Trees and Drought
Cost-Benefit Analysis of rainwater retention systems

Joris Voeten, Wageningen University and Research

ISA Conference, August 14th 2023

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The USA and the Netherlands

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Parking problems…

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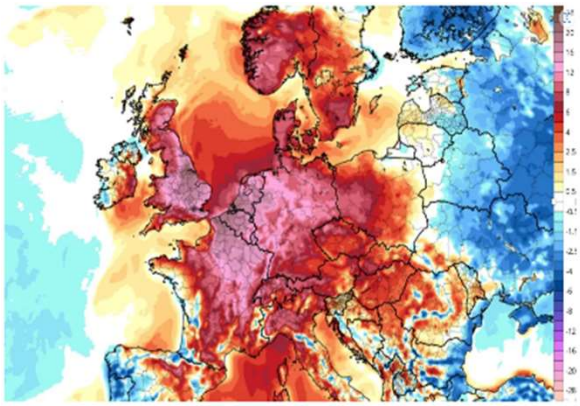
New issue: climate change, urban heat and drought



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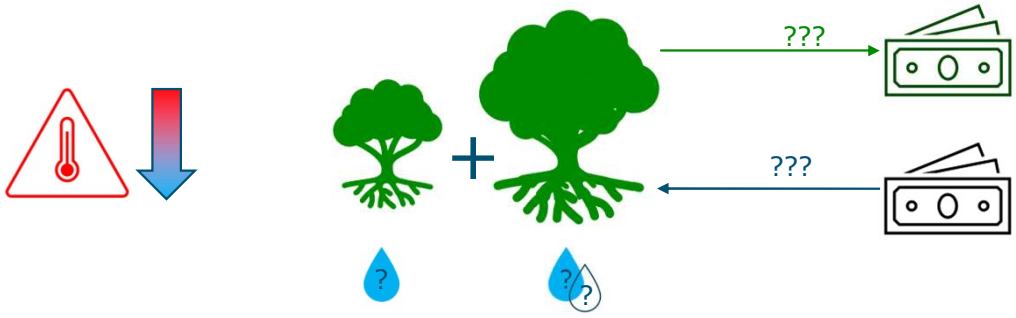
Research Question: Is it sensible to *invest* in more, healthy trees to increase Eco-System Services?



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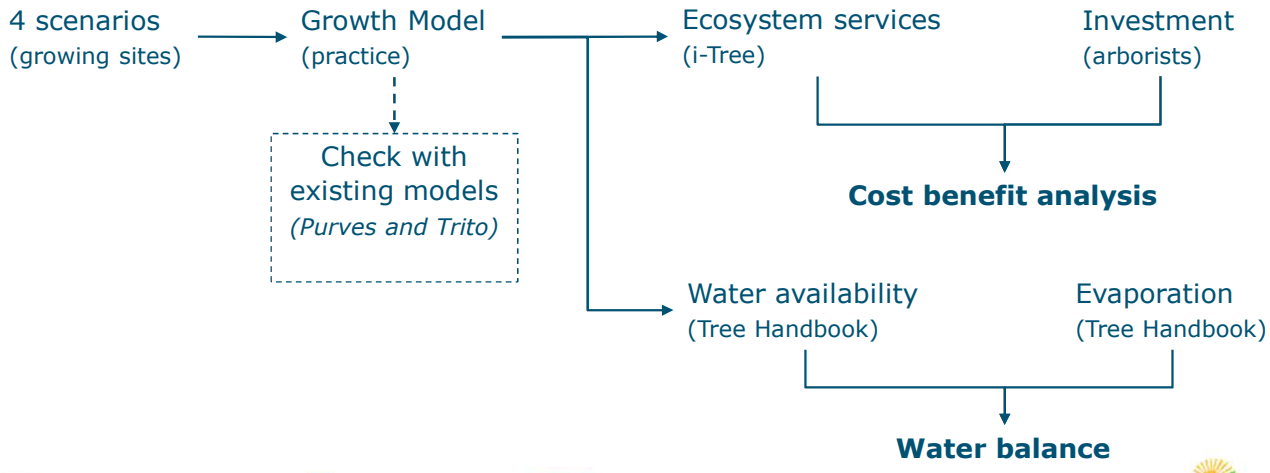
Research set-up



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4 Scenarios, 4 different growing sites, same tree

- Big-Leaf Linden (*Tilia Platyphyllos*)
- Planting size 20-25cm / 5m *(dbh 8-10 in. / 15 ft)*
- In concrete block pavers

- *120 year period*
- *Start from scratch*
- *End with empty growing site*

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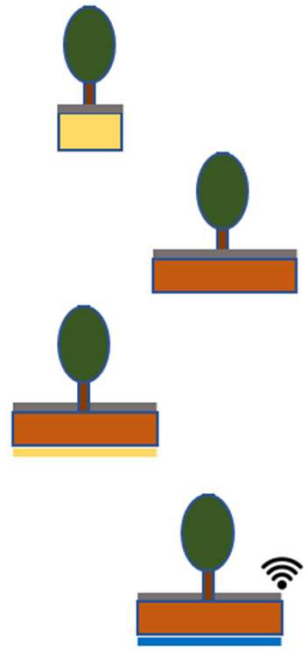
4 Scenario's



- **Conventional growing site** (9 m^2, 100 ft^2)
  - 1 m^3 (35 ft^3) tree sand mixed in
- **Amsterdam tree soil** (30m^2, 320 ft^2)
  - 30m^3 (1060 ft^3) tree sand
- **Retention Tree** (30m^2, 320 ft^2)
  - 30m^3 (1060 ft^3) tree sand
  - 150 mm (6 in.) rainwater retention capacity added
- **Capillary Irrigated Tree** (30m^2, 320 ft^2)
  - 30 m^3 (1060 ft^3) tree sand
  - 150 mm (6 in.) capillary irrigation, sensor & control

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1. Conventional (30 yr)

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2. Amsterdam Tree Soil (60 yr)

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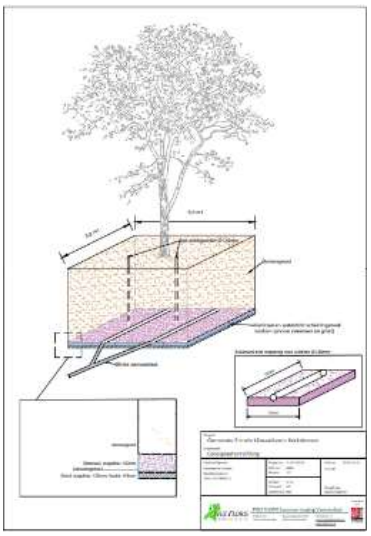
3. Retention tree (90 yr)



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4. Capillary Irrigated tree (120 yr)

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Growth models

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Growth model inputs (3 phases)

Conventional	Start (year)	End (year)	Diameter (cm/year)	Tree height (m/year)	Canopy Diameter (m/year)
Phase 1	0	10	1	0.4	0.3
Phase 2	11	20	0.5	0.1	0.1
Phase 3	21	30	0.25	0.05	0.05

Amsterdam Tree Soil	Start (year)	End (year)	Diameter (cm/year)	Tree height (m/year)	Canopy Diameter (m/year)
Phase 1	0	30	1	0.4	0.3
Phase 2	31	45	0.5	0.15	0.1
Phase 3	46	60	0.25	0.05	0.05

Retention tree	Start (year)	End (year)	Diameter (cm/year)	Tree height (m/year)	Canopy Diameter (m/year)
Phase 1	0	40	1	0.4	0.3
Phase 2	41	60	0.75	0.2	0.1
Phase 3	61	90	0.5	0.1	0.05

Capillary Irrigated tree	Start (year)	End (year)	Diameter (cm/year)	Tree height (m/year)	Canopy Diameter (m/year)
Phase 1	0	50	1	0.4	0.3
Phase 2	51	80	0.75	0.2	0.1
Phase 3	81	120	0.5	0.05	0.05

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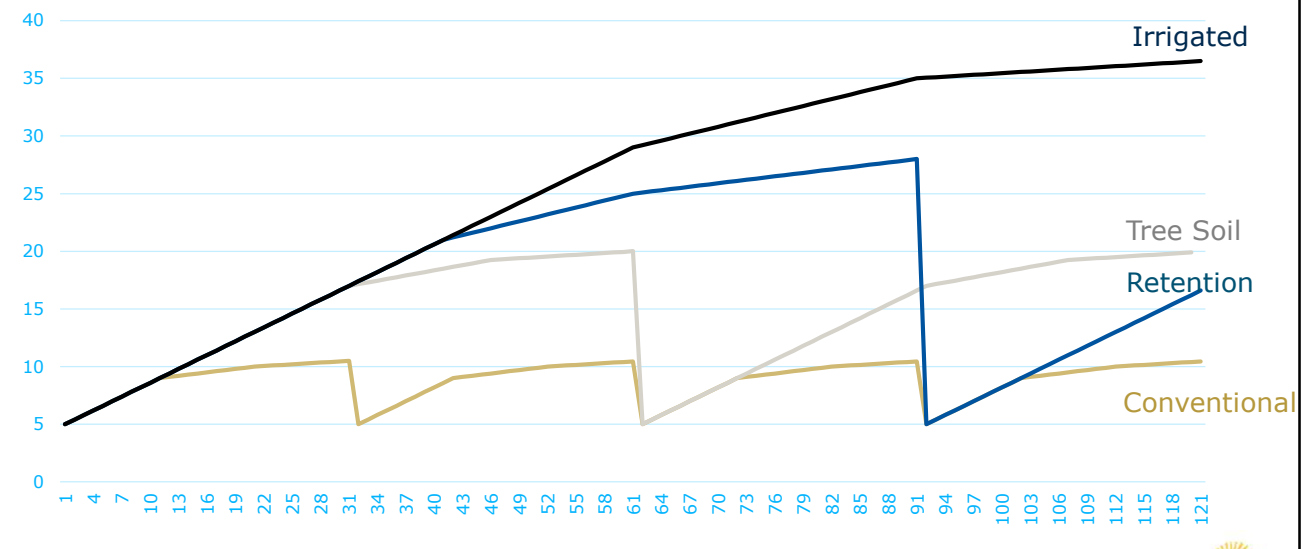
Tree height (*m*), 120 yr, for 4 scenarios



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Growth modelling check

Comparison with existing forestry growth models:

- TRITO - ITD Model (Purves, 2007)
- CwMax Model (Hasenauer, 1997)

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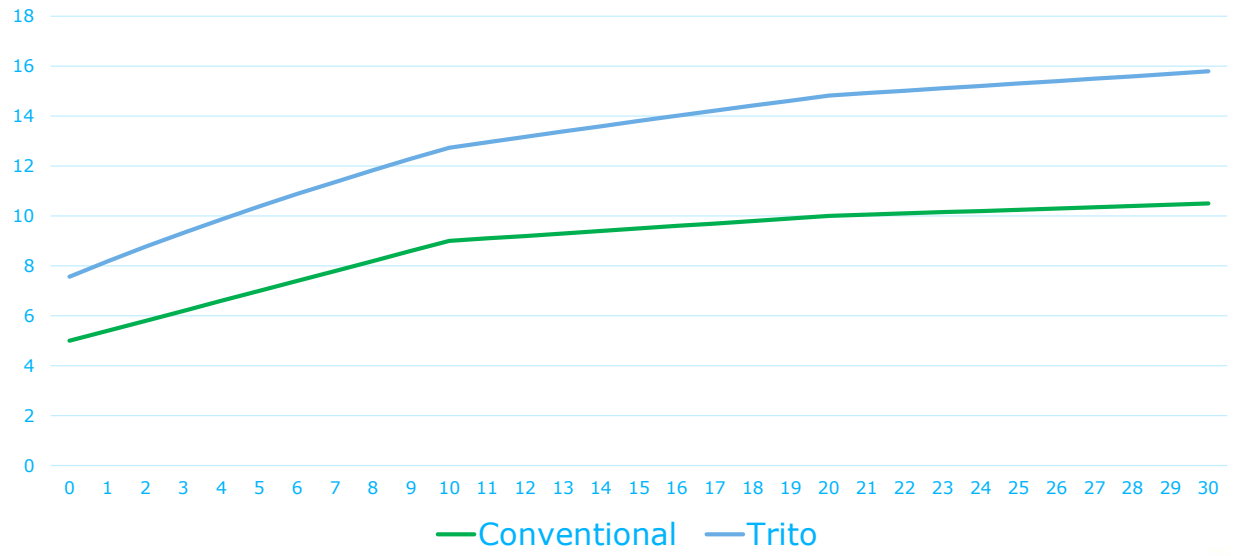
Conventional - Tree height (m)



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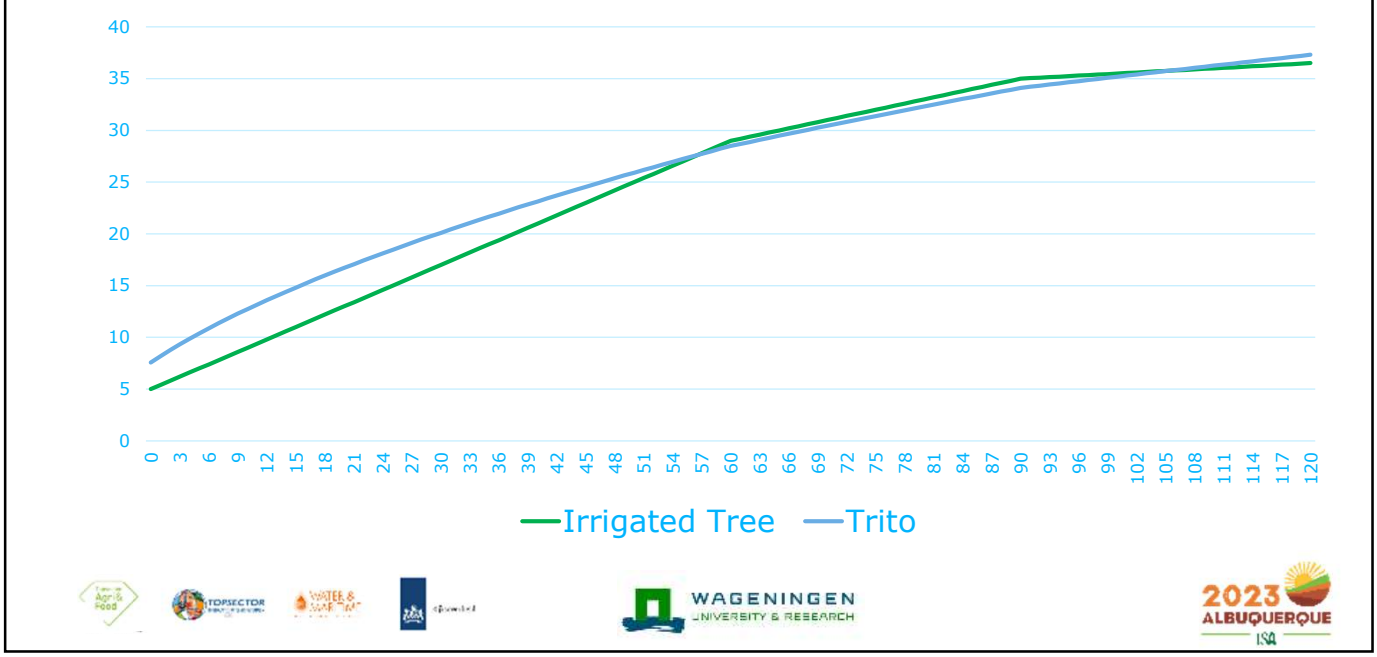
Capillary Irrigated Tree - Tree height (m)



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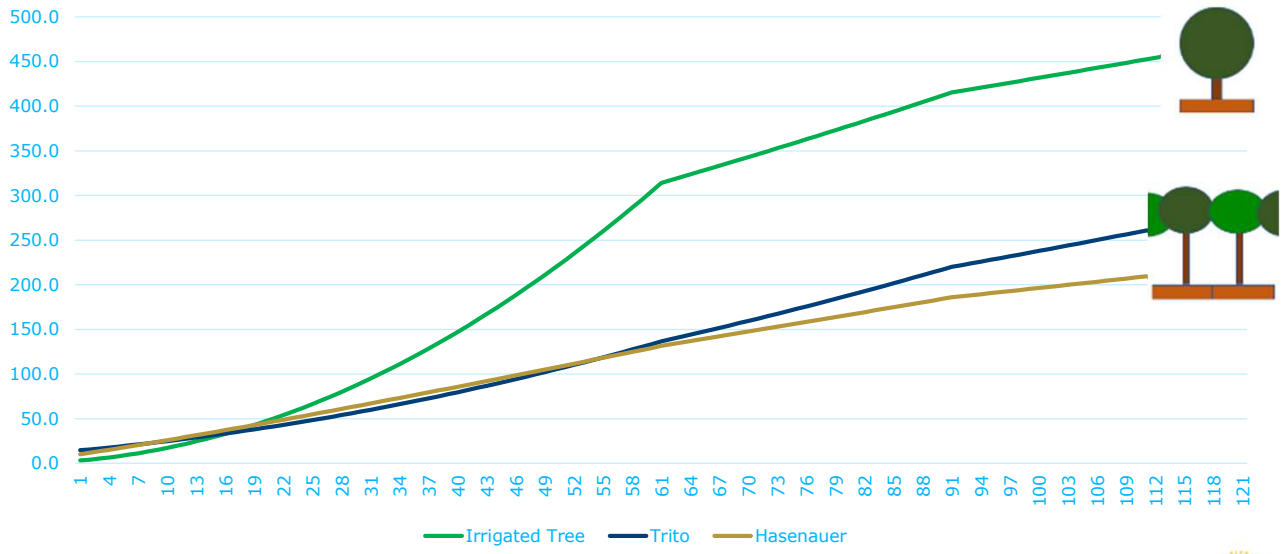
Irrigated Tree – Canopy Surface Area (m2)



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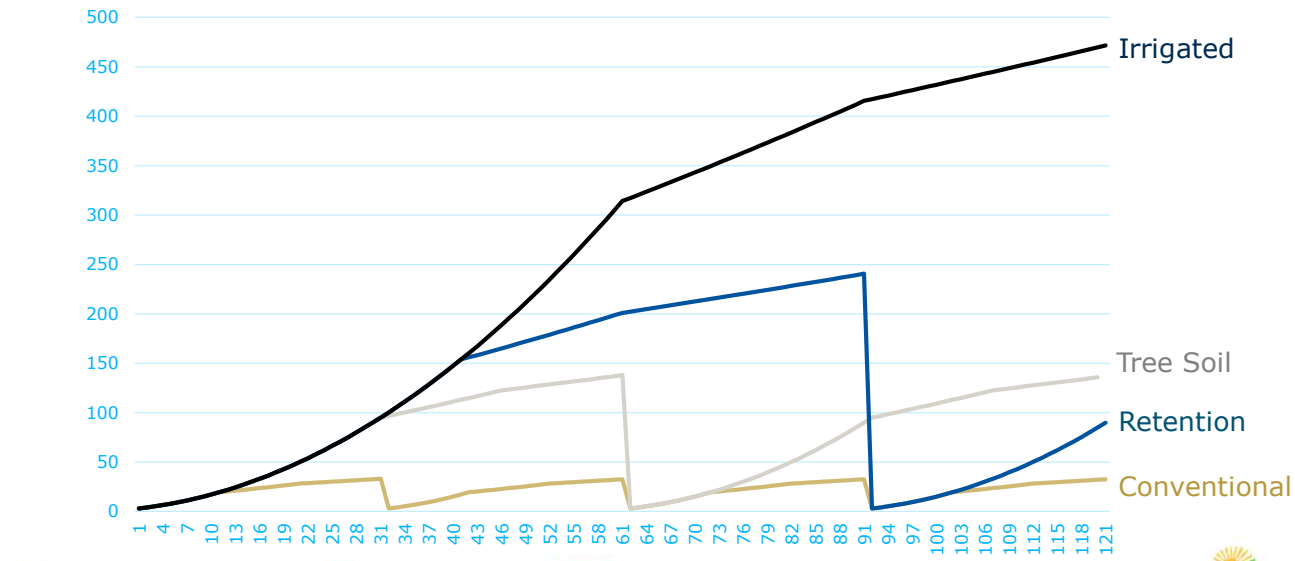
Canopy surface area for 4 scenarios



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Eco System Services

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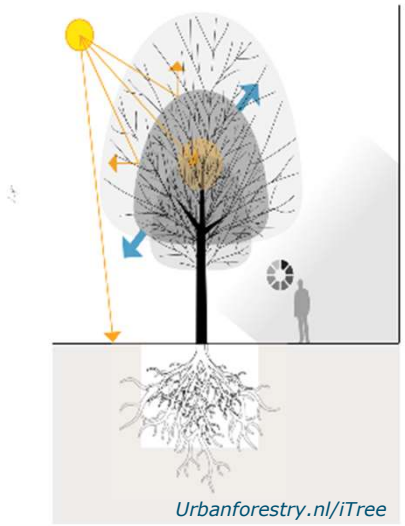
i-Tree: Eco System Services

- Input structure:
  - Growth models, 4 scenarios
- Function:
  - Determined by i-Tree NL
- Valued only:
  - Hydrological services
  - Carbon storage
  - Particulate matter filtration



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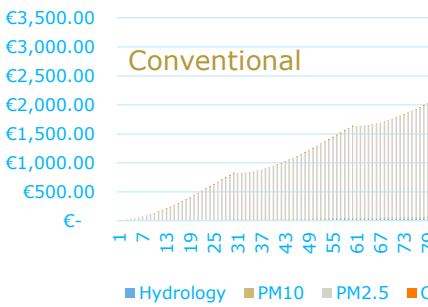
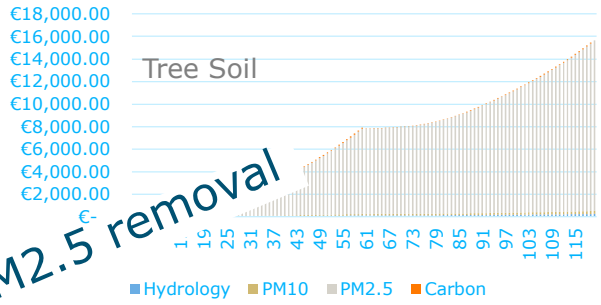
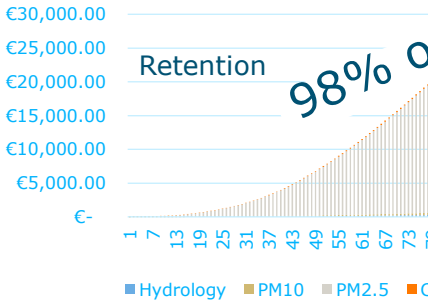
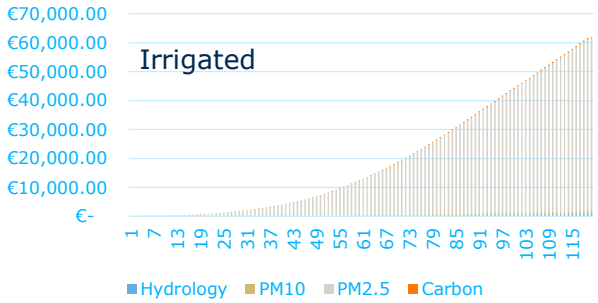




98% of ESS is PM2.5 removal





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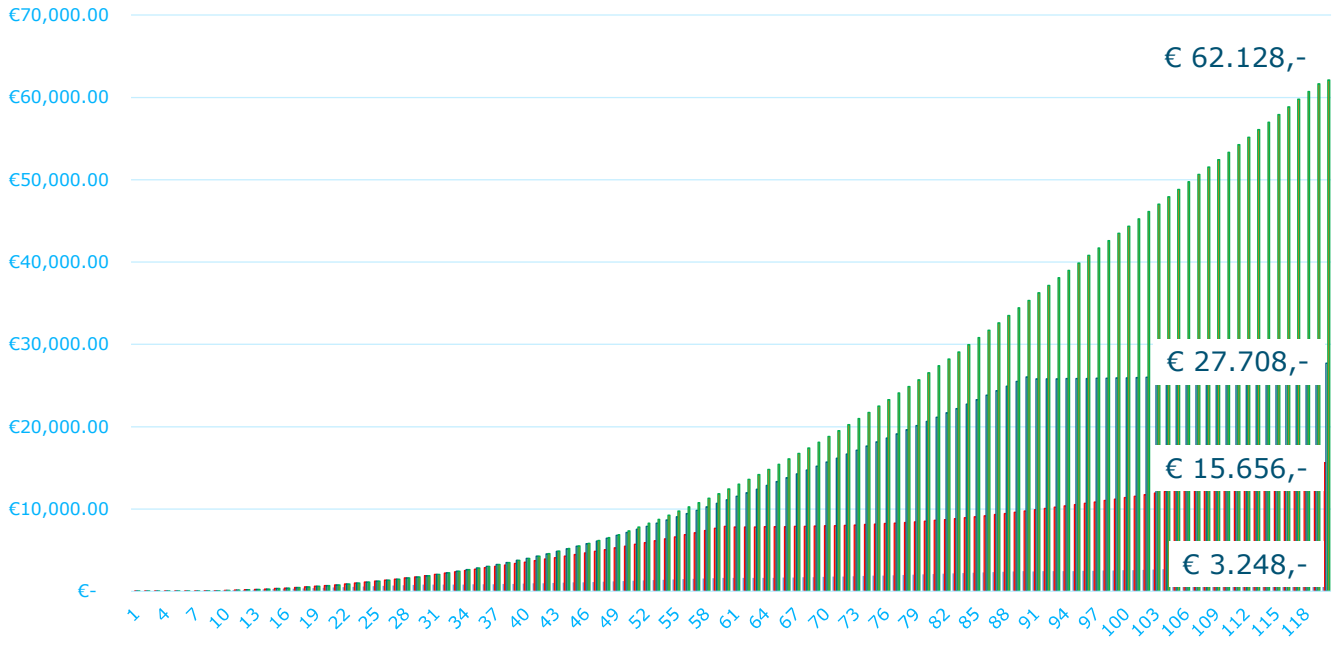
Cumulative Eco-System Services, 4 scenarios



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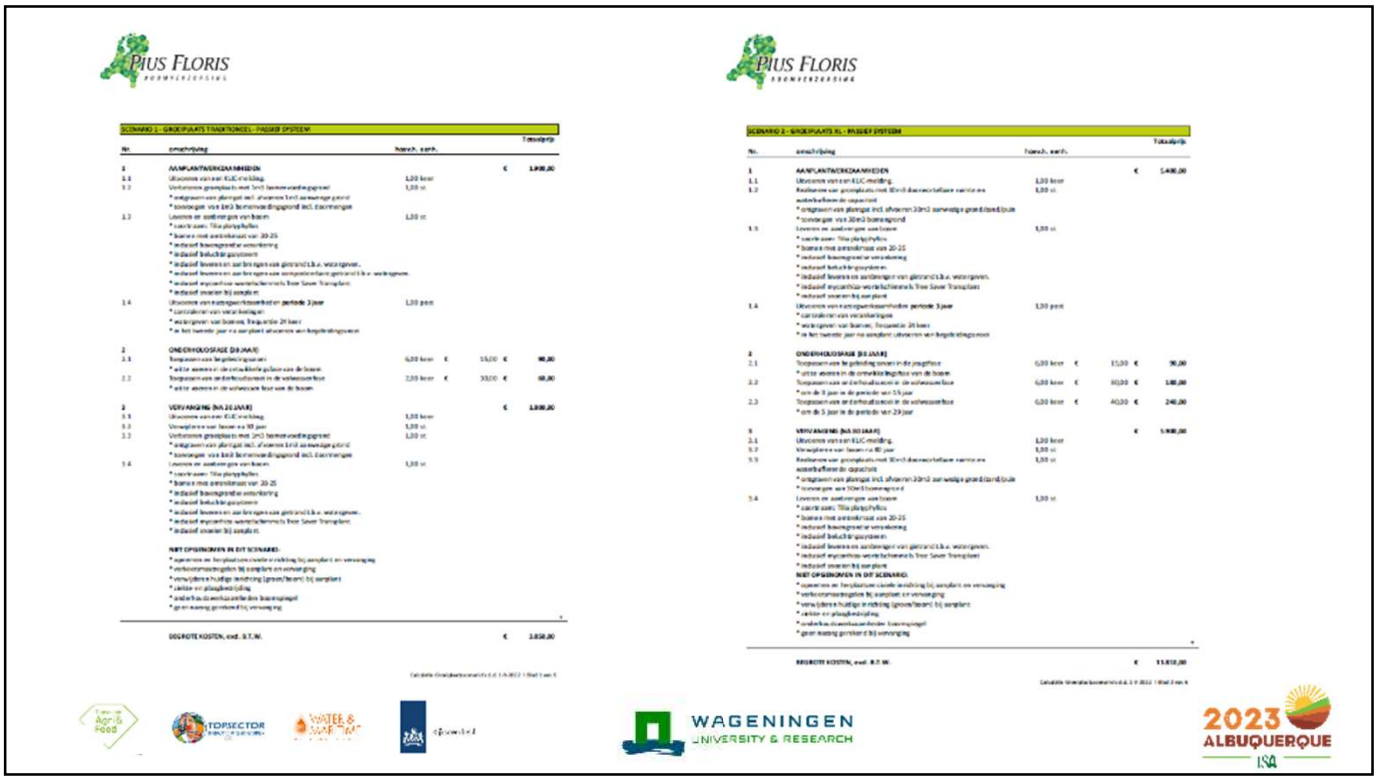
Planting, maintenance and removal Costs



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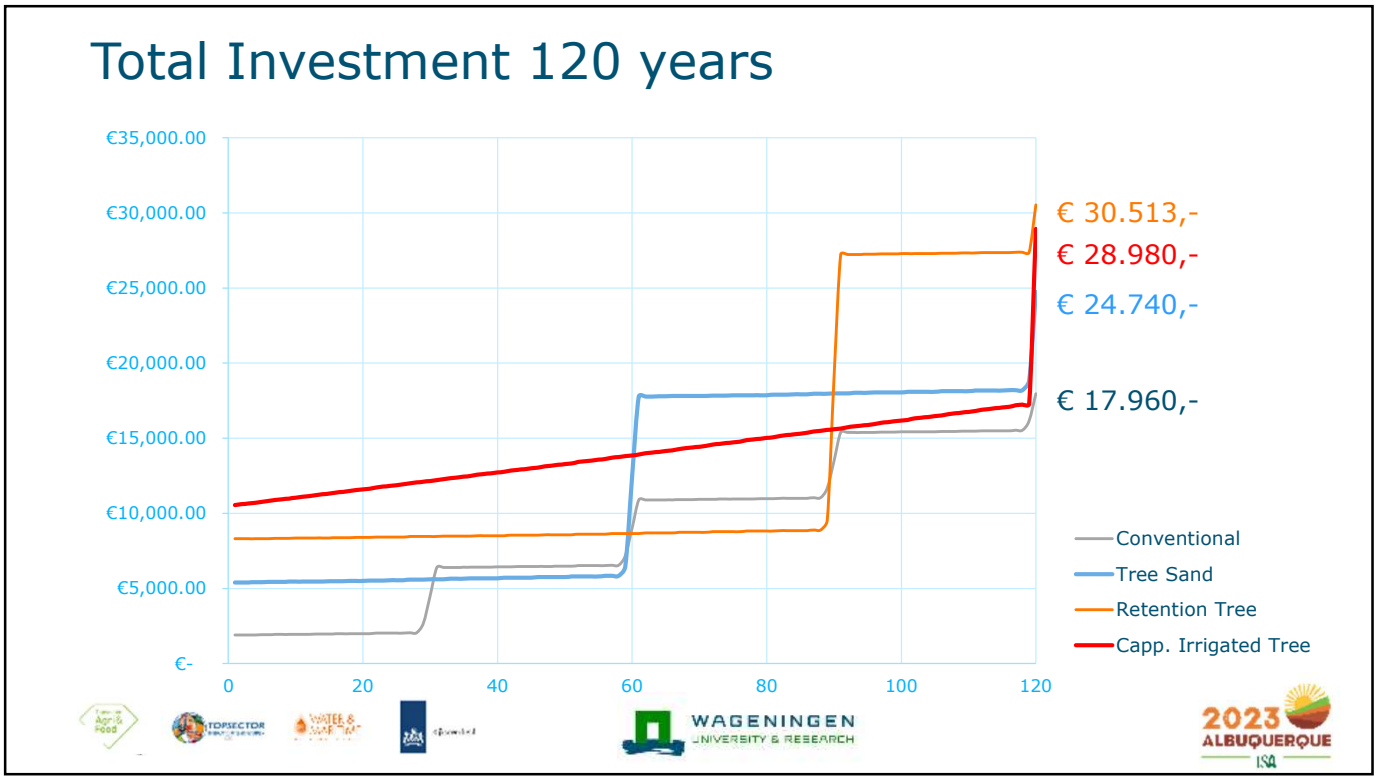
Total Investment 120 years
€35,000.00
€30,000.00
€25,000.00
€20,000.00
€15,000.00
€10,000.00
€5,000.00
€-
0
20
40
60
80
100
120
€ 30.513,-
€ 28.980,-
€ 24.740,-
€ 17.960,-
Conventional
Tree Sand
Retention Tree
Capp. Irrigated Tree

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Return on Investment over 120 year period

	Investment	ESS Value	Relative ROI
Conventional	€ 17.960	€ 3.248	**0.18**
Tree Sand	€ 24.740	€ 15.656	**0.63**
Retention Tree	€ 30.513	€ 27.708	**0.91**
Cap. Irrigated Tree	€ 28.930	€ 62.128	**2.14**

NOTE: not all Eco-System Services are accounted for, yet!

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Water modelling

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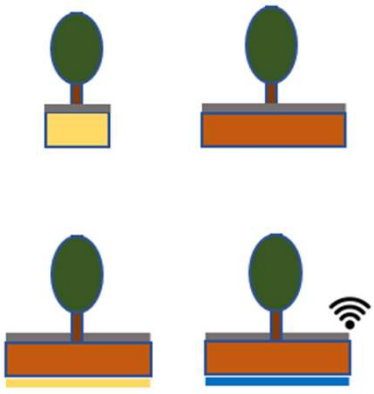
Water modelling

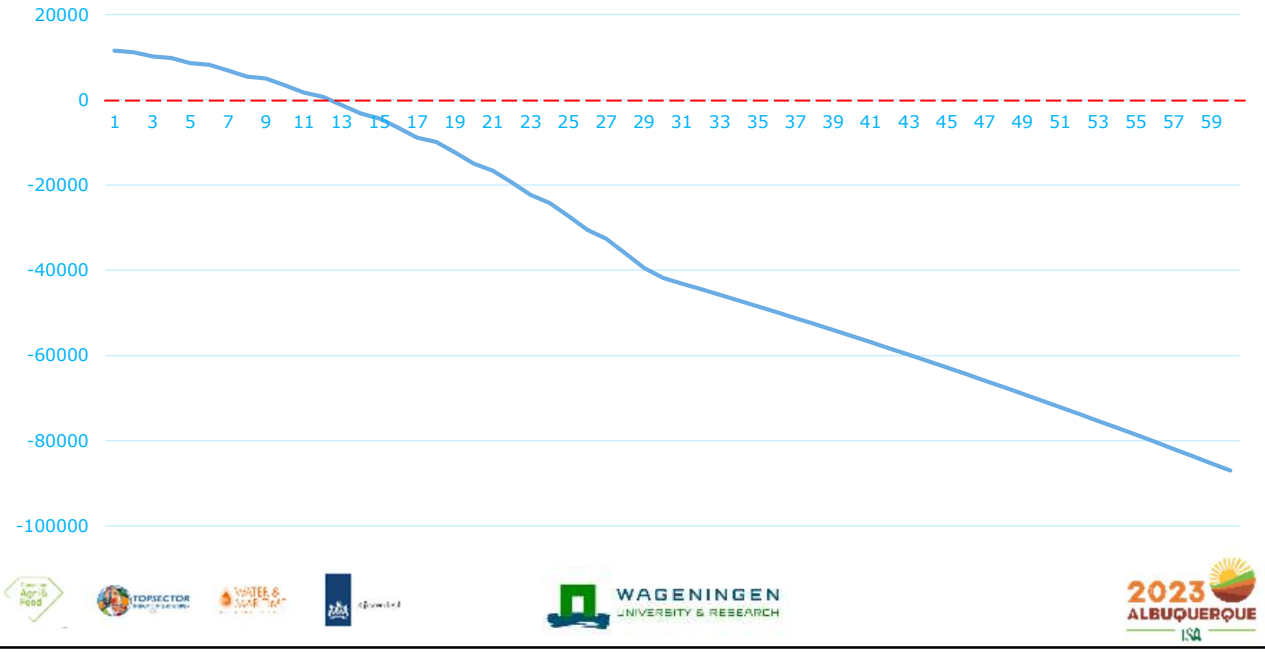
- Is there enough water available for the trees **in the created growing sites?**

Water modelling – Dutch Handbook of Arboriculture

Balance = Spring soil moisture storage
+ Infiltration from Precipitation
+ Capillary available ground water
+ Horizontal influx
- Evaporation



Amsterdam Tree Soil – Water Balance (l.)



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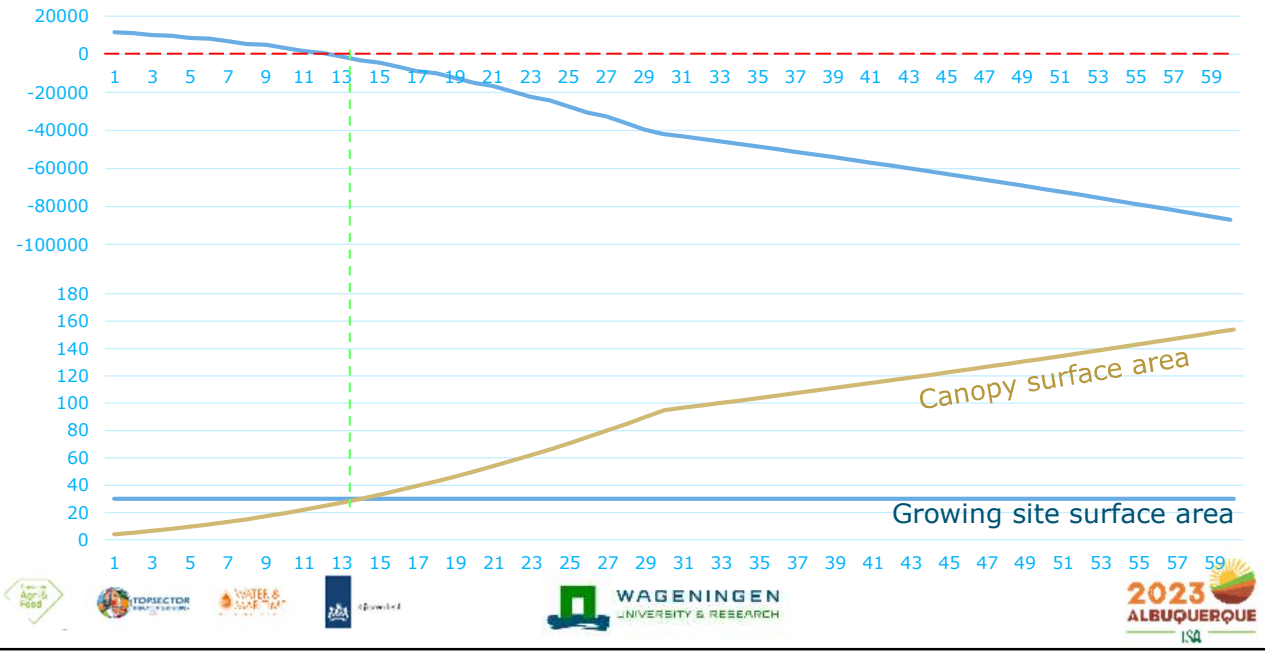
Amsterdam Tree Soil



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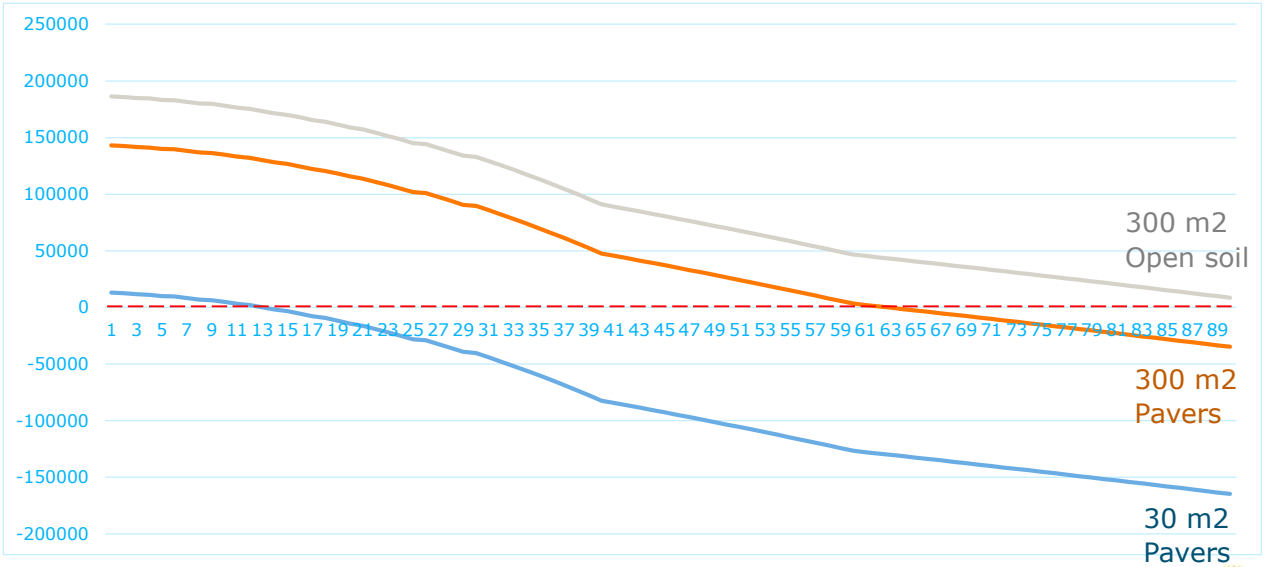
Retention Tree



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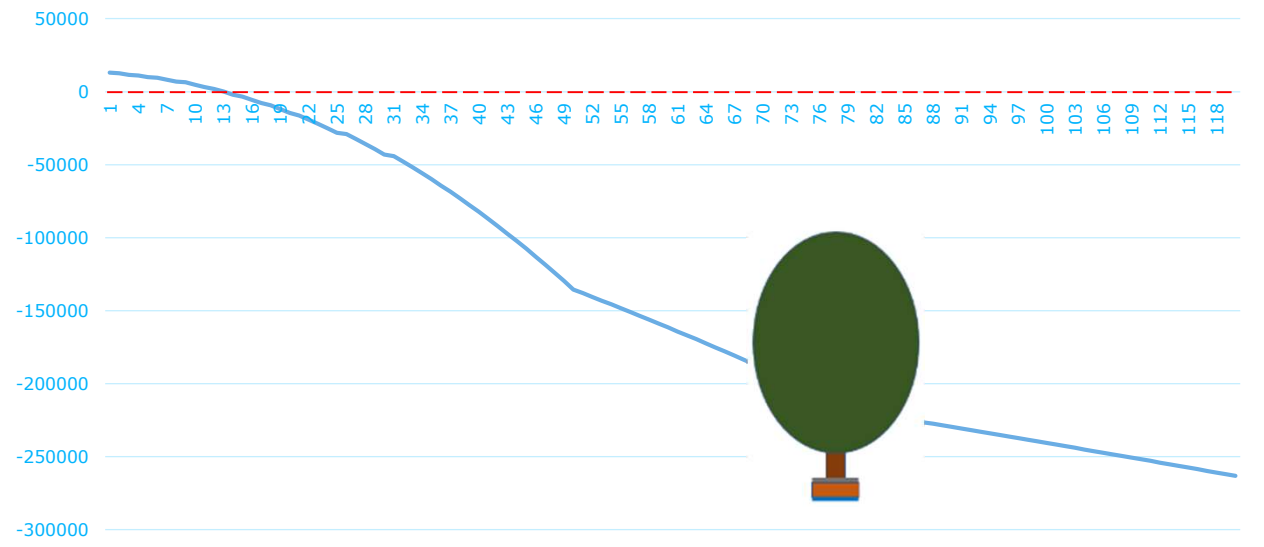
Capillary irrigated tree



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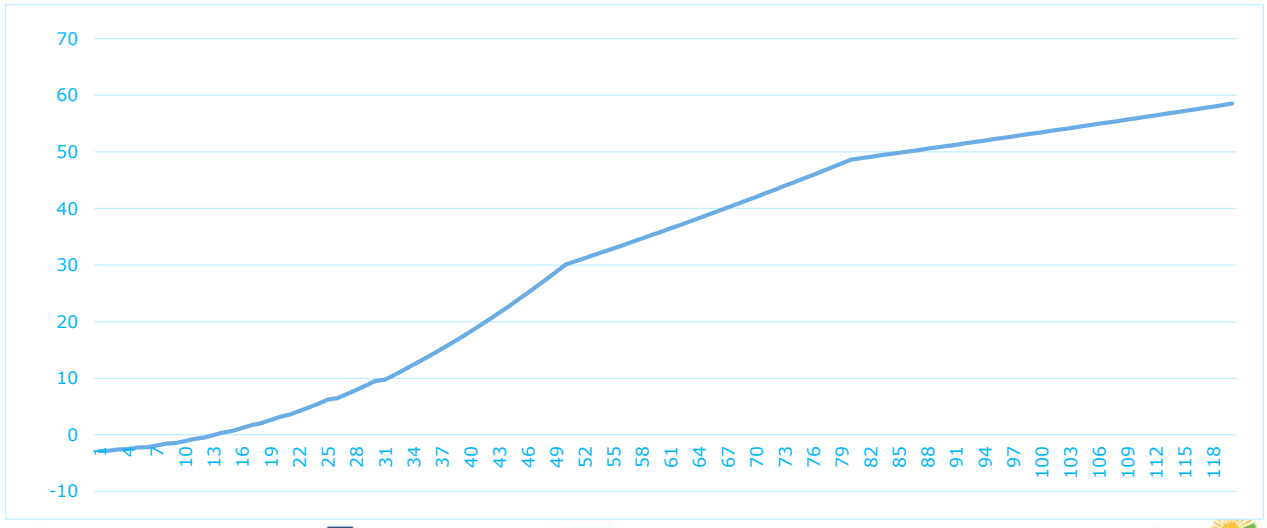
No of irrigation runs per year (truck)

(at 4.500 liters (1200 gallons) each)



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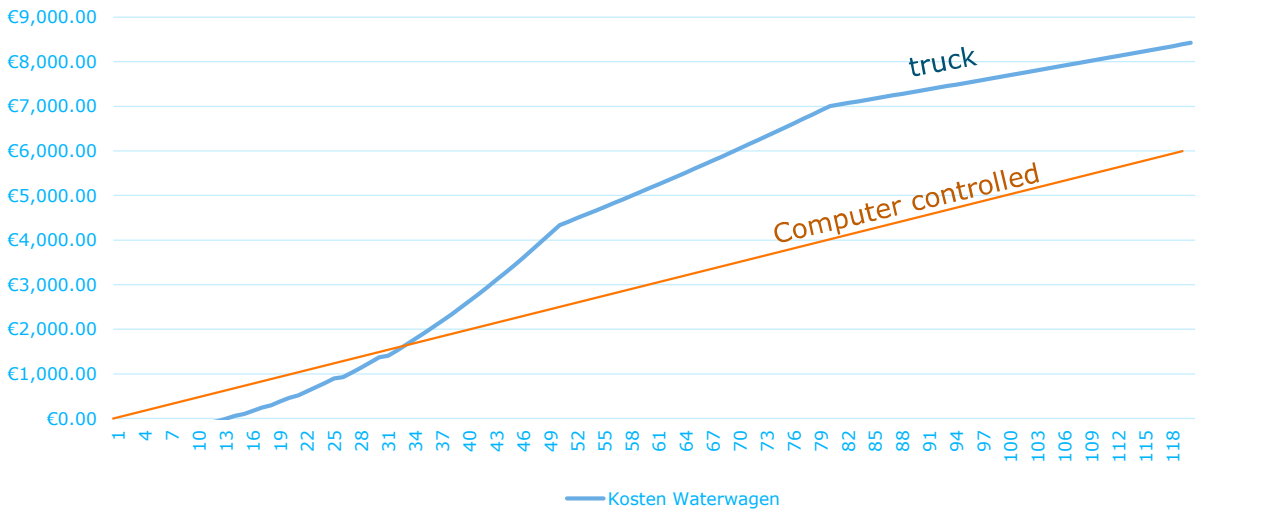
Total costs Water truck <> automated irr.



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Conclusions

- Investing in a tree's growing site significantly improves tree ESS
  - up to 19x
- Even with initial planting costs up to 5.5 times higher
  - ROI improves by a factor 12

We can no longer design trees without considering the required amount of water necessary for good growth

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Maybe we should plant (a little) less trees,

but give the growing sites of the trees we do plant more thought and consideration,

so they have a better chance at actually growing far into the future

J. Voeten, 2023

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Thank you!

Joris.Voeten@wur.nl

Pius Floris
Consulting Arborists

Koninklijke Ginkel Groep
Landscaping

City of Rotterdam
Urban Forestry Dept.

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