INNOVATIVE, DIVERSIFIED AGROFORESTRY PLANTINGS IN SUPPORT OF ENERGY SECURITY, ENVIRONMENTAL QUALITY, AND LOCAL ECONOMIES

ALTERNATIVE PERENNIALS IN AGROFORESTRY

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Introduction

Alley cropping systems comprised of perennial woody and herbaceous biomass crops may be able to provide feedstocks to support the development of alternative energy industries and also create sustainable agroecosystems. Such systems could provide long-term carbon storage, habitat for wildlife and non point-source pollution reduction in addition to annual biomass harvests to supplement landowner income. However, optimizing establishment and growth of these crops is essential to realizing highly productive agroecosystems and expanding possibilities for landowner adoption. The objective of this study is to determine establishment and yield parameters associated with the production of perennial biomass crops in an alley cropping system over a two-year period.

In May 2010, two short rotation woody crops and four herbaceous biomass crops were established in replicated alley cropping systems at two riparian sites near Fairmont, MN ("Fairmont site" and "Granada site") and one in Empire, MN ("Empire site"). Systems established include switchgrass (*Panicum virgatum* L), prairie cordgrass (*Spartina pectinata*), an alfalfa (*Medicago sativa* L.) and intermediate wheatgrass (*Thinopyrum intermedium)* mixture and a native tallgrass-forb-legume prairie polyculture planted in blocks between multi-row strips of poplar clone NM6 (Populus maximowiczii x P. nigra) and willow clone 9882-42 "Fish Creek" (Salix purpurea x S. purpurea).

Above average rainfall in spring 2010 induced moderate flooding at the two riparian research sites and heavy rainfall in fall 2010 induced severe flooding throughout the entire Minnesota River basin, submerging these research plots for over two weeks. These events will provide an excellent opportunity to evaluate the flood tolerance of these crops by contrasting fall 2010 and spring 2011 survival and establishment rates with those at the upland site.

This report summarizes the characteristics of the plant materials used, establishment progress and data collected for this research through fall 2010. In addition, Appendix I contains photographs of the research plots throughout the 2010 growing season, including documentation of fall flooding at the two riparian sites.

Plant materials

Short rotation woody crops

- Willow clone 9882-42 "Fish Creek" *(Salix purpurea x S. purpurea)*
  Characteristics
  - A fast growing shrub type willow
  - Propagates very easily from cuttings, has a quick growth cycle, and will regrow following harvest
  - Low incidence of rust disease or damage by beetle or sawfly
  - For this research, willow biomass will be harvested in the fall following the fourth growing season
  - Willow yields are typically in the range of 4 – 7 tons/acre/year and up to 28 tons/acre after four seasons

  Establishment:
  - Planted as 8 – 10 inch unrooted cuttings
  - Planted in a "twin row" configuration with 2.5 feet between rows, 5 feet between double rows and 2 feet between plants within a row for a planting density of approximately 6,000 plants/acre
  - Approximately 2,160 total willow clones were planted at each site; 6,480 total willow clones were planted

- Poplar clone NM6 *(Populus maximowiczii x P. nigra)*

  Characteristics
  - Cold hardy, disease resistant variety
  - A top ranked clone for use in the north central states
  - Will grow up to 10 feet per year in good growing conditions and climate
  - Typically harvested every 4 years for bioenergy
  - Clone NM6 has been found to yield in the range of 6 – 7.5 tons/acre/year and up to 29 tons/acre after four seasons

  Establishment
  - Planted as 8 – 10 inch un-rooted cuttings
  - Rows planted 4 feet apart with 4 feet between plants within a row for a planting density of approximately 2,700 plants/acre
  - 900 poplar clones were planted at each site; 2,700 total poplar clones were planted

Herbaceous biomass crops

- Switchgrass *(Panicum virgatum)*
  Characteristics
  - Most popular herbaceous biomass crop in the Midwestern states
  - Many improved varieties bred for biomass production
  - Switchgrass yields range from 2 - 7 tons/acre/year, when looked at over a 4-year period (Casler and Boe, 2003). Recent University of MN trials showed yields between 4 and 6 tons/acre
  - Unlimited persistence with single late fall biomass harvests

  Establishment
  - Yellow tag certified seed from Feder's Prairie Seed; seed origin is near Blue Earth, MN
  - Seed was hand broadcast at a rate of 12 pounds of pure live seed (PLS) per acre, then packed to ensure seed-soil contact

- Prairie cordgrass *(Spartina pectinata)*

  Characteristics
  - Very productive native warm season grass; adapted to wet or upland soil conditions
  - Recent University of MN trials showed yields between 8 and 9 tons/acre.
  - Will harvest once per year in late fall

  Establishment
  - At the Empire site, live rhizomes of "Red River" prairie cordgrass were planted at 1 foot by 1 foot spacing. Cuttings were obtained from University of MN research plots in St. Paul and Waseca, MN
  - At the Fairmont and Granada sites, live rhizomes of a local prairie cordgrass ecotype were planted at 1 foot by 1 foot spacing. Cuttings were obtained from a native stand located within 10 miles of the sites
  - Approximately 12,600 prairie cordgrass rhizomes were hand planted at each of the three sites, for a total of approximately 37,800 total rhizomes planted

- Native prairie polyculture

  Characteristics
  - Though typically less productive than monoculture plantings of grasses, native prairie mixes may offer additional environmental benefits such as habitat and food for wildlife (e.g. pollinating insects) and reduced carbon impact due to reduced inputs
  - Will harvest once per year in late fall
  - Contains 11 species, a mixture of 3 grasses, 4 legumes and 4 forbs:

Common name	Latin name
Canada Wild Rye	*Elymus canadensis*
Switchgrass	*Panicum virgatum*
Big Bluestem	*Andropogon girardii*
Partridge Pea	*Chamaecrista fasiculata*
Purple Prairie Clover	*Dalea pupureum*
Canada Milkvetch	*Astragalus canadensis*
Showy Tick-Trefoil	*Desmodium canadense*
Wild Bergamot	*Monarda fistulosa*
Maximilian Sunflower	*Helianthus maximiliani*
Smooth Blue Aster	*Symphyotrichum laeve*
Yellow Coneflower	*Ratibida pinnata*

Establishment

- Yellow tag certified seed from Feder's Prairie Seed; seed origin is near Blue Earth, MN
- Seed was hand broadcast at a rate of 15 pounds of pure live seed (PLS) per acre, then packed to ensure seed-soil contact

- Alfalfa - intermediate wheatgrass mixture

  Characteristics

  - Alfalfa (*Medicago sativa)* is a commonly used forage legume, intermediate wheatgrass (*Thinopyrum intermedium)* is a late maturing perennial grass suitable for single annual harvests
  - "Rush" intermediate wheatgrass cultivar was planted
  - Pioneer alfalfa variety 54V48 was planted

  Establishment

  - Wheatgrass was broadcast at 8 pounds pure live seed (PLS) per acre
  - Alfalfa was broadcast at 5 pounds pure live seed (PLS) per acre
  - Plots were packed following seeding to ensure seed-soil contact

Establishment summary

- May 2010:
  - The sites were field cultivated and packed to provide a firm seed bed
  - Un-rooted tree stock was hand planted
  - Hand broadcast seeding of the native prairie polyculture, switchgrass and alfalfa-intermediate wheatgrass mixture was completed. The herbaceous plots were packed again immediately following seeding.
  - Hand planting of prairie cordgrass rhizomes begins
  - Pre-emergent herbicides, Goal and Princep PE, were applied to the woody crops to control weeds

- June 2010:
  - Hand planting of prairie cordgrass was completed
  - Tree survival was estimated; dead or dying trees were replaced
- July, 2010:
  - Tree rows were hand weeded as needed
  - Plant counts obtained to estimate populations in each herbaceous treatment
  - Herbaceous crops were mowed for weed control, except prairie cordgrass, which was hand-weeded
  - Deer repellant was applied at each site as needed
- August 2010:
  - Soil samples were collected at all sites to estimate baseline total organic carbon (TOC), particulate organic matter carbon (POM C), total organic nitrogen (TON) and particulate organic matter nitrogen (POM N) at depths from zero to 6 inches, 6 to 12 inches, 12 to 24 inches and 24 to 36 inches
  - Plant counts obtained to estimate populations for herbaceous treatments
  - Damage from herbivory, disease and insect incidence were estimated for woody treatments. Tree survival estimated
  - Tree rows were hand weeded as needed
- November 2010: Samples of herbaceous plant materials were collected at all sites to estimate aboveground biomass production
- December 2010: Poplar stem heights and diameters were collected at all sites

Upcoming work

Spring 2011:
- Willow treatments will be coppiced and samples will be collected. Fresh and dry weights will be obtained and aboveground biomass production will be estimated. Harvested woody biomass will be ground and subject to analysis for mineral content (P, K, N, Ca, Mg) and energy content using the University of Minnesota Analytical lab.
- Plant populations and ground cover will be estimated for herbaceous treatments

Summer 2011:
- Tree survival and disease and insect incidence will be estimated for woody treatments; dead or dying trees will be replaced.
- Plant populations and ground cover will be estimated for herbaceous treatments

Fall 2011:
- Tree survival and disease and insect incidence will be estimated for woody treatments; dead or dying trees will be replaced.
- Plant populations and ground cover will be estimated for herbaceous treatments

- Samples of herbaceous biomass will be collected to estimate yields
- Tree stem heights and diameters will be collected to estimate yields

Preliminary data

Tree emergence and survival

In July 2010, initial tree emergence and survival data were collected. Where tree stock did not bud or had died since emergence, the replicate, plot, row and tree number was recorded and the tree was replaced with fresh un-rooted tree stock. In August 2010 tree survival was estimated again and damage from herbivory, disease and insects was recorded. The results are summarized below.

Table 1: First Year Tree Survival and Damage

	July survival	August survival	August damage*
Granada			
Willow	98.3%	95.8%	23.1%
Poplar	97.4%	95.0%	33.0%
Fairmont			
Willow	96.5%	97.6%	57.1%
Poplar	78.9%	97.2%	13.1%
Empire			
Willow	93.4%	96.4%	17.6%
Poplar	92.4%	98.1%	23.1%
Across sites			
Willow	*96.0%*	*96.6%*	*32.6%*
Poplar	*89.5%*	*96.8%*	*23.1%*

* Damage was due primarily to herbivory by deer, though some incidence of damage by insects was also recorded

Poplar stand counts

In December 2010 poplar stem height, diameter and number of stems per plant were collected for a subsample of trees at each site. Samples were collected at the tree/crop interface (representing a tree/crop interaction) and in the center of the plot (representing little or no interaction) for each treatment combination. Results have been composited because no tree/crop interaction was evident during the establishment year. Survival was estimated and basal area per tree was calculated. The results are summarized below.

Table 2: Poplar stand characteristics

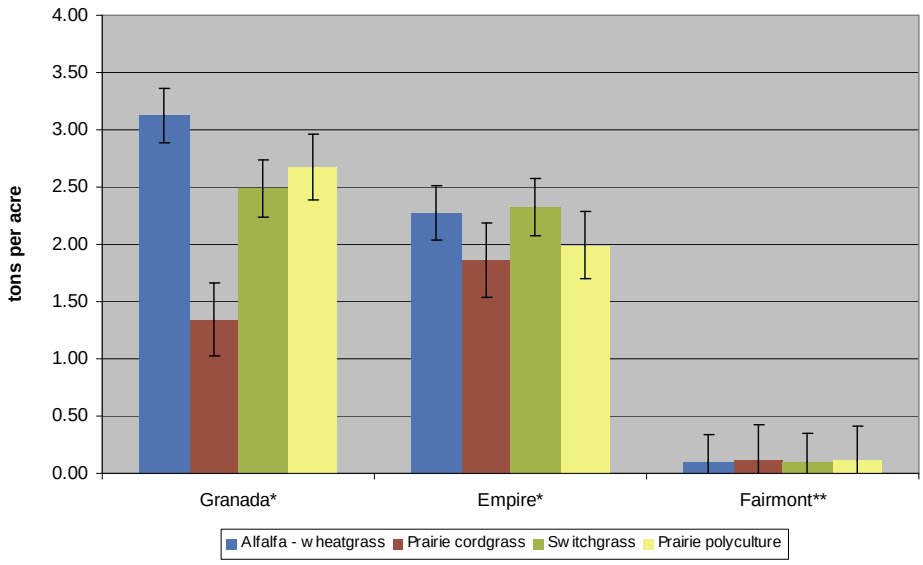
		Means			
Site	Clone	Height (cm)	Stems per plant	Stem diameter per plant	Basal area per plant (mm)
Empire*	poplar	188.7	1.6	17.7	396.2
Granada*	poplar	179.5	1.2	16.7	346.6
Fairmont**	poplar	133.3	1.3	11.3	140.8

*n=384 **n=256

Herbaceous biomass estimates

In November 2010, samples of herbaceous plant materials were collected to estimate aboveground biomass production. Samples were collected at the tree/crop interface (representing a tree/crop interaction) and in the center of the plot, approximately 6 m from the interface (representing little or no interaction) for each treatment combination. Results are composited because no tree/crop interaction was evident during the establishment year. Fresh weights for each sample were taken on site. The samples were dried to a constant weight in a 140º F oven and dry weights were obtained and yields were estimated. Harvested herbaceous biomass will be ground and subject to analysis for mineral content (P, K, N, Ca, Mg) and energy content using the University of Minnesota Analytical lab. Mean biomass yields by site and crop are depicted below.

Figure 1: 2010 herbaceous biomass yields by site*



*means ±standard errors, *n = 18. **n=12

Herbaceous plant population estimates

In July 2010, data was collected to estimate plant populations in each herbaceous treatment at each site, except for prairie cordgrass. Counts of desired and weed species were obtained in four randomly selected 1-foot by 1-foot sampling quadrates within each plot. Results for each plot were compiled by treatment and site and are summarized below.

Table 3: Plant counts by site, treatment and species

		Average plants / ft²			
Treatment	Name or category	Fairmont**	Empire*	Granada*	Across sites
Switchgrass					
	target species sum	4.6	28.5	48.7	27.3
	broadleaf weeds	1.4	7.4	1.8	3.5
	graminoid weeds	16.0	1	1.8	6.3
Alfalfa-intermediate wheatgrass mixture					
	target species sum	5.6	33.4	39.3	26.1
	broadleaf weeds	1.3	6.0	1.8	3.0
	graminoid weeds	16.5	0.4	1.0	6.0
Native prairie polyculture					
	target species sum	4.9	12.7	15.7	11.1
	broadleaf weeds	2.0	6.5	5.4	4.6
	graminoid weeds	15.6	0.3	1.3	5.7

*n=24 **n=16

Soil organic carbon and nitrogen

In August 2010 soil samples were collected at all sites to estimate baseline total organic carbon (TOC), particulate organic matter carbon (POM C), total organic nitrogen (TON) and particulate organic matter nitrogen (POM N) at depths from zero to 6 inches, 6 to 12 inches, 12 to 24 inches and 24 to 36 inches. This data will be used as a baseline for comparison throughout the study. The sample results are summarized below.

Table 4: 2010 Mean total and particulate organic carbon and nitrogen by depth*

		Whole Soil			POM + Sand				
	Depth	Carbon	Nitrogen		Carbon	Nitrogen		POM C/TOC	POM N/TON
Site	(in)	(%)	(%)	C/N Ratio	(%)	(%)	C/N Ratio	(%)	(%)
Fairmont	0-6	3.68	0.33	10.98	1.48	0.12	12.72	11.17	9.59
	6-12	2.96	0.24	12.56	0.38	0.02	18.02	3.56	2.52
	12-24	2.15	0.15	13.90	0.21	0.01	18.36	2.82	2.18
	24-36	1.69	0.12	14.06	0.15	0.01	21.56	2.67	2.50
Empire	0-6	2.36	0.21	8.98	1.18	0.10	9.18	16.88	16.56
	6-12	1.99	0.16	12.17	0.37	0.02	15.35	8.29	6.58
	12-24	0.83	0.07	11.76	0.09	0.01	39.94	5.72	3.23
	24-36	0.47	0.04	11.16	0.07	0.00	30.77	8.58	4.17
Granada	0-6	1.65	0.14	11.96	0.34	0.03	13.65	11.01	10.01
	6-12	1.46	0.12	12.76	0.13	0.01	22.45	5.09	4.32
	12-24	0.92	0.06	15.75	0.07	0.00	23.61	4.37	3.78
	24-36	0.64	0.04	17.27	0.05	0.01	12.17	5.46	8.38

*Results represent the means of 3 composite samples. Each composite was comprised of 12 subsamples.

APPENDIX I:
PHOTOS

Granada site, June 2010: herbaceous crop emergence

Granada site, June 2010: willow rows

Empire site, late July 2010: poplar rows

Empire site, late July 2010: willow rows

Fairmont site, early August 2010

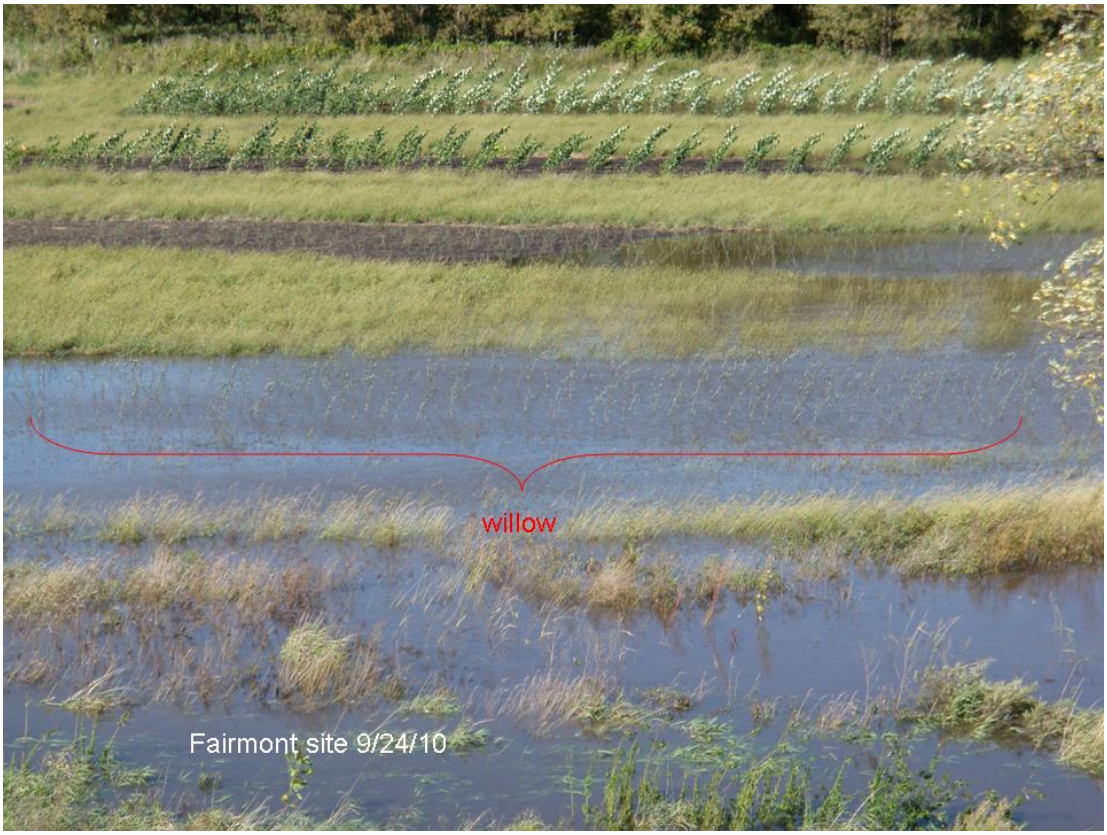
Granada site, early August 2010: prairie cordgrass

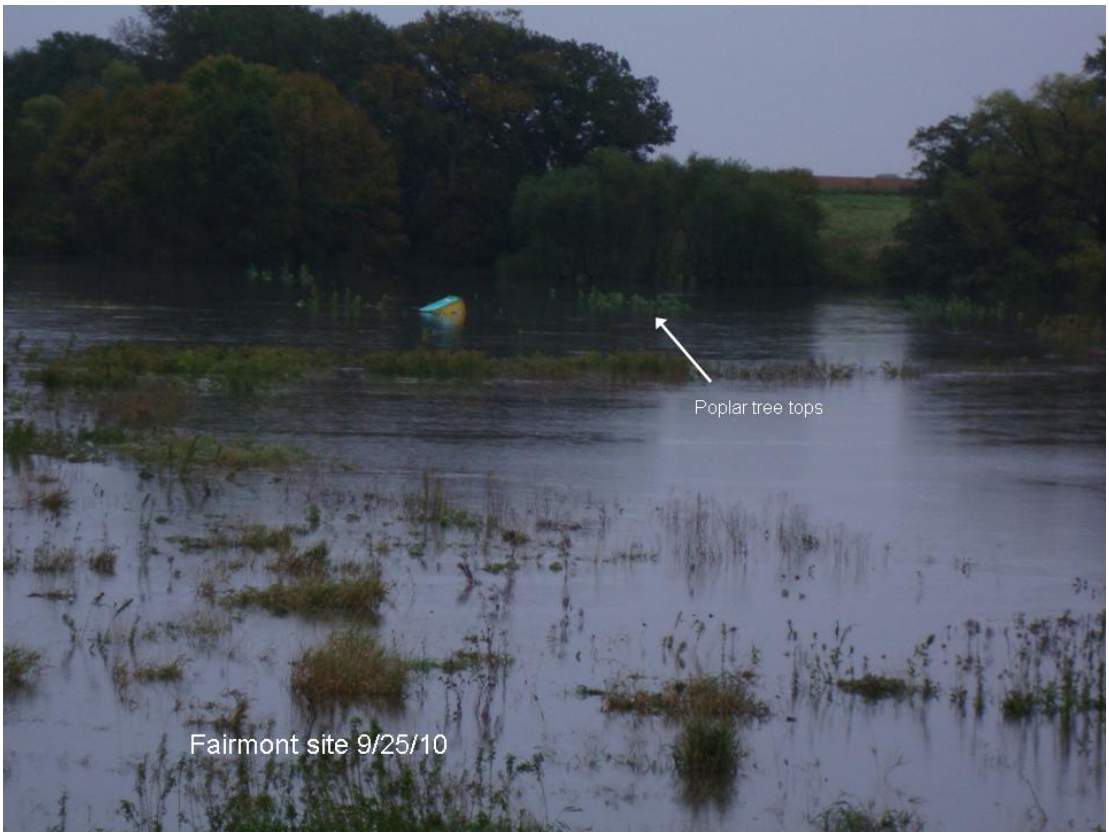
Empire site, August 2010: poplar rows

Empire site, Late September 2010: willow rows


Granada site: 9/24/10


Granada site: 9/24/10


willow
Fairmont site 9/24/10


Poplar tree tops
Fairmont site 9/25/10