Predicting Late-Season Rye Cover Crop Biomass from Early-Season Observations

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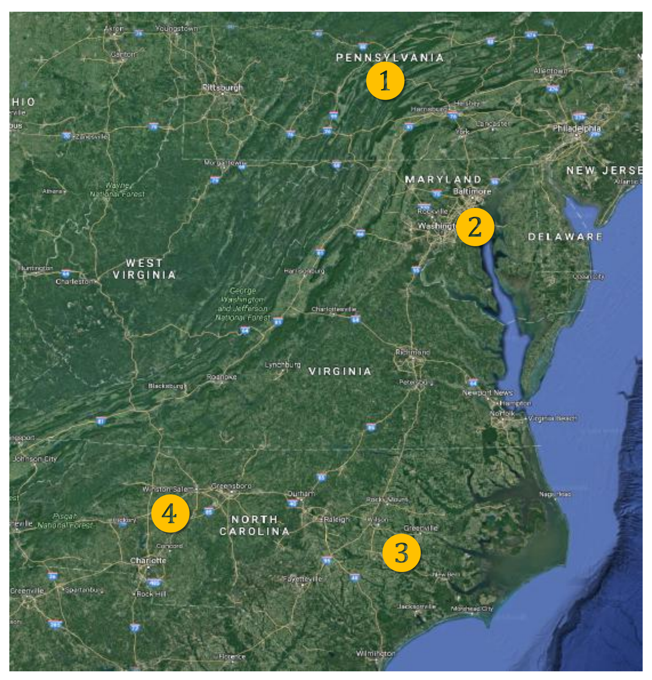
Cereal rye (*Secale cereale*) provides multiple ecosystem services, such as weed suppression, soil protection, and N and C sequestration. The extent to which services are provisioned is generally contingent on biomass production. Understanding rye biomass response to climate and residual N is fundamental to predicting the potential for ecosystem services provision. Furthermore, early season environmental growth responses could be useful for predicting late season biomass and thus aid in management decisions.

Study objective: Characterize response of cereal rye to varying climatic regions and levels of residual soil N

Figure 1. Rye growth study locations in Maryland, North Carolina, and Pennsylvania.



1. Rock Springs, PA 2012 (PA12)
2. Beltsville MD 2009 – 2012 (MD10, MD11, MD12)
3. Kinston, NC 2012 (NCK12)
4. Salisbury, NC 2012 (NCS12)

Field Management and Data Collection

- Figure 1. shows locations.
- Table 1. lists field operations.
- Growing degree day (GDD, 4 °C base) and precipitation are presented in Figure 2.
- Rye cultivar 'Aroostook' @ 123-157 kg ha^{-1}.
- Fall N: 0, 30, 60, 90, and 150 kg N ha^{-1}.
- Aboveground biomass and shoot density at Zadok's growth stage (GS) 20-25, 30, and 60.
- Biomass analyzed for total N.
- NDVI using a Crop Circle ACS 210 (590 and 880 nm) or ACS 470 (650 and 760 nm).

Table 1. Field operation dates and mean fall residual soil [NO_3 + NH_4]-N in 0 N plots.

	Maryland 2010	Maryland 2011	Maryland 2012	Pennsylvania 2012	North Carolina Kinston 2012	North Carolina Salisbury 2012
Field operations						
Rye planting	9-10-09	10-13-10	10-6-11	9-19-11	10-26-11	10-24-11
Fall N application	9-21-09	10-25-10	10-6-11	9-19-11	11-22-11	11-21-11
GS20-25 sampling	3-25-10	3-2-11	3-1-12	3-12-12	-	2-28-12
GS30 sampling	4-20-10	3-28-11	3-22-12	4-3-12	3-7-12	3-19-12
GS60 sampling	5-11-10	5-2-11	4-20-12	5-10-12	5-10-12	5-21-12
Baseline fall [NO_3 + NH_4]-N kg N ha^{-1}						
0-30-cm	-	46.0	23.5	21.5	34.6	72.9
30-60-cm	-	35.0	20.3	13.9	33.0	57.0
60-90-cm	-	34.8	15.7	17.8	30.1	47.4
Profile mineral N	-	115.8	59.5	53.1	97.7	177.3

Figure 3:

- ❖ Biomass response to fall N (slope of linear portion of linear plateau) was similar at GS25 and GS30 at each location.
- ❖ Mean biomass response across all data was 0.272, 0.298, and 0.260 at GS25, GS30, and GS60, respectively.
- ❖ Maximum biomass occurred at 71.5, 80.7 and 65.0 kg N ha^{-1} for GS25, GS30, and GS60,
- ❖ Maximum N accumulation occurred at 84.9 kg N ha^{-1} (MD10 GS25) to 143.9 kg N ha^{-1} (MD11 GS30).
- ❖ Fraction of applied fertilizer N recovered ranged from 36% (PSU12) to 83% (MD12) and averaged a little less than 50%.

Figure 4:

- ➢ Of the early season measurements, biomass had the greatest correlation with late season biomass and total N content.
- ➢ Difference between GS25 and GS30 correlations to GS60 biomass and total N content may have resulted from early spring weather events (e.g., frost) that negatively impacted cereal rye growth at GS30 but was compensated for by GS60.

Table 2:

- Multiple regression models of early season measurements were generally best fit with three parameters.
- 38 to 65 % of the variance within the models was uniquely attributable to biomass.
- Commonality analysis indicated most of the variance described by other variables was also described by biomass.
- Measuring only biomass at GS25 appears to be the best approach for estimating GS60 biomass and total N.

Figure 2. Cumulative GDD and precipitation for rye growing seasons in Maryland, North Carolina, and Pennsylvania.

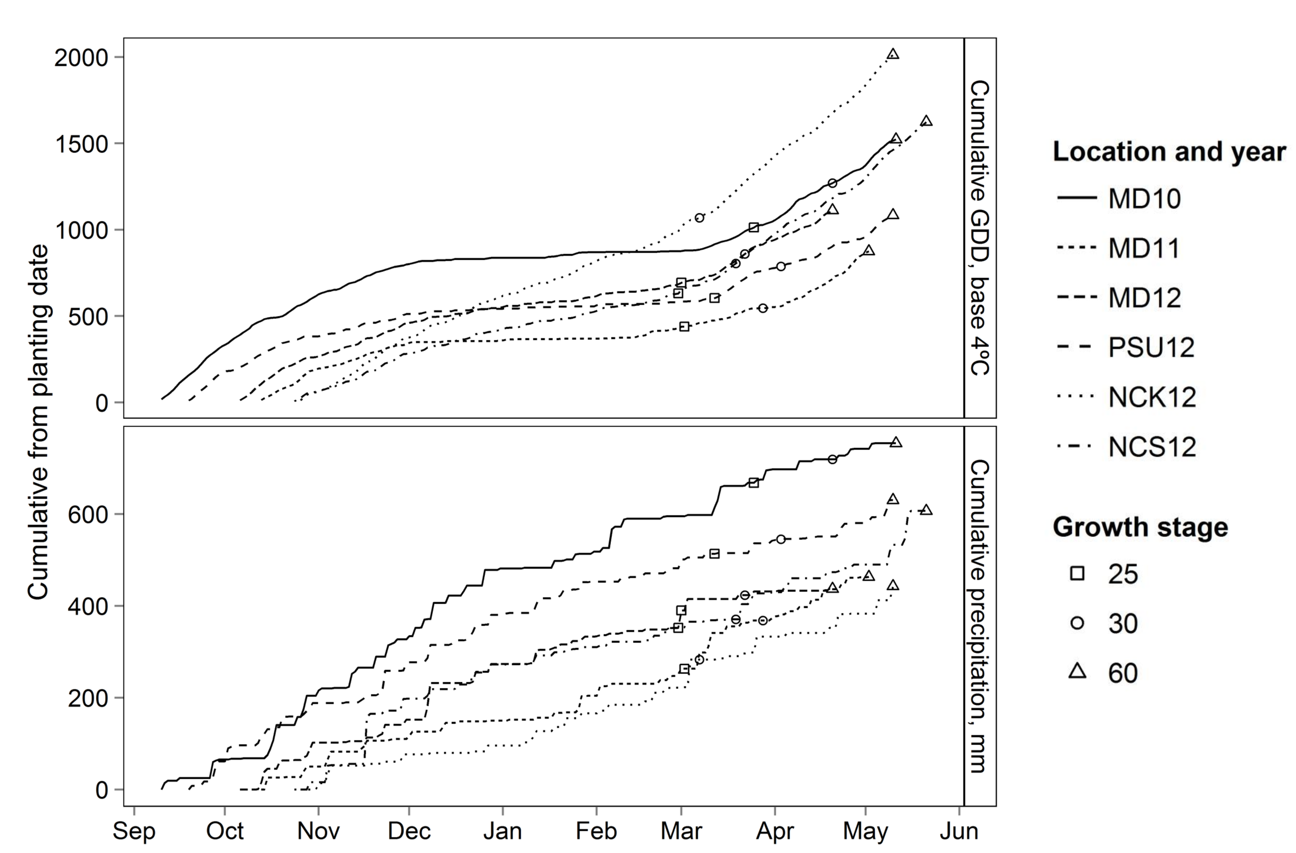


Figure 3. Rye biomass (top row) and N content (bottom row) response to fall N application at GS25, 30, and 60. Data fit to a linear plateau regression model after square root transformation.

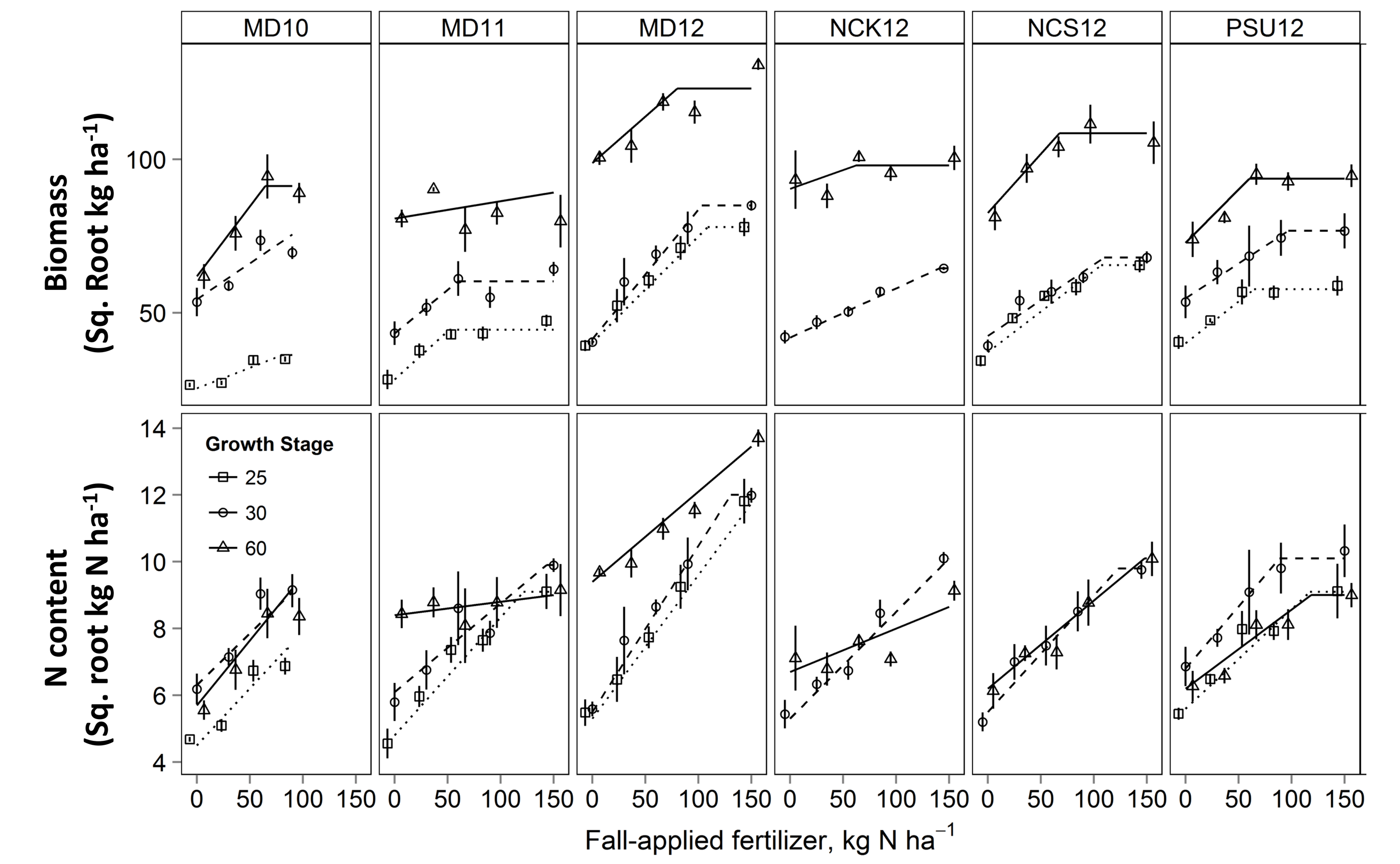


Figure 4. Correlation matrix comparing GS25 (left) and GS30 (right) rye biomass (Mg ha^{-1}), N content (kg ha^{-1}), NDVI, and tiller count measurements to GS60 biomass and N content.

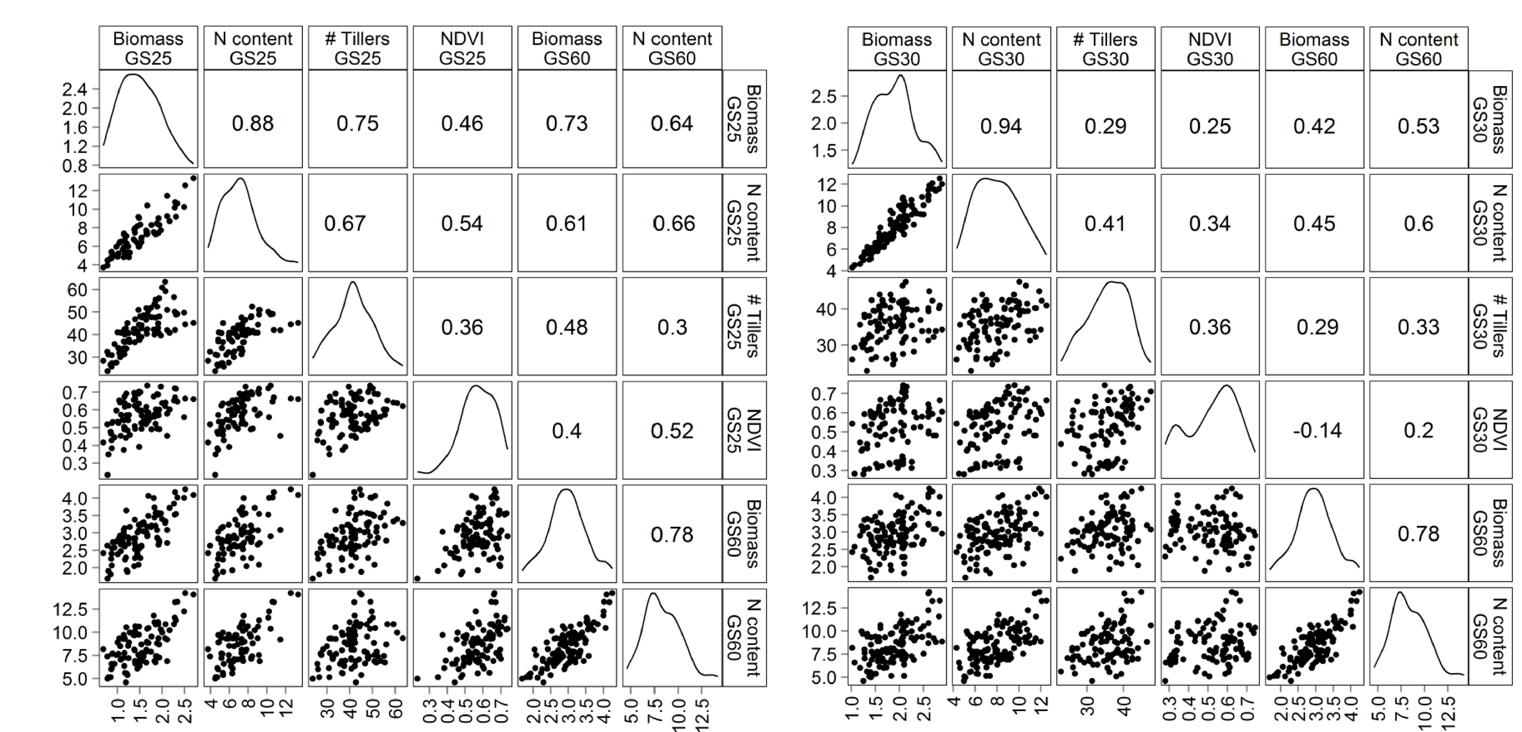


Table 2. Models to predict rye biomass and N content at GS60.

Params in Model	Intercept	√Mg ha^{-1}	√Tillers	√%N	NDVI§	R^2	Adj. R^2	C(p)¶	MSE#	Root MSE
GS25 vs.GS60										
Biomass†										
1	1.632†	0.871	.	.	.	0.53	0.52	16.4	0.146	0.382
2	2.252	1.199	-0.028	.	.	0.57	0.56	9	0.133	0.365
3	1.887	1.176	-0.033	.	1.001	0.60	0.59	4.8	0.125	0.354
4	2.366	1.104	-0.036	-0.268	1.340	0.61	0.59	5	0.124	0.352
Total N‡										
1	4.576‡	2.906	.	.	.	0.44	0.43	14.6	2.295	1.515
2	2.102	2.489	.	5.242	.	0.51	0.49	5.5	2.052	1.432
3	3.469	3.327	-0.076	5.922	.	0.53	0.51	3.38	1.975	1.405
4	2.595	3.459	-0.070	5.303	0.490	0.53	0.51	5	1.990	1.411
GS30 vs. GS60										
Biomass†										
1	2.048	0.525	.	.	.	0.20	0.20	19.6	0.207	0.455
2	2.475	0.609	.	.	-1.12	0.28	0.26	11	0.19	0.436
3	1.827	0.541	0.027	.	-1.46	0.35	0.32	3.1	0.174	0.417
4	1.981	0.539	0.028	-0.15	-1.44	0.35	0.32	5	0.175	0.419
Total N‡										
1	3.913‡	2.493	.	.	.	0.31	0.30	5.7	2.694	1.641
2	-0.43	2.416	.	3.316	.	0.34	0.33	3	2.594	1.611
3	-0.53	2.272	0.048	2.328	.	0.35	0.33	3.1	2.57	1.603
4	-0.57	2.291	0.049	2.427	-0.37	0.35	0.33	5	2.595	1.611

† Square root biomass (Mg ha^{-1}), ‡ Square root of N content (kg ha^{-1}), § Normalized Difference Vegetation Index, ¶ Mallows' C_p, # Mean square error

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