PfynDrought

Experimental manipulation of atmospheric & soil drought

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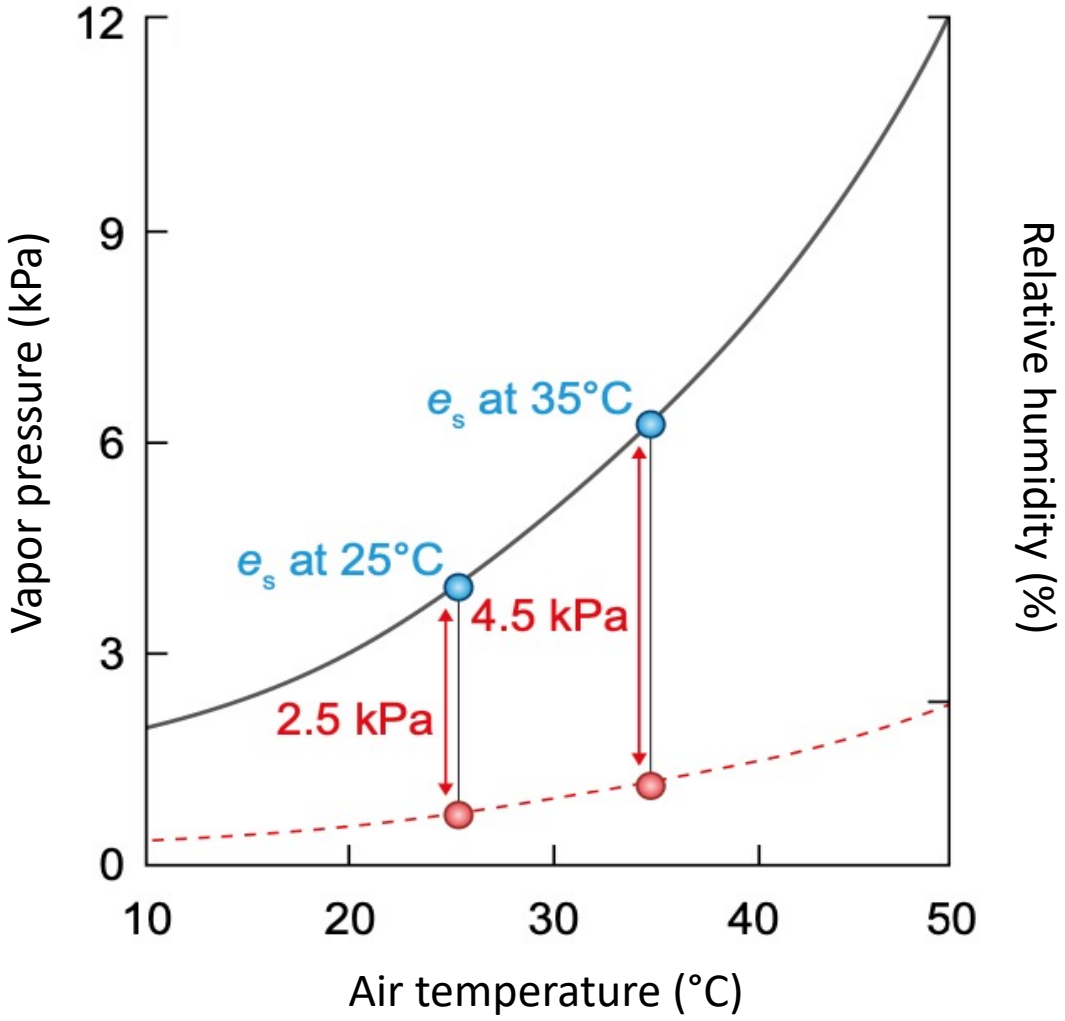
UNI BASEL

Increasing *VPD due to rising temperature*



Grossiord *et al*. 2020, *New Phytologist*

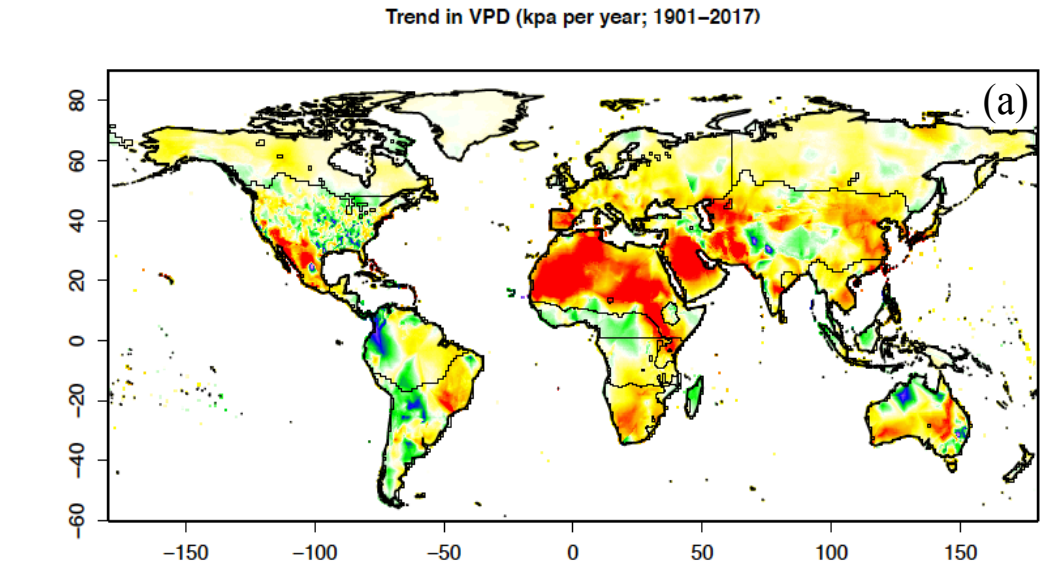
Atmospheric *vs*. soil drought

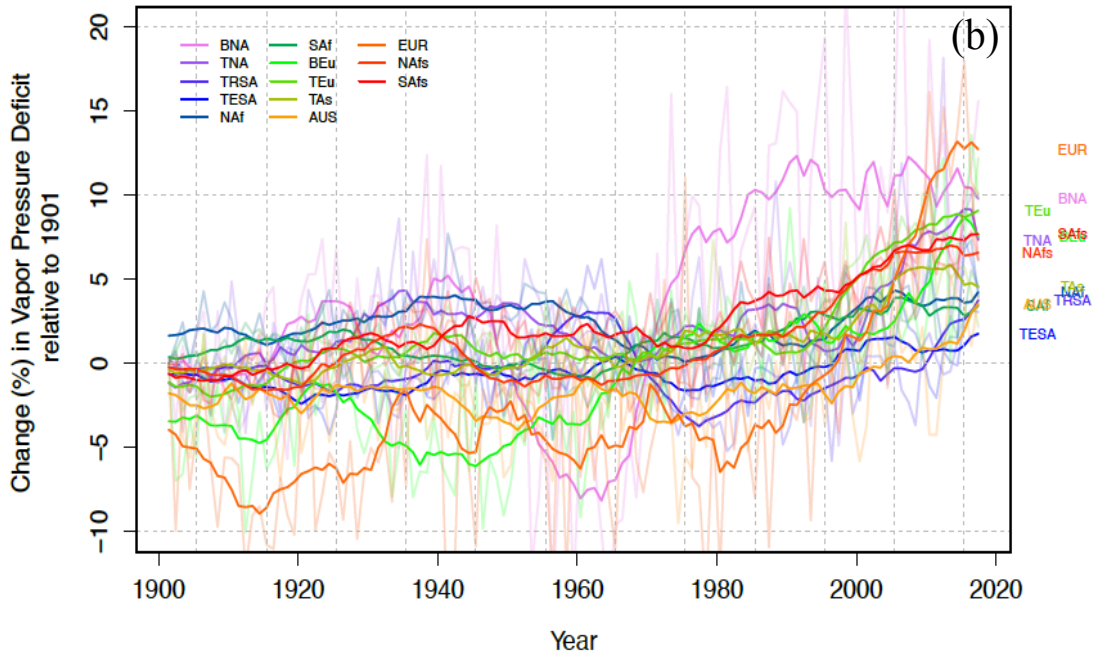
- Increasing **temperatures (*T*)** and reduced **soil water content (*SWC*)**, resulting in an exponential climb in leaf vapor pressure deficit (*VPD_leaf*).

- *VPD* has been identified as a major contributor in recent **drought-induced plant mortality**, independently from other drivers associated with climate change.

- Only few studies have disentangled the physiological response of plant functioning to **atmospheric (*VPD*)** and **soil drought (*SWC*)**.

Grossiord *et al*. 2020, *New Phytologist*

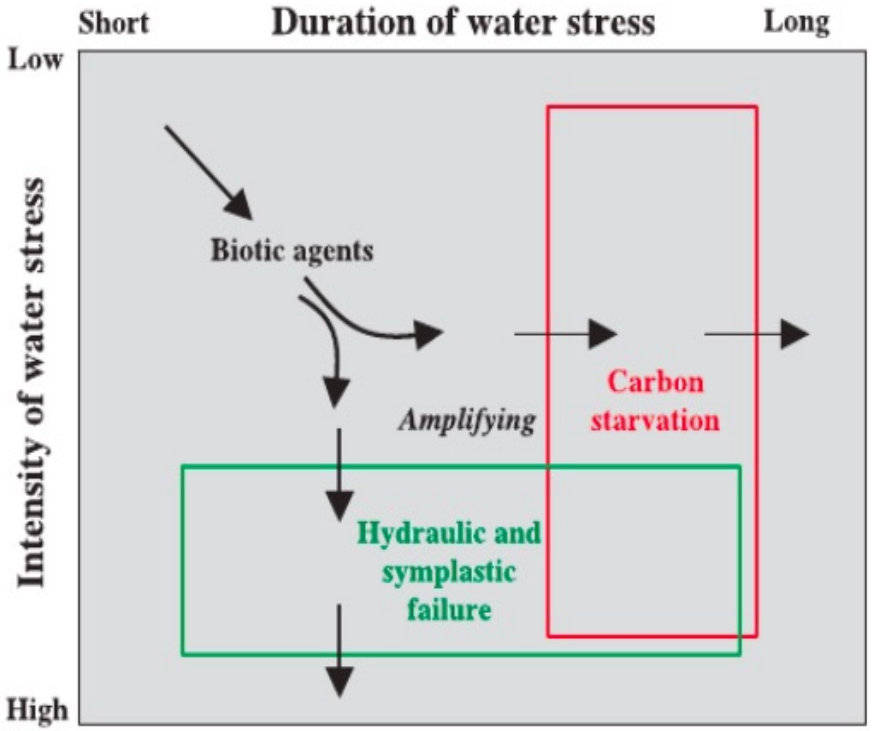




Droughts are linked to wide range of climate conditions

- increased **mean** and **max air temp** -> rise in *ET*
- reduced **precipitation** -> reduced *SWC*
- more **sunshine**
- **elevated** ***VPD*** -> reduced g_{stom}, reduced CO_2 *uptake*
- **seasonality**
- **timing**
- trees' **legacy** (stress memory), **resistance** and **resilience**

- ➢ **not always the same drought/climate conditions**
- ➢ **different impacts on plant-water and carbon relations** (hydraulic failure *vs*. carbon starvation)
- ➢ **different impacts on forest growth**



Theoretical relationship between carbon starvation and hydraulic failure (McDowell *et al*. 2008)

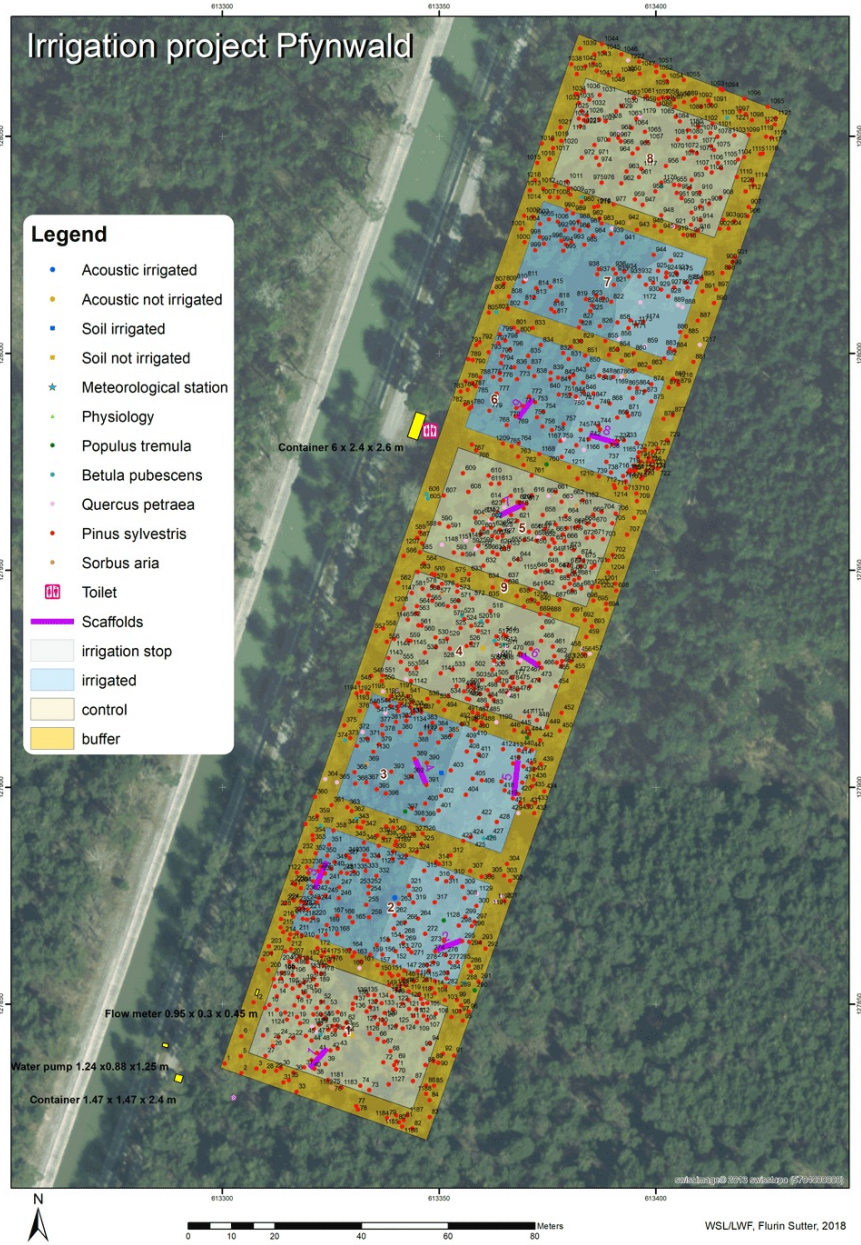
De Boeck & Verbeeck 2011; Anderegg *et al*. 2013 & 2015

The missing piece

- Long-term field experiments where *VPD* is manipulated
- Effects may occur in cascades (i.e., short *vs*. long-term impacts)
- Using mist fumigation increases *RH* over ambient levels (i.e. reducing *VPD*) and reduces *T*
- **Combination of multiple stresses (e.g. *VPD* × *SWC*)** for a better understanding of atmospheric *vs*. soil drought effects

- Example 1: Free air humidity manipulation in an experimental boreal forest at FAHM, Estonia
- Example 2: ICOS rain exclusion experiment at Puéchabon, France
- Example 3: Rain exclusion experiment at Hölstein, Uni Basel, Switzerland

The Pfynwald long-term irrigation experiment



- Coordinates: 46° 18' N, 7° 36’ E
- Elevation: 615 m a.s.l.
- Temp average Jan-Dec: 9.2 °C
- Precipitation: 657 mm (average 1961-1990)
- Vegetation: Natural pine forest, 100 years old, 13 m high
- Area: 876 trees covering 1.2 ha (8 plots x 1'000 m^2)

- Treatments
  - Ambient: natural precipitation
  - Irrigation: since 2003, Apr–Oct, 4 plots, +700 mm
  - Irrigation-stop: since 2014, upper 1/3 of irrigated plots

- Approx. 180 variables
- > 50 publications since 2006
- National & international partners

The *PfynDrought* approach

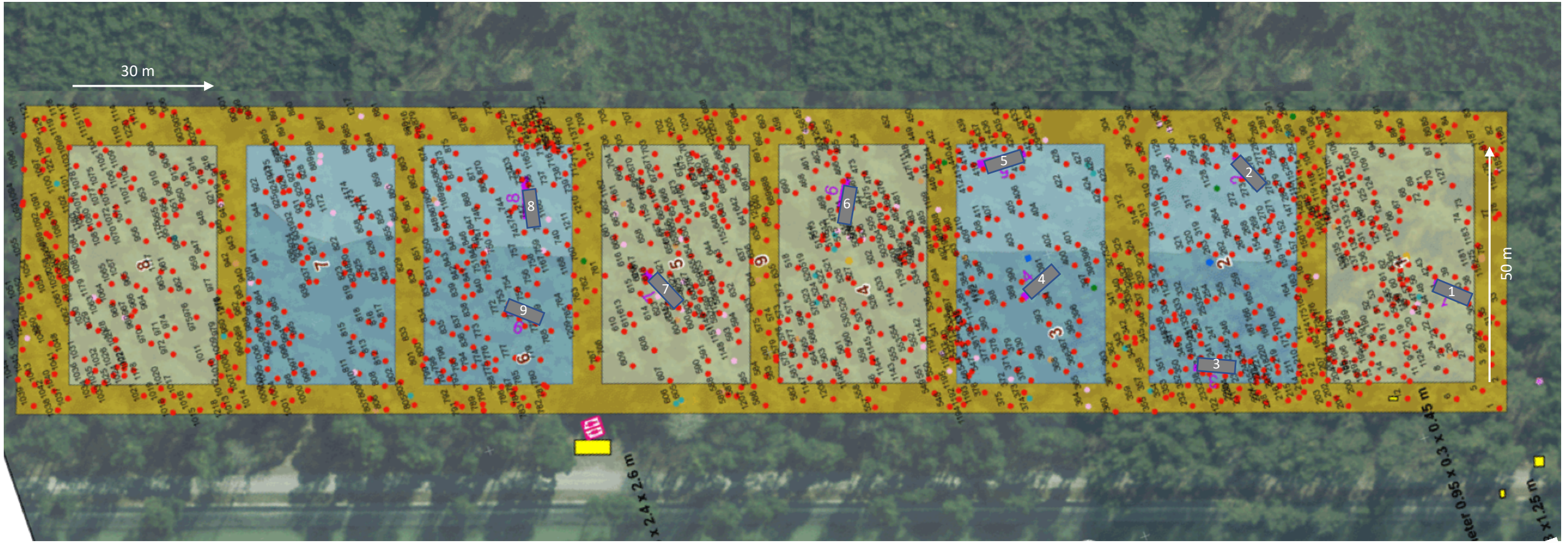
1) Make use of existing RI of the world-wide unique **Pfynwald long-term irrigation experimental platform**

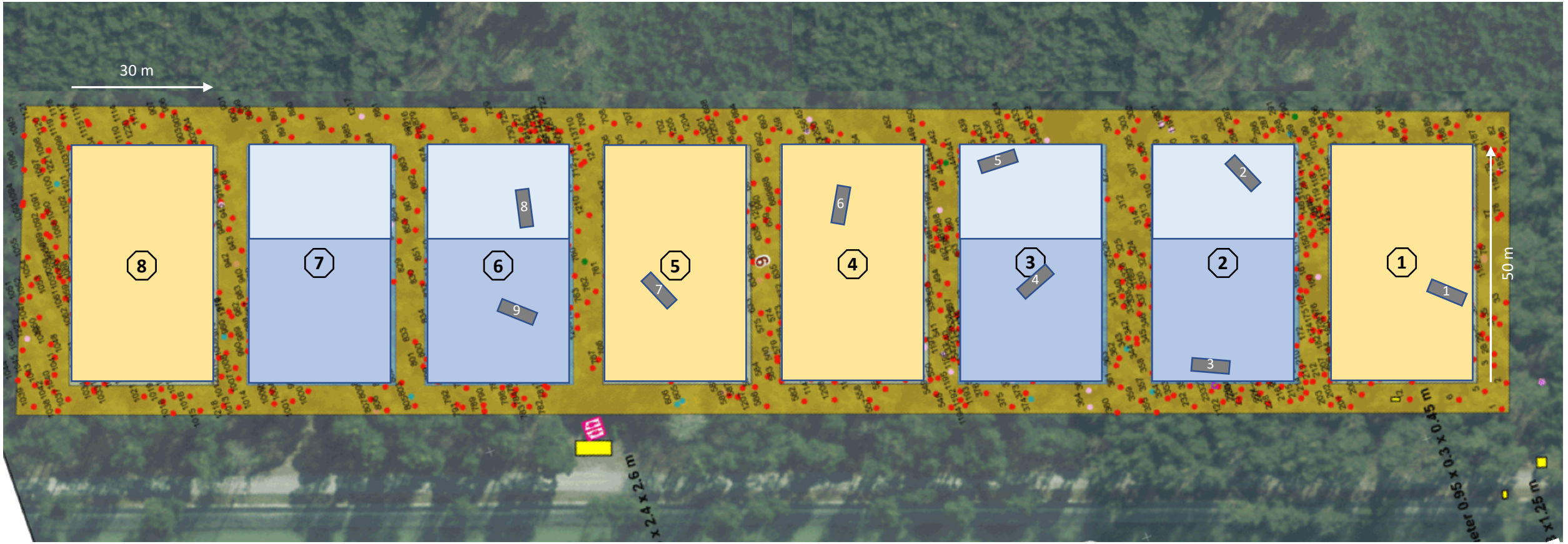
2) Build upon **16-years time series**

3) Extend Pfynwald experiment by another **6 years** (2023-2028)

4) Add **rain shelters** to **reduce natural precipitation by 30-50%** and to further increase terrestrial drought

5) Add **water spraying system** to **reduce** ***VPD*** by ca. 20%


30 m
50 m
8
Existing plots
Control plots
Irrigated plots
Irrigation stop
Existing containers
4
Existing scaffolds



8 Existing plots

Existing containers

Control plots

Irrigated plots

Irrigation stop

4 Existing scaffolds

N

8 Existing plots

Existing containers

Planned container & water tanks

Control plots

Rain shelters

Manipulation of VPD on scaffolds

Irrigated plots

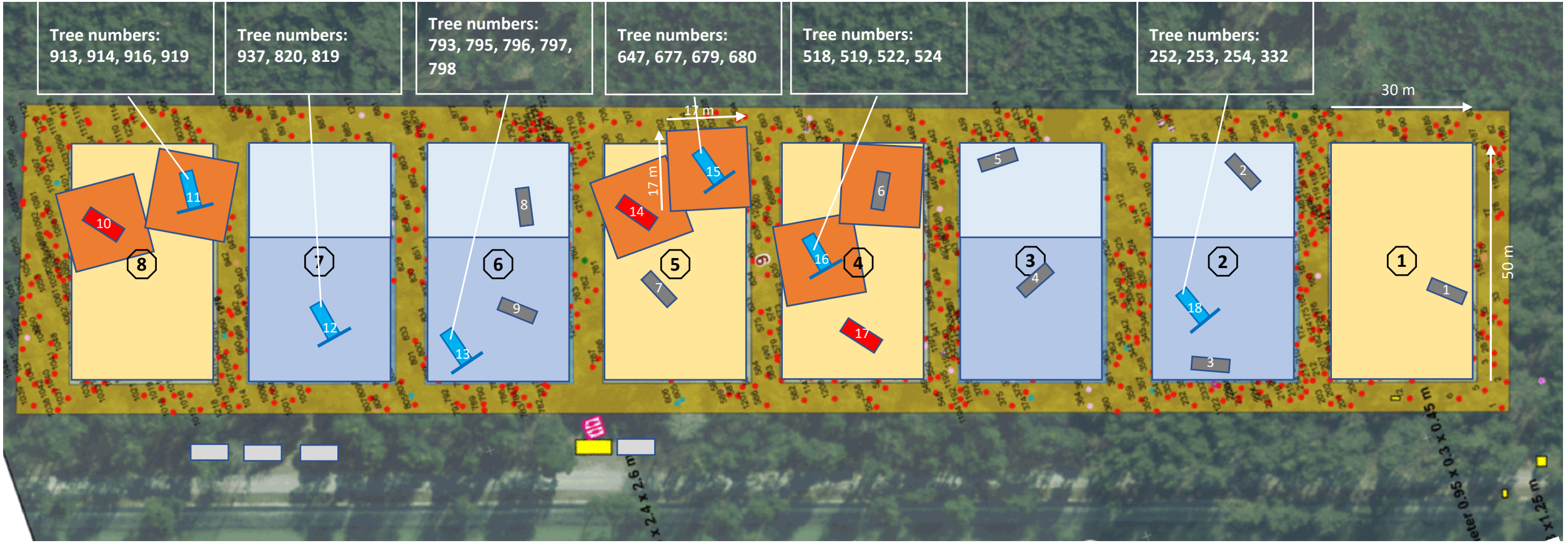
4 Existing scaffolds

18 Planned scaffolds

Irrigation stop

Main wind direction (255°)

N



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Planned container & water tanks

Control plots

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Manipulation of VPD on scaffolds

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Irrigation stop

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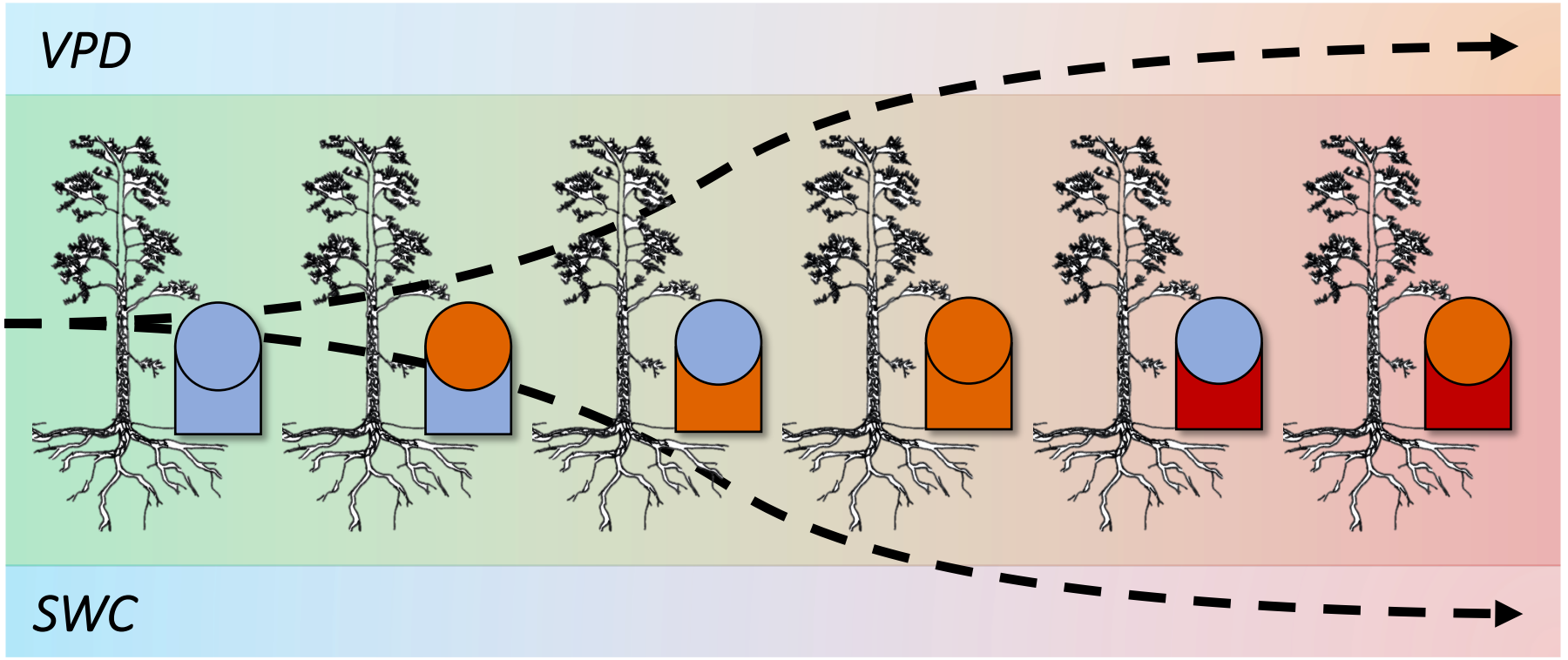
N

Design



TerrestrialIrrigated (TerrIrr)

TerrestrialControl (TerrContr)

TerrestrialRainExclusion (TerrRE)

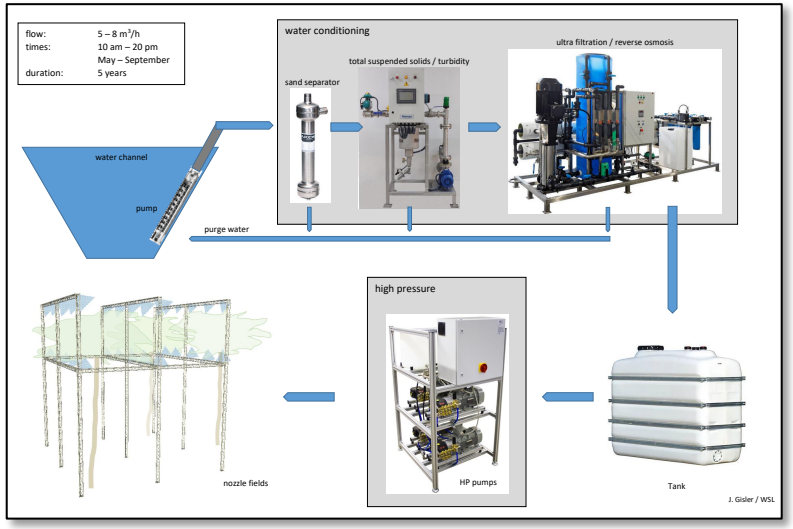
AtmosphericVPD (AtmVPD)

AtmosphericControl (AtmContr)

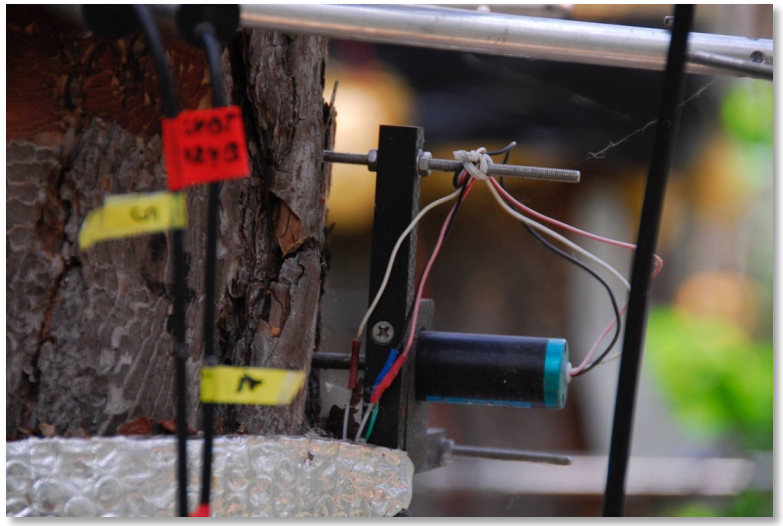
PfynDrought infrastructure

(1) Rain shelters

(2) VPD manipulation



(3) Sensors



PfynDrought infrastructure

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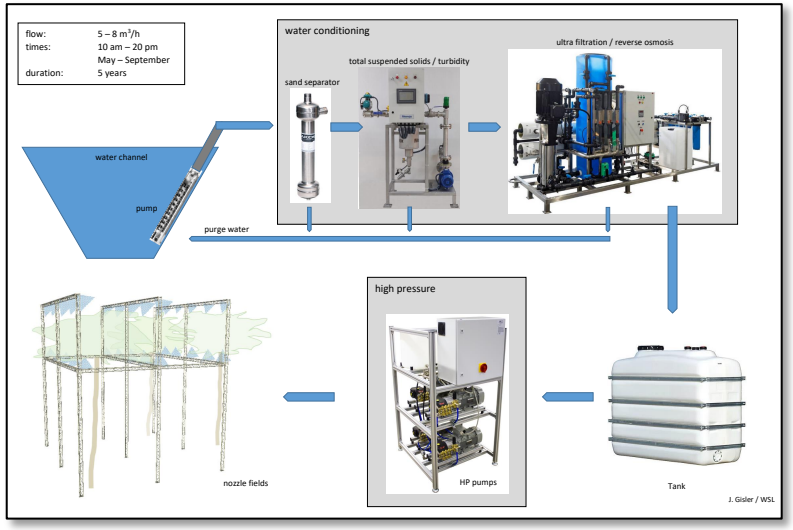
(2) VPD manipulation



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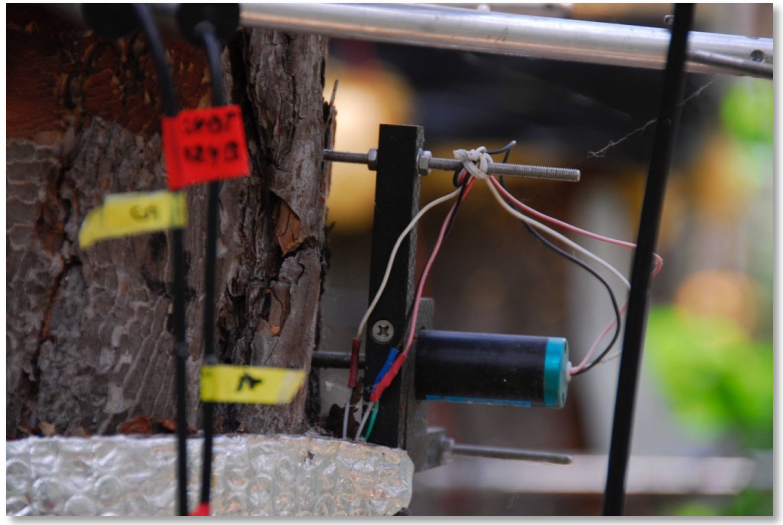
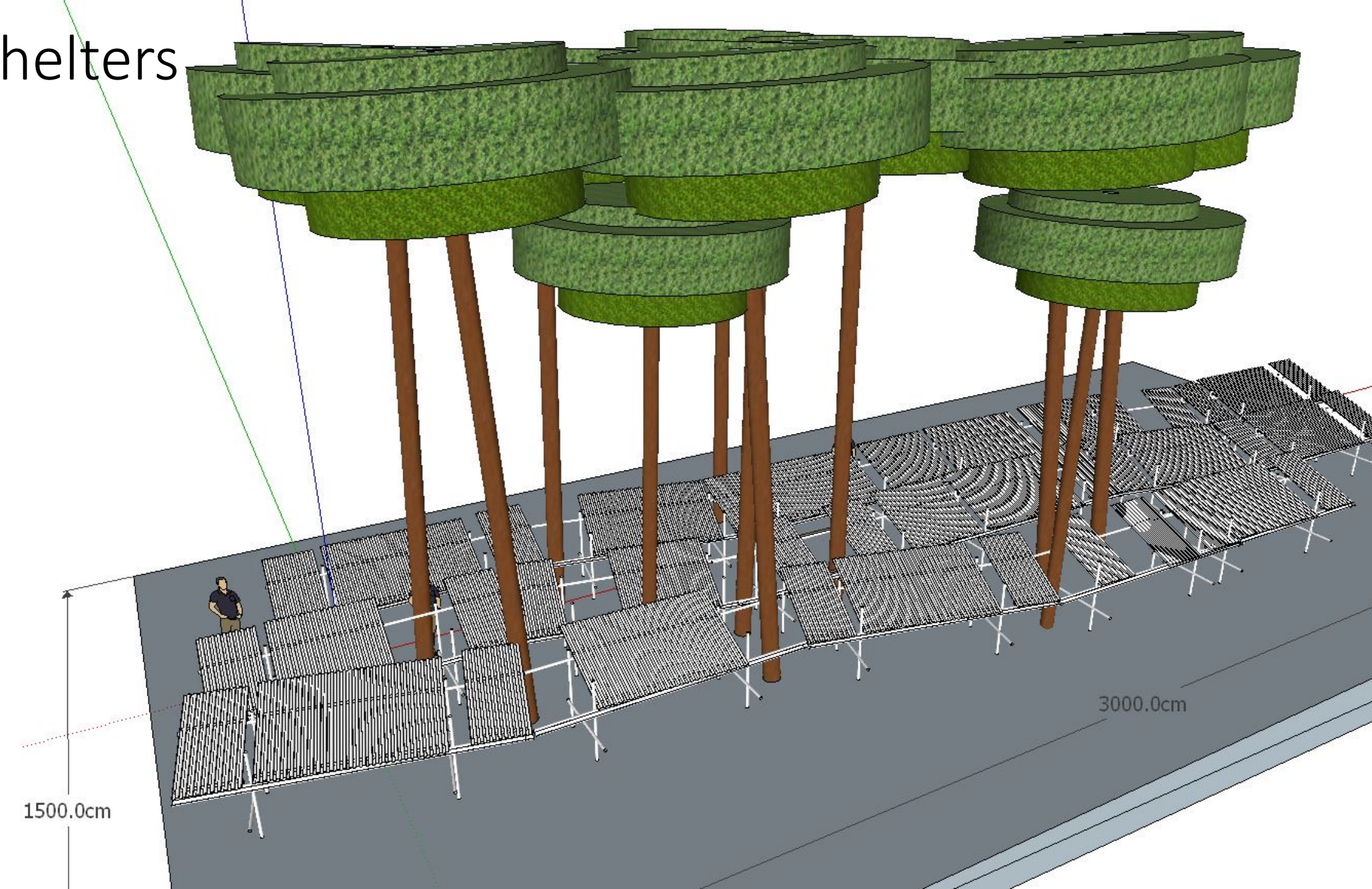


Rain shelters



Rain shelters

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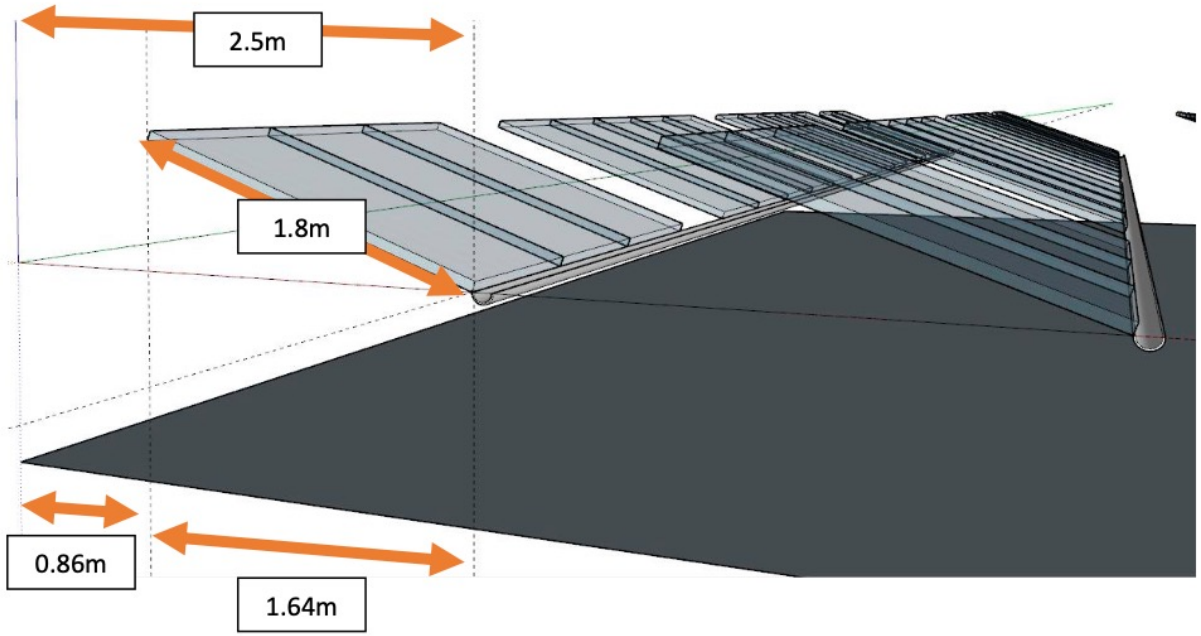
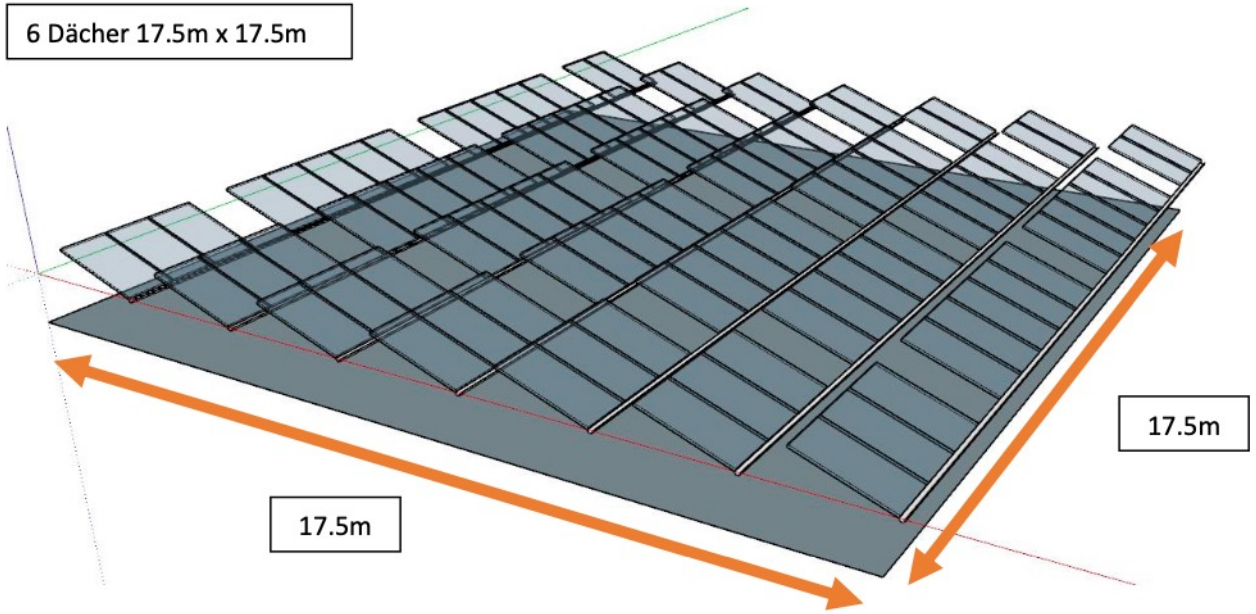
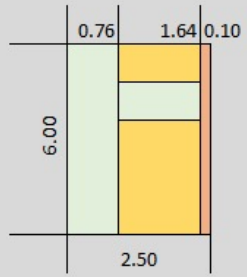




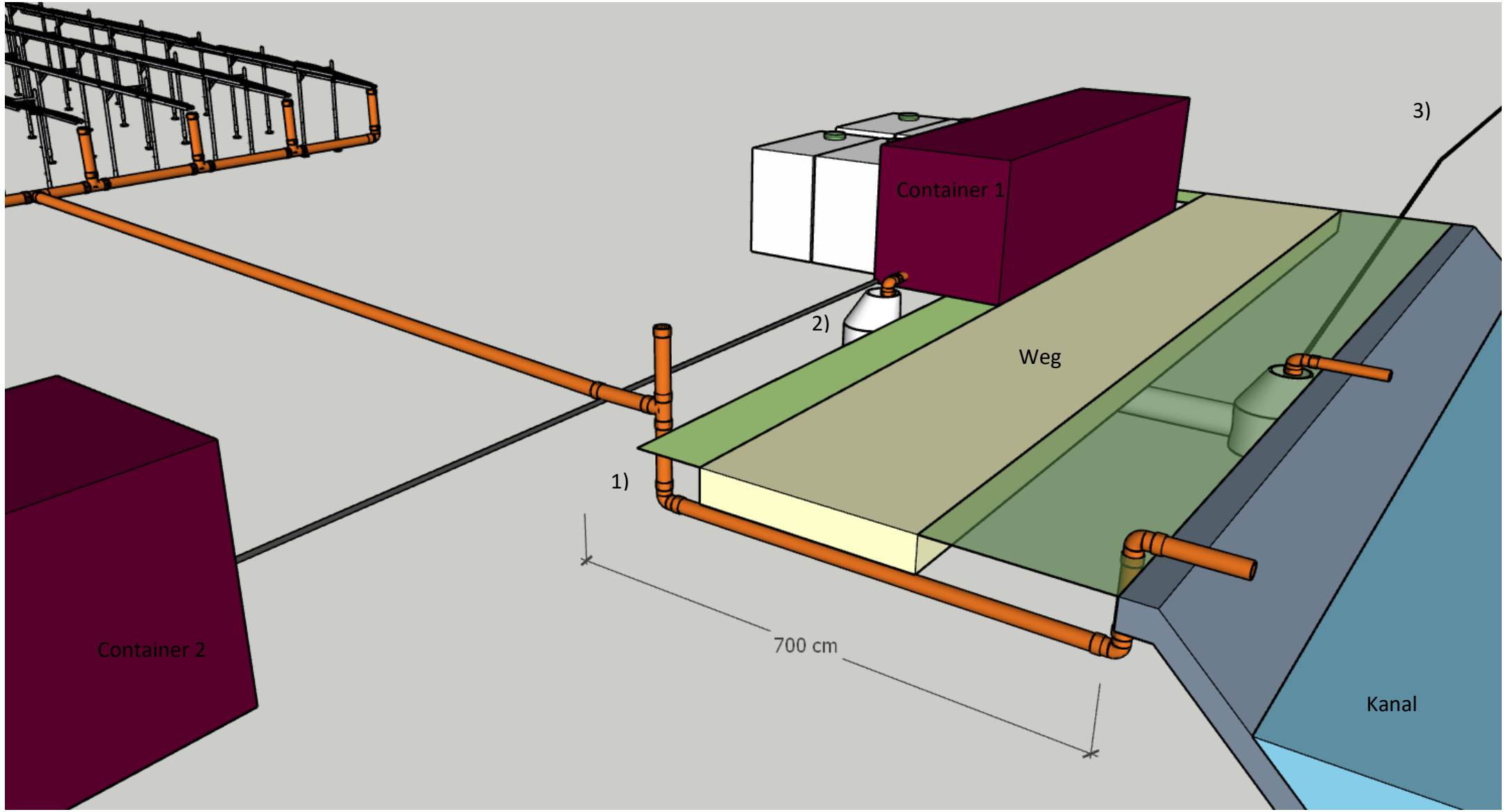
Dachflächenrechner

	Gesamt		Abdeckung		
			n Platten	5.5	
Länge	6.00	m	Fläche gestellt	1.23 m2	
Breite	2.50	m	Fläche Känel	0.60 m2	**Prozentuale Abdeckung**
Fläche	15.00	m2		7.38 m2	**49.22** %

Länge Wellplatte	1.75	m
Breite Wellplatte	0.75	m
Breite Dachkänel	0.10	m
Aufstellwinkel	20	°
Länge gestellt	1.64	m
Reihenabstand	0.76	m



Rain shelters



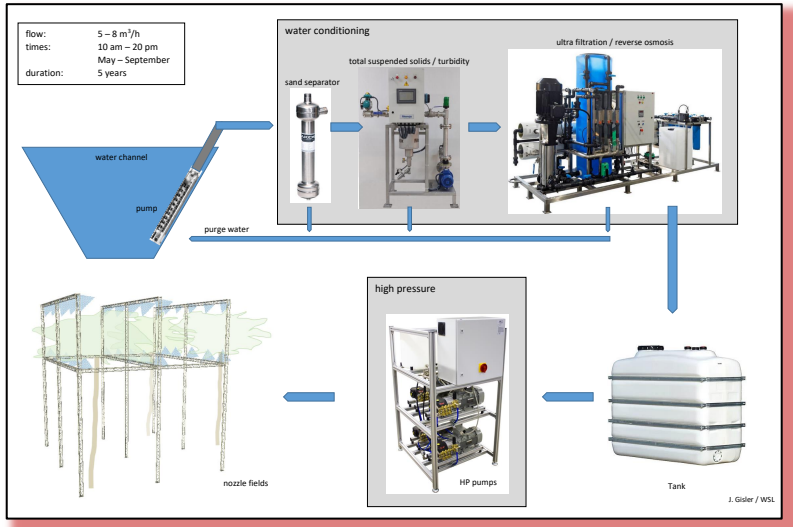
Rain shelters

Contractor:	Tobler, Hornbach, Neomat
Quote/estimate:	CHF 340’000.-
Design:	6 rain shelters
Dimensions:	6 x 17.5 m x 17.5 m
Treatment:	50% reductio of precipitation
Note:	Installation by WSL staff

PfynDrought infrastructure

(1) Rain shelters

(2) VPD manipulation



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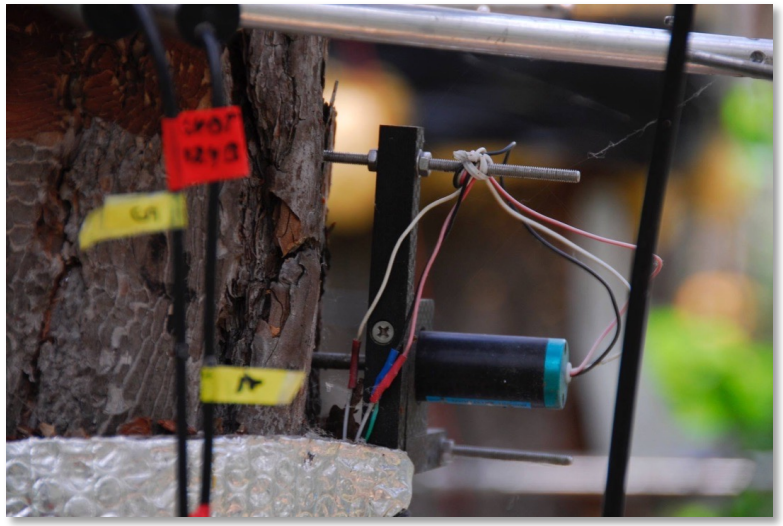


VPD manipulation

- Time period for effective VPD manipulation: **10-20 UTC+1 during Apr - Sept**
- **Local wind conditions** are crucial for VPD manipulation. Further wind measurements and experiments on wind flow dynamics (e.g. by using a smoke generator) may be beneficial

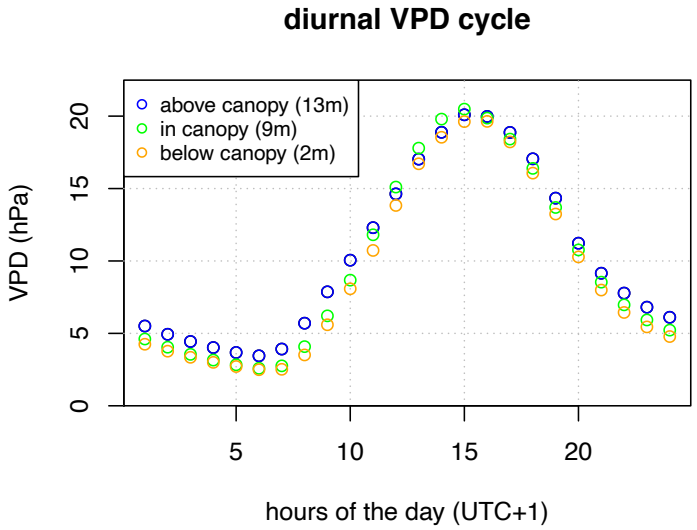


Fig 1. Diurnal VPD cycle in Pfynwald 2016-2020 (Decentlab) above, in and below canopy

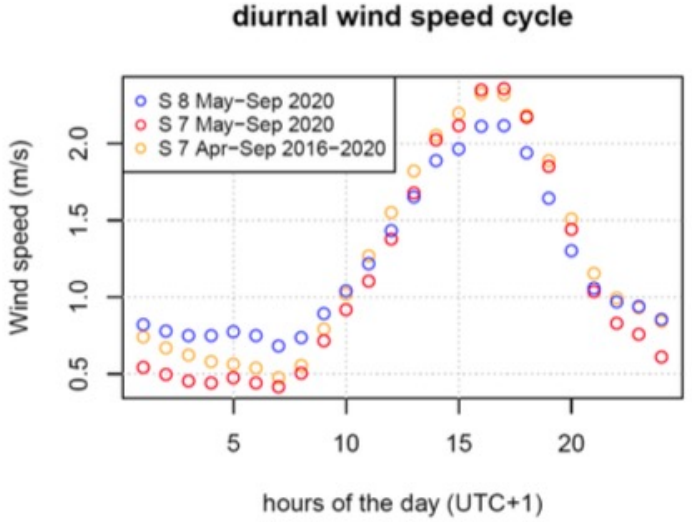


Fig 8. Diurnal wind speed cycle on scaffold 7 and 8 in Pfynwald from 21 May - 30 Sept 2020 and Apr - Sept 2016-2020.

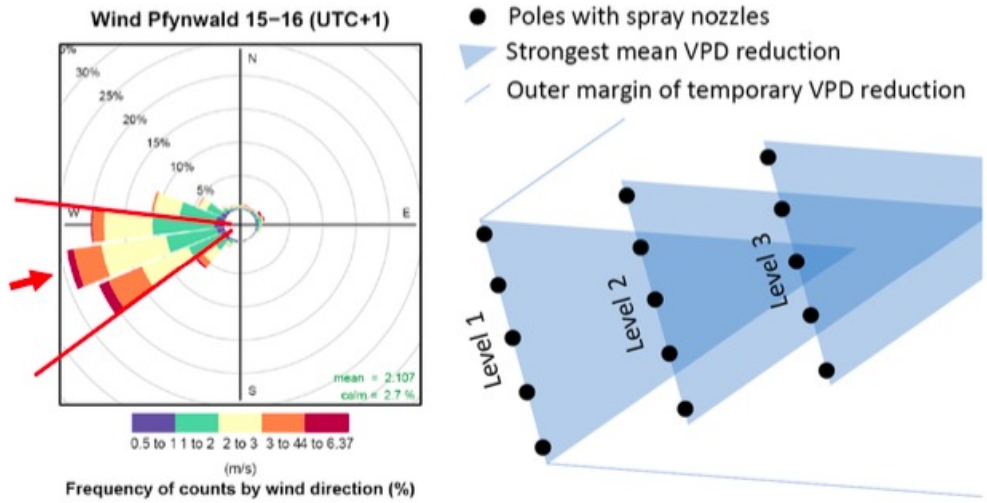
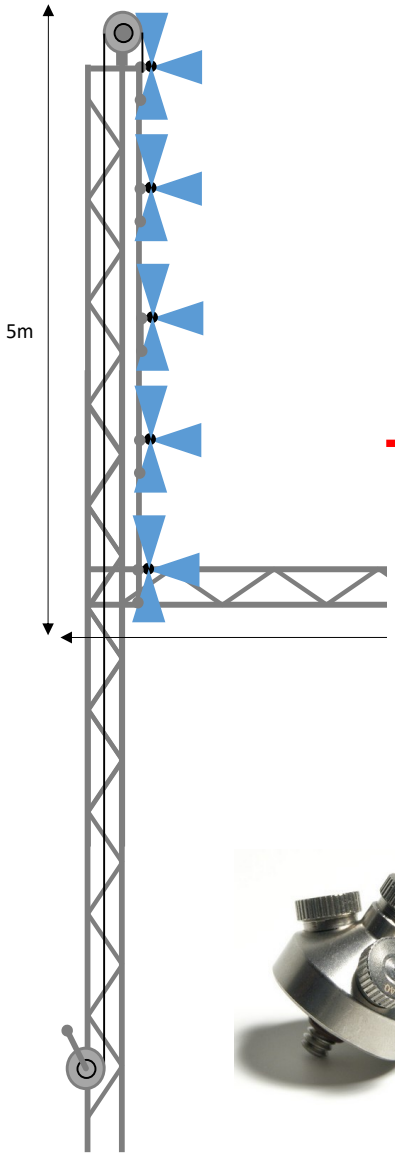
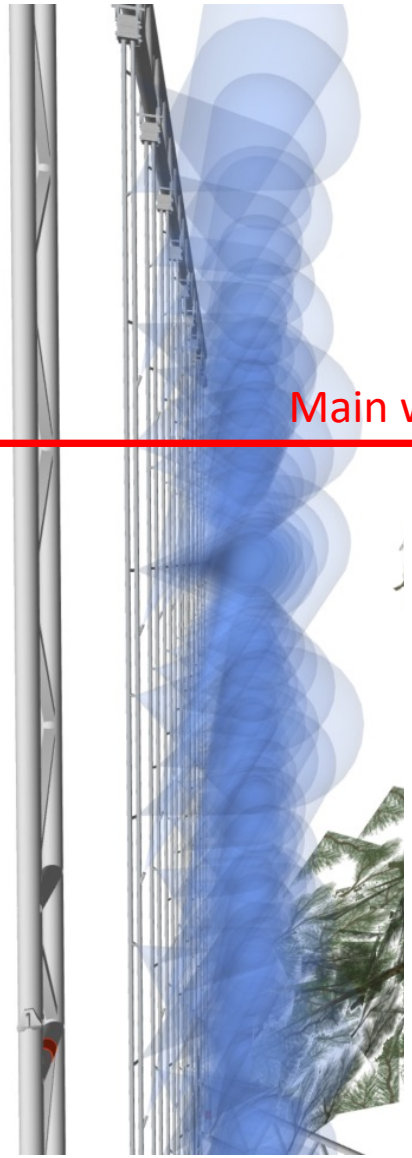


Fig 14. Suggested VPD manipulation experiment design. In this example, the spraying system is only active if wind direction is within the 45° wind field between 232.5°-277.5°.

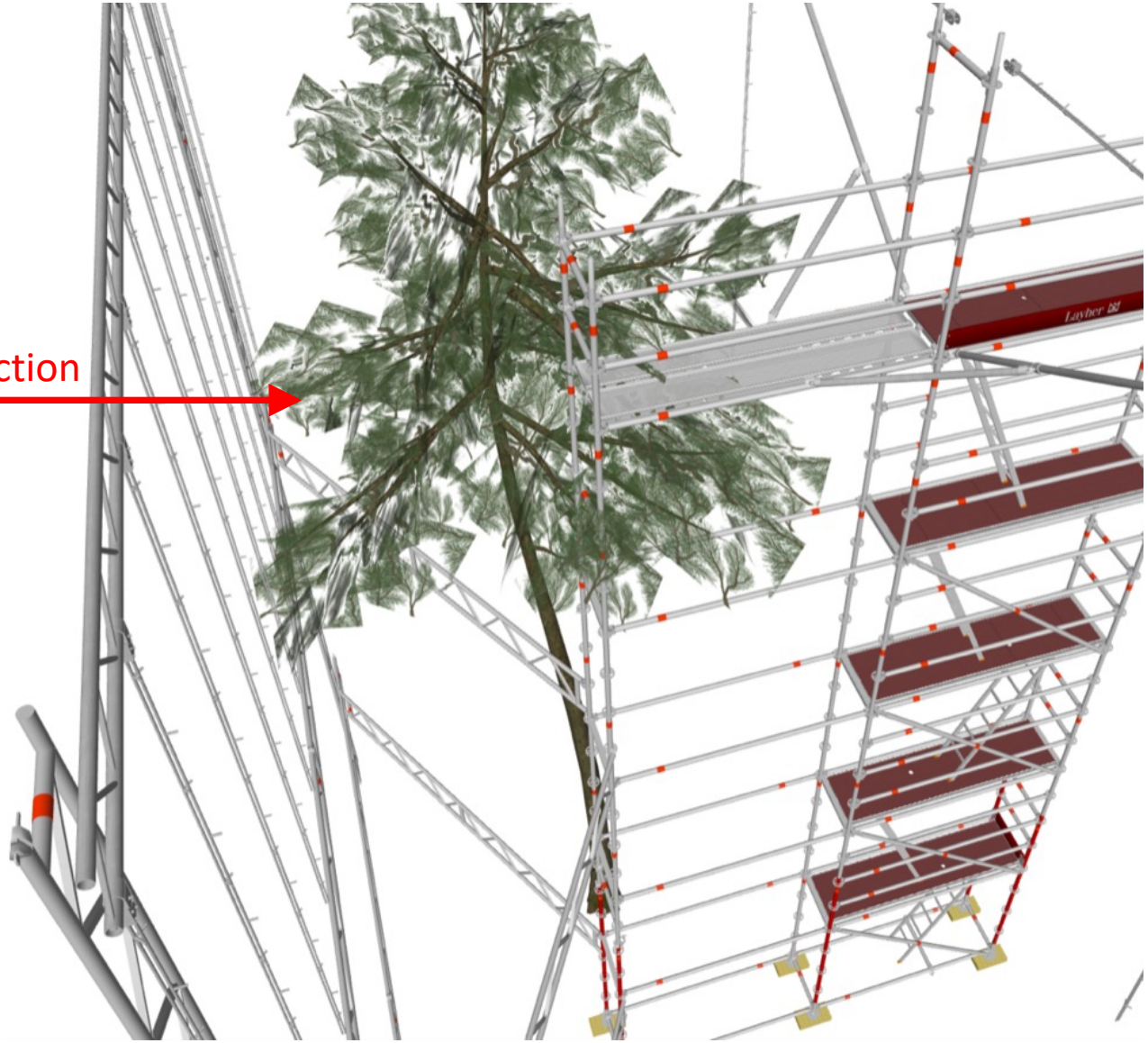
Source: Stefan Hunziker, 05.01.2021, V2

Nozzle system





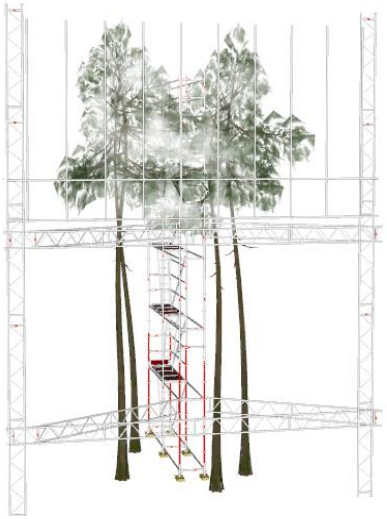
Main wind direction



Water supply chain

high pressure

HP pumps



ultra filtration / reverse osmosis

Tab water

Bezug ab Netz max. 40 m³ pro Tag
Bezug ab Netz max. 1500 m³ pro Jahr
(April – Oktober)

1.66 m³ / h
40 m³ / 24h

Enthärtung
Umkehrosmose

Puffertank

ca. 13.4 m³

Hochdruck

3 m³ / h
10 – 20 Uhr
30 m³ / 10 h

0.4 m³ / h
10 m³ / 24 h

Rohnekanal

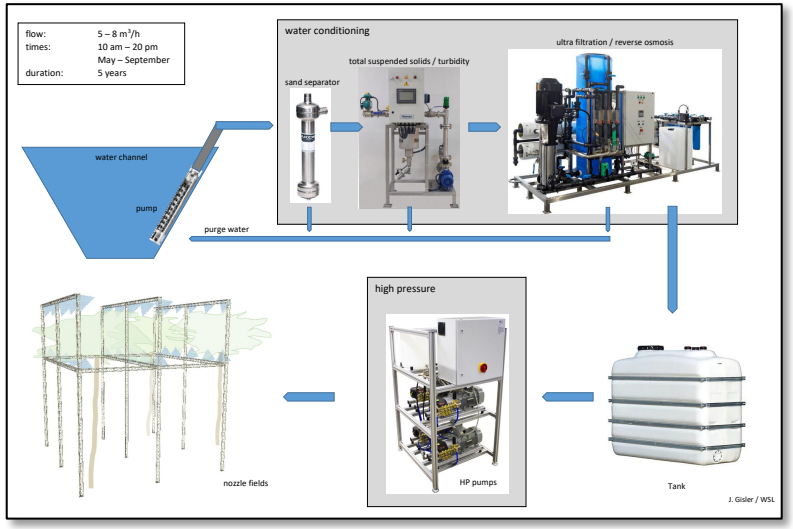
J. Gisler / WSL

The proof of concept

PfynDrought infrastructure

(1) Rain shelters

(2) VPD manipulation



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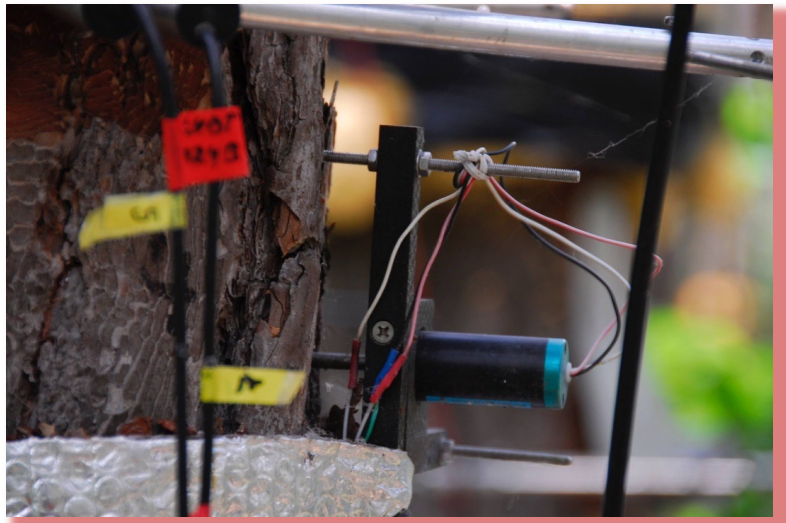
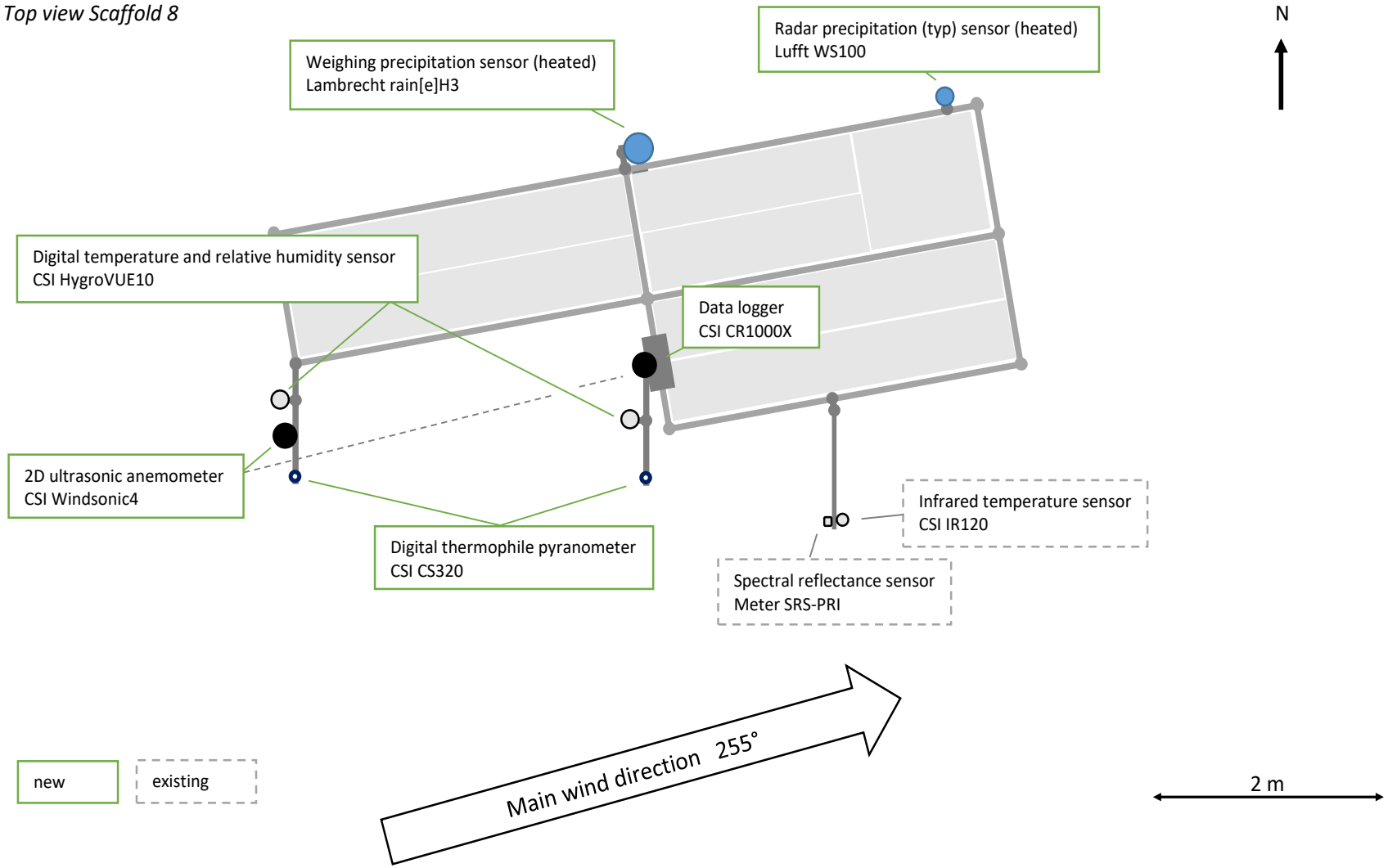


Sensors

Meteorological measurements in Pfynwald

Jonas Gisler, 16.12.2020, V1.1

Top view Scaffold 8



Sensors

Kostenabschätzung Sensoren - J. Gisler, 17. März 2021

		Shelter	VPD fields	Logger	TempRH	Wind	SMP	SWC	Sapflow	Dendrometer	
		6	6	15	48	6	30	30	45	45	Total no
Control	3			1	2		2	2	3	3	no/plot
Irrigated	3			1	1		2	2	3	3	no/plot
Irrigated & VPD	3			1	5	1	2	2	3	3	no/plot
Dry	3			1	2		2	2	3	3	no/plot
Dry & VPD	3			1	6	1	2	2	3	3	no/plot
Replicates	3	0	0	45'000	14'400	6'000	15'000	15'000	67'500	31'500	
Trees / repl.	3										
Plots	15										
Trees	45										

Unit	Price / unit
Logger/Box/Kabel	3'000
TempRH	300
Wind	1'000
SMP / SWC	500
Sapflow	1'500
Dendrometer	700

Total **194'400**

Additional variables to be measured from related fields? To be discussed with interested partners.

Thank you for your attention …