2021 LTER Standard Sampling Report

Main Cropping System Experiment (MCSE)

Soil

Soil was regularly sampled on the LTER to a depth of 25cm at each of 5 stations in all replicates (R) of all treatments (T) 1-8, CF, DF, and SF. Samples were taken once or twice each month, for a total of twelve times between March 23 and November 30. Soil was sampled using a ¾" diameter push corer when soil moisture conditions allowed. Two cores were taken from each station with all 10 cores composited for each plot. Bucket augers, with 2¾" diameter, were used when soil was too dry for push coring on May 26 and June 9. In addition, T3 and T4 individual stations and prairie strip soil was sampled using push corers three times in 2021 (April, June, and October). Inorganic nitrogen extractions and soil moisture determinations were done on subsamples from all soil sampled. Analysis of the extracts for nitrate and ammonium should be completed by Cathy McMinn during winter 2021-2022.

The April 14 soil samples and April 27 T3, T4 station and prairie strip soil samples were air-dried and archived. A subsample from each of the July 6 soil samples and June 30 T3, T4 station and prairie strip soil samples was incubated in the field for 21 days and then inorganic nitrogen extracted to evaluate mineralization potential.

A post-harvest extensive grid soil sampling was done in all replicates of T1-6 and T8NT on November 17. This soil was air-dried and sent to the MSU Soil and Plant Nutrient Lab for standard analysis which includes pH, lime requirement, P, K, Ca, Mg, and estimated cation exchange capacity.

Gas

Greenhouse gases (N_2O, CO_2, CH_4) were sampled throughout the LTER using round static chambers between April 13 and November 16. With a sample frequency of once or twice each month, gas samples were taken twelve times during the 2021 field season. MCSE plots that were sampled include T1-7 R1-4, as well as the fertilized, untilled microplots in T7 R1-4 and prairie strips in T3, T4 (see MCSE Microplot section). Static chambers were also sampled in T8 R1-4 and all replicates of successional and forested sites, CF, DF, and SF. Sampling in the forest sites included the Nitrogen Deposition Study microplots. The MCSE (including T8) was sampled in the morning and forest sites sampled in the afternoon of the same day. Winter sampling began on December 10 and should continue monthly through March 2022. This sampling includes only T1-7 and DF. All chamber samples were put into Labco exetainers and transported back to the lab for analysis. They were analyzed for nitrous oxide, carbon dioxide and methane by Kevin Kahmark and Cathy McMinn using the Agilent/Gerstel automated GC in Academic 330.

Soil temperature and soil samples to determine moisture content were taken near each chamber when gas was sampled during the field season. HOBO dataloggers were not used in 2021 to measure air temperatures.

Water
Soil water samplers, or lysimeters, were used to collect water from the soil at about a 1m depth in T1-7 R2-4 and all replicates of CF, DF, and SF. Samplers were evacuated, and leachate collected once or twice each month. Eleven collections were made between March 18 and November 5. The volume of leachate collected was recorded. When 20mL or more of leachate was collected, the sample was filtered and frozen for analysis and archive. Analysis for nitrate and ammonium of all leachate samples taken should be completed by Cathy McMinn during winter 2021-2022.

Plants
Plant biomass samples were taken from plots prior to tillage, harvest, weed-control measures and at peak biomass. Plant species separations were completed for most but not all samplings. The rye cover crop was sampled ahead of tillage in T3 May 5-7 and T4 on May 10-13. The understory in T5 was sampled June 15 and again on July 12, ahead of mowing between poplar tree rows. The agronomy team intended to mow between tree rows right after our June 15 sampling but that never happened. The only mowing in T5 in 2021 was done on July 15. At peak biomass between July 28 and September 9, plant samples were taken from T6, T7, T8, SF and the prairie strips in T3 and T4. Soybeans were sampled ahead of harvest in T1-4 on September 21-27 (T1,2) and October 11-13 (T3,4). Poplar leaf litter was collected in ground traps from July 21-December 2. Leaf litter was collected in traps on the ground in CF, DF, and SF between September 10 and December 16. Leaf litter traps were checked, and leaves collected bi-weekly. On November 9 and 10, post-frost biomass samples were taken from all T7 plots. All plant material from all samplings was dried at 60^{o}C for at least 48 hours. All dried biomass will be weighed, ground and archived. Subsamples will be analyzed for carbon and nitrogen by Stacey VanderWulp.

In all replicates of CF and DF, all trees with a dbh (diameter at breast height) greater than or equal to 5cm are marked with a unique numbered tag. The dbh of all tagged trees was measured in January-February 2021. The diameter of the leading stem of ten randomly chosen poplar trees in each T5 plot were measured at 15cm above the ground on December 15.

All replicates of T7 were burned on March 17 to help control woody growth.

Switchgrass stand frequency was determined in May with stand counts done in all replicates of T6.

Yield data was collected from all mechanically harvested plots.

The Basso Lab used drones (DJI M100 and DJI M600 Pro) to fly from May to November 2021. Approximately every 2 weeks, at least once per month, LTER MCSE T1-7 were flown. The UAVs flew at 122m (400ft) and were equipped with a visual camera and either Micasense RedEdge 3 or Micasense Altum.

Insects
The Landis lab continued to monitor generalist insect predators for spatial and temporal dynamics using the 2019 protocol, https://lter.kbs.msu.edu/protocols/192. Coordination of that research was done by Elizabeth D'Auria until her departure from MSU in early May, then Stacey VanderWulp coordinated through communication with Doug Landis. The weekly survey was completed by two seasonal technicians. Being a soybean year, T-posts and sticky cards were installed beginning May

27 and weekly sampling started on June 3. Sampling concluded on August 20. Agronomic work occasionally interrupted the survey, but T-posts were removed and replaced in a timely fashion and noted on datasheets.

Monitoring was conducted by attaching one yellow sticky card (Great Lakes IPM, IPM-CRW-100 and PHEROCON AM No-Bait Traps) to a T-post about 1.2m above the ground at each of the five stations within each replicate of T1-T7 and the nine forest plots. The longtime standard trap (IPM-CRW-100) was discontinued, so comparison was needed between old and new traps (PHEROCON AM No-Bait). This was done by using old style cards for sampling stations 1, 3, and 5 in each replicate (all treatments in MCSE and forested plots) and new style cards for sampling stations 2 and 4. All used cards were collected and shipped to Christie Bahali at Kent State for evaluation.

This was the third year for surveying insects within the prairie strips of T3 and T4. The survey is conducted concurrently with the main survey, but data are recorded separately. The prairie strip sticky cards are located at the 0-meter mark (strip center) on the North, Central, and South transects through all replicates of these two treatments.

The target taxa consisted of 14 common to rare ladybug species (Order: Coleoptera, Family: Coccinellidae); soldier beetles (Cantharidae); fireflies (Lampyridae); scorpion flies (Order: Mecoptera); and other non-target generalist predators (e.g. 20 spotted ladybug).

A 22-foot-tall aphid suction tower onsite is part of a network of towers used to monitor regional aphid migration patterns in the Midwest. The fan on the tower was turned on and the first collection cup deployed on May 14. The collection cups were collected and replaced every Friday through October 22 at which time the tower was turned off. The samples were mailed to the University of Illinois at Urbana-Champaign for analysis.

Rainfall Exclusion Experiment (REX), T1 R1-4, T2 R1, 3, 4 and 6, T7 R1-6:

Rainout shelter construction was completed through the spring and early summer, led by Kevin Kahmark. Remaining trusses, Lexan roofs, caster wheels, gutters, irrigation systems and steel risers (T7s) were installed on all relevant shelters before field deployment. Shelters were deployed on July 1-2 and removed from footprints on September 7. After deployment, “average rainfall” footprints received the equivalent of 0.8” of water once a week (30-year growing season mean), “variable rainfall” footprints received the equivalent of 2.4” of water over two days once every three weeks, and “drought” footprints experienced a six-week period of no watering from July 15 to August 28 (and were watered 0.8” once a week all other weeks). Water was drawn from the pond lab reservoir and applied via a solar-powered pump system designed by Kevin Kahmark. Soil moisture and temperature sensors were installed in ~150 of the subplots by Kevin Kahmark in July.

In November and December 2020, forty lysimeters (porewater samplers) were installed using the Geoprobe and custom-made rods. Samplers were installed in all variable and control footprint subplots in T1 (two footprints x four subplots x four reps = 32) and in only the control subplots of T2 variable and average rainfall footprints (two footprints x one subplot x four reps = 8). Trenching of sampling lines to alleyway utility boxes was completed in spring 2021 by Kevin Kahmark, David Weed, and Mir Zaman Hussian. From June through December 2021, 96 leachate samples were collected from those samplers. These samples were analyzed for anions, cations, Non-purgeable

organic carbon (NPOC), Total dissolved nitrogen (TDN), and NH4-N (via IC). Other analyses may be completed on these as requested. Dave Weed was responsible for sampling and analysis.

Footprints and subplots in T7 were surveyed using the Emlid RS2 GPS units with Michigan CORS correction with accuracy to 2cm by Kevin Kahmark and Sven Bohm. T1, T2, and T7 footprints and subplots were flagged in May. Some of these points had to be re-surveyed by Hsun-yi Hsieh in June.

After flagging, T1 carbon additions (dried switchgrass, dried sorghum-sudangrass, and biochar) were added by Grant Falvo to relevant subplots (other than biochar in the Y2 and Y3 subplots, which was left until after Y1) and control subplots were tilled to matching depths on May 11-12 using a large roto-tiller. T2 and T7 carbon additions (dried sorghum-sudangrass) were added to relevant subplots on May 27 (T2) and May 28 and 31 (T7). After harvest, T1 plots were reflagged using the Emlid RS2 GPS units before biochar additions for Y2 and Y3 subplots were added on November 4, when all T1 footprints were roto-tilled for the ensuing wheat planting.

Initial T7 biocide additions were added by Jennifer Jones and Mark Hammond to relevant subplots on May 13 (T2 nematicide), 20 (T7 nematicide), 29 (T2 fungicide), and June 1 (T7 fungicide). The nematicide used was “Nimitz” (EPA# 66222-243), and the fungicide used was “Topsin 4.5L” (EPA# 73545-13-70506). Both were applied per manufacturer recommendations for a full application, after adjusting concentrations (i.e., the water used in application) for the amount of rainfall in the preceding weeks. After shelter deployment, a second biocide application was performed for all nematicide subplots on July 2, and for all fungicide subplots on July 3.

Soybeans were ineffectively planted in most T1 and T2 carbon addition subplots and had to be manually replanted by Grant Falvo from May 25-June 10. Most were planted early in that window, but some in T1R1 were replanted a second time after deer knocked them back.

Due to a drought during/after planting, the decision was made to water all T1, T2, and T7 footprints to the equivalent of 1” rainfall in order to ensure survival of soybeans in footprints. This emergency watering was performed by Brook Wilke, Yahn-Jauh Su, and Mark Hammond on May 26-27 (T1), June 1-2 (T2), and June 3-4 (T7), using water drawn from the pond lab reservoir.

PVC pitfall trap holders were installed into the center of each footprint on June 8 by Jamie Smith to sample ground-bound invertebrates. Pitfall traps were deployed and sampled weekly, from two weeks prior to shelter deployment through two weeks after shelters were removed from the plots.

All footprints and subplots that were to have shelters as well as the control subplots of footprints for Y2 and Y3 shelters were sampled for initial microbial community analyses on June 9-11. Sampling was performed using 1.25cm diameter corers sampled to 10cm, combining three cores per subplot to create one aggregate sample. Each core was taken using three different sampling locations to ensure samples were representative of the subplot area. Aggregated samples were sieved to 2mm in the field, before subsamples were flash frozen for RNA or archived on dry ice (DNA) or wet ice (microbial biomass, soil moisture, pH). A subsequent “peak-drought” sampling for microbial community analyses was performed on August 24-27, a “post-drought” sampling was performed on August 30-September 1, and a “recovery” sampling was performed on September 27-28. These samplings differed only in that they did not include subplots from the Y2 or Y3 footprints but did

include both OTC footprints in all the T7 reps. Microbial community sampling efforts were coordinated by Sarah Evans' lab (led by Jennifer Jones, Holly Vander Stel, and Moriah Young).

Initial nematode community sampling was done on T2 and T7 footprints on June 9-11. This was done by combining 2.5cm cores taken to 10cm depth from all five control, nematicide, or fungicide subplots in each rep to create one aggregate sample. Each core was taken based on an x,y coordinate system, and was back-filled using a mixture of leftover LTER core sampling soil from the same treatment mixed 50:50 with sterile sand. A subsequent "peak-drought" sampling for nematode community analyses was performed on August 24-27, a "post-drought" sampling was performed on August 30-September 1, and a "recovery" sampling was performed on September 27-28. These samplings could not be aggregated across footprints, and instead required 5 cores to be taken from each nematicide, fungicide, and control subplot in the T2 and T7 footprints that were sheltered this year. Nematode community sampling efforts were coordinated by Christine Sprunger's lab.

Soil biogeochemistry samples from all sheltered footprints were collected by Grant Falvo in June, August and September. This was done by collecting one 1.9cm diameter core taken to 25cm depth from each subplot of each footprint using the same aforementioned x,y coordinate system, and back-filling the core with the same mix of LTER soil and sterile sand. The "peak-drought" sampling for biogeochemical analyses was performed on August 23-26, and a "post-drought" sampling was performed on August 31-September 2. These samples were used for soil moisture, pH, nitrate, total nitrogen and carbon. Madaris Serrano-Perez also used these samples for measuring percent mycorrhizal root colonization

Grant Falvo installed gas flux chambers in all T1, T2 and T7 R1-R4 subplots that would be sheltered in Y1 in June. These chambers were used to measure N_2O, CO_2, CH_4 gas flux weekly after shelter deployment, with a focus on the time period after rewetting for subplots that were being watered weekly (average rainfall) or over set durations (variable rainfall, drought).

Mauricio Tejera measured T1 and T2 soybean photosynthetic activity in all sheltered non-amended subplots on July 20. Leaves were flash frozen in the field and stored.

Madaris Serrano-Perez measured Canada goldenrod (*Solidago canadensis*) and red clover (*Trifolium pratense*) traits such as plant height (3x throughout the summer), and specific leaf area and leaf dry matter content (twice throughout the summer) in T7 control, nematicide, and fungicide subplots within the average rainfall and Y1 drought footprints. For these subplots, she also measured percent plant cover, percent flower cover, and number of inflorescences for the subplots (three times throughout the summer). See REX T7 only – Zarnetske section as well.

Grant Falvo measured soybean morphological traits (stem width, plant height, pod widths, etc.) from all sheltered T1 and T2 subplots on August 4-5, 8-9, and then again on August 17-20, and finally at harvest. Just prior to combine harvest, during the week of September 26, all T1 and T2 soybean subplots were sampled by hand, including Y2 and Y3 footprints. All soybean stems within a one square meter area in the center of each subplot were counted and clipped at ground-level, according to the protocol used for the MCSE main plots. Samples were dried, weighed and then soybean grain mechanically separated from the soybean stover.

Grant Falvo arranged for a drone flight above the T1, T2, and T7 average rainfall and Y1 drought footprints on August 20, for which shelters were moved off the footprints in the morning and replaced in the afternoon after the flight. These spectra are intended to capture moisture stress exhibited by plants.

Jennifer Jones sampled soil from all control, sorghum, nematicide, and fungicide subplots from all sheltered non-OTC T7 footprints on August 18-19. Cores were taken with a 1.25cm corer to 15cm depth in four locations in each subplot. This soil will be used for metagenomic sequencing, carbon-degrading enzyme assays, extracellular polysaccharide analyses, microbial biomass, carbon use efficiency incubations, and soil moisture.

REX T7 only: The portion of REX within T7 had two principle investigators (labs) working with plants, Phoebe Zarnetske and Jen Lau.

Phoebe Zarnetske's lab used open-top chambers (OTCs) under rainout shelters in T7 to manipulate ambient air temperature and rainfall. OTCs were placed on the plots December 2, 2020 and remained there for the 2021 season, except March 16-21 when they were removed for burning T7. Aboveground net primary production (ANPP) was sampled from these REX T7 footprints on October 11. Aboveground biomass was clipped from a $0.20m^2$ area (1m x 0.20m) nearest the door entry for each plot. For plots on the north side, door entry was north into subplots. For plots on the southside, door entry is south orientation. Biomass was sorted to species, dried, and weighed. Phoebe's lab also surveyed the plots for phenology on a species-level basis within a 1m x 1m area through the growing season (April-October). Species were noted when flowering started and was underway. Flowering is typically defined as presence of exposed viable anther. Species were noted for the start of fruit maturation. This survey work included all of Phoebe's footprints and all subplots within her footprints, as well as, the control subplot in the irrigated control footprint. The survey work for the irrigated control started later in the season.

The same $1m^2$ areas was surveyed for visual percent cover on a species-level basis to provide some data on species composition. This assessment was done once every 4-5 weeks, or around important events, like irrigation. The control subplot in the irrigated control footprint was again included, in addition to all subplots within Phoebe's footprints.

We did more extensive monitoring and sampling on two species: Canada goldenrod (*Solidago canadensis*) and to a lesser extent red clover (*Trifolium pratense*). For both species, we did a visual assessment of leaf herbivory. During this time, we also collected leaf tissue which was dried and stored at room temperature for potential future carbon and nitrogen tissue analysis. In addition to this, for Canada goldenrod we surveyed phenology (flowering and fruiting), gall formation (presence and absence), gall size and dried mass, galling insect herbivory levels (number of larval chambers in gall), plant fitness (inflorescence fruit assessment and potentially seed counts), and size of plant at end of season.

We did start some monitoring of air temperature (HOBO pendants- 24 total) and humidity (HOBO- 4 total) to record environmental treatment conditions through the season. We had trouble with supply chain availability for these instruments, delaying start dates for monitoring.

All irrigation was completed by Phoebe's lab for her research footprints. Irrigation was completed using a small gas-powered pump with an attached garden hose and hose end nozzle. The volume of water added, and specific days of irrigation were coordinated to 'match' those of the associated LTER core footprints.

Moriah Young, with assistance from Kara Dobson, took a lead role and completed associated soil collection for LTER REX T7 for Phoebe's footprints. The protocol and sampling were coordinated with LTER Core footprint sampling led by Holly Vander Stel and Jennifer Jones. This entailed the collection of 10cm soil cores on May 12, August 24, 26, 30, and September 1, 28. These samples were sieved in the field and stored in a -80 freezer at KBS. The samples collected will be used to uncover the short and long-term temporal changes of the bacterial and fungal communities within these plots. DNA will be extracted and then sequenced from these samples to analyze the microbial communities within each sample and will be compared across treatments.

Jen Lau's lab harvested ANPP samples from all control subplots across REX T7 footprints between September 22 and October 2. Aboveground biomass was clipped from a $0.20m^2$ area (0.45m x 0.45m). Harvest locations were marked with temporary flags and are nearest the center of the footprint for each subplot. For all subplot controls, across all footprints clipped, biomass was sorted to species. All fungicide subplot samples were sorted to species, except for the Y3 drought footprints, in which case samples were clipped but not sorted to species. For all nematicide and sorghum subplots, samples were clipped but not sorted to species. Biomass was dried and weighed.

We also surveyed a $1m^2$ area for visual percent cover on a species-level basis to provide some data on species composition. Typically, this assessment was completed at important dates for pre-drought, post-drought, and end of season. This assessment was done over all LTER T7 core footprints and subplots. Monitoring was more frequent in the control subplot within the irrigated control footprint where plant phenology was also monitored.

MCSE Microplot Experiments (other than REX)

Prairie strips (T3 R1-6, T4 R1-6): Planted with a 22 species prairie mix in 2019, these are 15-foot-wide strips down the center of each T3 and T4 plot. On March 25, these strips were burned for the first time. There was 10' at the north end of each strip that was left unburned. Non-destructive species composition data was collected by the Haddad lab July 27-September 29. In August, three plant samples were collected from each strip. One sample from each strip was sorted to species. T3 and T4 individual station and prairie strip soil was sampled three times in 2021 (April, June, October), see MCSE soil section. Soil sampled on April 27 was air-dried and archived. Greenhouse gases were sampled twelve times in the prairie strips, as detailed in MCSE Gas section above.

Brome grass (T6 R1-6): When the main T6 plots were planted to switchgrass in June 2019, a 30-foot-wide by 30-foot-long area in the northwest corner of each plot was left unplanted. Brome grass was planted there September 22, 2020. Adjacent to the brome grass microplot, to the east, is a microplot of the same size. That area is planted to switchgrass and left unfertilized. Yield data was collected from mechanical harvest of a strip through the unfertilized microplots.

Disturbance/Fertilization Microplots (T7 R1-6): Started in 1989, these microplots are in the northwest corner of each T7 plot. There are four microplots in each plot; each microplot measures

5x5m. They combine disturbance/tillage and nitrogen fertilization in a full factorial design. Greenhouse gases were sampled twelve times in the untilled, fertilized microplots of T7 R1-4, as detailed in MCSE Gas section above.

Fertilizing and plant sampling was led by Mark Hammond, working with Jen Lau. The fertilized microplots received nitrogen in the form of urea on June 17. The T7 microplot aboveground plant biomass (ANPP) was sampled near its peak September 2-14. Species were separated for the tilled microplots only. In addition, a small aliquot of seeds was collected from selected species from the ANPP harvest collection. This was done after drying the plant material for two days. Our hopes are the seeds remained viable, and this collection may take advantage of the 2021 historical spring drought for future ecology/evolutionary research on these species across multiple years. All plant samples were then further dried for 2 more additional days (minimum of 4 days total) and then weighed. Soil was not sampled for inorganic nitrogen as in years past.

Nitrogen Deposition Study

Nitrogen is applied to subplots within each of the three replicated sites of CF, DF, and SF. Fertilizer solutions were applied to the 1F, 3F and 10F subplots in this study on three dates. Urea (46% N) was applied on April 19-20, July 15-16 and October 20-21. Rates of fertilization are $1gN/m^2$/year for the 1F subplots, $3gN/m^2$/year for the 3F subplots, and $10gN/m^2$/year for the 10F subplots. Gas was sampled on a routine basis in this study; see the Gas section under MCSE.

Resource Gradient Experiment

Soil samples were taken on November 29. Four cores (0-25cm) were pooled from each plot, two in the crop row and two between rows. The soil was air-dried and sent to the MSU Soil and Plant Nutrient Lab for standard analysis.

Soil water samplers were not sampled here in 2021. The LTER Resource Gradient experiment automated trace gas system remained dormant in 2021.

Yield data was collected from mechanical harvest.

Interaction Experiment

Rainout shelters were installed in all four no-tillage, no-fertilizer plots to manipulate soil wetting/drying regimes to examine the relationship between ANF and switchgrass phenology, diazotroph communities and nitrogenase iron protein (nifH) expression. This work is led by Sarah Roley and Carmella Vizza.

Switchgrass stand frequency was determined in May with stand counts done in all plots 1-16.

Yield data was collected from mechanical harvest. A subsample of the harvested biomass was dried and will be ground and analyzed for carbon and nitrogen by Stacey VanderWulp.

Biodiversity Study

This experiment was retired after harvest in 2019 and planted to sorghum sudangrass in 2020. There was no data collected from this study after 2020.

Cellulosic Biofuel Experiment

Yield data was collected from mechanical harvest.

Written by Stacey VanderWulp with contributions from Nameer Baker, Mark Hammond, Kevin Kahmark, Ruben Ulbrich and Dave Weed

Archived Material

Experiment	sample type	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
LTER MCSE	leachate											
LTER MCSE	plants											
LTER MCSE	T7 microplot plants											
LTER MCSE	surface soil											
LTER MCSE	T7 microplot surface soil											

Experiment	sample type	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
LTER MCSE	leachate											
LTER MCSE	plants											
LTER MCSE	T7 microplot plants											
LTER MCSE	surface soil											
LTER MCSE	T7 microplot surface soil											
LTER MCSE	deep core soil											
LTER Biodiversity Study	surface soil											
LTER Resource Gradient	surface soil											

Experiment	sample type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
LTER MCSE	leachate												
LTER MCSE	plants												
LTER MCSE	T7 microplot plants												
LTER MCSE	surface soil												
LTER MCSE	T7 microplot surface soil												
LTER MCSE	deep core soil												
LTER Biodiversity Study	surface soil											deep core	
LTER Resource Gradient	surface soil												

Agronomic Soil Analysis

Experiment	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
LTER MCSE														
LTER Resource Gradient														
GLBRC BCSE main														
GLBRC BCSE micro														
GLBRC BCSE deep core														
GLBRC Scale-up														
GLBRC MLE														
GLBRC Switchgrass Gradient														