Soil Carbon Dynamics of Tree Plantings for Woody Biomass Feedstock

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INTRODUCTION. Tree windbreaks represent an attractive multiple-benefit land use through their ability to mitigate climate change by modifying the local microclimate to improve crop growth and by sequestering carbon in the soil and tree biomass. There are many examples of changes in soil organic carbon (SOC) content following changes in management practices however, basic studies of the specific biogeochemical drivers of these changes are still relatively uncommon. This study was designed to address specific questions regarding tree plantings on former agricultural lands to more accurately assess the potential for bioenergy production and C sequestration. Understanding of drivers of C accumulation enables the estimation of soil carbon stocks in existing windbreaks and the prediction of potential carbon sequestration in future plantings.

OBJECTIVE. Determine the soil C sequestration potential of tree planting on marginal or degraded agricultural soils across climatic gradients in the U.S. Great Plains and Russian Central Uplands.

MATERIALS & METHODS

- Six sample sites in U.S. and Russia with a range of mean annual temperature (MAT) , mean annual precipitation (MAP), and hydrothermal coefficient (HTC, Selyaninov, 1928).
- Three soil samples collected and composited by depth (0-15 and 15-30 cm) in 3 parallel transects spaced 4 to 5.5 m apart with approximately the same spacing within transects.
- Soil was air-dried, ground to pass a 2 mm sieve, and roller-milled before SOC, total N, and $\delta^{13}C$ isotopic composition determination by dry combustion on a Fison NA 15000 Elemental Analyzer (ThermoQuest Corp., Austin, TX) interfaced to an isotope-ratio mass spectrometer (Delta V Advantage, Thermo Fisher Scientific, Waltham, MA).
- Reference soil samples were collected from local native grassland sites.
- Russian soil samples were analyzed for permanganate oxidizable organic carbon (POXC) using method of Culman et al., 2012 (SSSAJ 76:494-504).

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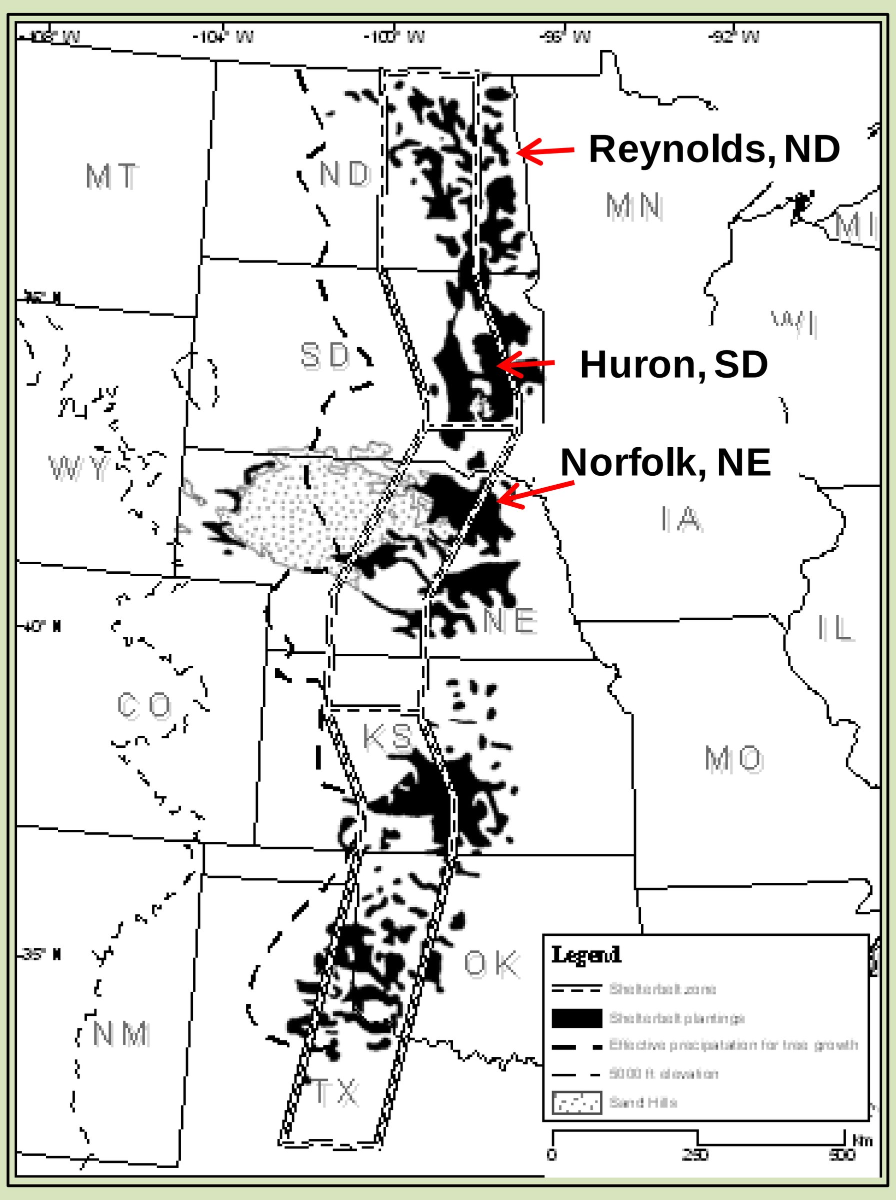

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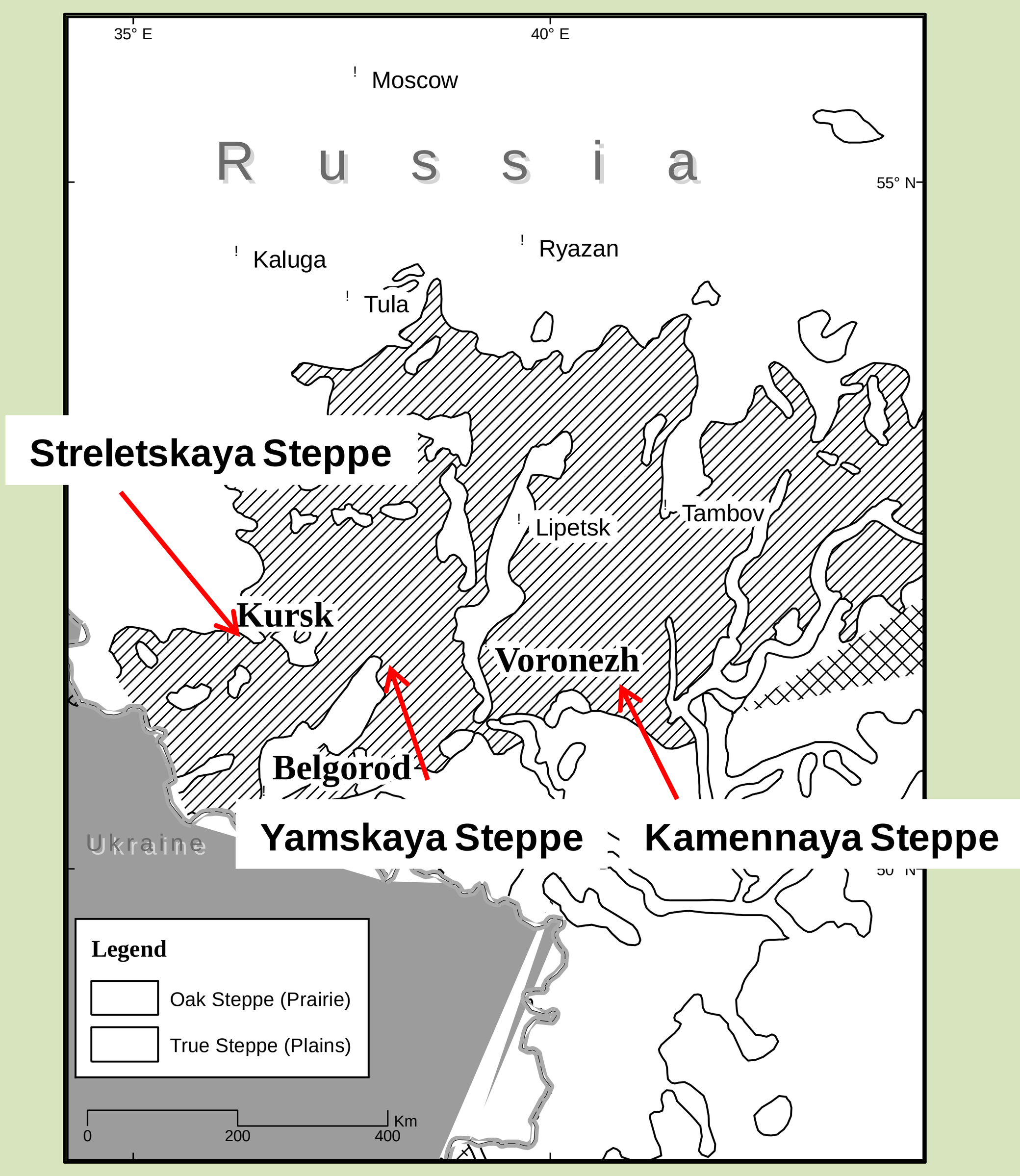

Sampling teams in Russia (above) and South Dakota (below).

Site	MAT	MAP	HTC	Site	MAT	MAP	HTC
Reynolds	4.4°C	528 mm	1.41	Streletskaya	5.3°C	585 mm	1.23
Huron	7.7	582	1.31	Yamskaya	5.6	535	1.10
Norfolk	9.6	696	1.47	Kamennaya	5.8	485	1.0

Site	Soil Texture	Trees (age)	Crops (length of cultivation)
Reynolds	loam	Green ash (*Fraxinus pennsylvanica*) Redcedar (*Juniperus virginiana*) (53 yrs)	Wheat (*Triticum aestivum*, L.), corn (*Zea mays*, L.), soybean (*Glycine max* (L.) Merr.), & sunflower (*Helianthus annuus*) (~110 yrs)
Huron	loam	Green ash (19 yrs)	Corn, soybean, & grain sorghum (*Sorghum bicolor* (L.) Moench) (21 yrs)
Norfolk	loamy sand	Siberian elm (*Ulmus pumila,* L.) Mulberry (*Morus rubra,* L.) Cottonwood (*Populus deltoides*) (70 yrs)	Corn, soybean, wheat, & alfalfa (*Medicago sativa*, L.) (~120 yrs)
Streletskaya	loam	Black poplar (*Populus nigra*) Silver birch (*Betula pendula*) (55 yrs)	Wheat (140 yrs)
Yamskaya	loam	Box elder (*Acer negundo*) (57 yrs)	Wheat, corn, & soybean (140 yrs)
Kamennaya	clay loam	English oak (*Quercus robur*) Balsam poplar (*Populus balsamifera*) (57 yrs)	Wheat & sunflower (140-150 yrs)

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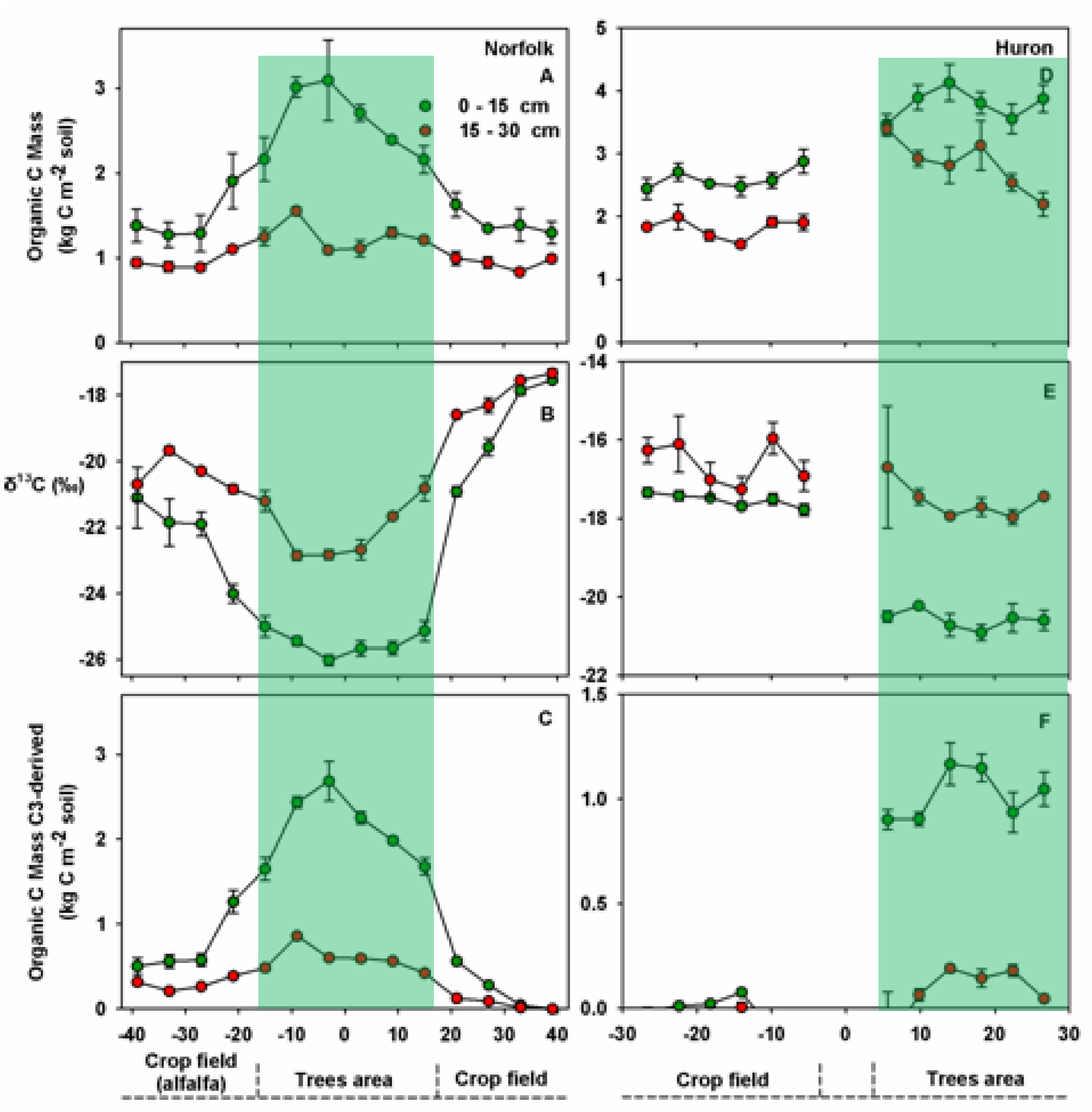
RESULTS



δ^{13}C Analyses

$$F_{tree\text{-}C} = \frac{\delta^{13}C_{afforested\ soil\ sample} - \delta^{13}C_{native\ soil}}{\delta^{13}C_{tree} - \delta^{13}C_{native\ soil}}$$

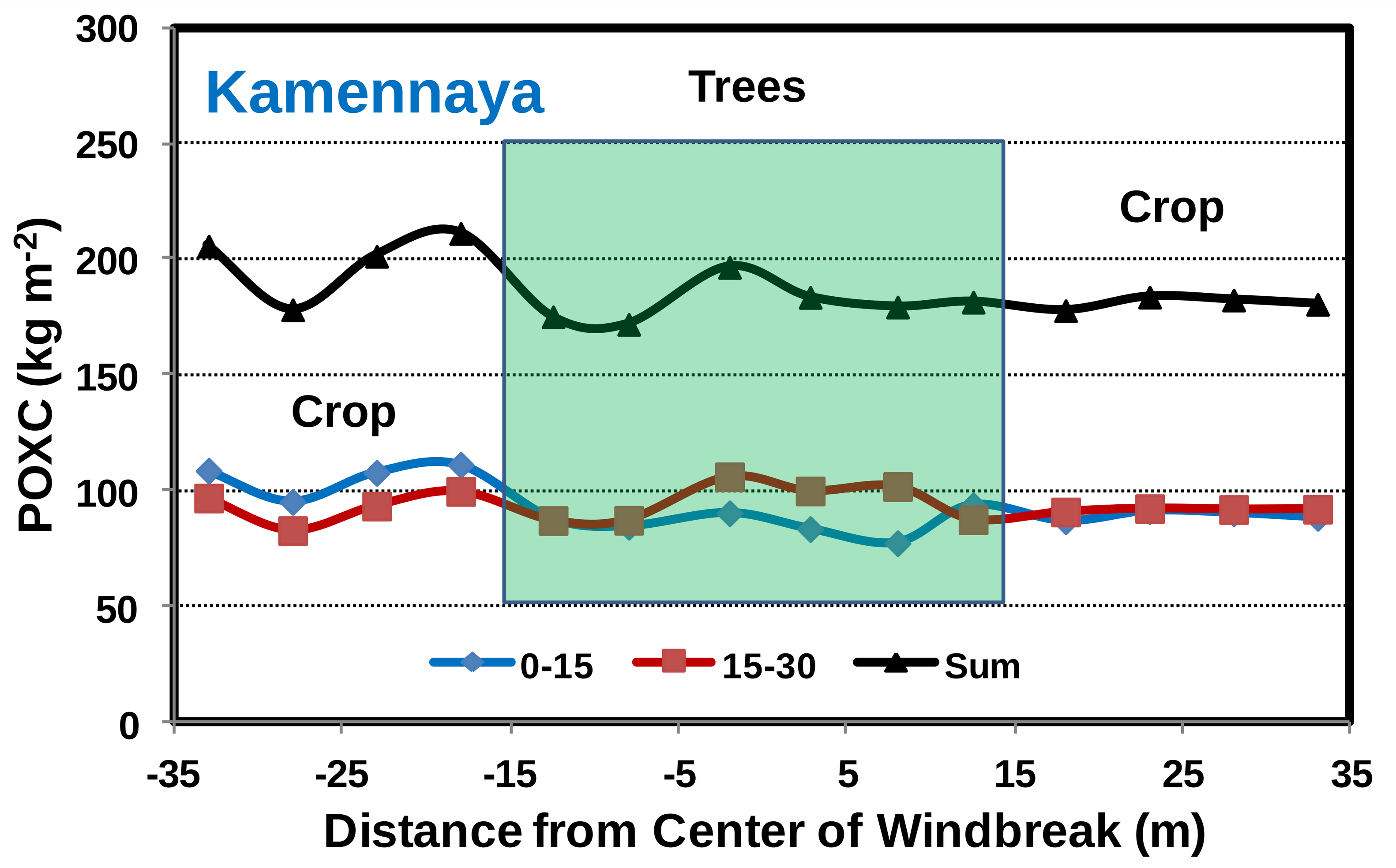
Norfolk

- Thurman loamy fine sand (sandy, mixed, mesic Udorthentic Haplustolls)
- 81.3% and 46.8% of SOC is tree-derived ($F_{tree\text{-}C}$) in the 0-15 and 15-30 cm layers
- Mean Residence Times (MRTs) of 42 & 117 yrs for 0-15 and 15-30 cm layers

Huron

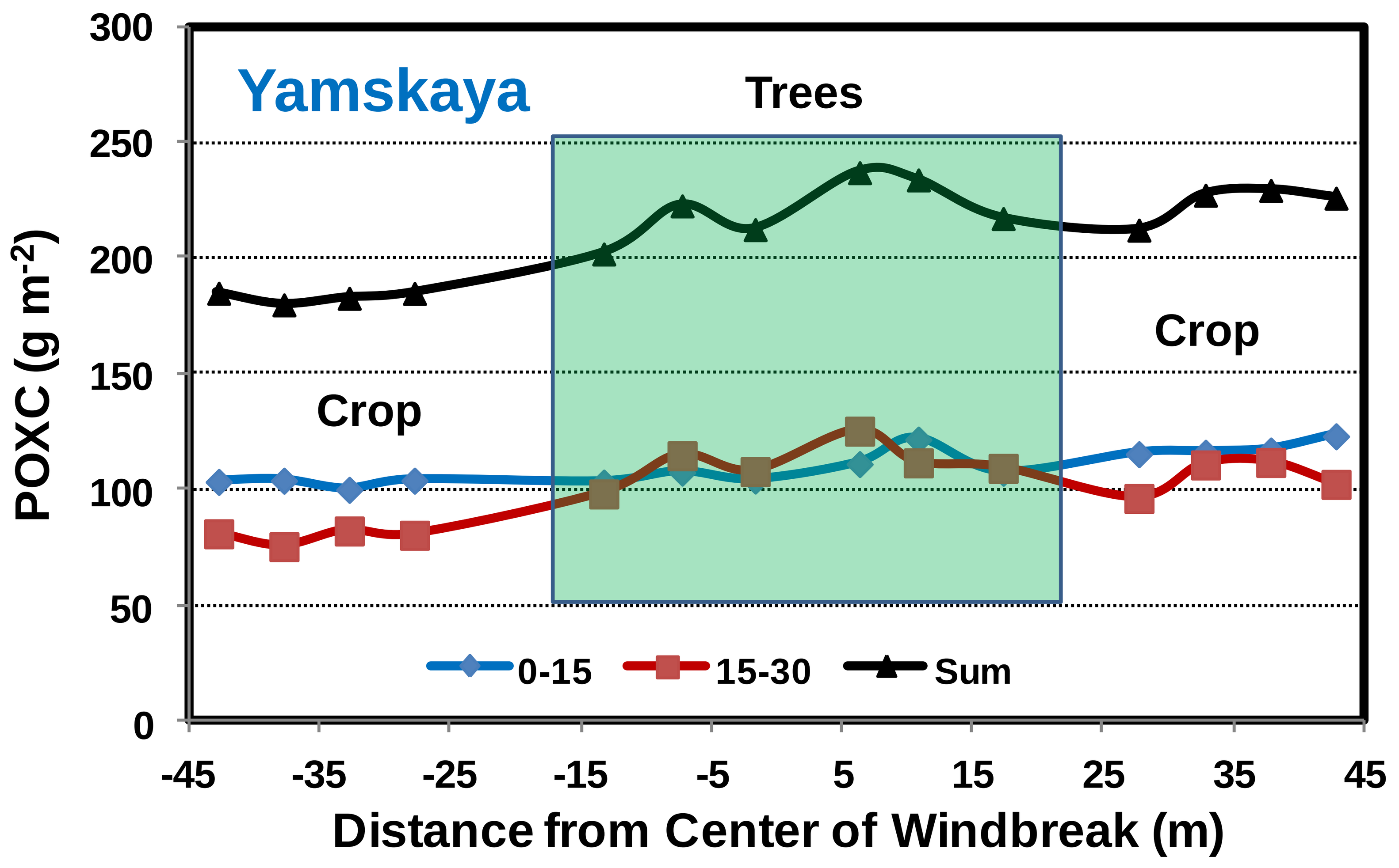
- Hand-Bonilla loams (fine-loamy, mixed, superactive mesic Typic and Pachic Haplustolls)
- 30.7% and 11.6% of SOC is tree-derived in the 0-15 and 15-30 cm layers
- MRTs of 53 and 131 yrs for 0-15 and 15-30 cm layers

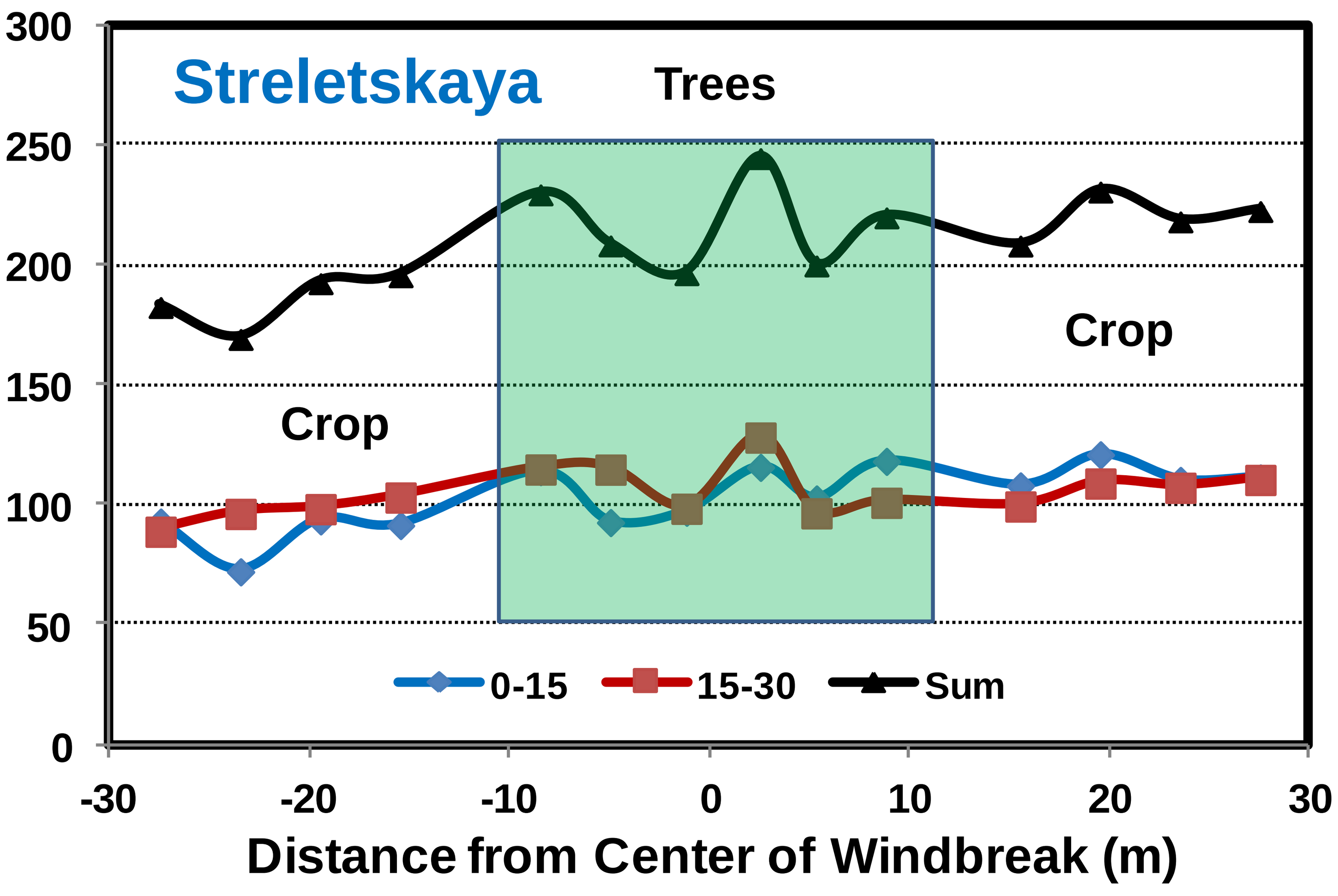
Note: Lack of sufficient discrimination in δ^{13}C between afforested and native soils at the Russian sites and evidence of erosion/deposition at the Reynolds site prevented application of the source-partitioning analysis at these locations.



POXC Analyses

- POXC is an indicator of active carbon, often correlated with SOC, particulate organic matter (POM), and microbial biomass carbon (MBC)
- POXC content averaged 2.45% of SOC across all sites and land uses
- POXC was significantly greater in soil beneath windbreaks at Streletskaya and Yamskaya but was greater in the crop field at Kamennaya
- POXC was linearly correlated with SOC (average R^2 = 0.63)





CONCLUSIONS

- For 0-30 cm surface layer at all 6 sites, SOC content beneath trees ranged from 2.5% less than to 62.6% greater than adjacent cropped fields (average 22.4% greater). Greater SOC accumulation was observed in cool, moist climates (higher HTC).
- δ^{13}C analysis indicates that the majority of SOC in the surface 30 cm of soil beneath trees at Norfolk was tree-derived 70 yrs after planting. Approximately 25% of the SOC beneath trees at Huron was tree-derived 19 years after tree planting.
- GIS analysis identified 1.62 million ha of marginal cropland in ND, SD, and NE (3.15% of the total cropland). SOC sequestration potential was estimated to be 13,677 Mg per year if one 15 m-wide windbreak was planted per 65 ha field.

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