From plant water use to rangeland carbon sequestration: progress of eco-physiology studies at CGREC in 2010

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Our work is targeted toward understanding important ecophysiological processes, such as plant water relations, photosynthesis, and ecosystem respiration regulating rangeland carbon flux and sequestration. To benefit the practice of rangeland management, our basic and applied research goes through the cycle of formulating ideas and project proposals, data collection, data analysis, publishing, and public feedback. In particular, this year's research achievements can be outlined as follows.

1. Following the initial presentation of plant water use modeling as included in last year's CGREC Annual Report, we conducted a further analysis on this topic by adopting the concept of "root water uptake compensation," in which the reduced plant water uptake from one part of the soil (due to soil drying) can be compensated through enhanced uptake from another soil depth where there is a better water supply. This allows our model to more accurately predict what the plants actually do in utilizing available soil water while mitigating the adverse impacts of soil drying, which occurs frequently on prairies, especially for the upper soil profile where the majority of plant roots reside. Published in the October 2010 issue of *Plant and Soil*, our work is perhaps the first to successfully apply the "macroscopic" root water uptake model to a prairie ecosystem, where the existence of multiple plant species with varied root distribution and rooting depth may otherwise pose difficulty for accurately predicting soil-plant system water dynamics. This effort receives benefits from the soil water field data collected at CGREC as well as our use of information from multiple disciplines, such as soil physics, hydrology and micro-meteorology. It shows that accurately predicting plant water use from a prairie ecosystem can be achieved using limited field data. Further research on this topic is in progress to consider water loss due to surface run-off.

2. This year, we continued our comparative study of the leaf water traits of a native species, western wheatgrass, and an introduced species, Kentucky bluegrass. This work provides empirical evidence regarding the contrasted ranges of leaf water potentials in which the leaf gas exchange of the two species operate under field conditions, and insight into the ecophysiological mechanisms driving the invasion of exotic plants in the prairie ecosystem. Results from this study will be placed on the Center's website: www.ag.ndsu.edu/CentralGrasslandsREC.

3. As with leaf water characteristics, biomass allocation among above- and belowground organs is also an important aspect of the "ecophysiological rules" that dictate, among other factors, the distribution of prairie species. This year, we studied biomass partitioning among shoots (leaves and stems), roots, rhizomes, and crowns in two native grasses (western wheatgrass and green needlegrass) and two invasive grasses (Kentucky bluegrass and smooth brome) (Figure 1). This experiment was conducted in the CGREC greenhouse using prairie soil, two treatments (drought and control) and six replications (Table 1). The two invasive species had a higher proportion (about 40%) of their total biomass invested in roots than the two native species (about 13 to 23%). Kentucky bluegrass had the highest investment in belowground rhizomes (4%), followed by western wheatgrass, while green needlegrass and smooth brome had minimum or near zero values. Green needlegrass had the highest investment in crowns (where the plant stem meets the root) at 10%. Drought tended to encourage investment in crowns in all four species, while it decreased investment in rhizomes in both Kentucky bluegrass and western wheatgrass.

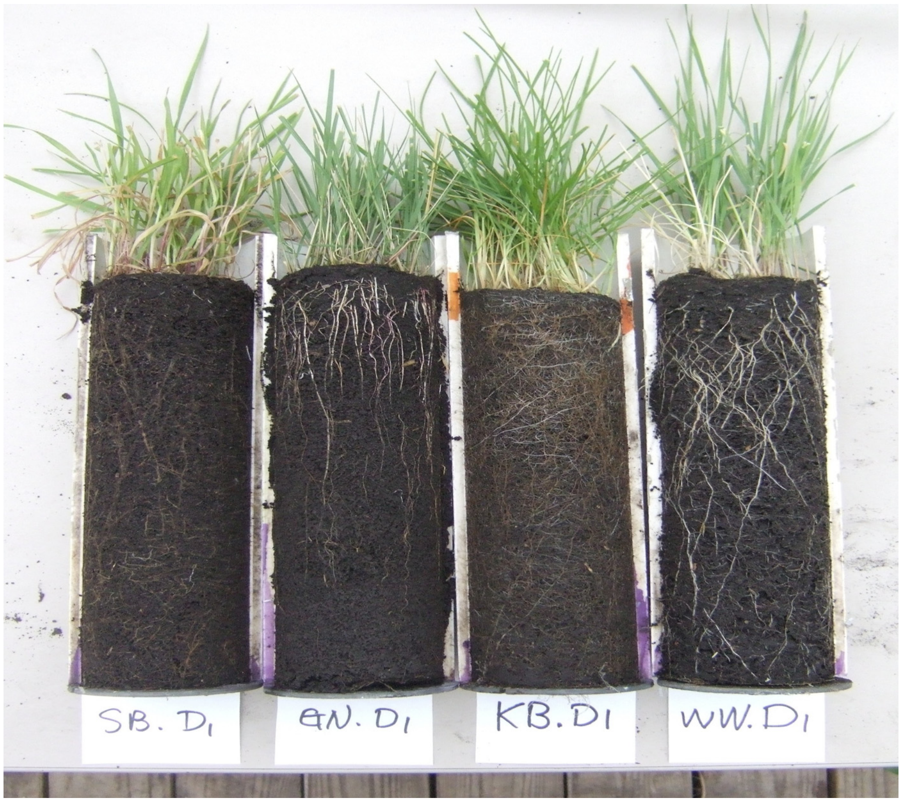

Figure 1. Roots ready to harvest for the four grasses grown in a greenhouse at CGREC. WW: western wheatgrass; GN: green needlegrass; KB: Kentucky bluegrass; SB: smooth brome grass. "D1" stands for "pot #1 of the drought treatment" (as opposed to "well-watered control," which is not shown).

Table 1. Biomass allocations (% of total biomass) into different vegetative organs of four grass species. From June to September 2010, plants were grown in a greenhouse in 48 pots, which were either well-watered or under drought (6 pots per species under each treatment).

Species	Kentucky bluegrass		Smooth Brome		Western wheatgrass		Green needlegrass	
Category	Control	Drought	Control	Drought	Control	Drought	Control	Drought
Crowns	1.8	2.7	4.0	4.5	3.3	3.6	10.1	12.5
Rhizomes	4.7	2.9	0.1	0.0	2.2	0.6	0.0	0.0
Roots	39.6	38.3	41.8	38.0	21.7	25.4	11.9	14.6
Shoots	53.9	56.0	54.0	57.5	72.8	70.4	78.1	72.9

4. This year we completed the five-year field measurements for rangeland CO_2 flux in support of our carbon sequestration project. The study is the result of collaborations among scientists and students from CGREC, NDSU Main Campus, and USDA-ARS, as well as the Chinese Academy of Sciences. The primary objective is to quantify environmental and photosynthetic controls of soil respiration on rangelands under animal grazing. In particular, through field trenching, we separated soil microbial respiration from plant root respiration. From July 2006 to October 2010, a large amount of data was collected from two field sites. Soil respiration rate was measured through the growing season at sunrise

and mid-afternoon on 76 days over the five-year period, resulting in 2432 measurements in total. Environmental data was also collected at each site, including: air temperature, soil temperature (at the surface and 10 cm deep), and soil water at nine depths. Leaf photosynthesis of about 20 dominant species (including grasses, forbs and shrubs) was measured on 81 selected non-rainy days, with a total of 1448 leaves measured. Meanwhile, canopy photosynthesis (see Figure 2) was measured for 32 selected clear days (with 3867 data points recorded). Analysis of the full datasets is in progress.

Figure 2. A transparent chamber and a gas exchange system were used to measure canopy photosynthesis from rangelands under different intensities of grazing. Various layers of cloth blankets were used to reduce light levels in order to calculate photosynthesis–light response curves.

On May 28, 2010, we seeded an alfalfa-tall fescue mixture trial at CGREC (Figure 3). This is part of a regional experiment established by plant eco-physiologists belonging to the North Central Coordination Committee on Eco-physiological Aspects of Forage Management (NCCC031). The project is temporarily entitled as “Sustaining legumes in grasslands to reduce nitrogen fertilization: A multi-regional assessment.” This experiment has been set up at twelve sites across several states in the North-Central USA. One major objective is to test the potential of using legumes in pastures to help increase forage productivity while reducing the need for N fertilizer input. Thirty plots (each 6 ft by 9 ft), with different ratios of alfalfa to grass, as well as different levels of N fertilizer input, were established. Starting with the second year, forage production will be determined by harvesting all plots three times a year, plus some chemical testing, in order to identify an optimal grass-legume balance in a mixture that sustains high yield-stability over time. The experiment will be conducted for at least 4-5 years.

Figure 3. Alfalfa-grass mixed plots in mid-September 2010.