Uzbekistan will be extended to the entire Tien Shan basin. The following describes detailed results to date.

Project progress 2022

Estimating hydrological processes is central to water resource management, water supply planning, ecological protection, and climate change impact assessment. In water resource management, hydrological processes such as surface runoff and streamflow are used to issue discharge permits. In water supply planning, hydrological processes are used to determine allowable water transfers and withdrawals. In ecological protection, hydrological processes are employed to assess terrestrial and aquatic habitats. In climate change impact assessment, patterns and variations of hydrological processes are critical indicators of climate variability. Mountains in Central Asia are the major source of water for rivers, terrestrial lives, and agricultural practices. Disturbance of mountain forests in Central Asia through overgrazing, illegal logging, drought, and wildfires have altered forest hydrological processes and accelerated soil erosion, mudflows, landslides, and downstream flooding. A thorough literature search reveals that very few efforts have been devoted to estimating mountain forest hydrological processes in Uzbekistan and the Kyrgyz Republic.

We developed a site-specific SWAT (Soil and Water Assessment Tool) model to characterize the mountain forest hydrological processes (*e.g.*, streamflow, evapotranspiration (ET), groundwater recharge to streams, surface runoff, snow melt, and water yield) in the Aktash River basin, Uzbekistan (Fig. 10) under a changing climate. The SWAT model input data such as digital elevation model (DEM), land use, soil type, and slope data are obtained from Google Earth, whereas the weather data such as air temperature and precipitation are provided by Dr. Marcus Williams. The model simulated ETs are compared with those ETs estimated from remote sensing (MODIS ET data from MOD16A2 with an 8-day interval and a 500m resolution for a period from 2000 to 2014) (https://modis.gsfc.nasa.gov/data/dataprod/mod16.php). Ideally, it would be good to calibrate

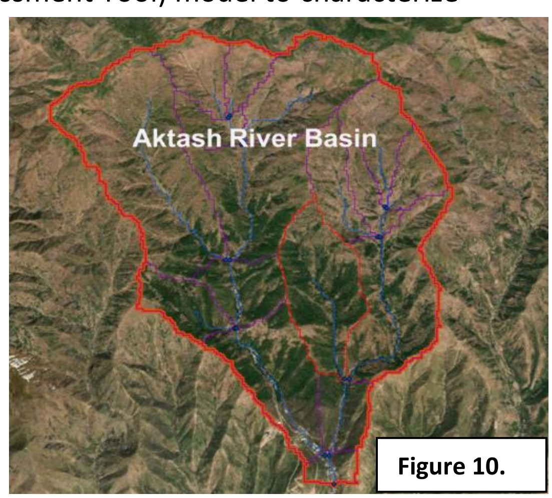
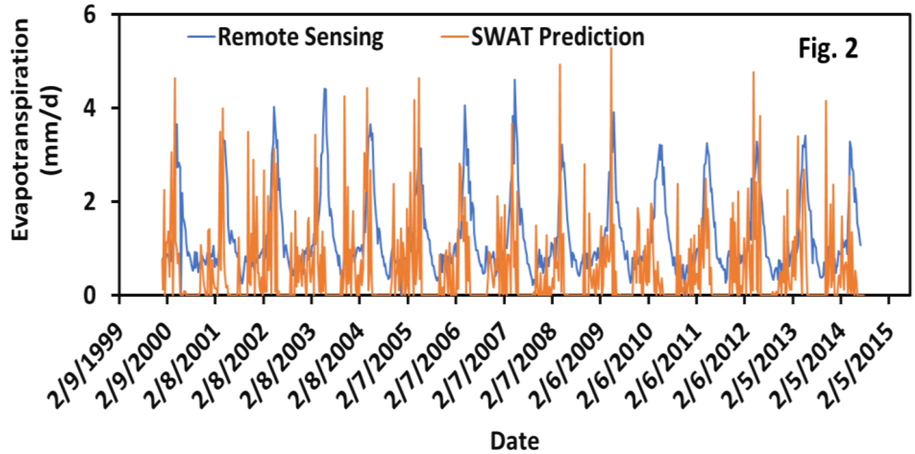


Figure 10.

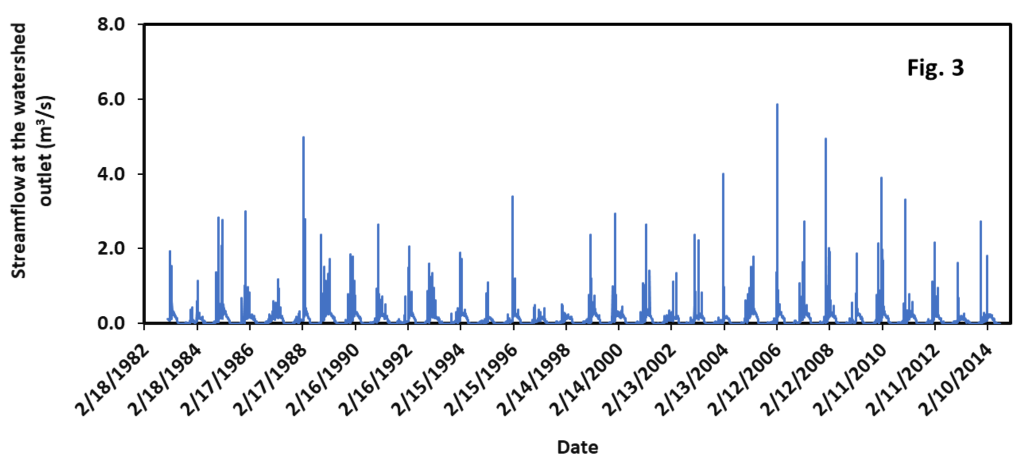
the SWAT model using field observations. Unfortunately, little to no field observations are available for this river basin.

A comparison of the ETs from SWAT model prediction and remote sensing for a simulation period from 2000 to 2014 is shown in Fig. 2. In general, the ETs predicted from SWAT are within the range of the ETs estimated from remote sensing. Most of the ET peaks from SWAT reasonably matched with those from remote sensing. In particular, however, the ET valleys from SWAT are lower than those from remote sensing. While ETs from SWAT have uncertainties, the ETs from remote sensing with an 8-day interval and a 500m resolution are also rough estimations. Therefore, it is not appropriate to conclude that ETs from SWAT are better than those from remote sensing or vice versa. Nonetheless, they are within the range.



The minimum and maximum stream flows predicted from SWAT are 0.09 and 5.87 m^3/s, respectively. These values are consistent with those from the sparse field measurement for a period from 1947 to 1965 (personal communication) with the minimum and maximum of 0.08 and 7.1 m^3/s, respectively. This finding further confirms that streamflow simulations from SWAT are within the range of the limited field measurements.

Some simulated hydrological processes, namely the streamflow, surface runoff, snow melt, water yield and groundwater flow to streams, for a period from 1982 to 2014 are shown in Figs. 3-7.



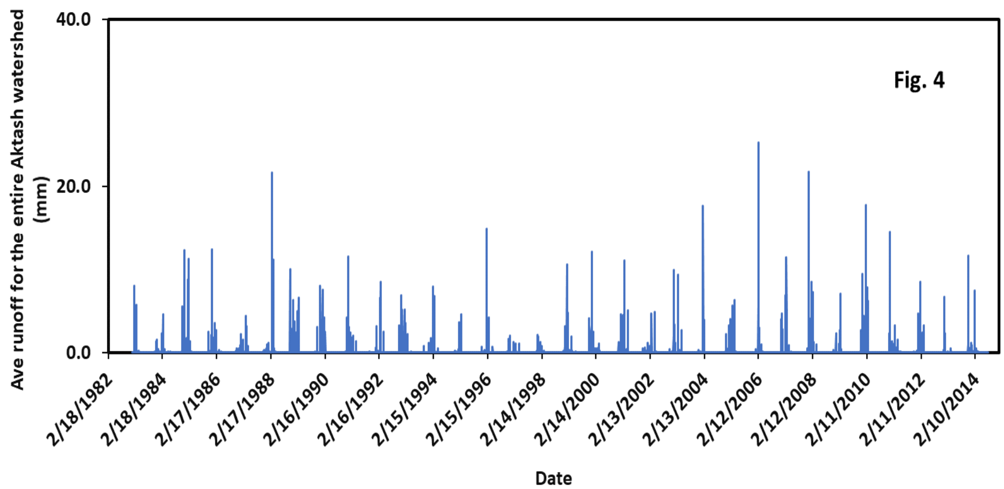


Fig. 4
Ave runoff for the entire Aktash watershed (mm)
40.0
20.0
0.0
2/18/1982
2/18/1984
2/17/1986
2/17/1988
2/16/1990
2/16/1992
2/15/1994
2/15/1996
2/14/1998
2/14/2000
2/13/2002
2/13/2004
2/12/2006
2/12/2008
2/11/2010
2/11/2012
2/10/2014
Date

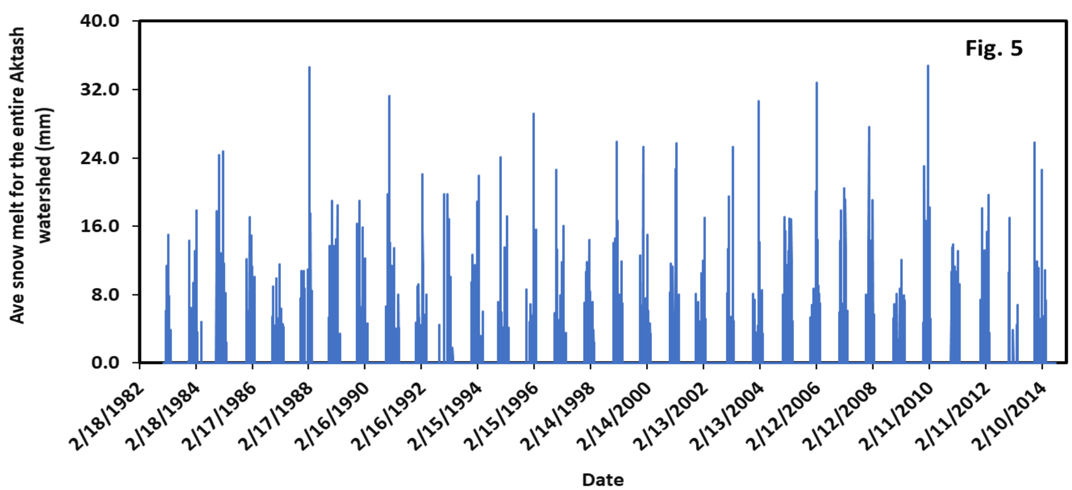


Fig. 5
Ave snow melt for the entire Aktash watershed (mm)
40.0
32.0
24.0
16.0
8.0
0.0
2/18/1982
2/18/1984
2/17/1986
2/17/1988
2/16/1990
2/16/1992
2/15/1994
2/15/1996
2/14/1998
2/14/2000
2/13/2002
2/13/2004
2/12/2006
2/12/2008
2/11/2010
2/11/2012
2/10/2014
Date

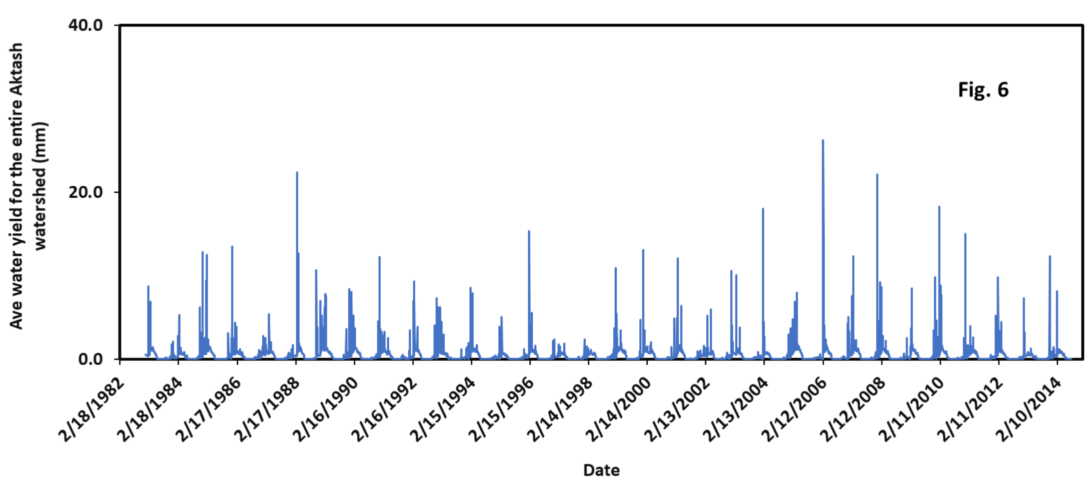
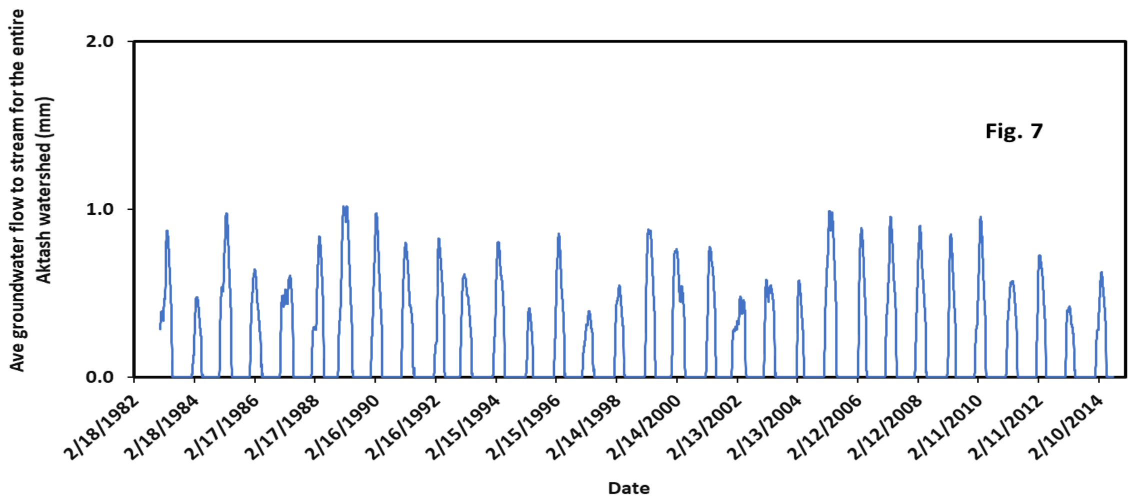


Fig. 6
Ave water yield for the entire Aktash watershed (mm)
40.0
20.0
0.0
2/18/1982
2/18/1984
2/17/1986
2/17/1988
2/16/1990
2/16/1992
2/15/1994
2/15/1996
2/14/1998
2/14/2000
2/13/2002
2/13/2004
2/12/2006
2/12/2008
2/11/2010
2/11/2012
2/10/2014
Date



Further study will focus on future climate change impacts on hydrological processes for the period from 2014 to 2070 when the weather data are available. A technical report entitled "Characterization of Mountain Forest Hydrological Processes in the Aktash River Basin of Uzbekistan, Central Asia over the Past 30 Years" will be prepared and used to prepare briefing papers for decisionmakers and a popular article for the public, showing the importance of mountain forests.

APPENDIX 1

Grower's manual

The Jiffy-7 plant mini grower manual
Suitable for the pilot-experimental Micro-nurseries

Peter Benfeldt

Woody plants grown in Jiffy-7 pellet

PACT Holding 7451 Sunds, Denma
Phone: +45 2240 3321

Foreword and disclaimer

This grower's manual is a condensed summary based on my (Peter's) 25 years of experience as a Jiffy-nursery owner and manager. The purpose is to provide the participants and collaborating scientists and practitioners a brief guidance to support their initial efforts to produce airpruned nursery plants in small experimental scale. The manual briefly describes some of the most important practical issues involved when initiating such a small-scale nursery.

This first year we start with the Micro-nurseries for you to gain the first experiences growing airpruned Jiffy-7 plants grown on tables with mainly irrigated by ebb-flow systems. The aim is you will have the first airpruned plants with vigorous roots prepared to capture and gain foothold of the experimental sites they are transplanted to.

Our hopes and expectations are that these plants will be better adapted to and show better establishment success than you generally are used to at your sites challenged by drought in the growing season. However, we cannot give you any guarantee for the success of your efforts, but we believe your chances for success are good if you:

- Read the manual carefully and ask Palle or me (us) if there is any doubt about some of it.
- Contact us by e-mail if questions or uncertainties emerge during 2023.
- Monitor the micro-nursery every day – and twice (morning and late afternoon) a day. When weather becomes sunny warm or hot a sufficient water supply is highly critical for the PLANT SURVIVAL.
- Malfunction for the Micro-nursery always needs to be discovered and corrected immediately!

We need to develop a mutual experience with the species we want to grow in the Micro-nurseries. To do so we need to keep in close contact, and we urge you to regularly send us photos with short descriptions of status. Especially, in case of emerging problems such as poor germination, dying off seedlings, discolouration or other damages of plants, excessive growth, technical problems with the Micro-nurseries etc. we prefer you contact us sooner rather than later on both benfeldt@jiffyplanter.dk and palle@innovasila.com.

Good luck growing airpruned plants!

Peter Benfeldt and Palle Madsen

Seed and plant health – pests, pathogens, frost, drought, hot weather, and lack of seedling movement by wind

Frost, drought, hot weather, and lack of seedling movement by wind

The early phases of a tree's life as a seed, germinating seed, and emerging seedling are very risky in the natural environments for tree and forest establishment. This is the main reason for adopting the technology and accepting the costs of establishing nurseries where the site conditions can be controlled and optimised to efficiently utilize the expensive seed and produce strong plants.

Frost, drought, and heat are some of the most important environmental stressors that need important attention when operating the Micro nurseries with Jiffy-7 pellets placed in airtrays, and further placed in ebb-flow trays for irrigation and as such lifted off the ground:

- Late spring frost may harm the above-ground parts of the seedlings if they emerge and start growing earlier than the risk of frost is over. Inside greenhouses this should not be a problem, but outside in case of additional sowing here to later fill up the greenhouse it might. Precautionary measures may include covering the seedlings in advance of frost events.
- Frost in the fall may become a problem if growth is not halted and dormancy initiated early enough for the trees to become frost tolerant. This may be avoided by proper regulation of the fertilizers, see further recommendations below.
- Winter frost from -5 C and below poses a threat for the below ground parts of the plants when they are placed above the ground and thereby isolated from the significant moderation of the winter temperatures down in the ground. Plants placed in the airtrays are exposed to such threat also inside greenhouses and sufficient precautionary measures must be taken.
- Risks of damages including lethal damages of the plants by drought and hot weather are to some extent the two sides of the same coin stressing the needs for regularly (daily – morning and afternoon) monitoring and control of the Jiffy-7 pellet moisture content (see further about "irrigation window" later). Additionally, the larger the plants are the more water they need, and when moved outside of the sheltering greenhouse the wind may increase the need for irrigation considerably. This is particularly true for the plants positioned in the outer rows of the airtrays on the tables and with the corner-plants as the most exposed. These corner-plants are good and highly visible indicators for upcoming needs for irrigation!
- The green house both provide shelter and protection in the early phases of germination and seedling development, but temperatures may easily become too high inside during hot sunny periods. Monitoring temperature and managing ventilation of the green house is important!
- Lack of seedling movement by wind is and undesired consequence of the greenhouse shelter which require either removal of the sides of the greenhouse or moving the airtrays and the plants outside for them to become exposed to the wind there. Otherwise, the plants will not get the necessary stiffness, but will remain too soft and bend down when they are finally transplanted to the field site.

Birds and rodents

Forest tree seed and seedlings are attractive food for various birds, rodents, and other animals may cause problems, too. Also here, just general descriptions and measures are mentioned to flag the issues, and with particular emphasis on the very early phases after sowing the seeds.
Having the Jiffy-7 pellets, seed and plants in closed greenhouses and lifted off the ground on the tables

offers opportunities to shelter the crop against these pests. Several preventive measures may/should be considered:

- Traps and/or cats may keep both the winged and the four-legged away.
- Preventing access for the rodents by climbing the legs of the tables.
- Birds may be kept away from feeding on the seed by temporary cover of fine mesh nets or similar that allow air, water, and moisture to penetrate or evaporate. This may be relevant in case of future sowing some species outside greenhouses or if the greenhouse cannot exclude the birds. However, such cover may attract rodents, so careful monitoring and preventive measures against them are needed.

Harmful fungi

Make sure the water used for irrigation in the nursery is clean – like drinking water!
Potentially, pathogens – like harmful fungi – can damage or kill the trees quickly.

Totally, avoiding harmful fungi is impossible, but you can keep their populations low by using a smaller water tank and only use its full capacity when the plants use lots of water such as in hot and/or windy periods or late in the season when the plants have grown big.

Additionally, use the Koppert Trianum-P bio-fungicide from the beginning of your irrigation program.
Firstly, add 50 grams of the Koppert Trianum-P to one litre of water, then add this suspension to the first 2-400 liter in your tank.
Read the instructions and Peter recommends avoiding inhalation of the spores, too.
More information about using it: https://www.koppert.com/trianum-p/#gallery-3 and general information: https://www.koppert.com/trianum-p/

Further, add 10 grams every week (first to one litre of water and then add this suspension into the tank) to maintain the level of Trichoderma in the system.
It will live on the pellets and roots and does no harm to the trees.
It keeps the medium occupied and works as an antagonist.

Insects

There were two types of insect traps sent with the Micro-nurseries:

- The red "Andermatt Biocontrol - Rebell rosso" which are plastic plates with glue designed to catch/monitor damaging barkbeetles (*Xyleborus dispar*) attracted by the color. The traps are no only specific for this species of barkbeetles but suitable for a range of damaging insect species that may become a threat to the aboveground parts of the plants.
- The yellow "Biobest - BB Sticky Trap Yellow NHS" which are plastic plates with glue designed to catch/monitor damaging mourning (sciarid) mosquitos attracted by the color. As with the red traps these yellow traps are not highly specific as well but are suitable for a range of damaging insect species that may become a threat to the roots of the plants.

Signs of potential pathogen attacks or when we want to expand the nursery

In larger nurseries damages by pathogens and pests are attracting considerable attention, and additional measures to what we described here are available. For example we may want to use "Fosfit" (https://agrilb.com/products/fosfit/) and/or organic oils which are easy to obtain in case pathogen attacks on some of the species. The most robust and tolerant species are typically pine and spruce.

In case of observations that need attention: take a photo, send it to us.

Pellet expansion – soaking them in water

Make sure the Jiffy-7 pellets they are TOTALLY UNDER water when you soak them in water. If not, they might unfold like a mushroom and the peat will grow out of the netting. When fully expanded, the pellets are now ready for seeding / inserting cuttings.

Irrigation systems in nurseries are commonly using irrigation booms with nozzles to spray (1,5 bar pressure) irrigate the crops. Peter uses this to soak the pellets and to keep them moist in the top while the seed are germinating and in the early phases of the tiny seedling's growth. In the Micro-nurseries we do not have the irrigation boom and soak the dry pellets to expand them carefully and quickly. Then we manually irrigate with a mist sprayer from the top until the seed have germinated and the seedlings emerged and start growing.

The "irrigation window"

We start by defining the "irrigation window" to define the correct level of water saturation in the Jiffy-7 pellets as long as the plants are in the nursery.

How to do:
Soak 10 Jiffy-7 pellets in water until the peat is saturated. Drain off excessive water leaving the pellets for a few minutes. Check they have full expansion.
Weigh them and divide by 10. Now you have the full saturated weight of one Jiffy-7.

We now define the saturated weight "7".
Dry pellet is app 1/7 of the wet, hence the name Jiffy-7 ☺.
Dry weight is then "1" equal to the pellet dry weight.
Running the irrigation safely means staying within the irrigation window between "4-6".

Start irrigating when the weight drops to "4-5". Irrigate up to "6" but avoid "7" = too wet.
The drying out in between is important. The roots in the centre of the pellet need air for their supply of oxygen!

Irrigation through the season(s)

From seed sowing and until the plants are transplanted into the field their requirements for nutrients – thus fertilizers – change.

The plant's needs for clean and non-toxic irrigation water remains high and unchanged throughout.

The requirements for fertilizers and pH of the irrigation water depend not only on seasonality (time in season) and plant size but very much on species, too. However, it is not realistic at this early stage in the introduction of the Micro-nurseries to provide specific guidance for the species involved.

Peter has no specific experience with most of the species we aim for in this project, and it is unlikely we can find it in the detail we need in the literature. Therefore, he recommends you use an all-round fertilizer regime and support it with proper monitoring of both EC and pH of the irrigation water and the substrate of the pellets. He expects this will work sufficiently well for all the species and the mixtures of species we grow in these pilot experiments. This will not optimise the individual species but the Micro-nurseries are still expected to deliver high quality plants.

Ideally, and in a future larger production, the fertilizer regimes and pH can we may seek to optimize for each species. It requires they are grown in separate sections with separate irrigation systems and using the experience and knowledge, we gain now in these pilot studies.

<u>The phases of fertilization and monitoring electrical conductivity and pH:</u>

- Initially and during the germination of the seed the irrigation water needs no fertilizer to be added.
- Monitor electrical conductivity (EC) and pH of the irrigation water. You have the EC-meter already. For pH-measurements you are recommended to use pH-indicator strips.
- Keep your recordings in a document (spreadsheet recommended, so you can easily exchange data with us) including date and observations and comments on the plants and the functionality of the Micro-nursery.
- When the seedlings start to appear, they need fertilizer to be added to the irrigation water. This will be the <u>standard-solution</u> that may be used throughout the growing season. Adjustments of the fertilizer solution late in the growing season may be needed - probably from Aug. or Sept. Please, consult us first and let us guide you.
- Adjustments of nutrient content in the irrigation water will aim to slow down growth and initiate the dormancy of the plants. Otherwise, there is a risk they keep growing through the fall until damaged by the first days of frost due to insufficient dormancy and frost hardiness.
- For the plants that need more than one growing season (most conifers do): Another fertilizer mix may be needed in the spring of the 2^{nd} season. Again: Please, consult us first and let us guide you.
- **The pH** of the substrate may not change or is changing slowly. Inadequate pH – either too high or too low – can cause poor growth and cause failure. The pH depends on the pH of the substrate and of the irrigation water. The monitoring is important since pH is critical, and adjustments are needed BEFORE the critical pH-level of the substrate is reached – then it may be too late to compensate and avoid damages. We hope to avoid problems – but are prepared to guide you if pH seems to head towards unsuitable values.

Fertilizer

<u>From granulates to fluid.</u>
Make a <u>start-solution</u> of e.g. 10%: 1 kg “White solid and complete fertilizer granules” to 9 litres of water.

The best and safest way is to have a plastic tank/container with a screw cap.

Write on the container that it contains the start-solution!
Shake it to make sure you have a fully dissolved solution.
No precipitates on the bottom inside it are allowed.
Warm (not hot!) water helps the fertilizer to quickly dissolve.

Controlling the electrical conductivity of the irrigation water before adding fertilizers:
Use our conductivity meter (measurer) – and calibrate it initially according to its instruction manual. Take your time to let the meter adapt to temperature. Then you measure the conductivity in your water source (usually tap water):

- If more than 0.3-0.5 mS (microSiemens) there are a lot of minerals in the water – and we should discuss what to do!

After adding the fertilizer (see below) the maximum/critical value of conductivity is 2.5 mS in the final fertilizer solution. For your information, the water in my (Peter's) nursery is 0.3 mS from the tap. After adding the fertilizer my irrigation water has a conductivity of 1.5 mS.
Target fertilizer solution of the irrigation water:

The target concentration for your standard-solution is 1.0 ‰ for the water used for irrigation.

Example:

- Your start-solution (see above) is 10%.
- You add start-solution to water:
  If you aim for 200 l standard-solution:
  1. Initially add 100 l to your tank.
  2. Add 2 l of your start-solution.
  3. Add another 100 l of water to a total of 200 l.
  4. You are now ready to irrigate with your standard-solution.

Important: Measure and continue to monitor the EC in your tank!
Is it at the target value - 1.5 mS - and not near the 2.5 mS?

Refilling the water tank:

- Make yourself a small simple table showing how much start-solution is needed for various amounts of added water from the tap to the tank.
- Measure and mark the water level in the tank for known volumes. Then it is easy for you monitor water use over the season, depending on weather, and needs for refill.
- Again: Check the conductivity regularly. You can measure it in the water on the table during irrigation.

Additional tips for managing the crop

Do your plants look good and healthy (colour, growth, normal leaves / needles)?

Monitor pH in the tank and in the Jiffy-7 pellets:

- Starting with unknown water quality both EC and pH are especially important to know.
- Monitoring pH in the Jiffy-7 pellets: Soak a pellet in demineralised water. After a while, press the water out and measure it.

- pH in the Jiffy-7 forestry pellet (white mesh) is 4.5-5.0 but tap water pH is often higher (7 or more). Over time the pH may increase. Optimum for most species are 4.5-5.5 – lowest for conifers and highest for broadleaves. pH must not exceed 5.5. If it reaches 6.0 some species start becoming necrotic and suffer from nutrient deficiency, because the pH makes it impossible for the plant to take up e.g. magnesium.
- pH in the Jiffy-7 horticulture pellet (brown mesh – a sample of 108 was included in the shipment) is 5.0-5.5. Test them by sowing some of the broadleaved species in them. Still pH must not exceed 5.5 and 6.0 will damage most species.

Once pH induced damages have appeared it is impossible bring the plants back to acceptable quality.

We need to find critical spare components especially an extra submersible water pump in case there is a stoppage of operation of the one we sent you.

Supplementary information about the Jiffy-7 pellet system

The Jiffy-7 Forestry pellet system – a versatile substrate for woody species (trees, shrubs) based on peat.

Airpruning trays are important – they allow the roots to develop freely in all directions by having an airflow on all sides of the growing media. The trays are PP or PS plastic with a 20–30-year lifespan.

There are the following formats:
25 mm diameter – 11x11 cavities per tray – 815 / m^2
36 mm diameter – 8 x 8 cavities per tray – 430 / m^2
42 mm diameter – 7 x 7 cavities per tray – 330 / m^2
50 mm diameter – 6 x 6 cavities per tray – 240 / m^2

Jiffy-7 forestry peat pellet types to load the trays

25 mm diameter pellet, expanded height:	75 or 85 mm	volume 50 cm^3
36 mm diameter pellet, expanded height:	normally 100 mm	volume 110 cm^3
42 mm diameter pellet, expanded height:	100 or 125 mm	volume 150/180 cm^3
50 mm diameter pellet, expanded height:	90-100-140 mm	volume 225-300 cm^3

Left: 25-36-42-50 mm dry Jiffy-7 pellets
Shown on top of a tray with micro 18mm small "starter-pellets"
This tray is <u>not</u> air pruning tray, and the plants only germinate and grow initially (max 4-10 weeks) in it. Then they are transplanted into the larger Jiffy-7 pellets and placed in airtrays. This system may be considered if the seed pretreatment is complicated and germination rather unpredictable.

Additional useful information

- pH can be either "Forestry" 4.5-5.0 = normal or "Horticulture" 5.0-5,5.
- A large variety of horticulture pellets are available for cuttings, ornamentals and other species depending on higher pH than most woody species.
- The system is designed for dry sowing with a sowing machine for example the Hamilton Natural Seeder that Peter is using.
- The peat is pure, sterilized, and has no fertilizer added, nutrients are supplied in the water by irrigation.
- Adding an antagonist fungus such as Trichoderma sp. can sometimes reduce the growth of mosses and algae on the pellet surface, if added right after expansion.

Figure 1.
Left: Systems used for growing / irrigation are simple tables of metal og even wood, or as shown in the photo, regular ebb-flood-benches used with recirculated water.
Right: The Hamilton ImproSeeder (Modified by Peter) - http://www.hamilton-design.co.uk/index.html

Figure 2.
Left: Growing oak (Quercus petrea) for forest regeneration or afforestation in Denmark.
Right: A 50/100 mm Jiffy-7, 1-year crop of Douglas fir (Pseudotsuga menziesii) outside the greenhouse to obtain firmness and dormancy in the late part of the season. Note the woody benches, treated with linseed oil and an expected lifespan of 5-7 years.

Using airpruning a symmetrical and natural root system is achievable on all species as tested and grown in Denmark (50 conifers, hardwood and shrubs 1993-2022)

Results:

- Fast establishment
- Double height first season in the field
- Full diameter growth from time of planting
- Straight stem, improved wood properties
- Maximum stability against windthrow
- Optimum health for a planted crop

The photo shows the roots of a 10-year-old hybridlarch (Larix eurolepis) sown and started in a 42/100 Jiffy-7 and transplanted to the field after 1 year in nursery.