Addition of New Cover Crop Species with Nitrogen Reduction Efficiencies

New Cover Crop Species Proposed:

- **Annual Ryegrass**
- **Annual Legumes**
- **Annual Legume plus Grass Mixtures**
- **Brassica (winter hardy)**
- **Forage Radish**
- **Forage Radish plus Grass Mixtures**
- **Triticale**
- **Oats (winter hardy)**
- **Oats (winter killed)**

Recommendations for Approval by the Water Quality Goal Implementation Team's Watershed Technical and Agricultural Workgroups

Introduction

Cover crops are one of the most valuable management practices available for protecting water quality, especially groundwater quality, which is a difficult resource to protect from non-point sources of soluble nutrients like nitrate nitrogen. Cover crops entered the Bay Model in 1997 and have been strongly endorsed by NRCS, State Environmental and Agricultural Agencies, and farm-producer advocacy groups like the Farm Bureau and The American Farmland Trust. More importantly, they have been widely adapted by producers across the Bay Watershed because in addition to conserving expensive nitrogen (N), they provide other benefits such as adding soil organic matter, improving soil structure, and improving soil health. There are also some habitat benefits provided by an actively growing off-season crop compared to the traditional fallow-weed cover, as well as some social benefits derived from seeing landscapes remaining "green" during the fall-spring seasons. However, the water quality benefits for N were the singular point of emphasis being considered by the panel for the new species.

This document summarizes the recommendations of the 2012 Cover Crop Expert Panel for New Species with accompanying Nitrogen Reduction Efficiencies. The Panel's membership was:

Panelist	Affiliation
Andy Clark	Univ. of Maryland, Sustainable Agriculture Research & Education
Barbie Elliott	West Virginia Conservation Agency
Charlie White	Penn State University

Chris Lawrence	USDA Natural Resources Conservation Service, Virginia
Dean Hively	USDA & U.S. Geologic Survey
Patrick Bowen	USDA Natural Resources Conservation Service, West Virginia
Jamie Ulrich	Pennsylvania Department of Agriculture
Ken Staver	University of Maryland
Mark Goodson	USDA Natural Resources Conservation Service, Pennsylvania
Paul Salon	USDA Natural Resources Conservation Service, New York
Quirine Ketterings	Cornell University
Ray Weil	University of Maryland
Robert Baldwin	Delaware Dept. of Natural Resources & Environmental Control
Ron Hoover	Penn State University
Royden Powell	Maryland Department of Agriculture
Sjoerd Duiker	Penn State University
Tim Sexton	Virginia Department of Conservation and Recreation
Wade Thomason	Virginia Tech
Jack Meisinger	USDA Agricultural Research Service (Panel Chair)
Mark Dubin	University of Maryland (Panel Coordinator)
Technical support by Steve Dressing, Don Meals, Jennifer Ferrando (TetraTech), Jeff Sweeney (EPA CBPO), Matt Johnston (UMD CBPO) and Emma Giese (CRC).	

Practice Definition

The new cover crop species will be added within the existing Traditional Cover Crop definition, no modifications of the existing definition are being recommended at this time.

This practice is recommended for revision because the existing species of rye, wheat, and barley do not adequately capture the diversity and extent of current cover crop practices being deployed in the Watershed.

The purpose of this revision is to allow the Bay Model to better represent current cover crop cultural practices and acreages, which have significantly expanded since 2007 when the Cover Crop BMP was last revised.

The purpose of the cover crop practice is to reduce nutrient losses to ground and surface water by sequestering them in a short-term crop grown after the main cropping season. The sub-categories are the cover crop species, the planting time, and the seeding method.

This practice meets the criteria standards under the USDA-NRCS National Handbook of Conservation Practices (NHCP) (http://directives.sc.egov.usda.gov/viewerFS.aspx?hid=22299) and the Field Office Technical Guides (http://www.nrcs.usda.gov/technical/efotg/) for each state.

Effectiveness Estimates with Brief Justification

The N Effectiveness estimates are the only water quality parameter included for the new species because: 1) cover crops primarily function to trap or sequester N, with only minor reductions for phosphorus (P) and sediment (S); and 2) there are very few conservation-tillage era studies on surface runoff losses of P or S reductions for cover crops. Hence, a place holder, or interim, value of "0" will be used for the P and S effectiveness estimates for all new species, which will be replaced later with the Panel's recommended values derived from best available data or from estimates provided from an independent agricultural model such as APEX.

Relative Nitrogen Reduction Efficiency (RNRE) Estimates

The RNRE estimates for the new species were all derived from replicated field studies using peer reviewed papers, current Land Grant University (LGU) cover crop or forage species trials, graduate student theses, or outside grant research projects at LGUs. Each of these trials was required to have a rye treatment with either total N or ^{15}N uptake, or dry matter, measured in the spring at a time when a traditional cover crop would be terminated, or in the fall if the cover crop was not winter hardy. The presence of the rye N uptake or dry matter data provided a watershed wide "internal standard" that allowed *a direct comparison of each new species with rye, within each individual study*. This comparison involved simply calculating the ratio of the quantity of total N or ^{15}N uptake, or dry matter, in the new species to the corresponding measurement in rye, this ratio (e.g. = (total N uptake)$_{\text{species 'A'}}$ / (total N uptake)$_{\text{rye}}$) defines the term "Relative Nitrogen Reduction Efficiency (RNRE)" used throughout this report, with the word "relative" in this context meaning "relative to rye". The Panel calculated the final RNRE for each new species from the average of applicable individual studies. Further details and examples of calculating the RNREs are in Appendix A.

A second major advantage of comparing all the new species to rye is that the Bay Model calibration already includes rye as a cover crop. Thus, the final N Effectiveness estimate for each new species can be made by simply multiplying the RNRE (defined above) by the existing value of the rye N Effectiveness (which is already in the Model with adjustments for spatial scale-up from plot to field, and adjustments for the hydrologic partitioning of N losses to ground water vs. surface runoff). Using the RNREs with the current rye N Effectiveness values thus eliminates the need to recalibrate the model for the new species (Pers. Comm. Jeff Sweeney, 4-24-2013). Further details and examples of calculating the final N Effectiveness values for the new species are given below and in Appendix A.

A summary of the RNREs for each new species and relevant species mixtures are listed in Table 1. An example interpretation of the RNRE values is that, on average, the total N uptake of Annual Ryegrass was 66% of the corresponding rye N uptake.

Table 1. Average RNRE, number of individual studies contributing to the average, and recommended planting times for the new cover crop species and species mixtures. Seeding methods are not listed because every new species will utilize existing seeding methods of drilled, other, aerial/soybean, and aerial/corn according to the existing relative relations between these seeding methods in the current model.

Proposed New Species or Species Mixtures	Relative Nitrogen Reduction Efficiency (relative to Rye)	Number of Individual Studies	Recommended Planting Time [1]
Annual Ryegrass	0.66	5	Early and Normal
Annual Legume	0.16	4	Early and Normal
Annual Legume + Grass	Avg. (0.16 + Avg. Grass)	NA	Early and Normal
Brassica (winter hardy)	0.70	13	Early only
Forage Radish	0.58	12	Early only
Forage Radish + Grass	Avg. (0.58 + Avg. Grass)	NA	Early and Normal
Triticale	0.86	10	Early, Normal, Late
Oats (winter hardy)	0.55	11	Early and Normal
Oats (winter killed)	0.40	4	Early only

[1] Early is more than two weeks before the average frost date, Normal is between the average frost date and two weeks before that date, Late is within three weeks after the average frost date.

Some noteworthy observations from Table 1 are that annual legumes are the poorest at recovering N compared to rye, but if they are grown in a grass mixture the recovery improves substantially (see discussion below for Table 2). The grass’s contribution to the mixtures utilized a “generic grass” that is an average value across all grass species in the model. Thus, the credit for an annual legume plus grass mixture will be considerable above the legume value because all the grass covers contribute substantial N savings compared to the legumes. A pure stand of forage radish, over the course of the entire fall-spring (Sept to late-April) cover crop season, is credited with recovering about 58% as much N as pure rye, which includes the likely loss of N after the forage radish is killed by frost (commonly in mid-late Dec.) followed by decomposition of the radish residues with no growing cover-crop present. However, a cover crop made up of a forage radish plus grass provides a continuous growing cover-crop that can trap N released by radish decomposition, which is also taken into account by utilizing a “generic grass” derived as described above for legume-grass mixtures. This approach increases the credit for radish-grass mixtures somewhat because most grass species, except oats, have higher N recoveries that radish. The grouped winter-hardy Brassica species have a higher RNRE of 0.70 compared to forage radish because they are not killed by frost and maintain an actively growing crop throughout the winter. The total N uptake of Triticale was about 85% of the corresponding rye N uptake and the N credit of winter-hardy Oats was 55% of rye, while the N credit for the winter-killed oats was 40%, which adjusts for likely loss of some N during decomposition of oat residues in the winter-spring seasons.

The recommended planting periods for each of the new species are also listed in Table 1. The Panel recommended these dates based on the agronomic optimums for establishing each species, with particular attention given to the last planting dates that would likely produce acceptable growth and avoid seeding failure.

Recommended N Effectiveness Estimates

The Relative N Reduction Efficiencies from Table 1 form the basis for estimating the final N Effectiveness estimates for the Phase 5.3.2 update of the Model. Table 2 illustrates this calculation process for each new species or mixture. Table 2 also allows comparisons of two planting-date windows (early vs. normal), and two establishment methods (drill seeded vs. aerial seeding into soybeans).

Table 2. Examples of new cover crop species, and cover crop mixtures, Relative N Reduction Efficiencies and final N Effectiveness values for selected planting and seeding methods in the Coastal Plain, Piedmont, or Karst physiographic regions of the Bay Model. A complete listing of the N Effectiveness values is given in Appendix B.

Proposed New Species, or Reference Species (i.e. Rye)	Relative Nitrogen Reduction Efficiency (relative to rye)	Final Nitrogen Effectiveness Phase 5.3.2
----------- Early planting by Drill seeding (high soil contact) -----------		
Annual Ryegrass (ARG)	0.66	0.30
Annual Legume	0.16	0.07
Annual Legume + Grass	Avg. (0.16 + Avg. Grass)	0.20

Brassica (winter hardy)	0.70	0.32
Forage Radish	0.58	0.26
Forage Radish + Grass	Avg.(0.58 + Avg. Grass)	0.29
Triticale	0.86	0.39
Oats (winter hardy)	0.55	0.25
Oats (winter killed)	0.40	0.18
Rye (Ref. Species)	1.00	0.45
------ Early planting, Aerial seeding in Soybeans (low soil contact) ------		
Annual Ryegrass (ARG)	0.66	0.20
Annual Legume	0.16	0.05
Annual Legume + Grass	Avg. (0.16 + Avg. Grass)	0.14
Brassica (winter hardy)	0.70	0.22
Forage Radish	0.58	0.18
Forage Radish + Grass	Avg.(0.58 + Avg. Grass)	0.20
Triticale	0.86	0.27
Oats (winter hardy)	0.55	0.17
Oats (winter killed)	0.40	0.13
Rye (Ref. Value)	1.00	0.31
---------- Normal planting by Drill seeding (high soil contact) ----------		
Annual Ryegrass (ARG)	0.66	0.27
Annual Legume	0.16	0.06
Annual Legume + Grass	Avg. (0.16 + Avg. Grass)	0.19
Brassica (winter hardy)	NA[1]	NA
Forage Radish	NA[1]	NA
Forage Radish + Grass	NA[1]	NA
Triticale	0.86	0.35
Oats (winter hardy)	0.55	0.23
Oats (winter killed)	NA[1]	NA
Rye (Ref. Value)	1.00	0.41

[1] Only recommended for early planting time, not for normal planting time.

Calculating the final N Effectiveness values for each new species simply involves multiplying the RNRE for each new species by the corresponding Rye N Effectiveness value that is currently in the calibrated model. For example, in the Atlantic Coastal Plain, Piedmont, or Karst regions an early-seeded cover crop of Annual Ryegrass using a drill would be assigned a final N Effectiveness value of 0.30 (= (0.66 for ARG)*(0.45 for Rye planted early by drill)). It is interesting to note in Table 2 that the triticale (which is a cross between rye and wheat) N Effectiveness value of 0.39 (as estimated through the RNRE approach) agrees very well with the prior N Efficiency averages for Rye (=0.45) and Wheat (=0.31), which provides a rye-wheat average of 0.38 for early-planted drilled covers. The N Effectiveness values were first calculated for all pure stand entries, followed by estimation of the N Effectiveness's for the mixtures. Calculating the mixture N Effectiveness's, for example an Annual Legume plus Grass mixture, first involves averaging the N Effectiveness values across all the grass species in the model (rye, wheat, barley, annual ryegrass, triticale, winter-hardy oats, and winter-killed oats), which is 0.32 for all early-planting drilled grasses, and then averaging the annual legume N Effectiveness of 0.07 with the average grass value, to produces a final N Effectiveness for the legume-grass mixtures of 0.20 (= average of 0.32 and 0.07, rounded off). The results of corresponding calculations of N Effectiveness are illustrated in Table 2 for two other seeding methods (drilled vs. aerial seeding into soybean) and two other planting times (early vs. normal) with each scenario based on the current Rye N Effectiveness value that is already in the model for the corresponding planting seeding methods and planting periods.

The Panel recommends maintaining the Aerial seeding category as two separate classes, one for soybean and one for corn, for the new species and species mixtures. This recommendation resulted from a lack of data to reject the proposition that any of the new species differed from the cereal grains in their aerial establishment success, and that aerial seeding into soybeans is generally more successful than into corn, as documented in the previous Cover Crop Panel Report (MAWQP. 2007. Reduction for Aerial Seeding. p. 110-113).

Description of New Species and Estimation of RNRE

This section provides a short description of each new species or mixture, and a summary of how the RNRE for each new entry was developed. Appendix A contains a detailed description of the specific literature sources and the calculations of the RNRE for each new species or mixture.

Annual Ryegrass

Annual Ryegrass, also known as Italian Ryegrass, is a cool season annual grass that does a good job of accumulating nutrients, although it does not grow as well as rye during the colder months in the Bay watershed. It has an extensive soil holding root system that establishes quickly, which is the basis for its reputation as a soil erosion fighter. It is a common component of mixtures, where it is often aerial seeded (USDA, SARE 2007).

The Panel utilized five individual studies from within the Bay watershed to estimate the RNRE; two from PA, two from MD, and one from NY. All studies were planted in the early- or normal-planting period and all harvests were in mid-April to early-May (MD and PA), or in mid-May (NY), which is consistent with spring crop development.

The five site-years of data were summarized by calculating a simple weighted average (each mean was weighted by the number of site-years it contained), which produced a final weighted average RNRE of 0.66 that is listed in Tables 1 and 2.

A summary of the studies and methods to estimate the Annual Ryegrass RNRE follows:

a) The PA data (Houser et al.,2012 & 2013) were from the "Short-lived cool-season forage trial" planted in 2011 and 2012 that received 30 lbs starter-N/ac in the fall and 100 lbs N/ac in the spring for all entries, including the rye reference entry. The PA data consisted of the yearly average total N uptake across five annual ryegrass varieties that were all present in 2011 and 2012, which contributed two individual site-years of data having an average RNRE of 0.77.

b) The MD data were from the peer-reviewed publication of Shipley et al, (1992) that added a luxury amount of ^{15}N labeled fertilizer to corn and measured the fall residual soil ^{15}N, followed by establishment of fall cover crops of annual ryegrass and rye, and measurement of the ^{15}N in these covers the following spring. This study was conducted in the 1986-87 and 1987-88 cover crop seasons on the Eastern Shore of MD. The average RNRE from these two site-years was 0.68.

c) The NY data are from an unpublished NRCS study in 2010 that evaluated cover crop planting dates (three Sept. planting dates) that compared spring dry matter (DM) production from annual ryegrass to that of rye. The Panel chose to accept DM data as a surrogate for total N uptake since annual ryegrass and rye are both cool-season grasses, and because the NY data added information capturing the large north-south range of growing conditions within the Bay watershed. The NY data were averaged across the three planting dates which produced a RNRE of 0.40 for annual ryegrass.

Annual Legumes and Grass Legume Mixtures

Annual legume cover crops are winter annuals that are primarily used to supply N to the next crop due to their ability to fix significant quantities of atmospheric N. But they also provide a living crop that can scavenge small amounts of residual nutrients as well as provide some erosion protection during the spring runoff season (USDA, SARE, 2007).

In the Bay watershed, the most common annual legumes are Hairy Vetch and Crimson Clover. The Panel recommends combining these two legume species, and other winter annual legumes, into one category because all the existing data on legume recovery of residual N studied either hairy vetch and/or crimson clover. Another reason to include pure legume stands is the rapidly growing popularity of grass-legume mixtures, which can absorb significant quantities of fall nutrients by the grass in the mixture. Thus, the Panel recommends adding both the Annual Legume and Annual Legume plus Grass categories to the Phase 5.3.2 update.

There were only two peer-reviewed studies, each with two site-years of data, available for estimating the RNRE for annual legumes in the Bay watershed. This is because ^{15}N is needed to directly estimate the recovery of fall N in a legume, which also contains N derived from decomposition of soil organic matter plus large quantities of N derived from atmospheric fixation. Both of these studies used early- and normal-planting dates along with a mid-April harvest.

The four site-years of ^{15}N data produced a final weighted average estimate of the Annual Legume RNRE of 0.16. The Panel recommended that the estimate for an Annual Legume plus Grass mixture should be the average of the annual legume and the “generic grass” component.

A summary of these two Bay area Annual Legume studies is given below, along with a summary of two other studies that provide corroborating data for the results from the Bay area research:

a) The peer-reviewed ^{15}N publication of Shipley et al, (1992), described above in the Annual Ryegrass section, also documented the recovery of fall ^{15}N labeled fertilizer by hairy vetch, crimson clover, and rye in a silt loam soil on Maryland’s Eastern Shore. The average RNRE from the 1986-87 and 1987-88 cover crop seasons was 0.22 for hairy vetch and 0.17 for crimson clover, which gives a combined average RNRE for Annual Legumes of 0.19.

b) The second peer-reviewed ^{15}N publication was by Ranells & Wagger (1997) who added ^{15}N labeled nitrate to fall seeded crimson clover, rye, and a crimson clover plus rye mixture in a loamy sand soil on North Carolina’s Eastern Shore. The average RNRE for crimson clover over the 1993-1994 and 1994-1995 cover crop seasons was 0.09. The lower ^{15}N recovery by crimson clover in the NC study is likely due to greater ^{15}N leaching in the coarse-textured loamy sand soil, compared to the finer-textured silt loam in MD. The average N Efficiency of the crimson clover plus rye mixture converts to a N Effectiveness value of 0.25, that is satisfactory support for the “generic grass” N Effectiveness of 0.20 in Table 2. No other studies could be found in the literature that would provide other estimates of the N Effectiveness’s of legume plus grass mixtures.

c) Two other studies were identified that provided corroborative data on N recoveries by legumes vs. grasses, and on the value of legume-grass mixtures. These studies could not be used to estimate a RNRE because they did not have a direct comparison with rye. Gabreil and Quemada (2011) conducted a ^{15}N recovery study with barley and hairy vetch in Spain and reported that barley recovered 10% of the residual ^{15}N, while vetch recovered only 1%. In Oregon, Feaga et al. (2010) used multi-year field lysimeter data to document that the average nitrate concentration in drainage below grass covers that was 34% less than without a cover; while a vetch-triticale mixture averaged 19% less than without a cover. These two studies support the view that grasses are much better than legumes at recovering residual N, and that a legume-grass cover is about half as effective as a pure grass cover at reducing the nitrate concentration in soil drainage water.

Brassicas (winter-hardy)

Two species of winter-hardy *Brassicas* are proposed for inclusion in the model: Canola and Rape. Both are technically rapeseed, and both can take up significant amounts of N, often comparable to rye, but only if planted early. The winter-hardy Brassicas provide full fall-winter-spring crop growth and residue cover that avoids possible residue decomposition losses while providing soil cover to manage erosion (USDA, SARE, 2007).

The Panel reviewed 13 site-years of data. Studies from within the Bay watershed include three site-years from a peer-reviewed MD study, six site-years from an unpublished VA study, and one site-year from a PA extension publication. Other studies that the Panel considered valid and which had a direct comparison to rye, were from peer-reviewed research done in Oregon (two site-years) and France (one site-year).

Rape and Canola are grouped together because they have similar fall and spring growth in the Bay watershed. Both should be planted early; they survive the winter and continue to accumulate biomass and N in the spring, as well as provide soil cover for erosion control.

The 13 site-years of data were initially summarized by calculating a simple weighted average as for the other species, which produced a final weighted average RNRE of 0.80. However, due to high pre-planting available N and very early planting in some site-years, and because of the wide range of N uptakes for rape; the Panel unanimously voted to recommend a more conservative RNRE of 0.70.

The data summary for rape and canola listed in Tables 1 and 2 are:

a) The largest data set is from the Eastern and Western VA studies (Pers. Comm. Wade Thomason, 2013) from studies in 2010-2012 (3 site-years each). The studies include rye, pure oats and an oat plus canola mixture. Cover crops were planted in the early-planting period for each location and followed cash grain-crops. The average canola N uptake value (57 lbs N/ac) was estimated by subtracting the pure oat uptake (17 lbs N/ac) from the oat/canola mixture uptake (74 lbs N/ac), while the rye N uptake was 98 lbs N/ac. Thus, the average RNRE for Canola from these six site-years was 0.62.

b) The MD data (Dean and Weil, 2009) are based on one site-year (2004) from the Piedmont and two site-years (2003) from the Coastal Plain. In two of these studies, rape and rye were planted following mowing of a soybean crop that added an estimated 207 lbs of readily decomposable N/ac to the soil. The average RNRE for rape from these three site-years was

1.2. However, due to the high N environment in these studies, the Panel voted unanimously to adjust the final efficiency for rape as described above.

c) The PA data (Finney and Kaye, 2013) came from one site-year of data (2011). The Hagerstown soil was conventionally tilled following an oat crop; rye and rape were planted in late August and harvested in mid-May. The Rape N uptake was 108 lbs N/ac compared to 67 lbs N/ac for rye, giving a Relative N Reduction of 1.6.

d) Data from France (Muller, et al., 1989) was included because it had a rye cover crop whose N uptake values were similar to a high N supplying site in the Bay watershed. These data (one site-year) followed wheat and also demonstrate the effect of slightly later planting (but still in the early-planting period) on rape N uptake, which was harvested in early March. Rye N uptake was 120 lbs N/ac, but the rape N uptake was 23 lbs N/ac due to overwinter damage that would be common in the more northern areas of the Bay watershed. The resulting RNRE for rape was 0.19, which illustrates the highly variable performance of Brassica's.

e) Data from Oregon (Fernando, et al., 1996) was included because the Adkins fine sandy loam and rainfall pattern is similar to the Bay watershed. The other cover crops in this study (rye, wheat and triticale) also had N uptakes that corresponded well with data from the Bay watershed. Two site-years of data were reported (1992-1993 and 1993-1994) as part of this Ph.D thesis. Cover crops were planted in mid-September and harvested in mid-March or early-April. The average rye N uptake was 102 lbs N/ac while rape was 68 lbs N/ac, giving a RNRE of 0.62.

Forage Radish

The Forage Radish, also known as tillage radish, is a popular deep-rooted cover crop that grows fast with warm temperatures and an ample supply of N. It can recover substantial quantities of residual N, and often accumulates as much, or more, N in the fall than rye. However, it is subject to winter killing following a few days below 25 F. After winter-kill the radish residues decompose rapidly, leaving the soil bare and making it vulnerable for some nitrate-N leaching depending on weather and soil conditions, during the remaining winter and early-spring seasons (USDA, SARE, 2007).

Twelve site-years of Forage Radish N uptake data, with corresponding rye data, were available from MD, PA, and VA with all planting done during the early-planting period. All harvests were in the fall before frost killing, which is consistent with crop development.

The 12 site-years of data were initially summarized by calculating a simple weighted average as for the other species, which produced a final weighted average RNRE for forage radish of 1.00. However, due to high pre-plant available N and very early-planting in some site-years, and because of the wide range of N uptakes for forage radish compared to rye; the Panel chose to conduct an anonymous poll to allow each member to interpret the data and submit their estimate of the radish RNRE. The Panel then pursued detailed discussions about various interpretations of the data. The Panel concluded by voting unanimously to recommend acceptance of the average RNRE from the anonymous poll, which is 0.58.

The summary for the forage radish data are given below:

a) The largest data set is from the Eastern and Western VA studies (Pers. Comm. Wade Thomason, 2013) in 2010-2012, with each area contributing 3 site-years of data. These studies included fall N uptakes for pure rye and pure radish, with the details of this study given in the Brassica (winter-hardy) section above. The average N uptakes, in lbs N/ac, in Eastern VA were 62 and 53, for rye and radish, respectively. The corresponding N uptakes (lbs N/ac) for the Western VA were 134 and 96, for rye and radish, respectively. These six site-years of data produced an average RNRE for forage radish of 0.79.

b) The MD data is from Dean and Weil (2009) and unpublished data from C. White's Ph.D thesis. The studies have two site-years from the Piedmont and three site-years from the Coastal Plain. In three of these studies, the radish and rye were planted following mowing of a soybean crop that added several hundred pounds of N/ac to the soil. The average fall N uptake for the rye from these five site-years was 106 lbs N/ac, while corresponding value for forage radish was 130 lb N/ac. These data provide a RNRE of 1.23.

c) The PA data was from an Extension demonstration study from one site-year of data (2011), which is described above in the Brassica section. The forage radish N uptake was 27 lbs N/ac compared to 67 lbs N/ac for rye, giving a Relative N Reduction of 0.40.

Forage Radish and Grass

The general biological characteristics and uses of Forage Radish and Grass cover crops can be gleaned from their accompanying descriptions in the Forage Radish and Triticale species sections. The Forage Radish plus Grass category is listed as a separate group because: i) it combines two distinctly different species, each contributing their own advantages to the resulting mixture, and ii) there are good data available for estimating an initial RNRE for this mixture.

The Panel utilized individual studies from PA and VA that provided 15 site-years of data for estimating the RNRE for a Forage Radish plus Grass mixtures, with virtually all of the studies using Rye as the grass species. All studies were planted in the early- or normal-planting period and all harvests were in mid-April to early-May, which is consistent with crop development in the spring.

The 15 site-years of Forage Radish plus Rye data were initially summarized using a weighted average based on the number of site-years in each mean, which produced a final RNRE of 0.86 and a N Effectiveness for early-planted drill-seeding of Forage Radish plus Rye of 0.39 (= 0.86*0.45). However, the Agriculture Work Group requested that the Forage Radish plus Grass mixture use the same estimation approach as the legume-grass mixture. Accordingly, the final N Effectiveness of early-planted drill-seeded Forage Radish plus "generic-grass" category in Table 2 is 0.29 (= average N effectiveness of forage radish (0.26) and the "generic grass" (0.32)), which is somewhat less than the above estimate of 0.39 if rye is the dominant component in the mixture because the other grass covers (especially oats) recover less N than rye. The Panel recommends that future updates of the Cover Crop BMP consider using individual grass species rather than a "generic grass", because that would provide incentive to use the most efficient grass species in the Bay watershed. Another alternative would be to use a weighted average of the "generic grass" species, rather than a simple average, with the weighting factor being based on estimates of the most common grass species used in cover-crop mixtures in the watershed.

A summary of data and methods used to estimate the initial Forage Radish and Grass RNRE follows:

a) The Pennsylvania Cover Crop after Corn Silage Trial was the main source of data. This is an unpublished (still in progress) data set from Dr. Sjoerd Duiker containing one year of data from 10 different on-farm field locations across PA. Each location followed silage corn and contained a direct comparison of the total N uptake of rye vs. a forage radish plus rye mixture. The average RNRE from these 10 site-years of data was 0.89.

b) The other PA data came from two site-years from the "Short-lived cool-season forage trial" of Houser et al. (2011 and 2012) that is described in the Annual Ryegrass section. In this trial rye was compared to a mixture Forage Radish plus Annual Ryegrass, which produced a RNRE of 0.76.

c) Data from VA is from three site-years of data from the Radish and Mixed Species trial (Pers. Comm. Wade Thomason, 2013) that is summarized in the Brassica section and contains three years of western VA data comparing rye with a mixture of forage radish plus rye plus annual ryegrass (a three species mixture containing two grasses). The resulting RNRE is 0.79.

Oats (winter-hardy) and Oats (winter-killed)

Oats is a cool season annual cereal having varieties that are winter hardy in some areas of the Bay watershed, and some varieties that are winter killed. Oats are primarily used as a short-term N scavenger with secondary benefits of reducing soil erosion. In circumstances where herbicides are not used a winter-killed oat variety is often preferred to winter-hardy cereal covers (USDA, SARE, 2007).

Virginia provided the most complete data base for winter-hardy oats, which was 11 years of data (Smith et al., 2009) comparing total N uptake from a single winter-hardy variety with corresponding data from rye. The Panel recommended that the planting periods for winter-hardy oats be early and normal, while the planting period for winter-killed oats should only be early.

The winter-hardy oat data provided the base line for estimating the winter-killed RNRE, which is described in more detail below. The Panel's recommendation for the RNRE of winter-hardy oats is 0.55, and for winter-killed oats is 0.40.

A summary of the data and the methods to estimate the RNRE of winter-hardy and winter-killed oats follows:

a) The source of data for winter-hardy oats was the Virginia small grain forage variety testing report: long-term summary (1994-2004) reported by Smith et al. (2009). This study received 25-30 lbs starter-N/ac in the fall and 60 lbs N/ac in the spring for all entries, including the rye reference entry. The VA study documented the average total N uptake for a single winter-hardy oat variety and a single rye variety that were both present in 11years of the long-term study, thus providing 11site-years of data having an average RNRE of 0.55.

b) The winter-killed oat RNRE was estimated from the above winter-hardy oat data base that was adjusted for estimates of over-winter N loss. One adjustment was based on the assumption that all the fall nitrate-N content of oats was lost (nitrate data provided by pers. comm. with Ms. Natalie Lounsbury, Univ. MD), which amounted to an 18% loss of the oat total N. The second approach was based on the loss of total N in the oat residues during the over-winter period from another unpublished (Pers. Comm. Dr. Wade Thomason, 2013) three-year VA trial studying Radish and Mixed Species Cover Crops, which amounted to a 36% loss in oat total N. These two loss estimates for winter-killed oats were averaged together and related to the rye N uptake, which resulted in a RNRE for winter-killed oat of 0.40.

Triticale

Triticale is a cool season annual cereal that is a cross between wheat and rye, giving it characteristics from each parent. It serves the dual purpose roles of being a N scavenger and an erosion fighter. It grows almost as well as rye in cold months, but is easier to manage in the spring because it is less subject to the rapid spring growth, that can present management difficulties with rye.

The Panel utilized individual studies from MD, NY, PA, and VA that provided ten site-years of data for estimating the RNRE for triticale. All studies were planted in the early- or normal-planting period and all harvests were in mid-April to early-May or in mid-May (NY), which is consistent with crop development in the spring. These studies did not include a late planting, but in the Panel's professional judgment it recommends including a late-planted category, this is the same procedure used by the 2007 Cover Crop Panel for the late-planting category of rye and wheat (MAWQP, Cover Crop Report, 2007).

The ten site-years of triticale and rye data were summarized using a weighted average based on the number of site-years in each mean as before, which produced a final RNRE of 0.86 for triticale that is listed in Tables 1 and 2.

Summaries of the triticale data are:

a) The MD cover crop studies with triticale were the peer-reviewed paper of Coale et al. (2001) and unpublished 2004 data from Dr. Ken Staver. Each study contributed one site-year. The Staver data provided N uptake data and a RNRE of 0.84. The Coale et al. (2001) N uptake data resulted in a RNRE of 1.15, which indicates that triticale took up about 15% more N than rye – a fact that should be occasionally expected since rye was one of the parents of triticale.

b) The NY data are from the same unpublished 2010 NRCS cover crop planting date study that is described in the Annual Ryegrass section. The NY data were averaged across the three planting dates which produced a Relative DM Production Efficiency of 0.64 for triticale.

c) The PA data from the "Short-lived cool-season forage trial" planted in 2012 (Houser et al., 2013) are the basis for the RNRE. A summarized description of this study is given in the Annual Ryegrass section. The triticale total N uptake contributed a single site-year of data having an average RNRE of 0.70.

d) The largest triticale data set came from the Virginia small grain forage variety testing report: long-term summary (1994-2004) reported by Smith et al. (2009). The VA study received 25-30 lbs starter-N/ac in the fall and 60 lbs N/ac in the spring for all entries, including the rye reference entry. The VA data consisted of the average total N uptake for a single triticale variety and a single rye variety that were both present in 6 years of the long-term study, thus providing six site-years of data having an average RNRE of 0.88.

Research Needs

The Cover Crop Panel's future research recommendations are:

a) Include some measure of fall residual N in the version 6 Model, to allow adjustment of N Effectiveness's for small vs. medium vs. large levels of residual N and provide possible targeting of cover crops to high residual N locations.

b) Include some measure of soil properties (drainage class, slope, texture, etc.) in the version 6 Model so estimates of N, P, and sediment Effectiveness can be more accurate.

c) Conduct research to quantify the N losses during the winter-spring decomposition period of winter killed covers, especially the fate of forage radish N.

d) Conduct research on phosphorus and sediment losses from cover crops used in modern conservation tillage systems, especially cropping systems with silage corn.

e) Provide for grass-specific mixtures in version 6 Model, i.e. allow mixtures to have their own specific grass component rather than a “generic grass”, to increase the incentive for planting the most efficient N scavengers.

f) Provide for nutrient, especially phosphorus, accumulation and decline in soils as affected by cover crops.

Technical Requirements for Entering the Cover Crops BMPs into Scenario Builder and the Watershed Model

Background: In June, 2013 the Water Quality Goal Implementation Team (WQGIT) agreed that each BMP expert panel would work with CBPO staff and the Watershed Technical Workgroup (WTWG) to develop a technical appendix for each expert report. The purpose of the technical appendix is to describe how the expert panel’s recommendations will be integrated into the modeling tools including NEIEN, Scenario Builder and the Watershed Model.

Q1: What are the nitrogen efficiency reductions a jurisdiction can claim for implementing and reporting the new cover crop species?

A1: The table below shows the reduction efficiencies for nitrogen for each of the new cover crop species.

Table 1: Nitrogen Reduction Benefits for New Cover Crop Species

Species	BMP Short Name	Maximum N Efficiency	
		Upland	Coastal Plain
Forage Radish, Early, Drilled	CoverCropEDFR	20	26
Forage Radish, Early, Other	CoverCropEOFR	17	22
Forage Radish, Early, Aerial, After Soy	CoverCropEASFR	14	18
Forage Radish, Early, Aerial	CoverCropEAFR	8	10
Forage Radish + Grass , Early, Drilled	CoverCropEDFRG	22	29
Forage Radish + Grass, Early, Other	CoverCropEOFRG	19	25
Forage Radish + Grass, Early, Aerial, After Soy	CoverCropEASFRG	15	20
Forage Radish + Grass, Early, Aerial	CoverCropEAFRG	9	12
Annual Legume, Early, Drilled	CoverCropEDL	5	7
Annual Legume, Early, Other	CoverCropEOL	5	6
Annual Legume, Early, Aerial, After Soy	CoverCropEASL	4	5

Annual Legume, Early, Aerial	CoverCropEAL	2	3
Annual Legume, Normal, Drilled	CoverCropSDL	5	6
Annual Legume, Normal, Other	CoverCropSOL	4	6
Annual Legume + Grass, Early, Drilled	CoverCropEDLG	15	20
Annual Legume + Grass, Early, Other	CoverCropEOLG	13	17
Annual Legume + Grass, Early, Aerial, After Soy	CoverCropEALSG	10	14
Annual Legume + Grass, Early, Aerial	CoverCropEALG	6	8
Annual Legume + Grass, Normal, Drilled	CoverCropSDLG	14	19
Annual Legume + Grass, Normal, Other	CoverCropSOLG	12	16
Triticale, Early, Drilled	CoverCropEDT	29	39
Triticale, Early, Other	CoverCropEOT	25	33
Triticale, Early, Aerial, After Soy	CoverCropEAST	21	27
Triticale, Early, Aerial	CoverCropEAT	12	15
Triticale, Normal, Drilled	CoverCropSDT	27	35
Triticale, Normal, Other	CoverCropSOT	23	30
Triticale, Late, Drilled	CoverCropLDT	13	16
Triticale, Late, Other	CoverCropLOT	10	14
Annual Ryegrass, Early, Drilled	CoverCropEDAR	22	30
Annual Ryegrass, Early, Other	CoverCropEOAR	19	25
Annual Ryegrass, Early, Aerial, After Soy	CoverCropEASAR	16	20
Annual Ryegrass, Early, Aerial	CoverCropEAAR	9	12
Annual Ryegrass, Normal, Drilled	CoverCropSDAR	20	27
Annual Ryegrass, Normal, Other	CoverCropSOAR	18	23
Winter Hardy Oats, Early, Drilled	CoverCropEDHO	19	25
Winter Hardy Oats, Early, Other	CoverCropEOHO	16	21
Winter Hardy Oats, Early, Aerial, After Soy	CoverCropEASHO	13	17
Winter Hardy Oats, Early, Aerial	CoverCropEAHO	8	10
Winter Hardy Oats, Normal, Drilled	CoverCropSDHO	17	23
Winter Hardy Oats, Normal, Other	CoverCropSOHO	15	19
Winter Killed Oats, Early, Drilled	CoverCropEDKO	14	18
Winter Killed Oats, Early, Other	CoverCropEOKO	12	15
Winter Killed Oats, Early, Aerial, After Soy	CoverCropEASKO	10	13
Winter Killed Oats, Early, Aerial	CoverCropEAKO	6	7
Winter Hardy Brassica, Early, Drilled	CoverCropEDHB	24	32
Winter Hardy Brassica, Early, Other	CoverCropEOHB	20	27

Winter Hardy Brassica, Early, Aerial, After Soy	CoverCropEASHB	17	22
Winter Hardy Brassica, Early, Aerial	CoverCropEAHB	10	13

Q2: Why is there no credit given for phosphorus or sediment for the new cover crops species?
A2: As of publication of this document, the panel is recommending that consideration of phosphorus and sediment reductions for the new species will take place at a later time, due to the lack of data on the effect of cover crops on phosphorus and sediment losses. The panel's final Phase 5.3.2 report will therefore address nitrogen, and will consider phosphorus and sediment reductions for all species at a later time, most likely when the expanded modeling expertise with the NRCS APEX model is available (INSERT REFERENCE TO REPORT).

Q3: How is the reduction actually calculated in Scenario Builder and the Watershed Model?
A3: The total load reduction is determined by the Watershed Model as the product of the efficiency reduction listed in Table 1, the acres of agricultural land within the model segment with cover crops reported, and the total nitrogen load simulated for the model segment for those agricultural acres.

Q4: Did the panel alter the way existing cover crop species receive credit?
A4: No. The expert panel recommended that the current cover crop species be simulated in the same way they have historically been simulated using the Phase 5.3.2 Watershed Model (INSERT REFERENCE TO REPORT).

Q5: What does a jurisdiction need to report in order to receive credit for cover crop species?
A5: Jurisdictions should report the following information:

- Cover Crop Type: Species of cover crop
- Planting Method*: Aerial, Drilled, Other
- Planting Time Period*: Early, Standard, Late
- Crop preceding Cover Crop*: Corn, Soybean
- Land Use: Approved NEIEN Row Crop Land Uses
- Acres: Number of acres with reported species within geographic reporting unit
- Location: Approved NEIEN geographies: County; County (CBWS Only); Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4), State (CBWS Only)
- Date of Implementation: Year cover crop was planted

*These are preferred, but are not required. See Question 6 for a more detailed description of defaults if data is not provided.

Q6: Can a jurisdiction still receive credit if it cannot report the planting method, planting time, or preceding crop?

A6: Yes. Jurisdictions should always report the most specific information available to them for cover crop implementation. Data reported for CBP purposes should preferably include all elements listed in Question 5.

If any of this information is not reported, the default conditions for the unreported category will be the lowest nitrogen reduction benefit for that category in the approved expert panel report. If relevant, the phosphorus and sediment benefit associated with this model nitrogen reduction will also apply. If the lowest reduction benefit for the missing category is “0” or “NA,” then “0” is used for model credit.

For example, if a jurisdiction reports “Forage Radish” as a Cover Crop species, they will receive a 10% reduction in N which corresponds to the lowest reduction available in the “Forage Radish” category.