Report of Data from Plots at the Dickinson Research Extension Center

Results

We have two experiments located in two ecoregions: (**1**) Field 1: northern tall grass prairie (*NDSU Albert Ekre Grassland Preserve, SE ND*); and (**2**) Field 2: northern mixed grass prairie, (*NDSU Dickinson Research Extension Center, W ND*). In 2008 (Field 1) and 2009 (Field 2) we super-imposed a split plot experiment to test the effects of harvest periodicity on diversity and biomass production: (**1**) no harvest; (**2**) yearly fall harvest; and (**3**) every other year fall harvest.

The Dickinson Research Extension Center experiment was sampled in 2007-10. The result highlights are as follows. (**1**) Average production of seeded species was higher in 2009-10 than 2007-08 (156 ±67 vs. 105 ±36 $g.m^2$) and un-affected by N or P fertilization. Most of the change occurred in treatments with at least 6 seeded species species (424 ±12 vs. 208 ±123 $g.m^2$). The difference was due to higher growing season precipitation in 2009-10 visa vi 2007-08 (332 vs. 218 mm for the April-September period) which represented >90%, and 66% respectively of the long term average. (**2**) Invasive species biomass was higher in the N treatment (345 ±15 $g.m^{-2}$) than in the control and P treatments (234 ±28 $g.m^{-2}$), and it substantially increased from the 2007-2008 to the 2009-2010 growing seasons (152 ±21 $g.m^{-2}$ vs. 389 ±55 $g.m^{-2}$). (**3**) Seeded biomass was linearly related to species richness: $R^2=0.18$, $P<0.01$. Peak biomass and minimum biomass were also correlated ($P<0.01$) with species richness ($R^2 =0.33$, $P<0.01$). (**4**) The year to year variability in biomass for the 2007-10 period was inversely correlated with species richness across all treatments: $R^2=0.29$, $P<0.01$). (**5**) The biomass of invasive species was inversely related ($P<0.01$) to seeded biomass ($R^2=0.35$ for N and $R^2=0.23$ for P & no fertilization, $P<0.01$). (5) Seeded biomass was higher when the species in the mixture had higher relative growth rate (RGR: $g.g^{-1}.d^{-1}$), N uptake per unit of root surface area (Imax-N:$g.m^{-2}.d^{-1}$), root density, and lower root to shoot ratio (R:S). The stepwise regression involving these variables had an $R^2=0.32$, $P<0.01$.

In the next year we will complete the first rotation for biomass harvest. The data should give us the first indication regarding how fall harvesting (yearly or every other year) affects various aspects of plant richness, production, stability, and susceptibility for invasion.

Samples for C sequestration and dissolved organic carbon are currently being extracted and analyzed. The total organic C ($Kg.m^{-2}$ to a 91 cm depth) for an adjacent agricultural field was (11.4 ± 2.10).

A heuristic approach based on the Stollsteimer's algorithm was adapted to simulate the spatial equilibrium model to determine the optimal number, location and size of cellulose to ethanol processing plants in ND. First, a spatial equilibrium model based on a non-linear programming algorithm was developed to analyze several issues related to production of cellulose ethanol production under the Energy Security and Independence Act (ESIA) of 2007. Some of those issues are transportation of biomass from producing regions to ethanol production plants, availability of water for processing biomass, and availability of biomass. The objective of the model is to minimize total production costs of ethanol and transportation and handling costs of biomass from biomass producing regions to processing plants and those of ethanol from processing plants to blending facilities. This objective function is optimized subject to a set of linear constraints, including maximum supply of biomass in North Dakota, blending requirements under ESIA, availability of water required to process biomass. Second, we developed the relationship between the size of processing plant and processing cost under increasing return to scale and that between transportation costs and processing plants. It is assumed that the size of plant has an inverse relationship with the number of plant in a region. Our results indicate that the size of processing plant depends on density of biomass available in a region. The optimal size of plant in North Dakota is annual production capacity ranging between 90 million and 120 million gallons of ethanol, depending on density of biomass in sub-regions in North Dakota. The optimal number is 8 plants in North Dakota.

Outcomes/Impacts

Our first 4 years of data from Field 2 follow a pattern similar to the one we previously found in 10 years for Field 1. In both cases: (**1**) High levels of plant richness lead to higher levels of seeded above ground biomass and lower invasion by exotic plants. (**2**) The above ground biomass of seeded species increases as the species in the seed mixtures have high relative growth rates, root density, N uptake rates per unit of root surface area, and biomass allocation to stem and leaves. The data from 2010-2011 will test if yearly or rotation harvest has an impact on biomass production, stability, and susceptibility to invasion.

Our soil C sampling in coming years will test weather species composition, diversity, plant physiological characteristics and landscape location significantly affect C sequestration and by how much.

The economic model were are testing should provide information regarding the most efficient infrastructure in producing the cellulosic ethanol industry in ND. The method developed in this study can be used to optimize the cellulose ethanol production and distribution system in other regions.

In 2009-2010 we completed the code for 1DMIPS, the 1D version of 3DMIPS (our 3D plant-soil model). In 2011-12 we plan to conduct a rigorous testing comparing results from 1DMIPS, 3DMIPS, and field data. After that step we plant to incorporate the economic model to develop a user friendly tool for the planning, economical, and ecological assessments of CRP-ethanol projects across a variety of climatic and soils conditions.

Some Key Publications:

Johnson, H. and M.E. Biondini. 2001. Root morphological plasticity and nitrogen uptake of 59 plant species from the Great Plains grasslands, U.S.A. Basic and Applied Ecology 2:127-143.

Biondini, M. E. 2001. A three dimensional spatial model for plant competition in a heterogeneous soil environment. Ecological Modelling 142:189-225.

Levang-Brilz, N. and M.E. Biondini. 2002. Growth rate, root development and nutrient uptake of 55 plant species from the Great Plains Grasslands, U.S.A. Plant Ecology 165:117-144.

Biondini, M.E. 2007. Plant diversity, production, stability, and susceptibility to invasion in restored northern tall grass prairie (United States). Restoration Ecology 15:77-87.

Biondini M.E. 2008. Allometric scaling laws for water uptake by plant roots. Journal of

Theoretical Biology 251:35-59.

Bingham M. and M.E. Biondini. 2009. Mycorrhizal hyphal length as a function of plant community richness and composition in restored northern tallgrass prairies (U.S.A.). Rangeland Ecology and Management 62:60-67.

Bingham M. and M.E. Biondini. 2011. Nitrate leaching as a function of plant community richness and composition, and the scaling of soil nutrients. Plant Ecology doi 10.1007/s11258-010-9832-8.

Taylor R. and W. Koo. 2010. The Optimizing ethanol production in North Dakota, agribusiness and Applied Economics Report 656, Department of Agribusiness and Applied Economics, North Dakota State University.

Grygiel, C.E., J. Norland, and M. Biondini. 2011. Can carbon and phosphorous amendments increase native forbs in a restoration process? A case study in the northern tallgrass prairie (U.S.A.). Restoration Ecology doi:10.1155/2011/856869.

Participants:

Dr. Mario Biondini (PD) provides the oversight for the research including experimental and sampling design, data analysis, modeling, publications, and reporting.

Dr. Carolyn Grygiel (Co-PD) is responsible for managing the experiments in *Field* 1&2, and supervise the personal working on them.

Dr. Larry Cihacek (Co-PD) is responsible for the C sequestration component of the project and the associated personnel.

Dr. Won Koo (Co-PD) is responsible for the economic model and the associated personnel.

Target Audience:

The main target audience of this project are those involved in grassland restoration and management, C sequestration, and ethanol production. They include, but are not limited to rangeland ecologist, land managers, farmers and ranchers, extension personnel, and agricultural, environmental and land conservation organizations, and individual involved in the biofuel and C-sequestration industries.