Summary Paper:

Application of CBP Nutrient Management BMP on Full-Season Soybeans: Summary of deliberations related to CAST-19 comment period and CAST-21 Workplan Task 6.

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Background: Leading up to the release of CAST-19 (the most recent update to the Chesapeake Bay Watershed Model), several jurisdictions (VA, PA, DE) raised concerns regarding the application of the CBP (Chesapeake Bay Program) Nutrient Management (NM) best management practice (BMP) on full-season soybeans. Data pulled from 2017 Census of Agriculture indicated a proportional shift in soybean management: moving acres previously managed under double-cropping systems to full-season soybeans. This shift coincided with an increase in modeled nitrogen (N) loads for some counties in the watershed, due in part to loading rate assumptions associated with soybean acres. In an effort to identify a way to mitigate the increase in modeled N loading, jurisdictional partners noted that within the CBP-approved suite of NM BMPs, the N load reduction effectiveness value assigned to supplemental NM (place, rate, timing) for full-season soybeans is 0%, per a 2016 Expert Panel (EP) recommendation. The jurisdictions above indicated that this decision results in an "uncontrollable load" related to total N loss on full-season soybean acres. The CBP partnership asked that the AgWG revisit the NM EP approved recommendation.

Response: An initial response to the concern was addressed by the CBP CAST Team and can be found under *Model Documentation* for CAST-19 on the CAST website ("Comments from the Jurisdictions and the Chesapeake Bay Program Responses," pg. 2-3). To reach resolution, the CBPO provided the jurisdictions with comparative analyses of crop scenarios, peer-reviewed literature, and explanations of how scientific understanding of N dynamics related to soybean development are applied in the CBP modeling tools. The jurisdictions asked that the issue be further investigated as part of the CAST-21 Workplan.

Three aspects have come to light in attempting to address this issue: *1. Agricultural Loading Rates:* Why did N loads increase in relation to shifts in soybean management? *2. Census of Agriculture:* Is the data used from the 2017 Ag Census to estimate double-crops acres reasonably accurate? *3. CBP Nutrient Management BMP:* Is the 0% effectiveness value assigned to supplemental NM BMPs for full-season soybeans warranted and is it exacerbating jurisdictions' ability to control for the modeled N loads? The remainder of this document will address these three aspects based on current understanding.

#1: Agricultural Loading Rates

In the course of development for the Phase 6 CBWM, the Ag Loading Rate Review Steering Committee (subgroup of the Agricultural Modeling Subcommittee) identified appropriate nutrient and sediment loading rate ratios for agricultural land uses. These ratios provide baseline assumptions of N and phosphorus (P) loss from ag land uses before BMPs are applied on the landscape. The report was approved by the AgWG in January 2016 and can be found under *Phase 6 Dynamic Watershed Model and CAST-17 documentation* on the CAST website (Section 2. Appendix 2A: *Agricultural Loading Rates*). The final recommendations were based on available literature and the best professional judgement of the contributing panel of scientists.

Soybeans are legumes. Legumes have the ability to harness ("fix") N from the atmosphere via specific bacteria that reside in the root nodules of the plant. This fixed N is then available for the plant to use. Because a legume can produce its own N source, application of N in the form of fertilizer or manure is not considered necessary for the physiological development of the crop. The N fixed by a legume supplies N not only to the developing crop, but results in residual plant-available (i.e., soluble) N left in the soil after the legume has been harvested. This unique pool of residual soil N is accounted for when estimating nutrient loading rates for agricultural acres, similar to accounting for fertilizer that is not removed via crop uptake and is subsequently available for leaching loss. The Ag Loading Rate Review Steering Committee agreed that more peer-reviewed research on N fixation would improve confidence in its recommendations, but its best professional judgement view was that "N losses from soybeans are

only somewhat lower than corn, because N fixation inputs (which are poorly characterized) are apparently substituting for fertilizer inputs." (p.11) Relevant figure from the Ag Loading Rate Review Steering Committee's recommendations are in the Appendix following this summary.

The group explained the N loading rate ratio for full-season beans as follows (**emphasis** added):

> "This value results from the N added by full-season soybean N_2 fixation. The total aboveground N content of a good soybean crop can vary between 225 and 300 kg N ha^{-1}, with the majority of this N derived from N_2 fixation. **About half of this total aboveground N is removed in the soybean harvest, but the other half remains in the high-N content crop residues that readily decompose producing NO_3-N that is vulnerable to leaching during the following fall-winter-spring fallow season.** The relative to "corn, grain - no manure" ratios in Table 1 also capture an important generalization: that perennial crops like hay and agriculture open space land uses are quite efficient at conserving N compared to corn. This is because perennials have an actively growing crop continuously taking up N throughout the whole seven to nine month of the growing season, while annual crops have a limited growing season of about three to five months which leaves the remaining months fallow and subject to nitrate leaching. A final note is to point out that many land uses have only one or two references, and that the land uses without any references were estimated by best professional judgment calculations of the subcommittee (see Table 1 footnotes for the calculations). This **current scarcity of data calls for further future evaluations of the published and unpublished literature in order to provide improved estimates of the relative to "corn, grain - no manure" ratios for all Phase 6.0 land uses**." (pages 5-6)

Related to N loading rate rations the group also stated (**emphasis** added):

> "For future review: While our Sub-group feels that these are currently the best available estimates of relative N loading rates, we also note that **confidence in these estimates could be increased with additional studies for the land uses with ratios based on only 1 or 2 studies. In addition, more accurate ratios could be estimated with distributed information on local manure N application rates and crop N demand**." (page 8)

Further Discussions Regarding N Ratios (**emphasis** added):

> "…Surface runoff N losses were found to be about 30% less from soybeans than corn, and spring leaching potential was reduced due to later tillage and spring burndown. It is tricky in corn-soybean rotation data to sort out precisely what fraction of subsurface losses is from which crop, especially in a calendar year. However, **the general literature values and best professional judgment view is that N losses from soybeans are only somewhat lower than corn, because N fixation inputs (which are poorly characterized) are apparently substituting for fertilizer inputs. In addition, it's likely that the controlled studies tended to use lower N rates for corn than what are used in the real world, especially during the 1985 era.**
> The Agricultural Loading Rate Review Subgroup was asked to provide these general summaries in terms of a "relative to corn" basis on a very short time-frame. **The subgroup responded accordingly with our best professional judgment estimates, but it was our view that these were short-term temporary estimates to allow beta-version development and testing of the phase-6 model with more deliberate and research estimates provided at a later time**." (page 11)

Comment regarding relative importance of N loads from different land use types, Tom Jordan (September 8, 2015, **emphasis** added):

> "I multiplied the N load ratio (from Jack's latest estimate) times the acres (1997 land use areas, Gary Shenk personal communication) to get an estimate of the relative importance of the ag land use as an N source for the whole Chesapeake watershed.
> The most important crop is our standard corn without manure (sorghum is a minor part of that category too). **After corn without manure, the most important N sources are full season soybean and pasture.** Of those top three sources, pasture probably has the highest level of uncertainty due to the variability of management and settings of pastures. Maybe in the future (beyond our deadline), the pasture category should be subdivided according to factors that might influence N loads. In general**, I think the variability of manure applications may be one of the biggest sources of uncertainty in the nutrient loads for crops eligible for manure. This could be an important source of uncertainty for the Chesapeake watershed in general**." (p.48)

Simulation N fixation in CAST (sourced from CAST Section 3 documentation):

The rate of N fixation in CAST is influenced by soil N and applied N (fertilizer or manure) to account for the in-field biological processes. If the soybean crop can scavenge N from the immediately available sources, it will not expend unnecessary energy on N fixation.

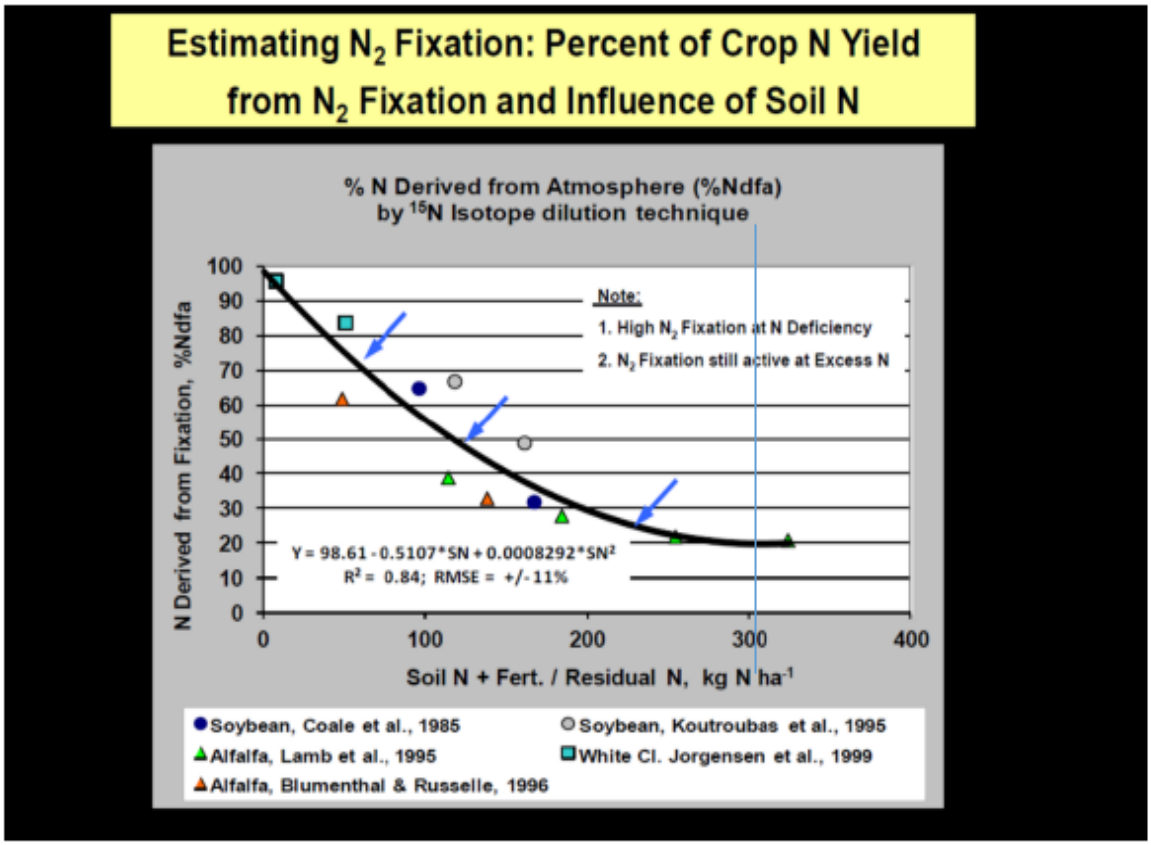


Figure 3-15: Nitrogen fixation as a percent of crop yield

#2: Census of Agriculture

There is concern among some CBP partners that data from the 2017 Census of Agriculture does not accurately represent trends in agricultural management. In the case of soybeans, there is concern that a significant trend toward more full-season acres and less double-crop acres may be not be representative of real-world conditions. Consultation with statisticians at USDA-NASS has not uncovered inconsistencies in their analysis. No alternative data sets have been provided to contrast with the 2017 census data. USDA-NASS was also consulted regarding the current method used to model double-crop acres and found the method to be sound.

The AgWG will be asked May 20th, 2021 to support adoption of a new proposed land use methodology for determining the change in total agricultural area from 2013 to 2017. This will allow the use of spatially distributed land use from the Land Cover/Land Use data team to determine total agricultural acres, while the Ag Census will continue to inform the distribution of agricultural land uses with that total area. It is expected that the acres assigned to full-season soybeans and double-crop systems will change and that this change may serve to mitigate the increase in modeled N loads that have driven jurisdictions' concerns.

#3: Nutrient Management BMP

The Phase 6 Nutrient Management Expert Panel based its recommendations on best professional judgment, regional land grant universities (LGUs) recommendations (Cornell, PSU, VT, UMD, NC State), published literature and USDA-ARS research. The recommendations were approved by the WQGIT in November 2016 after partnership review. A recurrent theme in the feedback submitted during the EP report review period was a lack of cited scientific literature to support final BMP effectiveness estimates. The panel responded by expanding a section of the report with discussion of the relationship between its best professional judgement and the relevant available literature. The section, however, does not offer an explicit explanation of its recommendations for full-season soybeans. After conferring with those who had participated in the NM Expert Panel discussions, salient points regarding soybeans are listed below:

- **LGUs do not recommend N application on soybeans** (regardless of source- fertilizer or manure) because soybeans are capable of fixing atmospheric N.
- **NM principles applied to soybeans are controlling for P** because N application is not needed nor recommended.
- **Recommendations for double-cropped soybeans are tied to management of the associated small grain.** For this reason, direct comparisons of double-cropped soybean recommendations to full-season soybean recommendations are misleading.
- **In CAST, full-season soybeans have a Crop Application Goal of 0.12 lbs N per bushel under nutrient management.**
    - Although N application is not recommended for soybeans, the EP understood that *real-world management will result in applied N on a fraction of soybean field across the CBW*, either via fertilizer application for P (e.g., MAP[1] or DAP[2]) or manure application for waste management, emergency disposal or the agronomic benefits of P, sulfur (S), and organic matter. [3] For this reason, the EP chose to assume a small N application on soybeans watershed-wide (CBW average = 3.58 lbs N/ac).[4]
    - A small *Crop Application Goal for N is necessary for the soybean land use to allow for appropriate nutrient distribution in CAST* on a county scale.
- **Core N and P Nutrient Management BMP is applicable to full-season soybeans.**
    - The Core BMP is applied to the Crop Application Goal (the modeled quantity of N or P applied in the growing season per unit crop). Soybeans acres without NM have an assumed crop application of 0.144 per bushel (Crop Application Goal 0.12 x non-NM multiplier 1.2). In other words, NM practices address the application of nutrients. Without NM, it is assumed that a little more N and/or be will be applied per acre.
- **Supplemental Nitrogen NM BMP effectiveness benefits (rate, placement, timing) are 0% for full-season soybeans**
    - **The supplemental BMPs are applied to edge-of-stream (EOS) delivery**
        - EOS nutrient loads are determined from average land use loading, nutrient inputs (e.g., fertilizer, manure), change in export load per change input load (i.e., sensitivity), land use

[1] monoammonium phosphate
[2] diammonium phosphate
[3] Assumption: "Nitrogen application is not recommended for soybean production, however, use of commercially available fertilizer formulations may result in application of up to 50 lb N / acre when fertilizer formulation and application rate is determined by crop P2O5, K2O, S, or other nutrient needs. Organic waste nitrogen application to full-season soybean is not recommended because it is an agronomically inefficient use of applied nutrients. Organic wastes should only be applied to small grain - double-crop soybean rotations at rates and timings to supply the recommended nitrogen rate to the small grain crop." – UME SFM-1
[4] Comments on CAST 19 (5/6/2020)

(e.g., corn for grain, full-season soybeans), reported BMPs and Phase 6 land-to-water factors.
    - The bulk of modeled N loads from full-season soybeans is attributable to N fixation, rather than N applied via commercial fertilizer and manure.
- **Applied N is a small fraction of the N pool that reaches the edge-of-stream.** Applied N is in addition to residual N available from both the crop's fixation and what is left in the remaining biomass post-harvest. The EP understood that applied N on soybeans will impact the rate at which the soybean crop fixes N, therefore CAST will reflect a decrease in N fixation, as more N is applied to an acre of soybeans (see figure above).
    - Applying an efficiency value to supplemental NM BMPs for N on full-season soybeans would result in N reduction exceeding N application.

Tracking & Reporting NM BMPs: Every Bay jurisdiction is unique and therefore each has some discretion in how it tracks BMPs and subsequently reports them to the CBP. Jurisdictions are expected to identify, track and report BMPs utilizing the definitions approved by the CBP partnership. State regulations may dictate that manure application on soybeans is allowable up to a maximum threshold (e.g., pounds N per acre or crop P removal rate). Manure application within the allowable threshold is compliant with state regulations but is not consistent with current NM best practices, as defined by regional LGUs. This is because manure application on soybeans is not considered an efficient use of the N therein and the goal of NM BMP is greater nutrient use efficiency in order to minimize nutrient loss to ground water and tributary networks.

Path Forward: An AgWG ad hoc group consisting of designated representatives of the AgWG state jurisdictions has dedicated approximately seven hours of meeting time, plus additional communications across CBP office staff, jurisdictional members and NM EP contributors. At this time, the jurisdictional representatives in the ad hoc have not reached consensus to endorse a change to the Supplemental NM BMP for N on full-season soybeans that would apply to CAST-21. However, some recommendations have been discussed:

Short-Term (CAST-21)

Landcover & LiDAR imagery to define Changes in total ag acres may improve accuracy of modeled crop Acres

Long-Term (post CAST-21)

Phase 7 Review of Ag Loading Rates/Ratios: Identification & consideration of new literature sources including:

- Improve understanding of N fixation
- Improve understanding of real-world soybean management
- Reconsider baseline assumptions related to soybean management
- Are CBP NM BMPs appropriately representing use of "4R*" practices?

Agricultural data inputs for CAST

- Continuation of efforts to supplement Ag Census with other data sources (subject to CBP partnership approval)

Acronyms:

AgWG- Agriculture Workgroup
AMS Agricultural Modeling Subcommittee
BMP- Best Management Practice
CAST- Chesapeake Assessment Scenario Tool (also referred to as "the model")
CBP- Chesapeake Bay Program
CBWM- Chesapeake Bay Watershed Model (also referred to as CAST)
EP- Expert Panel

LGU- Land Grant University
N- Nitrogen
NM- Nutrient Management
P- Phosphorus
USDA ARS- United States Department of Agriculture Agricultural Research Service

Appendix: Relevant figures from the Ag Loading Rate Review Steering Committee

Table 1. Phase 6.0 land uses and their corresponding relative to "corn, grain - no manure" ratios derived from published and unpublished literature (identified by italicized numbers) and from best professional judgment calculations (identified by italicized letters).

Data summary of Relative NO3-N Loading Estimates for Phase 6.0 Land Uses J.J. Meisinger			
	Phase 6.0 Land Uses (italicized numbers are citations, italicized letters are footnotes)	**Avg. ratio (# obs) to Corn, grain - no manure**	**Std. Error Mean**
1	Corn or sorghum, grain - eligible for manure *(1,2,3,10,11)*	1.40 (12)	0.20
2	Corn or sorghum, silage - eligible for manure *(10)*	1.62 (1)	NA
3	Corn or sorghum, grain - no manure *(standard of reference)*	1.00 (NA)	NA
4	Corn or sorghum, silage - no manure [A]	1.16 (NA)	NA
5	Small-grain w/ soybean double-crop - no manure *(9)*	0.79 (2)	0.09
6	Soybean, full-season - no manure *(3,4,5,10)*	0.71 (6)	0.11
7	Small-grain w/ forage establishment - eligible for manure [B]	0.84 (NA)	NA
8	Other agronomic crops (e.g., cotton, tobacco, peanuts) *(15)*	0.45 (1)	NA
9	Pasture, direct deposition - eligible for manure *(12,13,14)*	0.23 (10)	0.05
10	Hay, legume or legume-grass mix *(6,7)*	0.17 (4)	0.02
11	Other hay, (e.g., peren. grass, orch. grass, tall fescue) *(12,13)*	0.24 (4)	0.06
12	Agr. open space (e.g., peren. grass, tall fescue) *(8)*	0.10 (2)	0.01
13	Specialty crops - high input (e.g., potatoes, sweet corn) *(10)*	1.34 (1)	NA
14	Specialty crops - low input (e.g., orchards, beans, peas) [C]	0.31 (NA)	NA

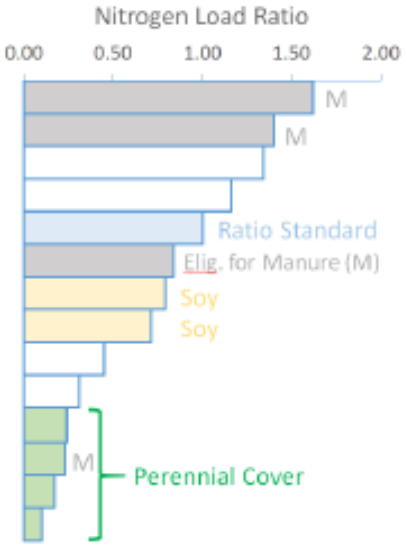
[A] Estimated from ratio of (Corn or sorghum, silage w/ manure) / (Corn or sorghum, grain w/ manure), calculation = 1.62 / 1.40 = 1.16.

[B] Estimated from Small-grain w/ soybean double-crop w/o manure, which is adjusted to small-grain only, followed by adding in a manure factor. For example: first estimate soybean double-crop factor, assuming double-crop soybean = 50% of full-season soybean, so small-grain w/o soybean = 0.79 - (0.71 / 2) = 0.44. Then, add small-grain w/ manure factor = 0.44 + (corn, grain w/ manure - corn, grain w/o manure) = 0.44 + (1.40 -1.00) = 0.84.

[C] Estimated from Other Hay value by adding 0.07 (due to greater loading w/ annuals) = 0.24 + 0.07 = 0.31.

- We estimated average N load ratio for crops receiving average manure applications (assuming that all manure-eligible lands get manure), as illustrated in Figure 2.

	Load Ratio	Std Err
Corn Silage Manure	1.62	
Corn Grain Manure	1.40	0.20
Specialty High	1.34	
Corn Silage *	1.16	
Corn Grain	1.00	
Sm Grain & Forage M.*	0.84	
Sm Grain & Soy	0.79	0.09
Full Season Soy	0.71	0.11
Other Ag Crops	0.45	
Specialty Low *	0.31	
Other Hay	0.24	0.06
Pasture Manure	0.23	0.06
Legume or Mix	0.17	0.02
Ag Open	0.10	0.01



* BPJ estimate by analogies to other crops

Figure 2. Nitrogen Load Ratio Relative to Corn (or Sorghum) Grain Without Manure

- In order to assess the relative impact of these relative ratios, we area-weighted the relative ratios by area of each land use throughout the Chesapeake Bay (1997 land use, Gary Shenk, personal communication), as shown in Figure 3. This figure shows that, in addition to the land use of our relative standard (Corn Grain without manure), the ratios that are deemed to be most critical will be for full season soybeans and pasture, because of their large land areas.

Abbrev Land Use	Load Ratio	Std Err	Acres	Area Wted Ratio
Corn Grain	1.00		1,253,584	1.00
Full Season Soy	0.71	0.11	1,237,398	0.70
Pasture M	0.23	0.06	3,595,223	0.66
Corn Silage	1.16		588,338	0.54
Corn Grain M	1.40	0.20	466,948	0.52
Sm Gr Forage M	0.84		631,886	0.42
Other Hay	0.24	0.06	1,947,683	0.37
Corn Silage M	1.62		250,184	0.32
Sm Gr Soy M	0.79	0.09	421,504	0.27
Legume or Mix	0.17	0.02	921,761	0.13
Specialty High	1.34		96,808	0.10
Other Ag Crops	0.45		195,099	0.07
Specialty Low	0.31		195,141	0.05
Ag Open	0.10	0.01	234,842	0.02

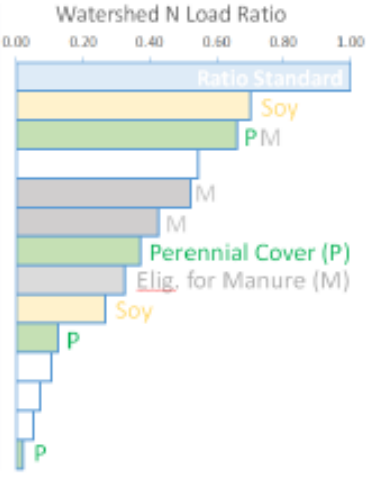


Figure 3. Area Weighted N Load Ratio Relative to Corn (or Sorghum) Grain Without Manure (Areas are coverage throughout the C. Bay watershed)