Scaling Up of Carbon Fluxes to Predict the Carbon Dynamics in Kazakhstan Central Asia

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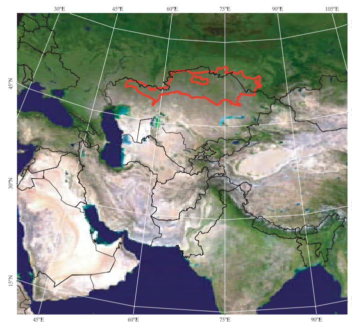

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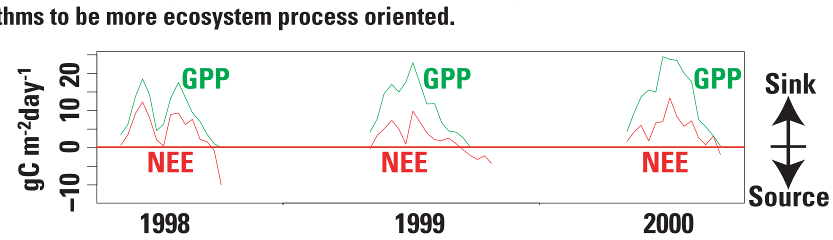
Rangelands are extensive terrestrial ecosystems, making up 30 to 40 percent of the Earth's land area. Since rangelands store most of their carbon below ground, their carbon stocks are protected from fire, but are in demand for agriculture. How can these carbon stocks be measured so the climate and management changes can be quantified and understood?

2 INTRODUCTION

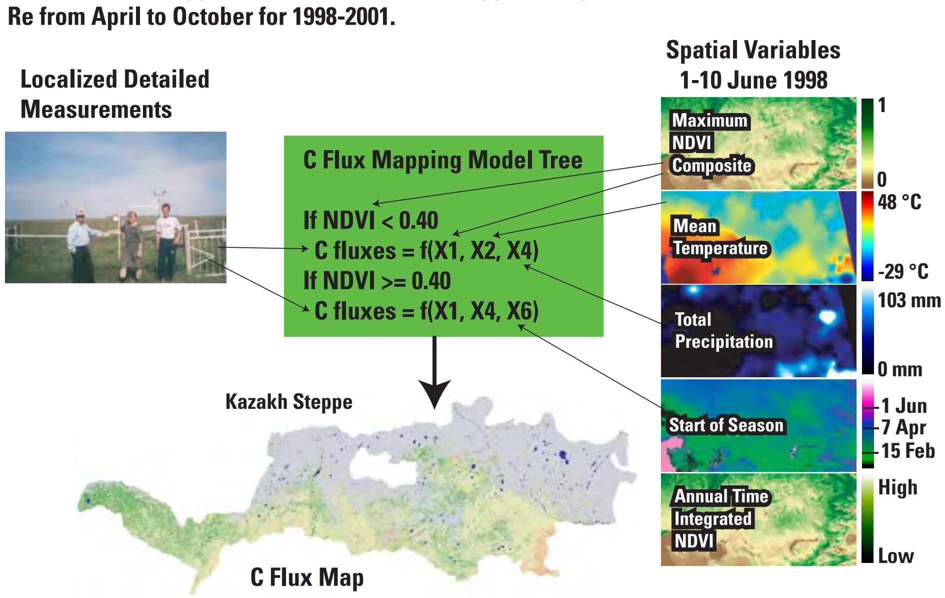
Climate and management determine whether rangelands are net carbon sources or carbon sinks. Regional carbon dynamics of the Kazakh Steppe has not been previously documented, and the area has undergone significant land use change with the collapse of agriculture and destocking of livestock following the dissolution of the Soviet Union. The objective of this study is to quantify the regional carbon flux dynamics of these extensive steppes.

3 METHODS

Carbon flux towers measure localized net fluxes of carbon dioxide (CO_2) between the ecosystem and the atmosphere. Light curve analysis on 30 minute CO_2 fluxes partitions these net fluxes into ecosystem respiration (Re) and photosynthesis (gross primary production, GPP). This provides quantification of basic ecosystem processes and allows scaling up algorithms to be more ecosystem process oriented.



We combined values at flux tower locations from the spatial and temporal data sets of solar radiation (RAD), temperature, precipitation, SPOT VEGETATION Normalized Difference Vegetation Index (NDVI), and NDVI derived metrics with flux tower derived gross primary production (GPP) and ecosystem respiration (Re) into a 10-day time step training database. Start of season usually occurs some time between 15 February and 7 April. Start of season dates outside of this range are usually false starts on barren lands or water. Model trees were parameterized using these training databases which included multiple year flux data from both the Northern Great Plains and Kazakh Steppe (one tower). These model trees were then applied across the Kazakh Steppe to map growing season 10-day GPP and Re from April to October for 1998-2001.



The growing season 10-day flux maps for 1998 to 2001 GPP and Re were converted growing season NEE maps (NEE = GPP - Re) and then to annual fluxes using gap-filled fluxes from the winter of 2001-2002. We assumed that the inter-annual variability of winter fluxes would be minor.

Inter-annual variability of annual NEE allowed the mapping of areas which were probable carbon sink, source, and equilibrium areas. Areas where the inter-annual average NEE was larger than, smaller than, or equal to equilibrium (zero) +- the inter-annual standard deviation were mapped as sink, source, and equilibrium areas respectively.

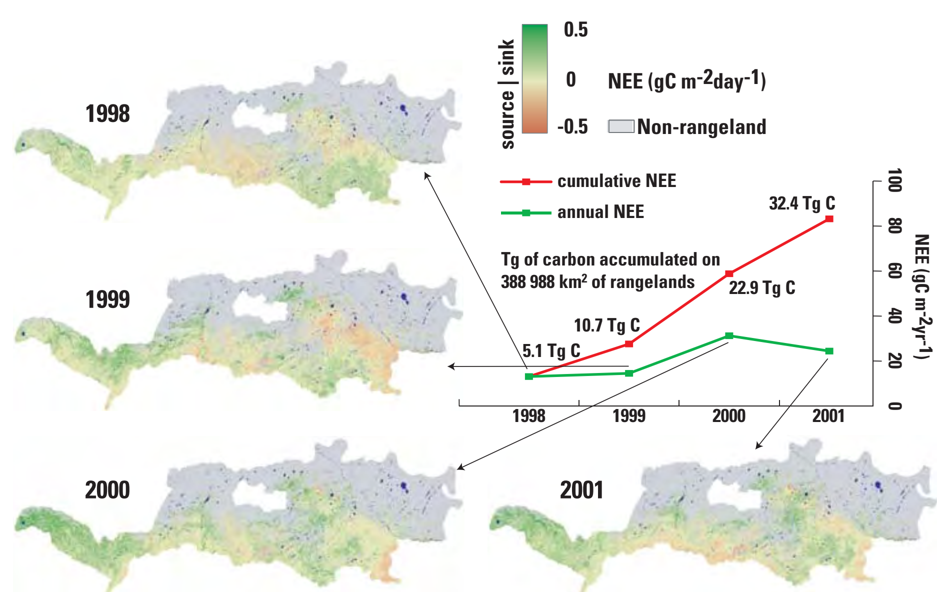
4 RESULTS

Model trees used for mapping of growing season 10-day GPP and Re were robust and accurate. Models were tested by withholding Kazakhstan flux tower yearly data sets as test data. The average accuracy from these withheld test data sets are lower but similar to the training accuracy of the model with all flux tower sites and years. Similar accuracies between test and training accuracies (shown below) are an indication of a robust model.

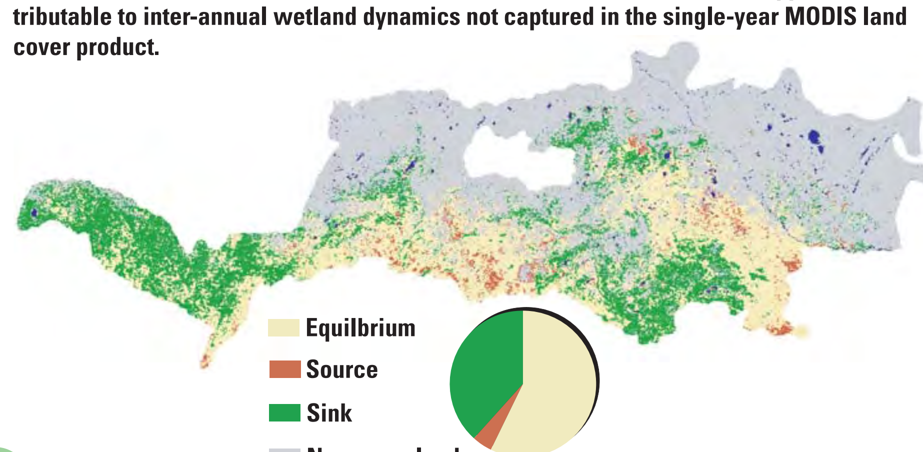
Kazakhstan Model Tree Accuracies

		R^2	Standard Error
GPP (gC m^{-2} day^{-1})	Kazakh Years withheld as Test	0.81	0.88
	All Sites and Years	0.83	0.48
		R^2	Standard Error
Re (gC m^{-2} day^{-1})	Kazakh Years withheld as Test	0.63	0.74
	All Sites and Years	0.77	0.36

The Kazakhstan winter flux estimate (0.34 g C m^{-2} day^{-1}) was used with growing season NEE mapped with the model tree algorithm to estimate annual NEE for each year from 1998 to 2001. The annual average NEE for the Kazakh Steppe was relatively stable with the greatest value occurring in 2000. This resulted in an increase in rangeland carbon accumulation for the four years as seen below.



The areas that had consistent 1998-2001 carbon sinks occurred on 38 percent of the rangelands. This takes into account inter-annual variability and average 1998-2001 NEE at each location. Carbon sources surrounding wetland areas within the Kazakh Steppe may be attributable to inter-annual wetland dynamics not captured in the single-year MODIS land cover product.



5 CONCLUSIONS

The results of this study show that model tree algorithms were effective when applied regionally to the Kazakh Steppe. This approach maximized the utility of intercontinental flux towers for regional mapping. Refinement in regional estimation of winter fluxes in the Kazakh Steppe would improve the annual NEE maps. The Kazakh Steppe rangelands were a sink of C for 1998-2001 with the biggest sink occurring in 2000. This C sink strength may be related to a combination of regional warming, land use changes from spring wheat to grassland, and low animal stocking rates. Wheat farming tends to deplete soil C, and soil C stocks can recover in healthy grasslands.

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