Water use efficiency of agroforestry systems in irrigated agriculture
Water use efficiency of agroforestry systems in irrigated agriculture

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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: 160,000 m³ per year

Timber supply:
- State Forest Fund: 30,000 to 45,000 m³/year
- Imports from Russia
- Illegal logging and collection from private land

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... 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)

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

Reference ET: Only depends on meteorological features.

\[ET_c = ET_o \times K_c\]

ET<sub>c</sub> – Crop evapo-transpiration
K<sub>c</sub> – Crop coefficient: depends on crop and crop management.

Radiation (R<sub>n</sub>)
Wind speed (u<sub>2</sub>)
Air humidity (e<sub>a</sub>)
Temperature (T)
Evapo-transpiration (ET)

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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)}
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Radiation \(R_n\)

Wind speed \(u_2\)

Air humidity \(e_a\)

Temperature \(T\)

Evapo-transpiration (ET) leeward of shelterbelt

\[ ET_0 = \frac{0.408\Delta (R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma (1 + 0.34u_2)} \]

Radiation \((R_n)\)
Wind speed \((u_2)\)
Air humidity \((e_a)\)
Temperature \((T)\)

Evapo-transpiration (ET) leeward of shelterbelt

\[
ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} - u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}
\]

- Radiation \((R_n)\)
- Wind speed \((u_2)\)
- 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

\[
ET_\circ = \frac{0.408 \Delta (R_n - G) + \gamma \frac{900}{T + 273} - u_2 (e_s - e_a)}{\Delta + \gamma (1 + 0.34u_2)}
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- Radiation \((R_n)\)
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- 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 $\rightarrow$ sap flow density

Sap flow density $\times$ spawood $\rightarrow$ water consumption

Umwelttechnische Produkte GmbH
www.worldagroforestry.org
ET$_0$ 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.
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

Sokuluk

Karasay Batyr

No shelterbelt

40 m from shelterbelt

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

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

ET of 100 m shelterbelt [m³/d]

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

<table>
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<th>ET with shelterbelt</th>
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Sokuluk

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<td>Average</td>
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<td>108,4</td>
<td>-0,2</td>
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Karasay Batyr

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