# Estimating Accumulated Biomass and Nitrogen Pools in Over-Wintered Cover Crops: Digital Image Analysis Versus Manual Sampling

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## Introduction

- Farmers recognize that over-wintered cover crops reduce risk of soil erosion and inorganic nitrogen (N) losses, and raise soil organic matter levels over time (Long et al., 2013).
- Farmers are becoming more interested in using cover crops as a catch crop to capture residual fall N and carry it over to the spring (Ort et al., 2013).
- For practical management, a simple farmer-accessible field technique is needed to predict total dry matter (DM) and N credits from cover crops for the following crop.
  - These predictions could aid in decisions about spring termination timing to increase benefits from cover crops.
- Manual sampling is an option, but this may be too time intensive and costly for practical use in the field.

## Objectives

- Estimate DM and N pools in over-wintered cover crop stands (Figure 1) in farmers' fields by:
  1) Manual sampling.
  2) Digital image analysis.
- Evaluate potential to estimate total DM and N (above and belowground) from aboveground DM.
- Develop and assess the efficacy of a rapid field technique (DM and N pool estimation from digital image analysis-generated ground cover and agronomic measures) versus a standard manual sampling method.

**Figure 1:** Wheat cover crop stand in Wyoming County, NY, March 2012.

## Sampling Process

- In spring 2012, representative samples of cereal rye, winter wheat, and oats ($n$=94) were identified in farmers' fields using a rectangular quadrat (0.199 $m^2$) to delineate the sampling area (Figure 2).
  - Samples represented a subset of a larger cover crop experiment.
- A digital image (5-Megapixel resolution) was taken of each quadrat area with a single digital camera (Canon PowerShot A3100 IS).
- Cover crop maximum and canopy height were recorded.
- Above- and belowground biomass were extracted within the quadrat area and taken to the laboratory for processing.
- Weeds were separated from cover crop shoots. Roots (washed to remove soil) and shoots were dried separately at 60ºC to stable weight to determine DM and analyzed for total carbon (C) and N (Table 1).
- Total cover crop DM ranged from 0.007 to 4.3 Mg/ha, representing N pools from 0.3 to 134.2 kg/ha.

**Table 1**: Spring 2012 sampling summary for aboveground (shoots), belowground (roots), and total C and N contributions from each.

| Cover Crop Component | $n$ | DM (Mg/ha) | C (% in DM) | N (% in DM) | N Pools (kg/ha) | C:N |
|---|---|---|---|---|---|---|
| | | (Mean ± $SD$) | | | | |
| Aboveground | 94[a] | 0.94 ± 0.90 | 42.3 ± 1.2 | 4.0 ± 1.1 | 31.2 ± 26.9 | 11.7:1 ± 3.7:1 |
| Belowground | 94[a] | 0.19 ± 0.20 | 40.8 ± 1.6 | 2.0 ± 0.6 | 3.4 ± 3.4 | 22.5:1 ± 7.3:1 |
| Total | 94[a] | 1.14 ± 1.06 | 42.0 ± 1.3 | 3.6 ± 1.0 | 34.6 ± 29.3 | 12.7:1 ± 4.1:1 |

[a]94 total samples consist of 16 oats, 32 cereal rye and 46 wheat samples.

## Estimating Ground Cover

- Digital image analysis (DIA) has been demonstrated as an effective, accurate, rapid alternative to estimate ground cover (e.g., Richardson et al., 2001; Booth et al., 2005; Luscier et al., 2006).
- Harvested area was manually cropped from the image (Figure 2).
- Cropped images were processed to measure ground cover (green pixels/total pixels) in each quadrat (Figure 2).
  - We developed an image processing program using a simple algorithm that counted pixels as green by comparing their green value with their red and blue values, and thresholding to ignore shadows and bright light (e.g., shiny rocks and corn stalks).

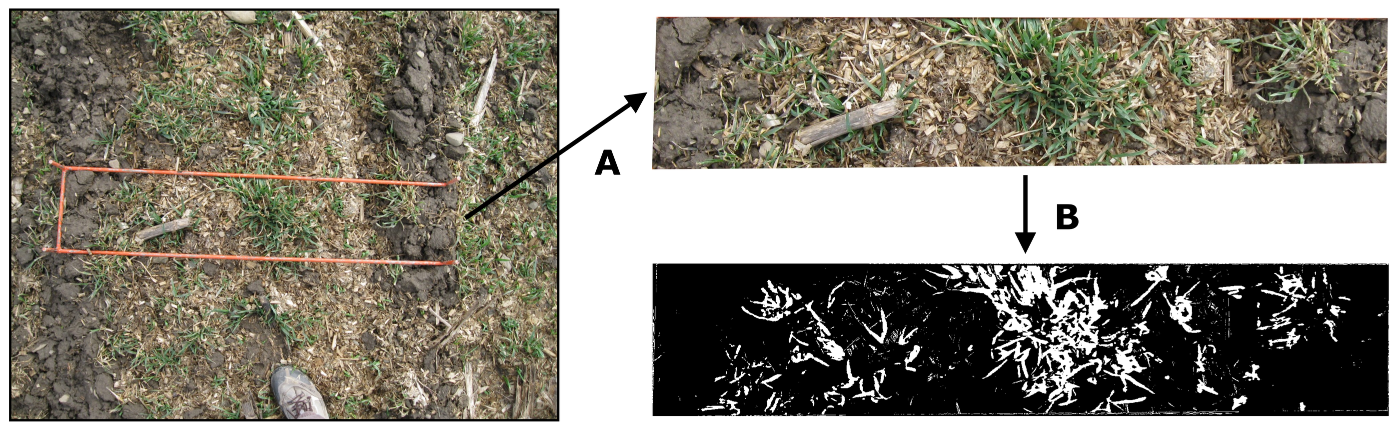


**Figure 2:** Step A: The area within the quadrat is manually cropped from the original image.
Step B: The cropped image is processed in our program. Pixels defined as green by the program are white. All other pixels are black.

## Estimating Total DM and N

- There is a strong relationship between total DM (Mg/ha) and aboveground DM (Mg/ha) (ADM), and total N pools (kg/ha) and ADM (Table 2).
- DM and N contributions from cover crops are dominated by aboveground biomass (ADM/total DM = 82.2% with $SD$ ± 12.0; N accumulated in ADM/total accumulated N = 89.3% ± 10.5).
- These relationships are consistent with larger fall and spring cover crop datasets collected throughout New York State (unpublished data), suggesting that it may be feasible to clip only aboveground biomass at ground level to estimate total DM and N pools using statistical relationships.
- DIA-generated ground cover estimates were positively correlated with cover crop DM and N pools (Table 2).
- Cover crops that accumulate 2.24 Mg DM/ha in spring may have a higher probability of being harvested for forage than terminated in the spring. Exclusion of samples above this level ($n$=13) impacted relationships (Table 2).

**Table 2**: Bivariate relationships between total DM or total N pools and DIA-estimated ground cover or aboveground DM (ADM). P<0.0001 for all relationships.

| Parameter | $n$ | $r^2$ | RMSE | Slope | Intercept |
|---|---|---|---|---|---|
| **Response: Total DM (Mg/ha) =** | | | | | |
| Ground Cover (%) | 94 | 0.62[a] | 0.658 Mg/ha[a] | 0.04 | -0.24 |
| ADM (Mg/ha) | 94 | 0.99 | 0.124 Mg/ha | 1.17 | 0.03 |
| Ground Cover (%) | 81[c] | 0.33[b] | 0.532 Mg/ha[b] | 0.03 | 0.11 |
| ADM (Mg/ha) | 81[c] | 0.97 | 0.103 Mg/ha | 1.15 | 0.04 |
| **Response: Total N pool (kg/ha) =** | | | | | |
| Ground Cover (%) | 94 | 0.66 | 17.09 kg/ha | 1.26 | -4.96 |
| ADM (Mg/ha) | 94 | 0.90 | 9.26 kg/ha | 31.0 | 5.29 |
| Ground Cover (%) | 81[c] | 0.37 | 15.31 kg/ha | 0.81 | 4.73 |
| ADM (Mg/ha) | 81[c] | 0.87 | 7.0 kg/ha | 32.05 | 4.77 |
| **Response: Aboveground DM (Mg/ha) =** | | | | | |
| Ground Cover (%) | 94 | 0.59 | 0.577 Mg/ha | 0.04 | -0.20 |
| Ground Cover (%) | 81[c] | 0.28 | 0.475 Mg/ha | 0.02 | 0.12 |

[a] Ground cover relationship with total DM increased $r^2$ to 0.68 and decreased RMSE to 0.589 Mg/ha when weed DM was added to total cover crop DM.

[b] Ground cover relationship with total DM increased $r^2$ to 0.46 and decreased RMSE to 0.465 Mg/ha when weed DM was added to total cover crop DM.

[c] Samples with total DM ≥ 2.24 Mg/ha ($n$=13) were excluded and analyses were rerun.

## Multivariate Model Development

- Relying on the strong statistical relationship between total DM and aboveground DM (ADM), and N pools and ADM, a ground cover-driven model only needs to estimate ADM.
- A strong candidate model is given by:
  - √ADM = 0.55 + 0.0066*ground cover + 0.053*grass canopy ht - 0.03*prev yr starter fertilizer rate - 0.0077*(grass canopy ht* prev yr starter fert rate).
  - $R^2$=0.91, $n$=94.
  - In the bivariate relationship between actual and model predicted ADM values (Figure 3), slope and intercept did not differ from 1 and 0, respectively.
- Starter fertilizer rate may no longer be significant with a larger dataset. Cover crop species is not included as a candidate covariate because it is confounded with field. More data are needed.

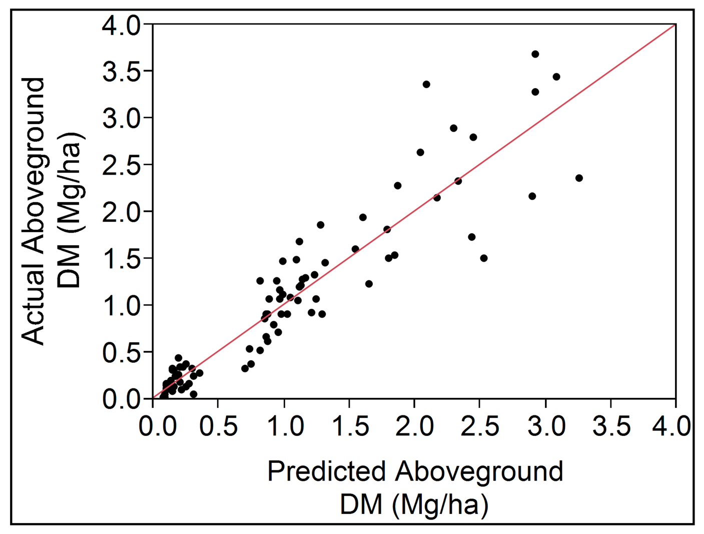


**Figure 3:** Actual versus model predicted values for ADM. Y=0.02 + 0.997x, $r^2$=0.87, RMSE = 0.321 Mg/ha.

## Next Steps

- A second sample set ($n$=90) was collected from different fields using multiple digital cameras in spring 2013. Only aboveground DM was measured. Samples are still being processed.
- Techniques developed will be further tested with 2013 data to evaluate robustness in different sampling years, fields, environmental conditions, and for images taken with different image acquisition devices (cameras and smartphones).
- Further development and testing of the DIA ground cover algorithm and statistical models are needed with the full dataset.
- If successful, the program will be developed into a farmer-friendly web application to accurately estimate accumulated DM and N pools from over-wintered cover crops to support spring termination timing and subsequent crop fertilization decisions.
  - Only materials necessary to use the program will be a digital or smartphone camera and a measuring stick.

## Summary

- Initial results are promising for collection of aboveground DM or use of DIA-generated ground cover and agronomic measures as rapid field techniques to estimate DM and N contributions from over-wintered cover crops.
- Further data and analysis are needed, especially to test effectiveness of DIA-generated ground cover for practical field use.

## Acknowledgments

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