Water use efficiency of agroforestry systens in irrigated agriculture

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Niels Thevs[1], Eva Strenge[2], Kumar Aliev[1], Azim Baibagysov[3], Maksat Eraaliev[4], Petra Lang[2], Frank Thomas[2]

[1]World Agroforestry Center, [2]University of Trier, [3]Kazakh National University, [4]German Kazakh University

Agroforestry: Integrate trees into agriculture

for:

- Fuel
- Timber
- Fruits
- Fodder
- and ecosystem services

Shelterbelts in irrigated agriculture, e.g. Chui Valley, Ferghana Valley

Silvo-pastoral systems in the mountains

Additional timber for Kyrgyzstan…

Timber demand

Timber supply

State Forest Fund: 30,000 to 45000 m³/year

Imports from Russia

Illegal logging and collection from private land

… other effects of trees in agroforestry often unclear

- Tree shelterbelts reduce water consumption of annual crops in irrigated agriculture, **but how much water do the trees need for this service?**
- Trees in agroforestry improve soil fertility or compete for nutrients?
- Crop yields increase under agroforestry, but trees shade part of the crop. Does this shading impact on overall crop yields and income?
- Trees in agroforestry cause costs. Do the costs justify advantages from agroforestry?

Evapo-transpiration (ET)

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

$ET_c = ET_o \times K_c$

ET_c – Crop evapo-transpiration

K_c – Crop coefficiant: depends on crop and crop management.

Reference ET: Only depends on meteorological features.

Radiation (R_n)

Wind speed (u_2)

Air humidity (e_a)

Temperature (T)

→ **ET_o**

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Allen, R.G., Pereira, L.S., Raes, D., Smith, M., 1998. Crop evapotranspiration - Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. FAO, Rome.

Evapo-transpiration (ET) leeward of shelterbelt

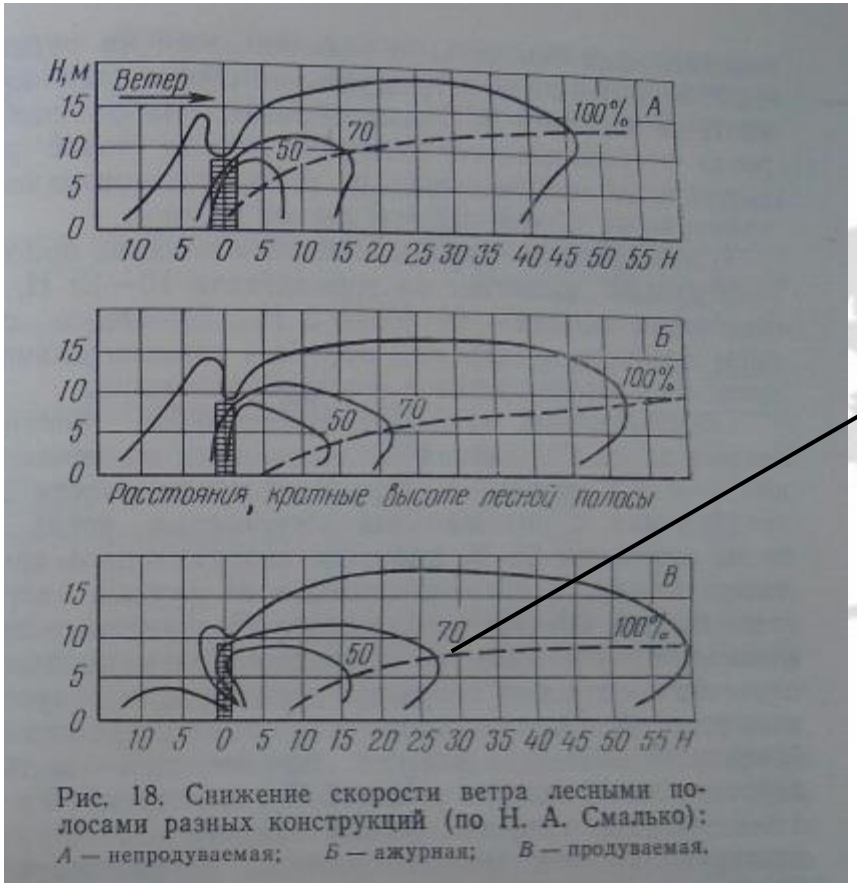

Рис. 18. Снижение скорости ветра лесными полосами разных конструкций (по Н. А. Смалько): А — непродуваемая; Б — ажурная; В — продуваемая.

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Wind speed (u_2) → **ET_o**

Air humidity (e_a)

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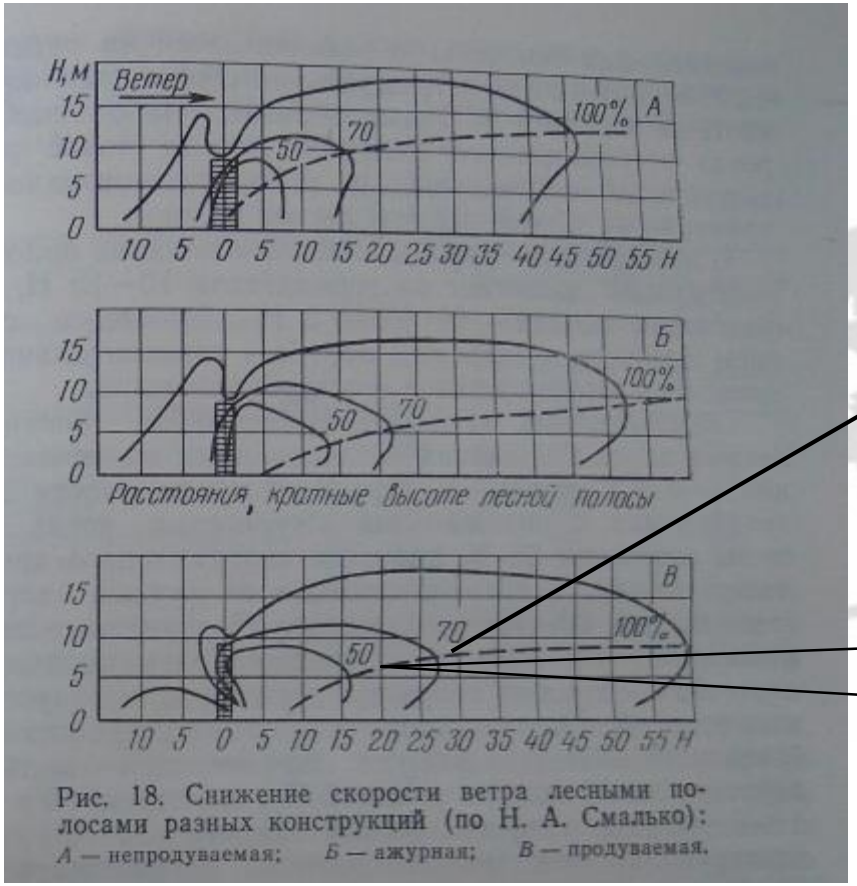
Vasilyev, M.E. (1980): Melioration through Woody Plants and Harvests. Kainar, Almaty.

Evapo-transpiration (ET) leeward of shelterbelt



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Radiation (R_n)

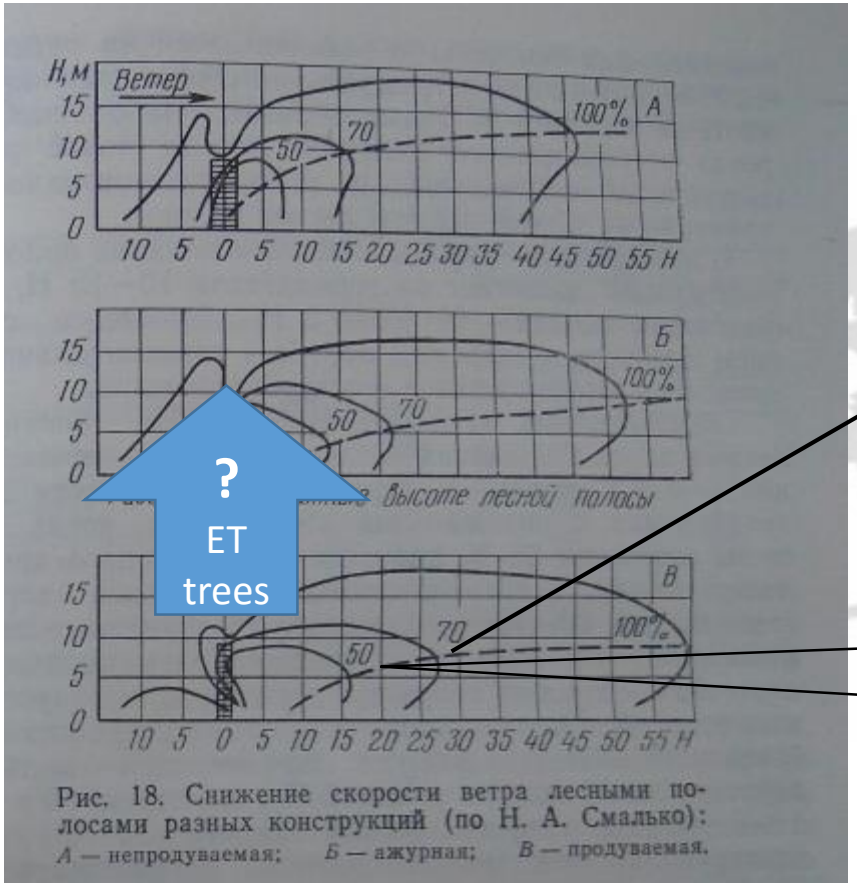
Wind speed (u_2) → **ET_o**

Air humidity (e_a)

Temperature (T)

Shelterbelt height 10 m:
150 m leeward wind speed 50% of wind speed outside shelterbelt system

Evapo-transpiration (ET) leeward of shelterbelt



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Wind speed (u_2) → **ET_o**

Air humidity (e_a)

Temperature (T)

Shelterbelt height 10 m:
150 m leeward wind speed 50% of wind speed outside shelterbelt system

Sites

Sokuluk
NW of Bishkek
Elm trees + corn, vegetables
Mainly W-, SW-wind

Karasay Batyr
Kazakhstan, near Tokmok
Poplar trees + potato, corn
Before 13:00 E-wind
After 13:00 W-wind

ET of trees: sap flow measurement

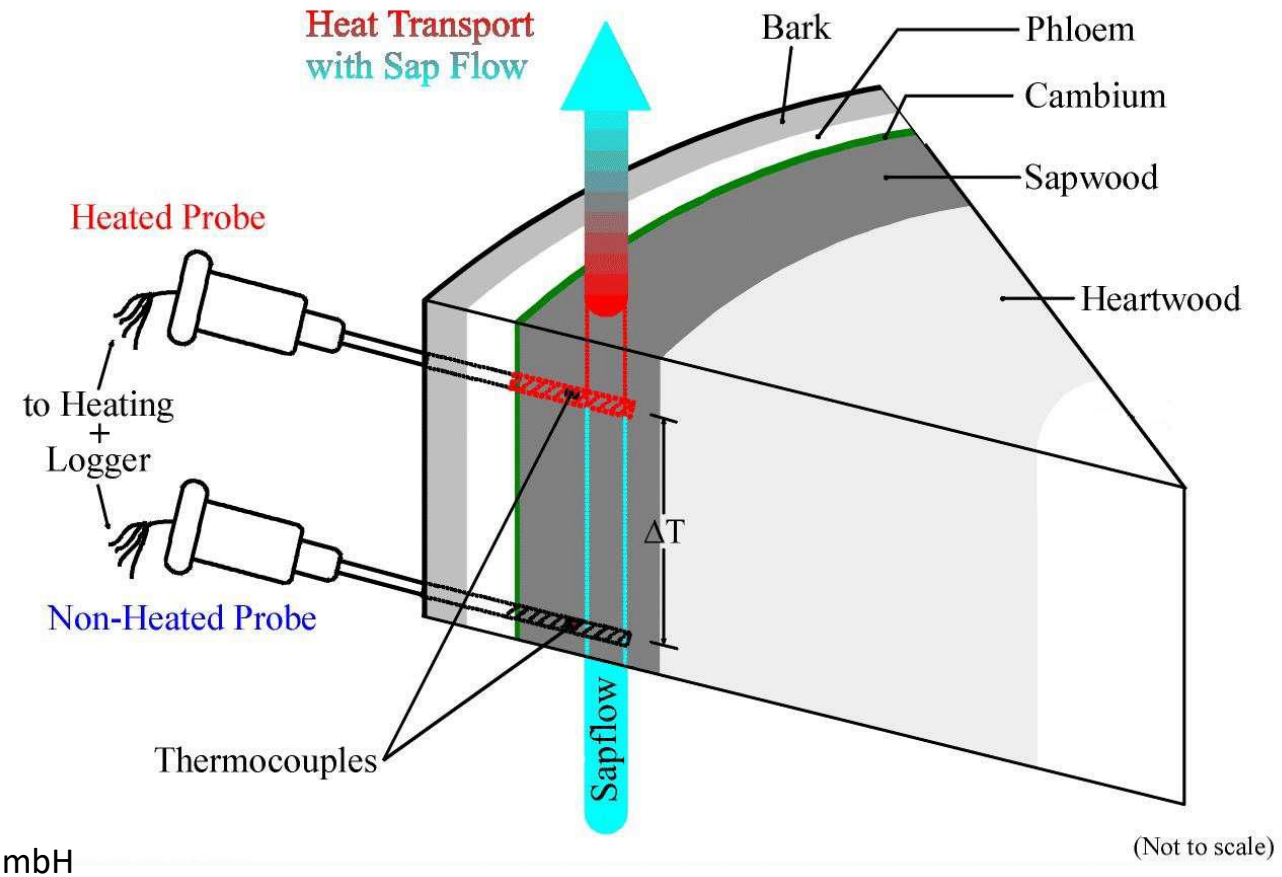
All water that is transpired / consumed by the tree passes through the stem.

Sheöterbelt Sokuluk, *Ulmus minor* + *Acacia* spec.

ET of trees: sap flow measurement

Sensors: Temperature difference -> sap flow density

Sap flow density x spawood -> water consumption



Umwelttechnische Produkte GmbH

ET_o and Crop ET

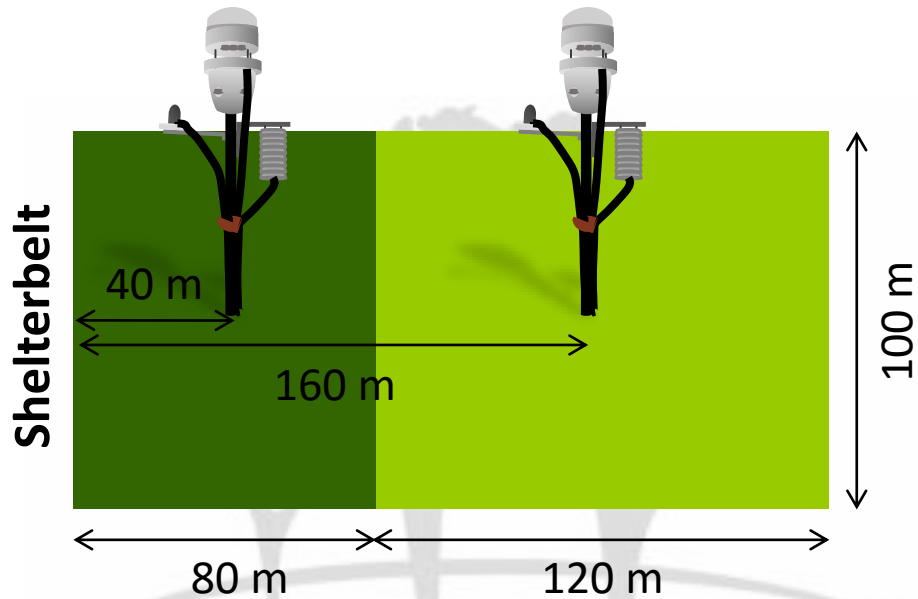
Penman-Monteith approach (FAO Irrigation and Drainage Paper 56)
Climate stations with sensors for radiation, wind speed, wind direction, air temperature, air humidity („EM-50 Family“, Decagon)

Stations 40 m and 160 m from shelterbelt

Control: Climate data from Bishkek Airport and Tokmok

Upscaling from point measurement to field

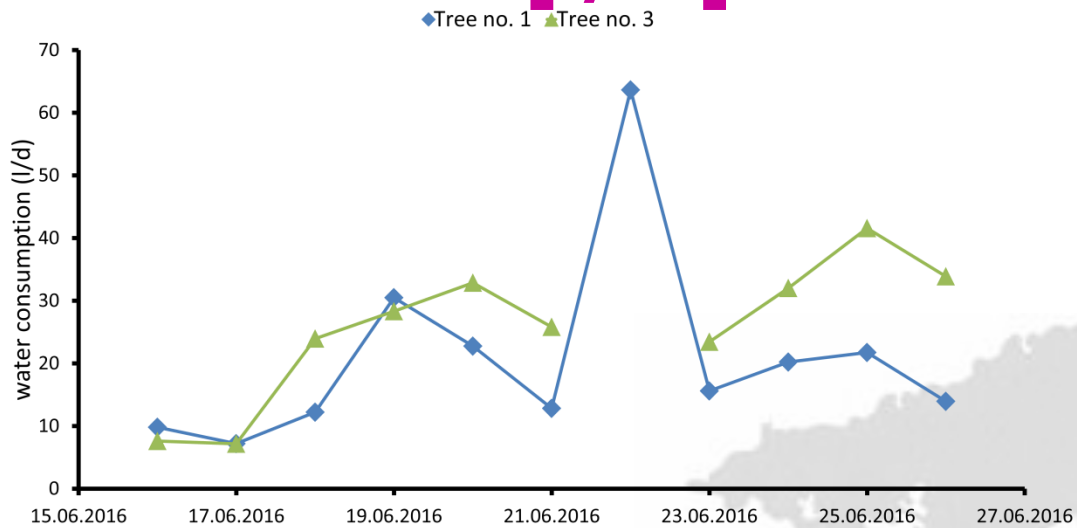
Upscaling to 100 m shelterbelt:
Tree map with dbh -> sapwood area of each tree. Sapflow density similar between trees -> ET of all trees.



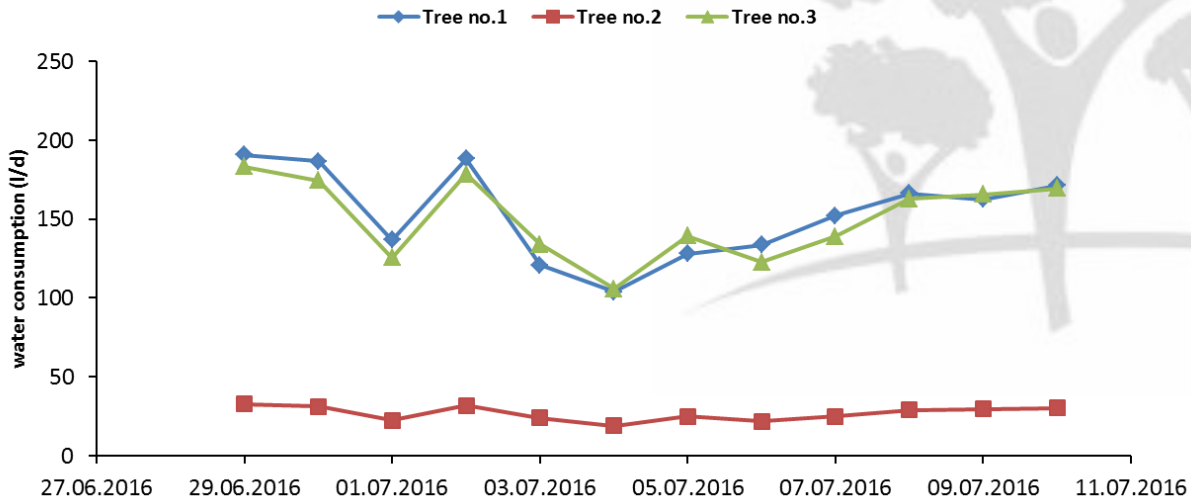
Climate station 1: represents 0-80 m

Climate station 2: represents 80-200 m

ET of trees [l/d]

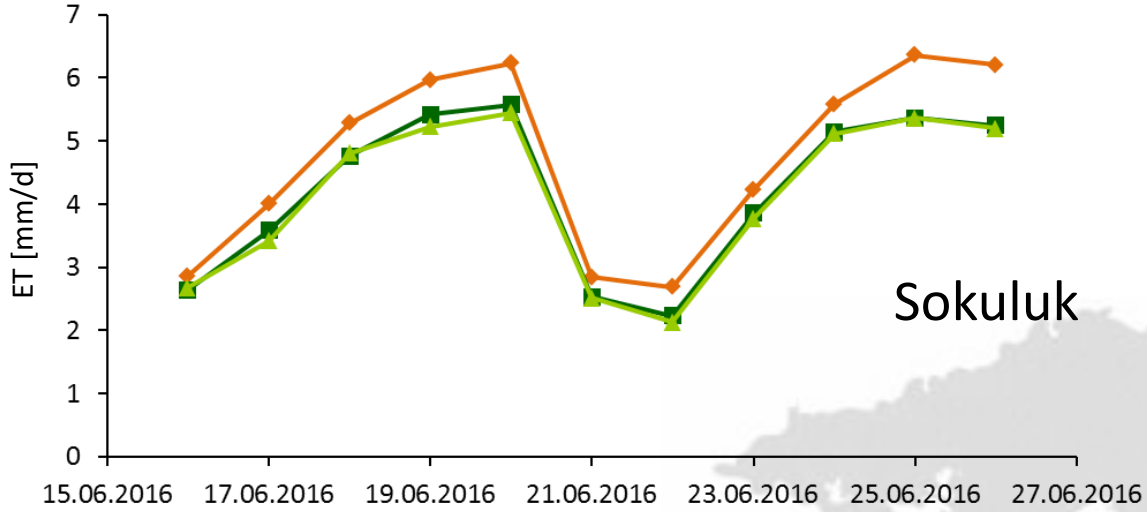


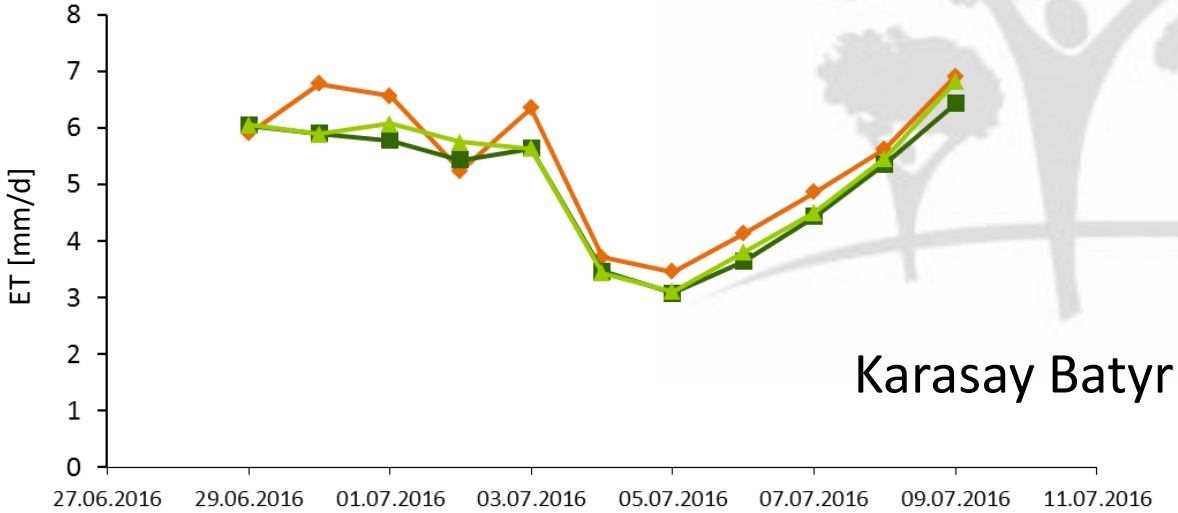
Elm trees
Height 8.6 m
DBH 14.3 cm and 13.8 cm
Sokuluk



Poplar trees
Height: 16 m
DBH 42.6 cm, 19.2 cm, and 31.5 cm
Karasay Batyr

ETo of annual crops



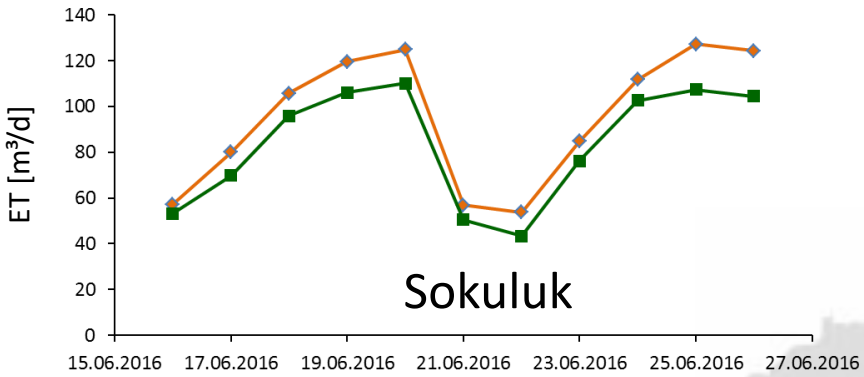


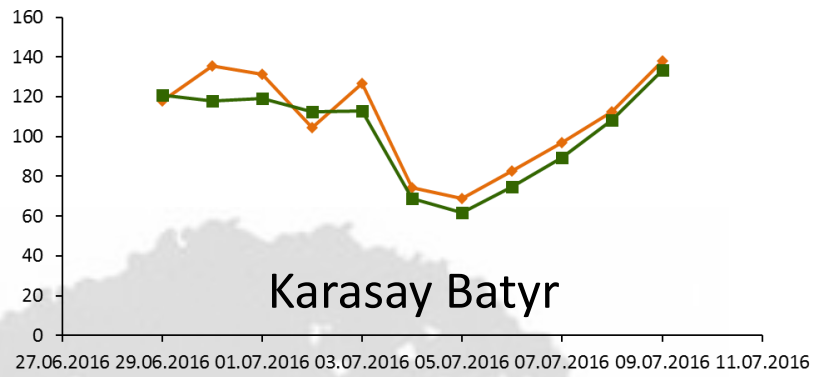
No shelterbelt

40 m from shelterbelt

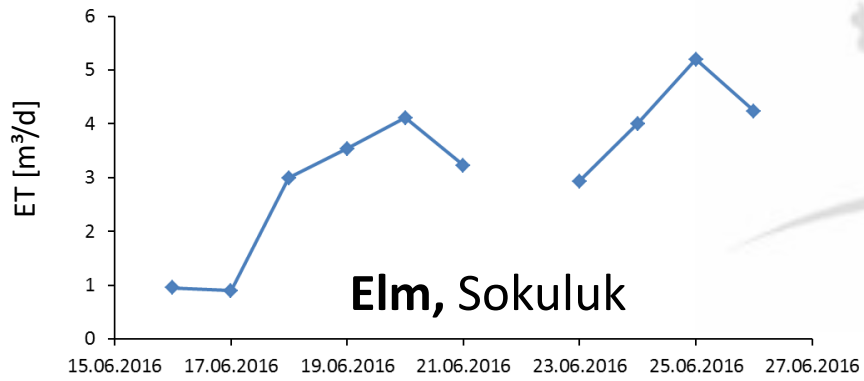
160 m from shelterbelt

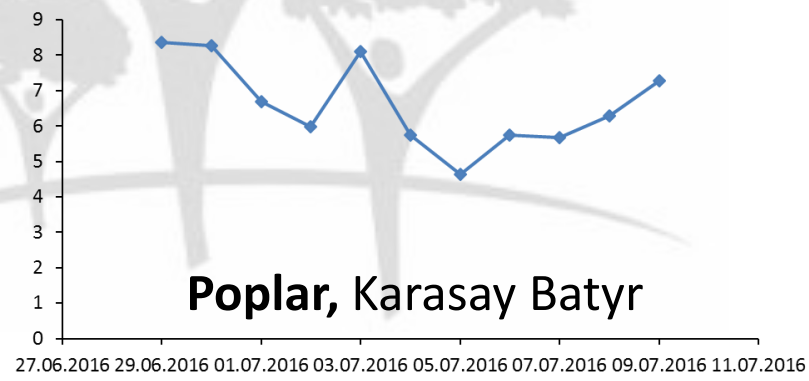
ET of crops and trees, 100 m shelterbelt, 2 ha field [m³/d]





ETo of 2 ha field [m³/d]: brown – no shelterbelt, green – with shelterbelt





ET of 100 m shelterbelt [m³/d]

ET reduction through shelterbelts [m³/d] on 2 ha and 100 m shelterbelt

Sokuluk

Date	ET no shelterbelt	ET with shelterbelt	ET reduction
16.06.2016	57,2	54,2	3,1
17.06.2016	80,0	70,5	9,4
18.06.2016	105,7	98,7	6,9
19.06.2016	119,4	109,6	9,8
20.06.2016	124,7	114,0	10,6
21.06.2016	56,8	53,6	3,2
22.06.2016	53,7		
23.06.2016	84,6	79,0	5,6
24.06.2016	111,6	106,6	5,1
25.06.2016	127,1	112,5	14,6
26.06.2016	124,1	108,6	15,6
Average	95,0	90,7	8,4

Karasay Batyr

Date	ET no shelterbelt	ET with shelterbelt	ET reduction
29.06.2016	118,1	129,4	-11,3
30.06.2016	135,6	126,1	9,4
01.07.2016	131,3	125,7	5,6
02.07.2016	104,7	118,3	-13,6
03.07.2016	126,9	120,8	6,1
04.07.2016	74,2	74,6	-0,4
05.07.2016	69,1	66,4	2,7
06.07.2016	82,5	80,4	2,1
07.07.2016	97,2	95,2	2,0
08.07.2016	112,5	114,6	-2,1
09.07.2016	138,2	140,6	-2,4
Average	108,2	108,4	-0,2

Note: Shelterbelt only works half days, during west wind.

Conclusions

- The results allow to think in the direction that shelterbelt agroforestry systems may have a lower water consumption than non-shelterbelt systems.
- This is certainly true for Ulmus due to its low water consumption compared to Poplar.
- The overall water use efficiency might also increase with Poplar shelterbelts, as Poplars provide additional income at the same water consumption as non-shelterbelt systems.

Thank you for your attention

Funding: GIZ-BEAF