SUDBURY AREA RISK ASSESSMENT

APPENDIX GG-4: DECOMPOSITION LOE RANKING REPORT

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GG-4-1.0 INTRODUCTION

The Ecological Risk Assessment (ERA) in Sudbury will evaluate the impact from airborne particulate emissions of the chemicals of concern (COC) to terrestrial ecological receptors. The soils in the Sudbury area contain a complex mixture of several metals that together will have a different toxicity potential than would be produced by a single metal. The COC for the Sudbury Risk Assessment are arsenic, copper, cadmium, cobalt, nickel, selenium and lead. The concentrations of these elements in Sudbury soils are generally highly positively correlated (MOE, 2004; CEM, 2004). The different smelters now and/or historically emitted the various metals in different proportions, causing the absolute levels and ratios of the metals to differ within the study area. The risk assessment must take into account the combined toxicity of these metal mixtures, which differ spatially in the study area, and which cannot be accurately predicted using traditional toxicological models.

Objective #1 of the ERA is to evaluate the extent to which the chemicals of concern (COC) are preventing the recovery of regionally representative, self-sustaining terrestrial plant communities. To fulfill this objective, multiple lines of evidence (LOE) were collected at 22 sites (18 test sites, three reference sites, and one historically limed and re-greened site) across the study area, the results of which were evaluated to contribute to an overall weight-of-evidence approach to assess risk to ecological receptors.

For each LOE, each test site was ranked based on a comparison to the reference sites. One of the lines of evidence was an *in situ* assessment of forest organic litter decomposition—the litter bag study. The ranking of the test sites for this LOE is the focus of this report.

The objective of this report is to compare decomposition at the test sites to the reference sites in order to rank each test site for this LOE. To do this, the rate of leaf litter decomposition and the total mass loss at each site were calculated.

GG-4-2.0 SITE LOCATIONS

Eighteen test sites, one historically limed site and three reference sites were located radiating from current and historical smelter sources in Copper Cliff (seven test sites), Falconbridge (five test sites) and Coniston (six test sites and one historically limed site). Two test sites on the Coniston transect are adjacent to each other. CON-07 has been historically limed and re-greened whereas CON-08 has received no treatment. Both sites are included in this ranking report but CON-07, the historically limed and re-greened site is not included in the overall site ranking. A comparison of the litter decomposition at CON-07 and CON-08 are dealt with further under separate cover in Chapter 3, Section 3.14.2.

The test sites provided a range of metal concentrations in soil. The three reference sites had a variety of soil characteristics and plant communities, but only background metal concentrations. The locations of the test and reference sites are shown in Figure GG-4-2-1. During the litter bag study it was necessary to revisit the test sites on a regular basis throughout the year. Two of the test sites, CC-03 and CON-05, were located on company property in areas where the access was restricted without guided entry for safety reasons. As a result of the complexities of co-ordinating the site entry on a regular basis (a Vale or Xstrata Nickel personnel had to accompany the SARA Group field crew), litter decomposition was not assessed at these two sites.

Figure GG-4-2-1: Site Locations

REF-02
144
FB-03
FB-02
FB-06
FB-01
REF-04
FB-05
REF-03
CC-01
CC-04
CC-02
Falconbridge Stack
CON-01
CC-06
CON-02
CON-07
CC-07
CON-03
Copper Cliff Stack
Coniston Stack
CC-08
CON-08
CON-06
17
Leaf litter collection area
17
69

Features

- Test Site
- Reference Site
- Limed Site
- Lakes
- City Boundary
- **CC** Copper Cliff Site
- **CON** Coniston Site
- **FB** Falconbridge Site
- South Westerly Prevailing Wind

N
W
E
S

Scale 1:320,000

0 5 10 20 Km

Sudbury Soils Study | Étude des sols sudburois
metals • health • environment
métaux • santé • environnement

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GG-4-3.0 METHODS

To evaluate and rank decomposition at the test sites, the following general approach was followed:

- Place litter bags at sites, collect a subset at various times after placement, calculate mass loss of organic matter over time.
- Use mass loss to evaluate decomposition at reference sites.
- Use mass loss to determine decomposition rate constants (k = slope of regression line) for each site.
- Compare k-values from each test site against the k-value of the mean of the reference sites to rank the test sites.

The test site ranks provide an indication of the ability of the microbial communities at each site to decompose organic matter. This ranking approach was developed in consultation with a soil scientist (Dr. Mark St. John, Colorado State University) after evaluating various literature sources and with faculty at Laurentian University (Drs. Graeme Spiers and Peter Beckett). As with the rankings of all other LOE, the three categories were as follows:

Rank	Description	Comment
Green	Low to not impacted in comparison to the reference site mean	There was no difference between the rate of decmoposition or the amount of mass loss at the test site when compared to the mean of the reference sites.
Yellow	Moderately impacted in comparison to the reference site mean	The rate of decomposition or mass loss was impacted with respect to the the mean of the the reference sites.
Red	Severely impacted in comparison to the reference site mean	The rate of decomposition or mass loss was severely impacted with respect to the the mean of the reference sites.

The approaches taken to collect the data, evaluate the reference sites and rank the test sites are described in more detail in the following sections.

GG-4-3.1 Field Collection and Analysis

The approach used to construct, lay and analyze the litter bags is presented in Appendix GB9, Protocol 9, and is described in the preliminary results report produced by Mirarco, provided in Appendix GG-1b of Volume III. The methods used to construct, place and analyze the litter bags were based on the work of

Johnson and Hale (2004) and the European Guidance Document: *Effects of Plant Protection Products on Functional Endpoints in Soil (EPFES), Lisboa, 2002*. The selection of the test and reference sites and the characterization of the other lines of evidence are presented under separate cover (Sudbury Ecological Risk Assessment, Chapter 3). The decomposition study was conducted by the SARA Group in partnership with researchers from Mirarco who are affiliated with Laurentian University. Mesh litter bags filled with fresh white birch leaves (*Betula papyrifera* Marshall) were laid on the surface of the soil at 20 sites (three reference sites, 16 test sites and CON-07 the historically limed and re-greened site) representing a range of Cu and Ni concentrations in the soil. Subsets of the bags were picked up on five different occasions over the course of a year (October, 2004 to November, 2005). The mass of organic matter lost was determined on each occasion.

GG-4-3.2 Reference Site Evaluation

The results obtained from the three reference sites were evaluated to determine the following:

- Whether the amount of decomposition, as determined by mass loss at the reference sites, was adequate (*i.e.,* what could be expected in the Sudbury ecosystem); and
- Whether the degree of variability between the reference sites was acceptable.

The approaches to determining an acceptable amount of decomposition (within a certain time-frame) and variability are described further below.

Assessment of the Acceptable Amount of Decomposition and Test Duration

Few studies have been conducted to date using foliar litter bags placed on surface soils in forested areas in Canada. The majority of the literature and guidance documents pertain to bags buried in agricultural soils or with studies conducted in Europe. These studies and guidance documents served as a useful guide on how to approach the study design; however, direct comparison between decomposition rates in agricultural soils and forested regions is tenuous. As a result, study features such as the amount of decomposition that can be considered representative or the length of the study had to be determined by the SARA Group. The only directly comparable literature is the work of Johnson and Hale (2004), which was conducted in the Sudbury region, using a very similar approach. In their study, the maximum mass loss of organic matter in 12 months was just over 50% and no further increase in mass loss occurred between months 12 and 18. The EPFES guidance document recommends that the litter bag test continue until 60% decomposition occurs in the bags laid at the reference sites, or if this is not attained, then the

test should continue for one year. These test duration times and percent decomposition were established for buried bags in agricultural soils. The SARA Group set the duration time and percent decomposition for the Sudbury ERA decomposition study to be one year or 50% decomposition at the reference sites. These values were selected by considering the recommendations in the EPFES document and the study results obtained from an uncontaminated Sudbury site by Johnson and Hale (2004).

Assessment of Variability

The variability of the results from the reference sites was assessed by evaluating the percentage mass loss between the sites and the collection dates using an Analysis of Variance (ANOVA) followed by Tukey's HSD multiple comparison test.

If the variability is low then it can be concluded that the decomposition in the diverse forested regions represented by the reference sites is similar at all sites. If the variability is high then it can be concluded that differences in soil structure, forest cover, *etc.*, at each of the reference sites cause differing rates of decomposition, regardless of the fact that metal levels in the soil are at background concentrations. If variability between the reference sites was high, it was decided to calculate a mean reference value (REF_{mean}) for the three reference sites that could be compared to results from each of the test sites. The REF_{mean} provides a comparative value that can be considered reflective of the natural variability that exists between forested communities in northeastern Ontario.

GG-4-3.3 Approach to Ranking Test Sites

The decomposition results at each test site were compared to the REF_{mean} to determine whether the ability of microorganisms to decompose matter was affected by site conditions including soil metal content. The site was ranked as one of three categories: severely impacted (red), moderately impacted (yellow), or low to non impacted (green). This ranking was achieved by comparing the rate of decay, represented by the regression slope (k-values), between test sites and REF_{mean}

An ANOVA was used to establish the rank at each test site, which depended upon the significance level of the difference between the test site and REF_{mean}. The ranking procedure is illustrated in Figure GG-4-3-1, and is further explained in the following sections.

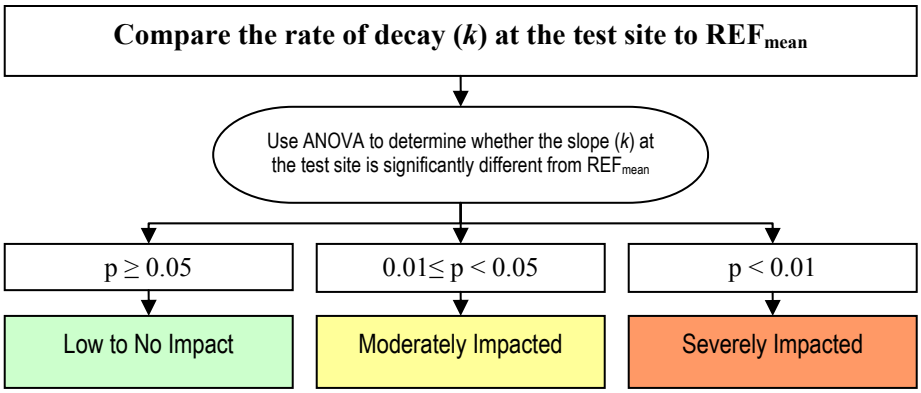


Figure GG-4-3-1 Litter Bag Ranking Approach Using ANOVA to Compare the Rate of Decay (*k*) at the Test Site to REF_{mean}

Decomposition rate constants (*k*) were calculated for each site using the dry weight remaining data. Decomposition over time was assumed to follow a simple single-exponential decay model where: $X_i/X_0 = e^{-kt}$ (Olson 1963). Trofymow et al. (2002) found the single-exponential decay model was a suitable functional form for describing the time-series data of white birch litter decomposition over 13 ecoclimatic provinces in Canada. Annual fractional weight losses (*k*; g dry weight/g dry weight/yr) were estimated by regression analysis using the following equation:

$$\ln(X_i/X_0) = -kt$$

where X_0 is the initial mass (dry weight)

X_i is the mass (dry weight) at time t

k is the decay constant (slope)

t is the time elapsed

Statistical comparison of the differences in decomposition rates between REF_{mean} and each site was determined to be the most objective approach to scoring the degree of site impact given the comparative, quantitative nature of the litter bag data. The approach taken for this was to use a standard ANOVA comparing regression slopes (*k*) (Dalgaard, 2002), where mass loss was the response variable of interest, time (cumulative days in the field) was the independent variable and site (test site vs. REF_{mean}) was a factor. The regression intercepts were set to zero since, by definition, there is no mass loss at time zero.

The significance level (*p*-value) of the difference between each site and REF_{mean} for *k* was used to rank the level of site impact:

P-values	Rank	Description
≥ 0.05	Green	Low to Not Impacted
0.01 ≤ *p* <0.05	Yellow	Moderately Impacted
< 0.01	Red	Severely Impacted

These cut-off *p*-values were chosen because of their well-established roles in statistics as indicators of the strength of evidence one has for determining differences as well as for being very conservative, thus minimizing type I errors (false positives, i.e. if a site is determined to be more impacted than it really is). It was determined that controlling for type II errors (false negatives, i.e. the case where a site is more impacted than the test implies) was not desirable (or even possible) since it would have been less conservative, requiring the estimation of the expected variance in the data and would require a much larger sample size than was logistically possible.

GG-4-4.0 RESULTS

In the following sections the suitability of the reference sites is described. The rate of decomposition (*k*) at all sites was compared to the reference sites and is presented below.

GG-4-4.1 Reference Site Evaluation

The fraction of initial white birch leaf mass remaining in litter bags at REF_{mean} is illustrated below as a function over time (days in field) in Figure GG-4-4-1.

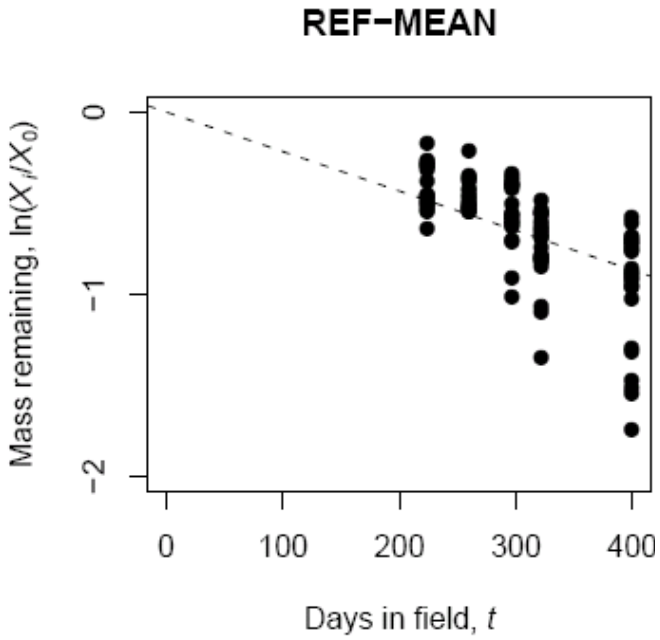


Figure GG-4-4-1 Fraction of initial White Birch Leaf Litter mass remaining ($ln(X_i/X_o)$) over time (days since bags deposited in field) at REF_{mean}

Assessment of the Mass Loss within One Year

As discussed in Section GG-4-2.2, for the test to be considered valid, a 50% mass loss was required at the reference sites after the bags were laid on the surface for one year. The mass loss at the three reference sites exceeded 50% therefore this criterion was met at the reference sites.

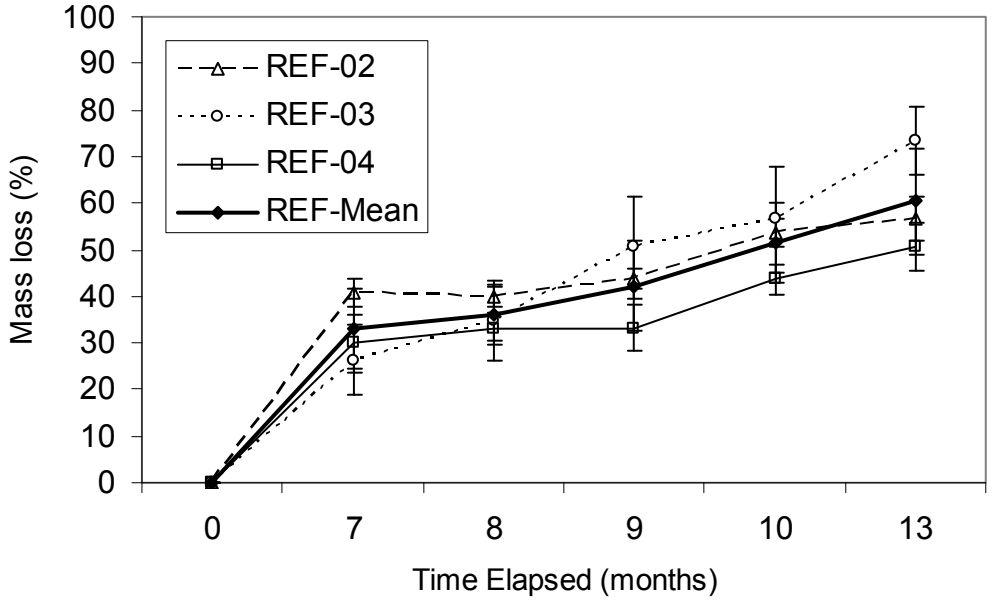
Assessment of Variability Among Reference Sites

The variability in plant species composition at the reference sites was reflected in the variability in mass loss and decomposition rates among the reference sites, typical for sites of mixed composition (Ostrofsky, 2007; Pandey *et al.*, 2007). After 13 months in the field, the final mass loss at REF-02, REF-03 and REF-04 was 57%, 73% and 51%, respectively. The accumulated mass loss at REF-03 exceeded the mass loss at REF-02 and REF-04 by 16% and 22%, respectively. The accumulated mass loss of white birch leaf litter at REF-04 was less (ANOVA: $F_{[2, 100]} = 6.620$, $P = 0.002$) than the accumulated mass loss of REF-02 and REF-03.

Decomposition rate (k) was highest at REF-03 (-0.930 ± 0.063, $R^2 = 0.88$), intermediate at REF-02 (-0.781 ± 0.016 $R^2 = 0.99$) and lowest at REF-04 (-0.608 ± 0.018 $R^2 = 0.97$). All regressions to calculate *k* were highly significant and of good fit to the data ($R^2 => 0.8$).

Establishment of REF_{mean}

A large variation in the final mass loss existed between the three reference sites. The reference sites each had different forested communities and different soil types (see Chapter 3 of the ERA for details). However, all three were found to be adequate reference sites when evaluated in terms of the nutrient status and binding capacity of the soils; the ability of plants to grow in the soil; and the plant community that existed at the sites. The variation between decomposition at these sites was used as an indicator of the natural decomposition variation within forested areas in northeastern Ontario. A mean of the mass loss of white birch leaf litter between the three reference sites results was calculated and referred to as REF_{mean}. The final mass loss for REF_{mean} (average of the three sites) was 60% and decomposition rate (*k)* was -0.792 ± 0.026. The REF_{mean} was used as the basis for subsequent comparisons of litter decomposition at each test site. REF_{mean} is shown graphically with the reference sites in Figure GG-4-4-2.



Note: Month 13 represents collections from October and November

Figure GG-4-4-2 Accumulated Mass Loss (% ± SD) of White Birch Leaf Litter at the Three Reference Sites Compared to REF_{mean}.

GG-4-4.2 Test Site Results

A full description of the accumulated mass loss for each test site is presented and discussed in the results report provided by MIRARCO (Appendix GG-4-1 of Volume III). The rates of decomposition at the test sites and REF_{mean} were calculated per day and per year. These results are summarized Table GG-4-4.1. The statistical evaluations used to rank the test sites are also presented in Table GG-4-4.1. A full table containing the *k* values and statistical evaluation are provided in Appendix GG-4-A.

The final ranking and the rationale for each rank are presented in individual summary tables later in this section.

Table GG-4-4.1 Statistical Comparisons to REF_{mean}

Comparison to REF_{mean}: Rate of Decomposition (*k* values)				Final LOE Rank
Site	*k* per day	*k* per year	p-value	
CC-01	-0.0017	-0.637	0.0056	Severely Impacted
CC-02	-0.0015	-0.545	0.0000	Severely Impacted
CC-04	-0.0020	-0.743	0.3747	Low to Not Impacted
CC-06	-0.0016	-0.531	0.0000	Severely Impacted
CC-07	-0.0017	-0.625	0.0029	Severely impacted
CC-08	-0.0018	-0.659	0.0187	Moderately Impacted
CON-01	-0.0016	-0.597	0.0005	Severely Impacted
CON-02	-0.0013	-0.464	0.0001	Severely Impacted
CON-03	-0.0013	-0.472	0.0000	Severely Impacted
CON-06	-0.0015	-0.562	0.0000	Severely Impacted
CON-07*	-0.0015	-0.549	0.0000	Severely Impacted
CON-08	-0.0007	-0.264	0.0000	Severely Impacted
FB-01	-0.0014	-0.500	0.0000	Severely impacted
FB-02	-0.0018	-0.646	0.0092	Severely Impacted
FB-03	-0.0018	-0.652	0.0133	Moderately Impacted
FB-05	-0.0019	-0.686	0.0628	Low to Not Impacted
FB-06	-0.0017	-0.605	0.0010	Severely Impacted
REF_{mean}	-0.0022	-0.792		

*CON-07, the historically limed and re-greened site, was ranked at the LOE level, but was not given an overall site rank.

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Figure GG-4-4-3: Decomposition LOE Overall Site Ranking

FB-03
FB-02
FB-05
FB-06
FB-01
Falconbridge Stack
CON-01
CC-04
CC-02
CON-02
CC-06
CC-01
CON-07
CON-03
CC-08
Copper Cliff Stack
Coniston Stack
CC-07
CON-08
CON-06
144
17
17
69
Leaf litter collection area

Features

Decomposition Ranking

- Severely Impacted
- Moderately Impacted
- Slightly Impacted to No Impact
- Test Site
- Limed Site
- Lakes
- City Boundary
- **CC** Copper Cliff
- **CON** Coniston
- **FB** Falconbridge
- South Westerly Prevailing Wind

N
W
E
S

Scale 1:300,000

0 5 10 20 *Km*

Sudbury Soils Study | Étude des sols sudburois
metals • health • environment
métaux • santé • environnement

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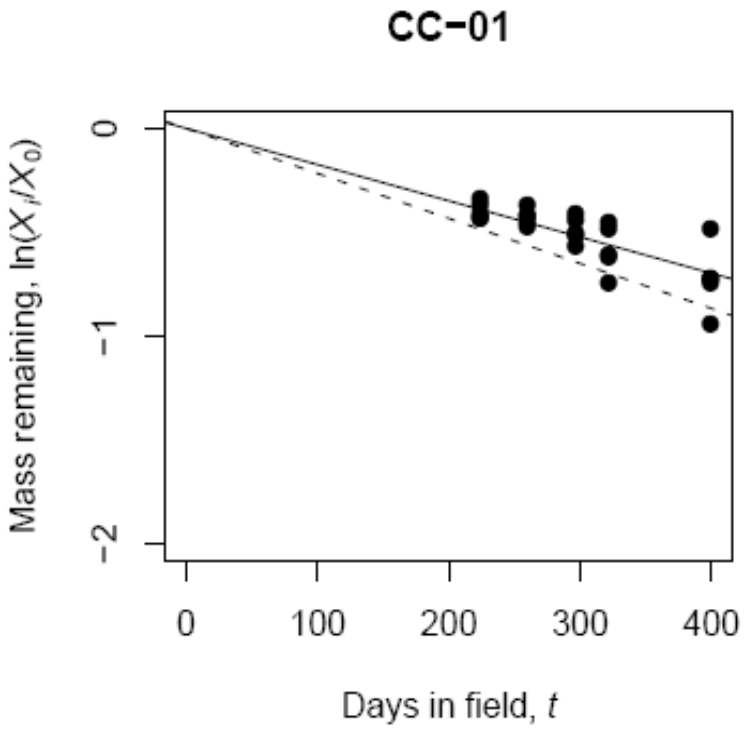
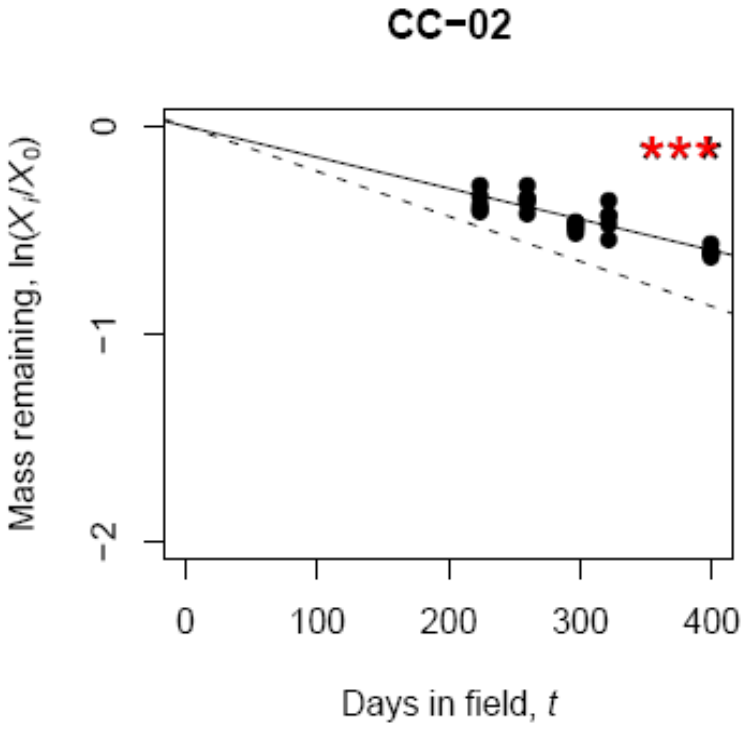
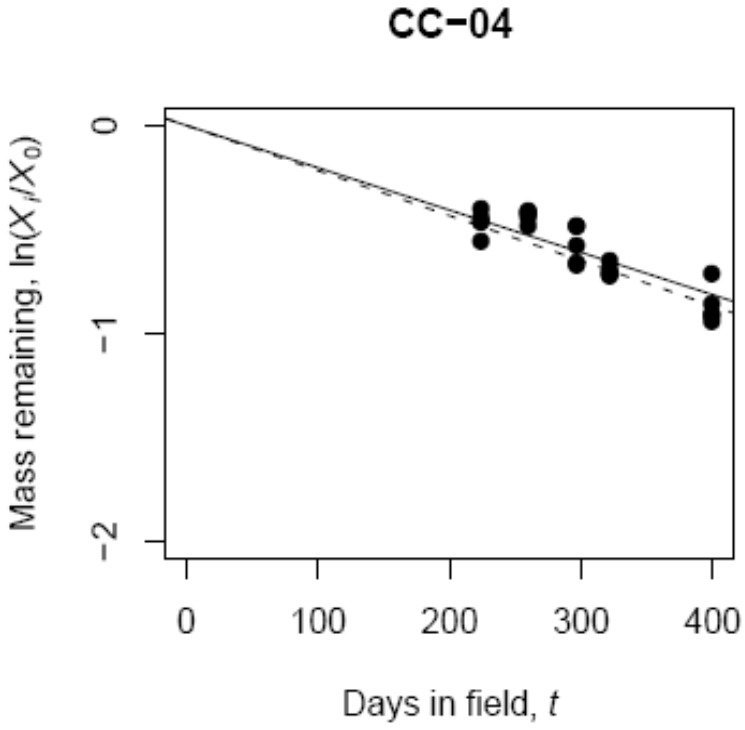
CC-01: Ranked Severely Impacted		
Parameters	**Rank**	**GG-4-5.0 COMMENTS**
Rate of Decomposition slope (k)	**Red**	Rate of decomposition (k) was significantly lower at CC-01 than REF_{mean}, indicating a severe impact ($p<0.01$) on this ecosystem function that will lead to increasingly larger differences in total decomposition over time.



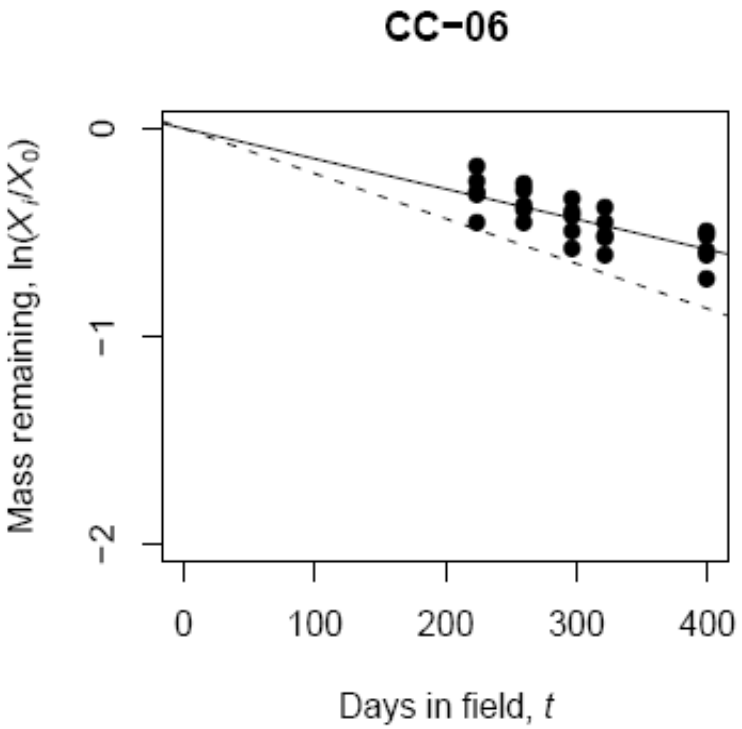
CC-02: Ranked Severely Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Red**	Rate of decomposition (k) was significantly lower at CC-02 than REF_{mean}, indicating a severe impact ($p<0.01$) on this ecosystem function that will lead to increasingly larger differences in total decomposition over time.



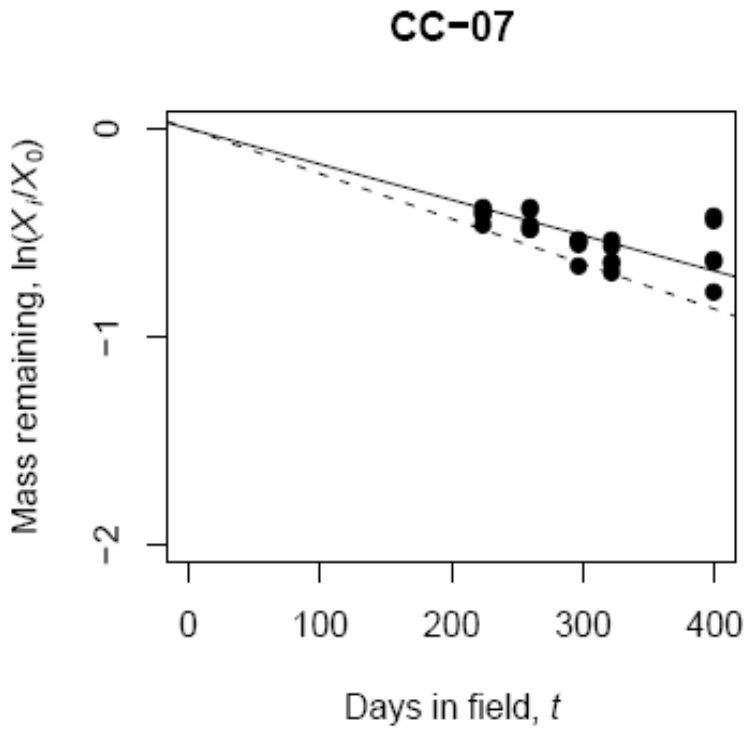
CC-04: Ranked Low to Not Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Green**	Neither rate of decomposition (k) nor total annual decomposition was significantly different between CC-04 and REF_{mean}, indicating low to no impact at CC-04.



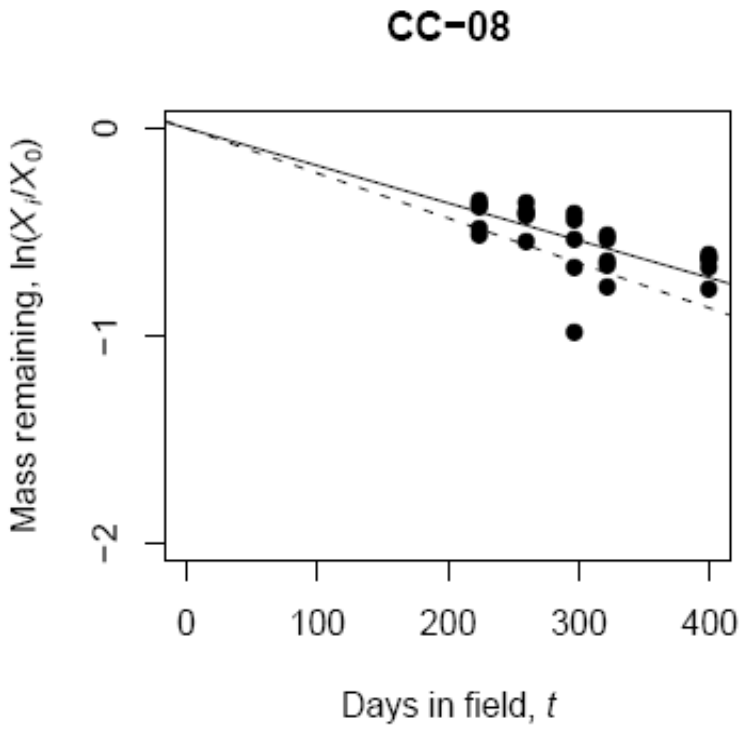
CC-06: Ranked Severely Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Red**	Rate of decomposition (k) was significantly lower at CC-06 than REF_{mean}, indicating a severe impact ($p<0.01$) on this ecosystem function that will lead to increasingly larger differences in total decomposition over time.



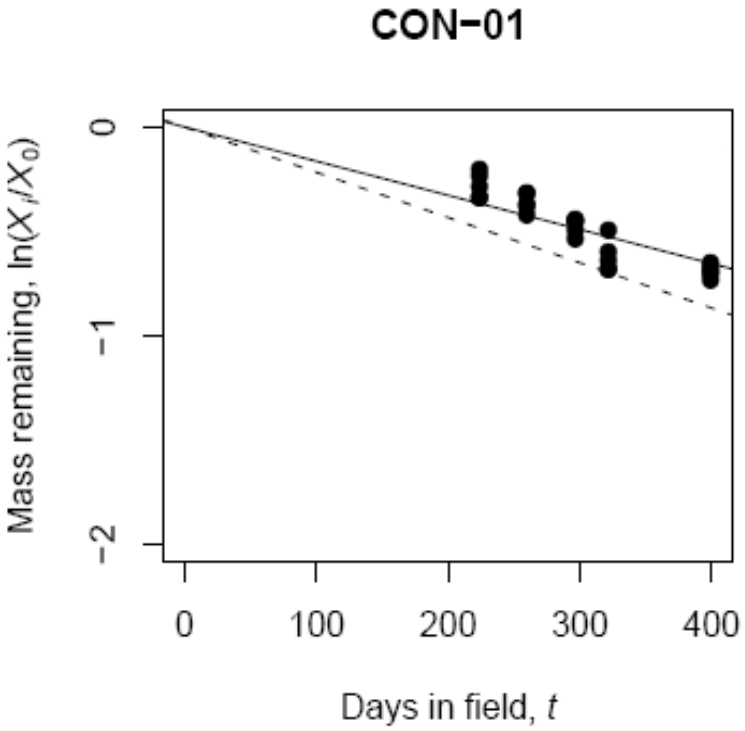
CC-07: Ranked Severely Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Red**	Rate of decomposition (k) was significantly lower at CC-07 than REF_{mean}, indicating a severe impact ($p<0.01$) on this ecosystem function that will lead to increasingly larger differences in total decomposition over time.



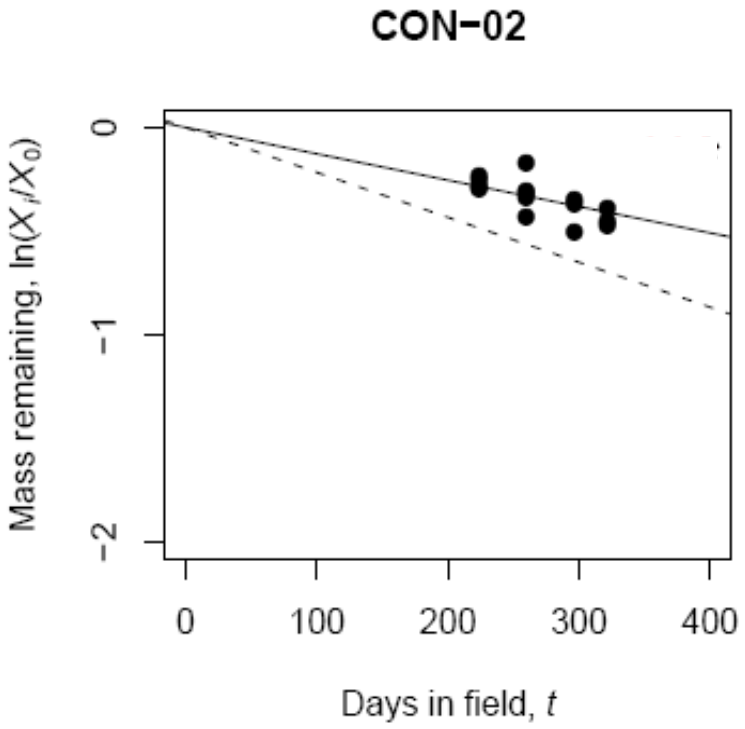
CC-08: Ranked Moderately Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Yellow**	Rate of decomposition (k) was significantly lower at CC-08 than REF_{mean}, indicating a moderate impact ($0.01<p<0.05$) on this ecosystem function that will lead to increasingly larger differences in total decomposition over time.



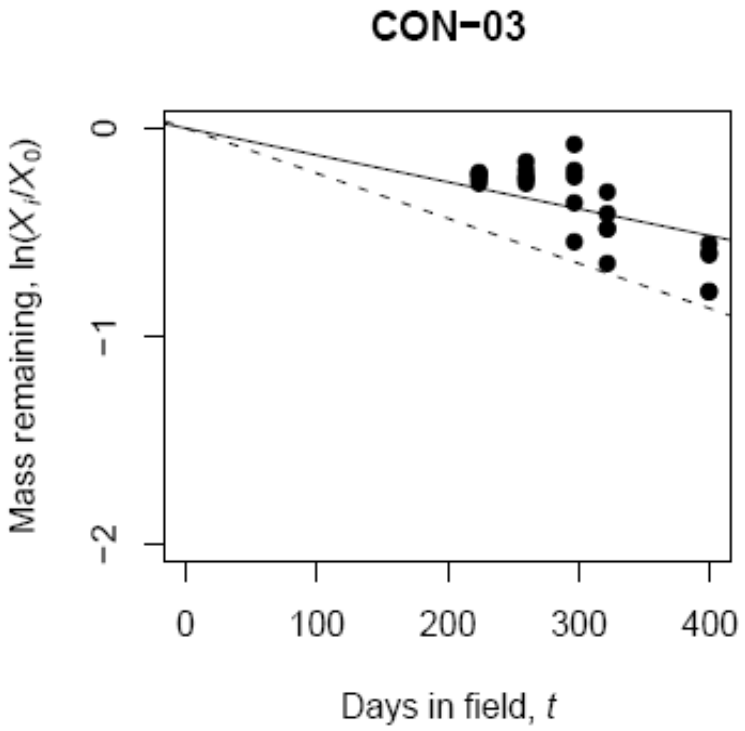
CON-01: Ranked Severely Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Red**	Rate of decomposition (k) was significantly lower at CON-01 than REF_{mean}, indicating a severe impact ($p<0.01$) on this ecosystem function that will lead to increasingly larger differences in total decomposition over time.



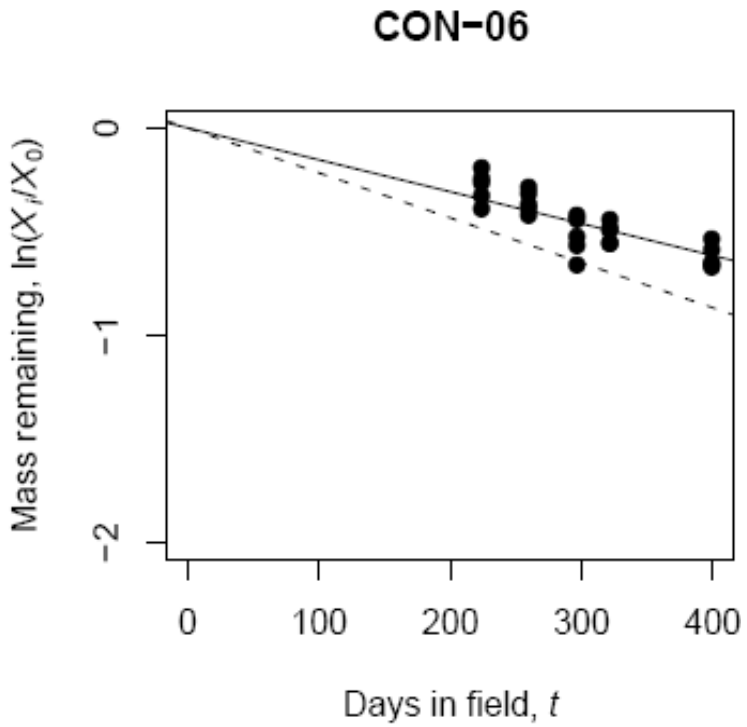
CON-02: Ranked Severely Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Red**	Rate of decomposition (k) was significantly lower at CON-02 than REF_{mean}, indicating a severe impact ($p<0.01$) on this ecosystem function that will lead to increasingly larger differences in total decomposition over time.



CON-03: Ranked Severely Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Red**	Rate of decomposition (k) was significantly lower at CON-03 than REF_{mean}, indicating a severe impact ($p<0.01$) on this ecosystem function that will lead to increasingly larger differences in total decomposition over time.

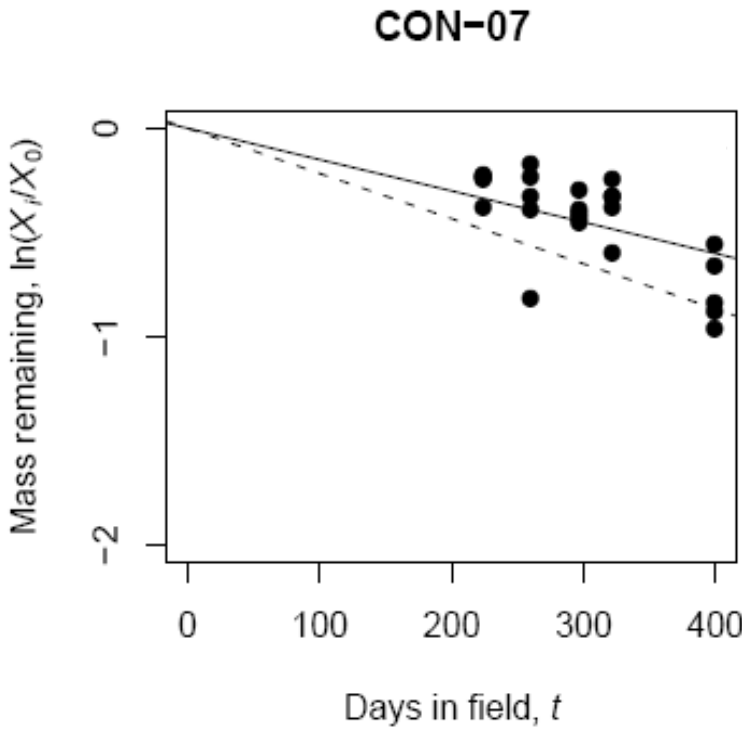


CON-06: Ranked Severely Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Red**	Rate of decomposition (k) was significantly lower at CON-06 than REF_{mean}, indicating a severe impact ($p<0.01$) on this ecosystem function that will lead to increasingly larger differences in total decomposition over time.

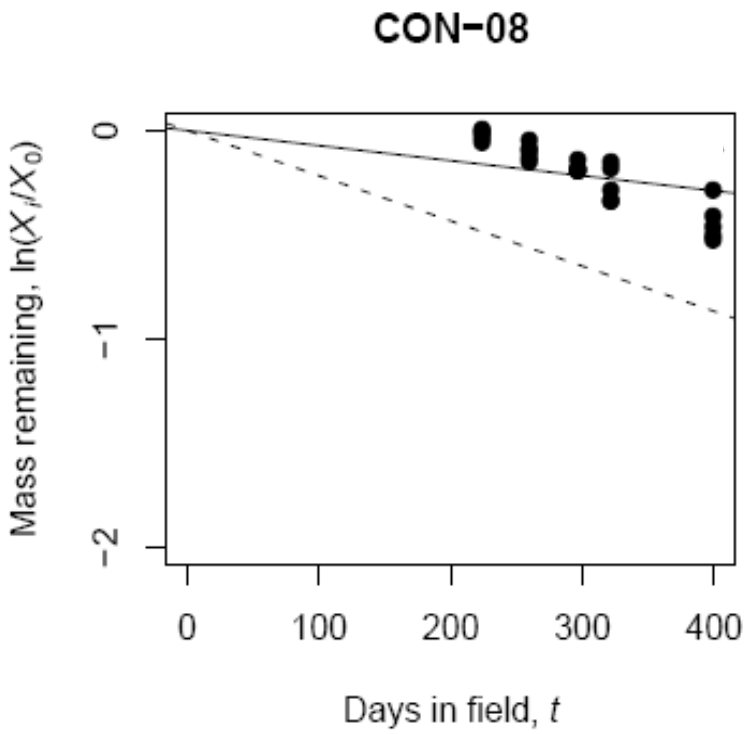


CON-07*: Ranked Severely Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Red**	Rate of decomposition (k) was significantly lower at CON-07 than REF_{mean}, indicating a severe impact ($p<0.01$) on this ecosystem function that will lead to increasingly larger differences in total decomposition over time.

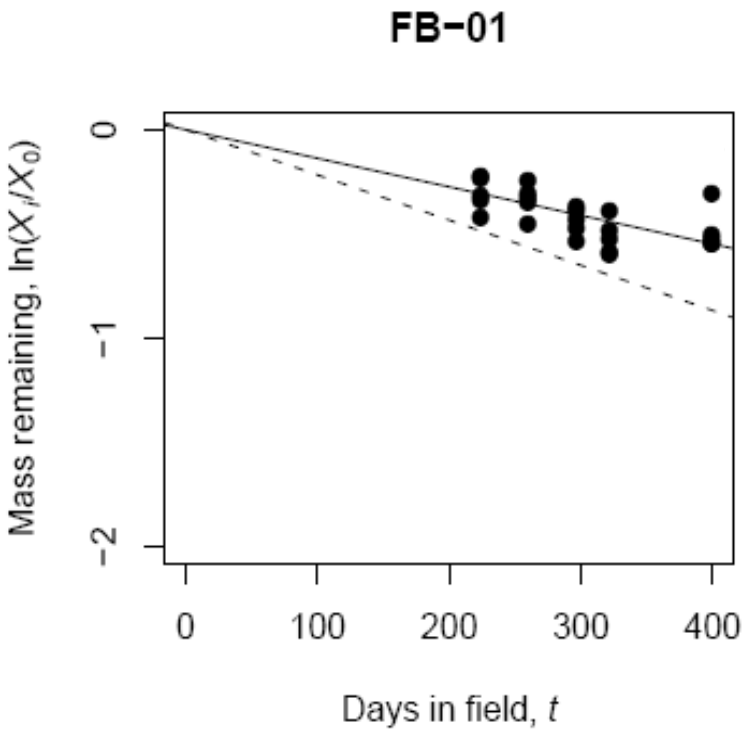
* CON-07, the historically limed and re-greened site, was ranked at the LOE level, but was not given an overall site rank.



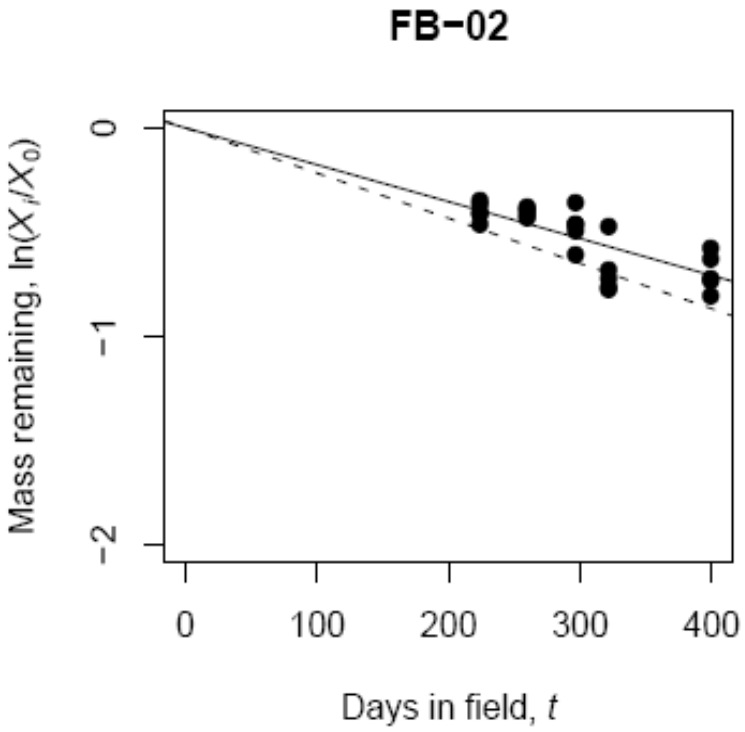
CON-08: Ranked Severely Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Red**	Rate of decomposition (k) was significantly lower at CON-08 than REF_{mean}, indicating a severe impact ($p<0.01$) on this ecosystem function that will lead to increasingly larger differences in total decomposition over time.



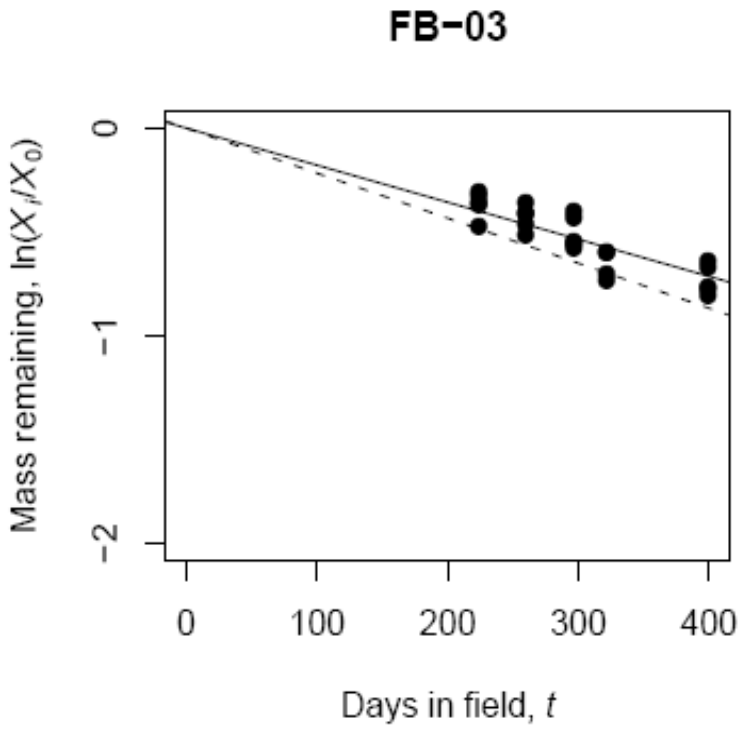
FB-01: Ranked Severely Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Red**	Rate of decomposition (k) was significantly lower at FB-01 than REF_{mean}, indicating a severe impact ($p<0.01$) on this ecosystem function that will lead to increasingly larger differences in total decomposition over time.



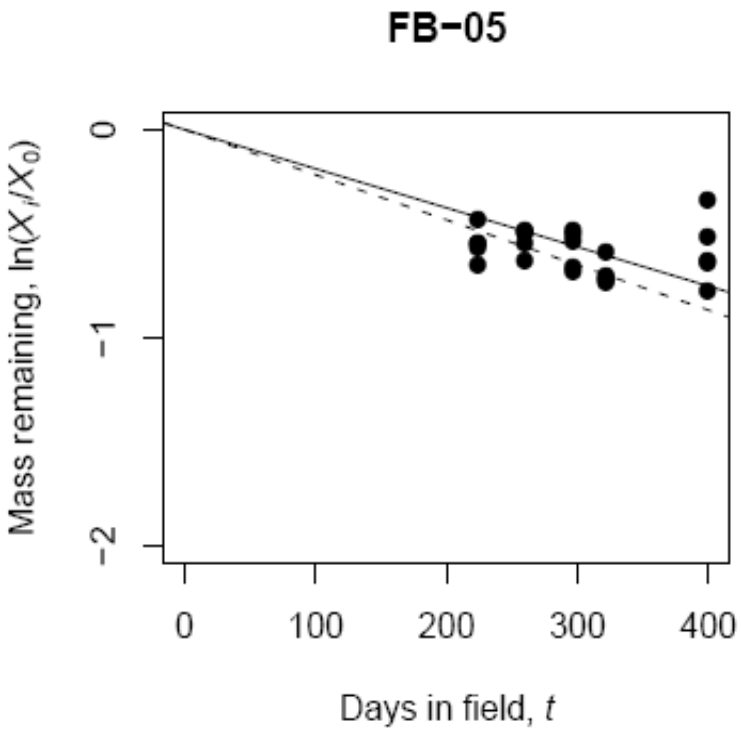
FB-02: Ranked Severely Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Red**	Rate of decomposition (k) was significantly lower at FB-02 than REF_{mean}, indicating a severe impact ($p<0.01$) on this ecosystem function that will lead to increasingly larger differences in total decomposition over time.



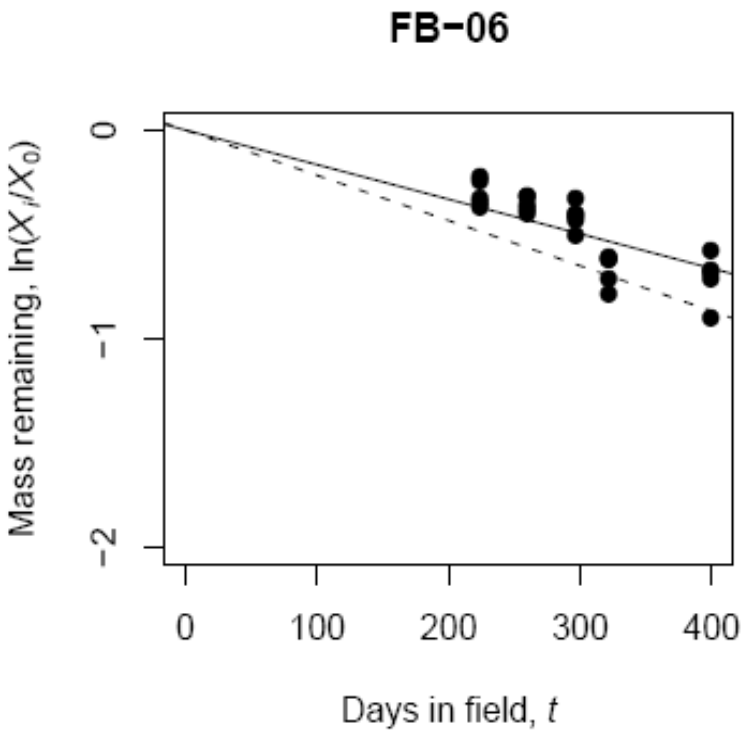
FB-03: Ranked Moderately Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Yellow**	Rate of decomposition (k) was significantly lower at FB-03 than REF_{mean}, indicating a moderate impact ($0.01<p<0.05$) on this ecosystem function that will lead to increasingly larger differences in total decomposition over time.



FB-05: Ranked Low to Not Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Green**	Neither rate of decomposition (k) nor total annual decomposition was significantly different between FB-05 and REF_{mean}, indicating low to no impact at FB-05.



FB-06: Ranked Severely Impacted		
Parameters	**Rank**	**Comments**
Rate of Decomposition slope (k)	**Red**	Rate of decomposition (k) was significantly lower at FB-06 than REF_{mean}, indicating a severe impact ($p<0.01$) on this ecosystem function that will lead to increasingly larger differences in total decomposition over time.



GG-4-6.0 UNCERTAINTY ANALYSIS

The litter bag analysis, while conclusive in its assessment of decomposition at each of the 22 field sites does have associated uncertainty. A summary of the specific uncertainties is provided below.

- The study of decomposition using litter bags is in the process of being standardized (OECD, 2006 – in draft), and its application includes contaminated lands. Without the option of a standardized test, background levels and documented natural variability were not available. This was made apparent with REF-04. REF-04 was a conifer site and therefore had a completely different faunal assemblage and therefore a lower decomposition capacity than the other reference sites. REF-04 was included as a reference site, for the purposes of transparency, and the reference rate of decomposition was taken as the average of the three sites.
- Unlike the other LOEs where many factors are considered in the overall ranking, the litter bag analysis takes into account one (decomposition). For this reason, the litter bag LOE received less weighting as compared to the other three.
- There are a number of factors that affect the results of the litter bag studies (not solely biological): temperature, wind, rain and snow cover, freezing and thawing, shade, sun and UV radiation – all contribute to desiccation and break-up of leaf litter materials. We could not discriminate between the biological and physical processes that contribute to decomposition. Instead, as we were comparing the test sites to the reference sites, the approach to take both into consideration at all sites negated the need for separation.

GG-4-7.0 CONCLUSIONS

The test sites were compared to the mean of the reference sites and a final ranking was obtained based on a ranking approach. With the exception of sites CC-04 and FB-05, the decomposition at all of the test sites evaluated was ranked either moderately or severely impacted when compared to the decomposition at the reference sites. These results provide a ranking for one of four lines of evidence evaluated as part of Step 1 of Objective #1 of the Sudbury ERA.

GG-4-8.0 REFERENCES

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APPENDIX GG4-A

LITTER BAG ASSESSMENT RESULTS

Table GG4-A.1 Statistical Comparisons to REF_{mean}

Comparison to REF_{mean}: Rate of Decomposition (k values)									
Site	*k* per day	Std. Error	*k* per year	% reduction	Std. Error	F-value	p-value	Significance	Final LOE Rank
CC-01	-0.0017	0.00006	-0.637	19.6	0.022	7.95	0.0056	**	Severely Impacted
CC-02	-0.0015	0.00004	-0.545	31.2	0.013	20.73	0.0000	***	Severely Impacted
CC-04	-0.0020	0.00005	-0.743	6.2	0.019	0.79	0.3747		Low to Not Impacted
CC-06	-0.0016	0.00006	-0.531	32.9	0.020	22.63	0.0000	***	Severely Impacted
CC-07	-0.0017	0.00006	-0.625	21.1	0.023	9.20	0.0029	**	Severely impacted
CC-08	-0.0018	0.00008	-0.659	16.8	0.030	5.67	0.0187	*	Moderately Impacted
CON-01	-0.0016	0.00005	-0.597	24.6	0.020	12.63	0.0005	***	Severely Impacted
CON-02	-0.0013	0.00006	-0.464	41.4	0.023	17.72	0.0001	***	Severely Impacted
CON-03	-0.0013	0.00009	-0.472	40.4	0.034	32.12	0.0000	***	Severely Impacted
CON-06	-0.0015	0.00005	-0.562	29.1	0.019	17.73	0.0000	***	Severely Impacted
CON-07*	-0.0015	0.00011	-0.549	30.7	0.042	17.86	0.0000	***	Severely Impacted
CON-08	-0.0007	0.00008	-0.264	66.7	0.028	90.11	0.0000	***	Severely Impacted
FB-01	-0.0014	0.00006	-0.500	36.8	0.022	28.18	0.0000	***	Severely impacted
FB-02	-0.0018	0.00006	-0.646	18.4	0.023	7.00	0.0092	***	Severely Impacted
FB-03	-0.0018	0.00005	-0.652	17.7	0.019	6.31	0.0133	*	Moderately Impacted
FB-05	-0.0019	0.00009	-0.686	13.3	0.033	3.52	0.0628		Low to Not Impacted
FB-06	-0.0017	0.00007	-0.605	23.6	0.027	11.34	0.0010	**	Severely Impacted
REF_{mean}	-0.0022	0.00007	-0.792		0.026				

*CON-07 is the historically limed and re-greened site. It is not included in the final site ranking.