Appendix 1

Mahesh Tapas

INTEGRATIVE ANALYSIS OF POLICY CHANGES FOR A COASTAL WATERSHED: IMPLICATIONS FOR AGRICULTURE AND ECOSYSTEM HEALTH

**Survey of Eastern North Carolina Farmers**

The purpose of this survey is to gain insights into the beliefs of farmers in North Carolina as well as the current agricultural, environmental, and public policy conditions they are facing on their farms. This survey is designed and conducted by researchers at East Carolina University as part of an interdisciplinary research project aimed at better understanding the important role that agriculture plays in preserving water quality in North Carolina.

We ask that the principal decision maker of the farm business answer this survey. Please respond to each question with the answer you believe is most representative of you and your farm. For many of the questions, are no wrong or right answers; we are only interested in your opinion. Please note that you do not have to answer an item that you feel is too personal or sensitive. ***We plan to share the findings of this survey with agricultural stakeholders and policy makers in North Carolina, and we encourage you to participate as fully as you are comfortable to make sure your voice and perspective are heard***.

**Thank you in advance for your time and attention!**

A purple logo with a dome and a building

Description automatically generated

**Section 1: About You and Your Farm**

1. Did you operate a farm in 2022?

Ο = No

Ο = Yes

2. Do you plan to operate a farm in 2023?

Ο = No

Ο = Yes

*If your answer is NO to question 2, please return the survey without completing it in the enclosed envelope. Postage is paid by the survey project. Otherwise, please continue…….*

3. Please *circle the number* that most accurately represents how concerned you are about nutrient loss occurring on your farm*.*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Not at all**  **concerned** | | | | **Extremely**  **concerned** | | | |
| 0 | 1 | 2 | 3 | | 4 | 5 | 6 |

4. Have you experienced salinity issues on any fields in your farming operation in recent years?

Ο = No

Ο = Yes

5. Please *circle the number* that most accurately represents your level of control over the following.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **How much control do you have over…** | **No**  **Control** | | | | | | **Complete Control** | |
| ...soil erosion on your farm? | 0 | 1 | 2 | 3 | 4 | 5 | | 6 |
| …your farm’s impact on local water quality? | 0 | 1 | 2 | 3 | 4 | 5 | | 6 |
| …nitrogen lost through surface runoff? | 0 | 1 | 2 | 3 | 4 | 5 | | 6 |
| …nitrogen lost through subsurface drainage? | 0 | 1 | 2 | 3 | 4 | 5 | | 6 |
| …nitrogen lost during heavy rainfall events? | 0 | 1 | 2 | 3 | 4 | 5 | | 6 |

**6. The following statements were taken from interviews with farmers and others familiar with Eastern North Carolina agriculture. Please indicate whether you agree or disagree with each of them:**

|  |  |  |
| --- | --- | --- |
| **Statement** |  |  |
| “Counties nearer the mouth of the Tar-Pamlico River need more water control than counties farther upstream.” | **Agree** | **Disagree** |
| “Forests in the Tar-Pamlico watershed prevent nutrient run-off from fields.” | **Agree** | **Disagree** |
| “Municipal waste reduces water quality more than agriculture.” | **Agree** | **Disagree** |
| “Adopting Best Management Practices with the Farm Service Agency involves too much paperwork.” | **Agree** | **Disagree** |
| “Wind brings a good deal of nutrients into the Tar-Pamlico.” | **Agree** | **Disagree** |
| “Farmers achieve higher crop yields with better water management.” | **Agree** | **Disagree** |
| “The tides just raise and lower water levels; you need a storm to flush rivers and estuaries out.” | **Agree** | **Disagree** |
| “The climate has always been changing.” | **Agree** | **Disagree** |
| “The reason it appears that farming contributes more to nutrient loading in the estuaries is that the farms down east get all the build-up of nutrients from the farms upstream.” | **Agree** | **Disagree** |
| “To farm much of Eastern North Carolina, you have to figure out how to separate the water from the earth.” | **Agree** | **Disagree** |
| “Water quality is better in the Pamlico River than the Tar because the major polluters are upstream from the Pamlico.” | **Agree** | **Disagree** |
| “Planting winter cover crops holds pollutants on the farms.” | **Agree** | **Disagree** |
| “Economics is less of a driver of farmer behavior than most people think.” | **Agree** | **Disagree** |
| “Most farmers are willing to work with the Soil Conservation Service as long as they share part of the costs of implementing Best Management Practices.” | **Agree** | **Disagree** |
| “Eastern North Carolina’s farmers are so varied that it’s difficult to find a one-size-fits-all solution to controlling nutrient run-off.” | **Agree** | **Disagree** |
| “With subsurface irrigation, the plant becomes the pump.” | **Agree** | **Disagree** |
| “If all farmers managed water, nitrogen and phosphorus in the rivers would not be a problem.” | **Agree** | **Disagree** |
| “Regulations developed for rivers don’t apply to estuaries.” | **Agree** | **Disagree** |
| “Different soil types pull water different distances.” | **Agree** | **Disagree** |
| “Woodlands assist in managing water.” | **Agree** | **Disagree** |
| “There is no way to measure carbon because its levels change through the year.” | **Agree** | **Disagree** |

**Section 2: Nutrient Management on a Specific Field**

Please answer the following questions in reference to **ONE** of the fields that you plan to operate for 2022 and 2023, that you are in charge of making land use and land management decisions, and where soil erosion and nutrient runoff may be a potential problem. If there are several possible fields to choose from, choose **the field where *erosion or runoff is of greatest concern***.

7. What is the size of this field in acres? \_\_\_\_\_\_\_\_\_\_\_\_\_\_ # acres

8. The map below breaks the Tar-Pamlico watershed into ten smaller sub-basins.

A map with black lines

Description automatically generated

To the best of your knowledge, which sub-basin does this field reside in?

Ο 1 Ο 2 Ο 3 Ο 4 Ο 5

Ο 6 Ο 7 Ο 8 Ο 9 Ο 10

1. What type of tillage was last used for crops in this field?

Ο Conventional (30% residue or less)

Ο Conservation (30 – 90% residue)

Ο No-till (90% residue or more)

1. What crop was most recently planted in this field?

Ο Corn

Ο Soybeans

Ο Cotton

Ο Other \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. What crop are you planning to plant in this field for the 2023 growing season?

Ο Corn

Ο Soybeans

Ο Cotton

Ο Other \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Is this field currently in an established rotation? *(Check one)*

Ο No

Ο Yes àPlease provide the rotation below (for example, Corn/Soybeans)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. In the upcoming crop year, what would fair market rent be for this field?

$\_\_\_\_\_\_\_\_\_\_\_/acre

1. What yield would you expect for this most recently planted crop in an average year?

\_\_\_\_\_\_\_\_ bushels/acre *OR*

\_\_\_\_\_\_\_\_ tons/acre (if forage)

1. Considering fertilizers on this field for your most recent crop, how much phosphorus and nitrogen was applied to this field last year and what was the price you paid? (please write ‘0’ if none was applied)

|  |  |  |
| --- | --- | --- |
|  | P | N |
| Rate (lbs/acre) | \_\_\_\_\_\_\_\_\_\_ | \_\_\_\_\_\_\_\_ |
| Price ($/ton) | \_\_\_\_\_\_\_\_\_\_ | \_\_\_\_\_\_\_\_ |

1. If you applied N, what form did it take?

Ο Urea

Ο Anhydrous Ammonia (NH3)

Ο Element N

Ο Other \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. If commercial nitrogen fertilizer prices had been **10% higher**, what rate of N would you have applied on this field for this most recent crop?

\_\_\_\_\_\_\_\_\_ lbs/acre

1. If commercial nitrogen fertilizer prices had been **10% lower**, what rate of N would you have applied on this field for this most recent crop?

\_\_\_\_\_\_\_\_\_ lbs/acre

1. When was fertilizer applied? *Check all that apply…..*

Ο Fall

Ο Winter

Ο Spring pre-planting

Ο Spring at planting

Ο After planting

Ο No fertilizer applied

…b. How was it applied? *Check all that*

*apply…..*

Ο Incorporated (w/tillage)

Ο Planter

Ο Spray

Ο Broadcast

Ο Other \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

20. What is the general slope of this field?

Ο = 0-5% Ο = More than 10%

Ο = 5-10% Ο = Not sure

21. Please use the descriptions of different soil types below to answer the next question.

**Group A** - Group A soils consist of deep, well drained sands or gravelly sands with high infiltration and low runoff rates.

**Group B** - Group B soils consist of deep well drained soils with a moderately fine to moderately coarse texture and a moderate rate of infiltration and runoff.

**Group C** - Group C consists of soils with a layer that impedes the downward movement of water or fine textured soils and a slow rate of infiltration.

**Group D** - Group D consists of soils with a very slow infiltration rate and high runoff potential. This group is composed of clays that have a high shrink-swell potential, soils with a high water table, soils that have a clay pan or clay layer at or near the surface, and soils that are shallow over nearly impervious material.

Which soil group best describes your field?

Ο Group A Ο Group C

Ο Group B Ο Group D

22. Have you experienced any salinity issues on this field in recent years?

Ο = No

Ο = Yes

23. Are there buffer strips on this field?

Ο = No

Ο Yes à what percentage of the field is taken by the buffer strip (best guess)? \_\_\_\_\_\_\_\_\_\_\_\_\_

24. Did this field have any cover crops between 2022 fall harvest and 2023 spring planting?

Ο = No

Ο = Yes

25. Was this field enrolled in any conservation programs in 2022? *(Check all that apply)*

Ο = Not enrolled Ο = CRP

Ο = EQIP Ο = CSP

Ο = CREP Ο = Other

26. Will this field be enrolled in any conservation programs in 2023? *(Check all that apply)*

Ο = Not enrolled Ο = CRP

Ο = EQIP Ο = CSP

Ο = CREP Ο = Other

27. When do you ***typically*** plant crops in this field?

Ο = April 1 or before Ο = May 1-15

Ο = April 1-15 Ο = May 16-31

Ο = April 16-30 Ο = June 1 or later

**Section 3: Hypothetical Voluntary Conservation Program for Your Field**

***Conservation Program Overview.***

Consider a hypothetical situation where ***a government agency or private conservation group*** is offering multiple ***voluntary conservation contracts*** *with different lengths* ***starting in the 2023 growing season*** (from planting in the spring of 2023 until before planting in the spring of 2024). All contracts include the adoption of one or more management practices to reduce nutrient loss, as well as an annual per-acre cost-share payment to the farmer. The practices, as well as the per-acre cost share, apply to the acreage of the entire field. In all cases, the funding group will conduct periodic observation of the field to ensure compliance over the period of the contract. Incentivized management practices in these conservation contracts can include the **planting of legume cover crops after harvest of the main crop** for the field, **restricting nutrient application** on the field, or **both practices**.

As there are many different management practices that can reduce soil and nutrient runoff, the funding group in the scenarios that follow offer multiple possible conservation contracts. We ask that you consider each contract and indicate which contract you would agree to for the field from Section 2 of this survey. If you would not want to agree to either of the offered contracts in a given choice, indicate that in the questions below.

While the questions that follow are hypothetical, we ask that you consider them carefully and ***do your best to answer as if they were real binding contracts***. Research has shown that when people are given a hypothetical situation, many times they say they would do something that, in real life, they would not actually do. This is called hypothetical bias. **We ask that you do your best to limit hypothetical bias by asking yourself, “Would I actually make this choice if I was given this situation in real life?”**

**Scenario 1**

**Please consider the terms of Programs A & B below for your field and answer the questions that follow as if a real conservation contract was being offered to you.**

|  |  |  |
| --- | --- | --- |
|  | Program A | Program B |
| Limited Nitrogen Application | Apply No more than 40 lbs. per acre | Apply No more than 60 lbs. per acre |
| Cover Crops (Planting a legume crop after harvesting the main cash crop) | Must be planted after 2023 harvest | No Requirement |
| Funding Source (who is providing the money and enforcing the contract) | Private Conservation Group | State and Federal Government Agencies |
| Annual Cost Share Payment to You | $130/acre | $10/acre |

28. Which program do you prefer?

1 = Program A 2 = Program B 3 = Neither program

29. How Certain are you about your choice?

1 2 3 4 5 6 7 8 9 10

Not at all Certain Very Certain

**Scenario 2**

**Please consider the terms of Programs A & B below for your field and answer the questions that follow as if a real conservation contract was being offered to you.**

|  |  |  |
| --- | --- | --- |
|  | Program A | Program B |
| Limited Nitrogen Application  (Applying no more than xx lbs. per acre) | No Requirement | Apply No more than 60 lbs. per acre |
| Cover Crops (Planting a legume crop after harvesting the main cash crop) | Must be planted after 2023 harvest | No Requirement |
| Funding Source (who is providing the money and enforcing the contract) | State and Federal Government Agencies | Private Conservation Group |
| Annual Cost Share Payment to You | $100/acre | $70/acre |

30. Which program do you prefer?

1 = Program A 2 = Program B 3 = Neither program

31. How Certain are you about your choice?

1 2 3 4 5 6 7 8 9 10

Not at all Certain Very Certain

32. As previously mentioned, the results of this survey will be presented and explained to state and local policy makers.

What do you think is the likelihood that these policy makers will be influenced by the results of this survey when they make agricultural policy decisions related to water quality?

0% 25% 50% 75% 100%

**|**-------------------|-------------------**|**-------------------|-------------------**|**

Extremely unlikely Neither likely nor unlikely Extremely likely

Somewhat unlikely Somewhat likely

**Section 4: About You and Your Farm**

This final section asks for basic demographic information. Why do we ask this? We like to understand if certain types of farms or farmers take different approaches or have different views about nutrient management. All information provided will be anonymous and never reported other than as averages across many other respondents. Thank you for your candid responses.

33. Are you: Ο = Male Ο = Female

34. What is your age? \_\_\_\_\_\_\_ years

35. How much formal education have you completed?

Ο = Some high school, no diploma

Ο =High School degree or equivalent

Ο = Some college, no degree

Ο = Associate’s degree

Ο = Bachelor’s degree

Ο = Graduate or Professional degree

36. In a normal year, what is your **total farm operation’s** annual gross income?

Ο = Less than $50,000

Ο = $50,000 - $99,999

Ο = $100,000 - $249,999

Ο = $250,000 - $499,999

Ο = $500,000 or greater

37. Do you currently manage livestock or poultry on your farm?

Ο = No

Ο = Yes→ How many of each do you manage?

*(Fill in the number below)*

\_\_\_\_\_\_ Dairy animals

\_\_\_\_\_\_ Poultry (one-time capacity)

\_\_\_\_\_\_ Beef (one-time capacity)

\_\_\_\_\_\_ Swine (one-time capacity)

\_\_\_\_\_\_ Other \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

38. How many years have you been farming?

\_\_\_\_\_\_\_\_\_years

39. How large is your **total farm operation**? For total acres, include cropland, woodland, pasture, wasteland, land in farmsteads, and land in government programs. Under planted acres, include any on which a crop was planted for harvest, including hay.

**Owned Rented**

Total Acres a. \_\_\_\_\_\_ d. \_\_\_\_\_\_\_

Planted Acres b. \_\_\_\_\_\_ e. \_\_\_\_\_\_\_

# of Fields c. \_\_\_\_\_\_ f. \_\_\_\_\_\_\_

40. How many of your acres are currently enrolled in any of the following programs? *(Please enter zero if you have no acres enrolled)*

EQIP \_\_\_\_\_\_ Acres

CRP \_\_\_\_\_\_ Acres

CREP \_\_\_\_\_\_ Acres

CSP \_\_\_\_\_\_ Acres

Other \_\_\_\_\_\_ Acres

Do you have any other thoughts or comments about farmers and their nutrient management decisions in North Carolina? Please share them with us here, or on the back of the survey:

**Thank you**!! Please place the completed survey in the postage-paid envelope and drop in the mail at your earliest convenience. Feel free to contact XXXXX with any questions at YYYYYY.

:

**Stata code:**

\*\*\* COMPILATION OF ALL STATA FSD DO-FILES (Mahesh Tapas)

\*\*\* FSD DO FILE 1 ------------------------------------------------------------

import excel "D:\All\research\CNH2 project\Farmer Survey\Data\Survey of Eastern North Carolina Farmers\_raw data 9\_11\_2023.xlsx", sheet("Survey of Eastern North Carolin") firstrow case(lower) clear

\* Data Cleaning

rename q9 q8

rename ax q9

\* Their response for q11\_4\_text was "veg", which wasn't very specific (Row 188)

\*replace q11 = "1" if q11=="1,4"

\* Changed "2 cows" to "2" (Row 91)

replace q37b\_5\_text = "2" if q37b\_5\_text=="2 cows"

\* Converted pounds to tons (Row 31), because they answered in pounds when the question was asked in tons/acre

replace q14\_2 = "0.6" if q14\_2=="1200 lbs"

\* One respondent put "all my life; however, they did not respond to the age question (Row 91)

replace q38 = "" if q38=="All my life"

\* We are looking for the highest level of education, so we selected the highest value

\*replace q35 = "4" if q35=="2,3,4"

\*replace q35 = "3" if q35=="2,3"

\* someone responded "2,3,4" (Row 189), so 3 was selected as as the average date range

\*replace q27 = "3" if q27=="2,3,4"

\* someone responded "2,3,4" (Row 181), so 3 was selected as as the average soil type

\*replace q21 = "3" if q21=="2,3,4"

\* Changed decimal answers to reflect integer percentages

replace q23\_2\_text = "5" if q23\_2\_text==".05"

replace q23\_2\_text = "10" if q23\_2\_text==".1"

replace q23\_2\_text = "32" if q23\_2\_text==".32"

replace q23\_2\_text = "15" if q23\_2\_text==".15"

replace q23\_2\_text = "40" if q23\_2\_text==".4"

replace q23\_2\_text = "20" if q23\_2\_text==".2"

replace q34="30" if q34==",30"

\* got rid of question marks and changed from string to long format

destring q11, replace

destring q14\_2, replace

destring q15\_2\_1, replace

destring q13, replace

destring q21, replace

destring q27, replace

destring q34, replace

destring q35, replace

destring q38, replace

destring q39\_3\_1, replace

destring q39\_3\_2, replace

destring q40\_2, replace

destring q40\_3, replace

destring q40\_5, replace

destring q37b\_5\_text, replace

\*\*\* Potential Outliers

\* Rows 185 and 192 in q13

\*\*\* Labels

label define CertaintyOfPolicyImpact 4 "75%" 3 "50%" 2 "25%" 1 "0%"

label values q32 CertaintyOfPolicyImpact

\*\*\*\*Fixing the CE variable names

rename ce\_b2s1 ce\_b1s2

rename ce\_b2s1cert\_nps\_group ce\_b1s2cert\_nps\_group

rename ce\_b2s1cert ce\_b1s2cert

rename cm ce\_b2s1

rename cn ce\_b2s1cert\_nps\_group

rename co ce\_b2s1cert

rename da ce\_b4s1cert

gen ce1=.

gen ce2=.

gen cecert1=.

gen cecert2=.

replace ce1=ce\_b1s1 if ce1==.

replace ce1=ce\_b2s1 if ce1==.

replace ce1=ce\_b3s1 if ce1==.

replace ce1=ce\_b4s1 if ce1==.

replace ce1=ce\_b5s1 if ce1==.

replace ce2=ce\_b1s2 if ce2==.

replace ce2=ce\_b2s2 if ce2==.

replace ce2=ce\_b3s2 if ce2==.

replace ce2=ce\_b4s2 if ce2==.

replace ce2=ce\_b5s2 if ce2==.

replace cecert1=ce\_b1s1cert if cecert1==.

replace cecert1=ce\_b2s1cert if cecert1==.

replace cecert1=ce\_b3s1cert if cecert1==.

replace cecert1=ce\_b4s1cert if cecert1==.

replace cecert1=ce\_b5s1cert if cecert1==.

replace cecert2=ce\_b1s2cert if cecert2==.

replace cecert2=ce\_b2s2cert if cecert2==.

replace cecert2=ce\_b3s2cert if cecert2==.

replace cecert2=ce\_b4s2cert if cecert2==.

replace cecert2=ce\_b5s2cert if cecert2==.

gen id=\_n

\*\*\* Reshaping the Data

reshape long ce cecert, i(id) j(set)

tab ce, missing

drop if ce==.

gen choice1=.

gen choice2=.

gen choice3=.

gen choicecert1=.

gen choicecert2=.

gen choicecert3=.

replace choice1=1 if ce==1

replace choice2=1 if ce==2

replace choice3=1 if ce==3

reshape long choice, i(id set) j(alternativeoptions)

replace choice=0 if choice==.

\*\*\* Creating Variables for Attribute Levels (Info from Optimal Design)

\* N Application (0 is Not Rquired, 1 is Lenient, 2 is Strict)

generate napplication = ., before(alternative)

replace napplication = 0 if alternativeoptions==3

replace napplication = 2 if block==1 & set==1 & alternativeoptions==1

replace napplication = 1 if block==1 & set==1 & alternativeoptions==2

replace napplication = 0 if block==1 & set==2 & alternativeoptions==1

replace napplication = 2 if block==1 & set==2 & alternativeoptions==2

replace napplication = 1 if block==2 & set==1 & alternativeoptions==1

replace napplication = 2 if block==2 & set==1 & alternativeoptions==2

replace napplication = 0 if block==2 & set==2 & alternativeoptions==1

replace napplication = 1 if block==2 & set==2 & alternativeoptions==2

replace napplication = 0 if block==3 & set==1 & alternativeoptions==1

replace napplication = 2 if block==3 & set==1 & alternativeoptions==2

replace napplication = 1 if block==3 & set==2 & alternativeoptions==1

replace napplication = 0 if block==3 & set==2 & alternativeoptions==2

replace napplication = 1 if block==4 & set==1 & alternativeoptions==1

replace napplication = 0 if block==4 & set==1 & alternativeoptions==2

replace napplication = 2 if block==4 & set==2 & alternativeoptions==1

replace napplication = 1 if block==4 & set==2 & alternativeoptions==2

replace napplication = 0 if block==5 & set==1 & alternativeoptions==1

replace napplication = 2 if block==5 & set==1 & alternativeoptions==2

replace napplication = 2 if block==5 & set==2 & alternativeoptions==1

replace napplication = 1 if block==5 & set==2 & alternativeoptions==2

\* Cover Crops (0 is Not Required, 1 is Required)

generate covercrops = ., before(alternative)

replace covercrops = 0 if alternativeoptions==3

replace covercrops = 1 if block==1 & set==1 & alternativeoptions==1

replace covercrops = 0 if block==1 & set==1 & alternativeoptions==2

replace covercrops = 1 if block==1 & set==2 & alternativeoptions==1

replace covercrops = 0 if block==1 & set==2 & alternativeoptions==2

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replace covercrops = 0 if block==4 & set==1 & alternativeoptions==1

replace covercrops = 1 if block==4 & set==1 & alternativeoptions==2

replace covercrops = 1 if block==4 & set==2 & alternativeoptions==1

replace covercrops = 0 if block==4 & set==2 & alternativeoptions==2

replace covercrops = 1 if block==5 & set==1 & alternativeoptions==1

replace covercrops = 1 if block==5 & set==1 & alternativeoptions==2

replace covercrops = 1 if block==5 & set==2 & alternativeoptions==1

replace covercrops = 0 if block==5 & set==2 & alternativeoptions==2

\* Funding Source (0 is No Source, 1 is State/Federal, 2 is Private)

generate fundingsource = ., before(alternative)

replace fundingsource = 0 if alternativeoptions==3

replace fundingsource = 2 if block==1 & set==1 & alternativeoptions==1

replace fundingsource = 1 if block==1 & set==1 & alternativeoptions==2

replace fundingsource = 1 if block==1 & set==2 & alternativeoptions==1

replace fundingsource = 2 if block==1 & set==2 & alternativeoptions==2

replace fundingsource = 2 if block==2 & set==1 & alternativeoptions==1

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replace fundingsource = 2 if block==3 & set==2 & alternativeoptions==2

replace fundingsource = 2 if block==4 & set==1 & alternativeoptions==1

replace fundingsource = 1 if block==4 & set==1 & alternativeoptions==2

replace fundingsource = 1 if block==4 & set==2 & alternativeoptions==1

replace fundingsource = 2 if block==4 & set==2 & alternativeoptions==2

replace fundingsource = 1 if block==5 & set==1 & alternativeoptions==1

replace fundingsource = 2 if block==5 & set==1 & alternativeoptions==2

replace fundingsource = 1 if block==5 & set==2 & alternativeoptions==1

replace fundingsource = 1 if block==5 & set==2 & alternativeoptions==2

\* Payment (0 is $0, 1 is $130, 2 is $100, 3 is $70, 4 is $40, 5 is $10)

generate payment = ., before(alternative)

replace payment = 0 if alternativeoptions==3

replace payment = 1 if block==1 & set==1 & alternativeoptions==1

replace payment = 5 if block==1 & set==1 & alternativeoptions==2

replace payment = 2 if block==1 & set==2 & alternativeoptions==1

replace payment = 3 if block==1 & set==2 & alternativeoptions==2

replace payment = 4 if block==2 & set==1 & alternativeoptions==1

replace payment = 5 if block==2 & set==1 & alternativeoptions==2

replace payment = 4 if block==2 & set==2 & alternativeoptions==1

replace payment = 1 if block==2 & set==2 & alternativeoptions==2

replace payment = 5 if block==3 & set==1 & alternativeoptions==1

replace payment = 4 if block==3 & set==1 & alternativeoptions==2

replace payment = 3 if block==3 & set==2 & alternativeoptions==1

replace payment = 1 if block==3 & set==2 & alternativeoptions==2

replace payment = 2 if block==4 & set==1 & alternativeoptions==1

replace payment = 3 if block==4 & set==1 & alternativeoptions==2

replace payment = 4 if block==4 & set==2 & alternativeoptions==1

replace payment = 2 if block==4 & set==2 & alternativeoptions==2

replace payment = 3 if block==5 & set==1 & alternativeoptions==1

replace payment = 5 if block==5 & set==1 & alternativeoptions==2

replace payment = 2 if block==5 & set==2 & alternativeoptions==1

replace payment = 1 if block==5 & set==2 & alternativeoptions==2

\* Adjust Payment Variable to Dollars

replace payment = 130 if payment==1

replace payment = 100 if payment==2

replace payment = 70 if payment==3

replace payment = 40 if payment==4

replace payment = 10 if payment==5

\*\*\* Creating Dummy Variables

\* N Application Dummy Variables

generate dummylenientn = ., before(covercrops)

replace dummylenientn = 1 if napplication==1

replace dummylenientn = 0 if napplication==0 | napplication==2

generate dummystrictn = ., before(covercrops)

replace dummystrictn = 1 if napplication==2

replace dummystrictn = 0 if napplication==0 | napplication==1

\* Funding Source Dummy Variables

generate dummystatefunding = ., before(payment)

replace dummystatefunding = 1 if fundingsource==1

replace dummystatefunding = 0 if fundingsource==0 | fundingsource==2

generate dummyprivatefunding = ., before(payment)

replace dummyprivatefunding = 1 if fundingsource==2

replace dummyprivatefunding = 0 if fundingsource==0 | fundingsource==1

\*\*\* Creating the Alternative Specific Constant (ASC)

\* ASC (0 if anything other than status quo, 1 if status quo)

generate asc = ., before(alternative)

replace asc = 1 if alternativeoptions==3

replace asc = 0 if alternativeoptions !=3

\*gen Case Variable

gen case=10\*id+set

sort case

by case: egen totalchosen=total(choice)

tab totalchosen

\*\*\* Running the Conditional Logit

\*\* Conditional Logit for all Variabes

\* Dummy Variables for N application, Cover Crops, and Funding Source

\* vce command clusters standard errors around farmers

clogit choice dummylenientn dummystrictn covercrops dummystatefunding payment asc, group(id) vce(cluster id)

mixlogit choice payment, rand(dummylenientn dummystrictn covercrops dummystatefunding asc) group(case) id(id) nrep(500)

mixlogit choice payment dummylenientn dummystrictn dummystatefunding , rand(asc covercrops) group(case ) id(id) nrep(500)

mixlogit choice dummylenientn dummystrictn dummystatefunding , rand(asc covercrops payment) ln(1) group(case) id(id) nrep(500)

mixlbeta dummylenientn dummystrictn dummystatefunding asc covercrops payment if e(sample)==1, sav("D:\All\Advising\Tapas\mixlbetas") replace

save "D:\All\Advising\Tapas\post mixlogit data.dta", replace

use "D:\All\Advising\Tapas\mixlbetas.dta" , clear

rename dummylenientn bdummylenientn

rename dummystrictn bdummystrictn

rename dummystatefunding bdummystatefunding

rename asc basc

rename covercrops bcovercrops

rename payment bpayment

save "D:\All\Advising\Tapas\mixlbetas.dta" , replace

use "D:\All\Advising\Tapas\post mixlogit data.dta", clear

duplicates drop id, force

merge 1:1 id using "D:\All\Advising\Tapas\mixlbetas.dta"

gen ones=1

drop if bpayment==.

replace q39\_3\_1="." if q39\_3\_1=="?"

replace q39\_3\_2="." if q39\_3\_2=="?"

destring q39\_3\_1 q39\_3\_2, replace

replace q7=q39\_1\_1/q39\_3\_1 if q7==.

\*\*\*Contract with strict N limit, state funding

gen WTA\_StrictN =(basc-bdummystrictn-bdummystatefunding)/bpayment

\*\*\*Contract with cover crops, state funding

gen WTA\_CC =(basc-bcovercrops-bdummystatefunding)/bpayment

gen stotalsamp=48

egen total\_acres=total(q7)

\*\*\*\*Total in sample: 4,607 acres

\*\*\*\*Total in Tar-Pamlico: 28% of land x 6,400 sq. miles in Tar-Pam \* 640 acres in sq. mile = 1,146,880 acres in Tar-Pamlico

\*\*\*\*One acre in our sample represents 250 acres in Tar Pam

\*\*\*Simulation for Strict N restriction

egen totalSN=count(ones) if WTA\_StrictN<=50

sum totalSN

scalar stotalSN=r(mean)

scalar penrolledSN=stotalSN/stotalsamp

di penrolledSN

\*\*\*Total acreage enrolled

egen total\_acreageSN=total(q7) if WTA\_StrictN<=50

sum total\_acreageSN

\*\*\*Total in sample: 1,382.277

\*total in Tar-Pam = 1,382.277\*250 = 345,569 acres at cost of 345,569\*50 = $17,278,462

\*\*\*Simulation for Cover Crops

egen totalCC=count(ones) if WTA\_CC<=70

sum totalCC

scalar stotalCC=r(mean)

scalar penrolledCC=stotalCC/stotalsamp

di penrolledCC

\*\*\*Total acreage enrolled

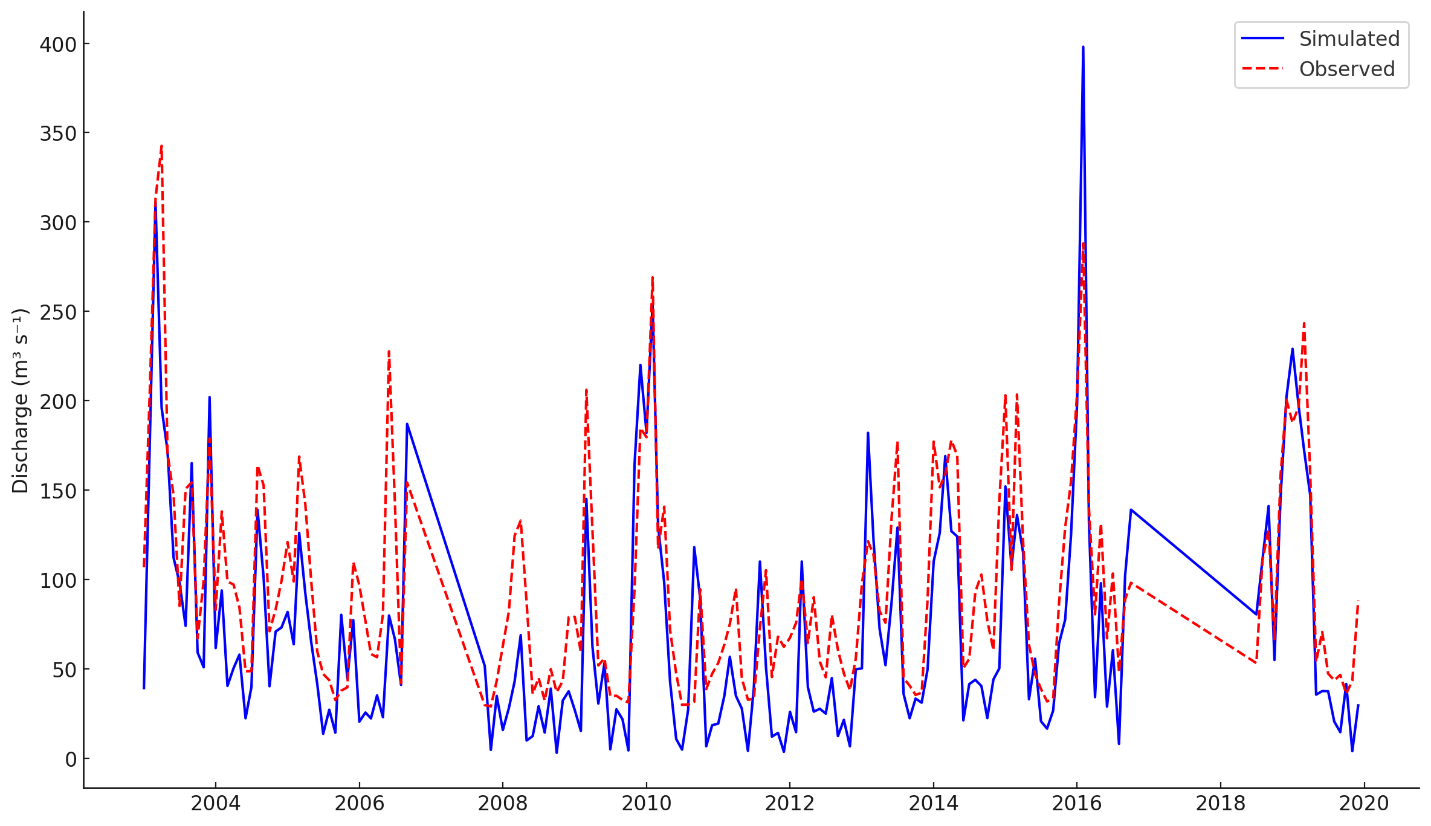
egen total\_acreageCC=total(q7) if WTA\_CC<=50

sum total\_acreageCC

\*\*\*Total in sample: 1,539.277

\*total in Tar-Pam = 1,539.277\*250 = 384,750 acres at cost of 384,750\*50 = $26,932,500

**Flow Calibration (Washington, NC)**



For flow optimization (Appendix-A) during the calibration period (Jan 2003 to Dec 2011), the model demonstrated a moderate ability to capture the observed flow dynamics, evidenced by Nash-Sutcliffe Efficiency (NSE) and Coefficient of Determination (R²) values of 0.488, along with a Kling-Gupta Efficiency (KGE) of 0.664. This performance was slightly improved in the validation period (Jan 2012 to Dec 2019), where NSE and R² values increased to 0.554, and KGE to 0.699. Notably, the model was more adept at capturing baseflows than peak flows, a common challenge in hydrological modeling due to the complex processes driving extreme events. The seasonal variation, with typically higher flows in spring and lower in summer and fall, was reasonably represented.

**Plant yield & denitrification (based on literature)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Plant | Denitrification rate (kg/ha) FRESH | Denitrification rate (kg/ha) SALT | Plant yield (kg/ha) FRESH | Plant yield (kg/ha) SALT | Notes |
| Corn | 7.48 kg N/ha during growing season (April-August) (10.2134/jeq1997.00472425002600020004x) | 2.244 | 8473.63 (https://www.nass.usda.gov/Quick\_Stats/Ag\_Overview/stateOverview.php?state=NORTH%20CAROLINA) | 7846.58 (based on Gibson et al. 2021, Table 1, see notebook) | Plant yields are all in kg/ha/year for all of North Carolina |
| Cotton | 65.05 | 19.515 | 1175.773 (https://www.nass.usda.gov/Quick\_Stats/Ag\_Overview/stateOverview.php?state=NORTH%20CAROLINA) | 1114.633 (based on Gibson et al. 2021, Table 1, see notebook) | cotton denitrification rate fresh is the average of 1995 and 1996 growing seasons, in terms of kg N/ha (https://link.springer.com/article/10.1007/s003740050656) |
| Soyb | 2.22-5.23 kg N/Ha \* growning season (up to 24 kg/Ha\*year) | 0.666-1.569 kg N/Ha \* growing season | 2589.17 (https://www.nass.usda.gov/Quick\_Stats/Ag\_Overview/stateOverview.php?state=NORTH%20CAROLINA) | 2071.34 (based on Gibson et al. 2021, Table 1, see notebook) | Denit based on https://cdnsciencepub.com/doi/abs/10.4141/S96-060 |
| Agrr (general) | 3 kg/ha (https://link.springer.com/article/10.1007/s10705-005-3109-y) | 0.9 | 4079.524333 | 3634.856 (based on Gibson et al. 2021, Table 1, see notebook) | Note that 3 kg/ha is not over time. The denit rates for corn an cotton are totalled over an entire growing season, so much larger than the 3 kg/ha number |
| Wetlands | 200.405 | 60.1215 | 4892.5 | 16655 |  |
|  | Above number: kgN/ha\*year. Average of values from https://link.springer.com/article/10.1007/s11104-006-9105-4/tables/2 | Above number: decreased denitrification by 70% in following saltwater intrusion into freshwater tidal marsh (https://link.springer.com/article/10.1007/s10021-018-0312-7) | For Wetlands (above), used Megagram/ha measure values for Maryland wetlands, from doi:10.2489/jswc.2020.00089 | For above, used average dry-weight yield of control from Spartina marsh in Louisiana (https://www.sciencedirect.com/science/article/pii/0302352476900062) |  |
| Wetlands (alternative, solution, probably better) |  |  | 4892.5 | 2206.5175 |  |
|  |  |  | Same method as above | Based on a -54.9% change in net ecosystem productivity, observed in experimental addition of salinity to tidal freshwater marsh: https://link.springer.com/article/10.1007/s12237-011-9455-x) |  |
|  |  | Could not find agricultural decreases in denitrification with saltwater intrusion. So, used 70% decrease from https://link.springer.com/article/10.1007/s10021-018-0312-7 for all agricultural denitrification |  |  |  |

Waste water treatment plant data, Tar-Pam

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NPDES permit number | Facility name | Latitude | Longitude | Permit type | Cooresponding Point in SWAT+ (old project) | Cooresponding Point in SWAT+ (new project) | Nitrate Limit (kg/yr) | PermittedFlow (gal/day) | Permitted flow (m3/day) | Flow for SWAT+ | N for SWAT | Remark |
| NC0025691 | Littleton WWTP | 36.41500 | -77.90611 | Municipal (< 1 Mgal/day) | 25 | 248 | 1801.85516 | 280,000 | 1059.9148 | 741.94036 | 4.442931 |  |
| NC0042269 | Bunn WWTP | 35.94472 | -78.26139 | Municipal (< 1 Mgal/day) | 36 | 202 | 1941 | 150,000 | 567.8115 | 397.46805 | 4.786027 |  |
| NC0038580 | Eastman Middle School WWTP | 36.23944 | -77.85056 | 100% Domestic (< 1 Mgal/day) | 43 | 222 | 30.8889456 | 4,800 | 18.169968 | 12.7189776 | 0.076165 |  |
| NC0020834 | Warrenton WWTP | 36.37972 | -78.16861 | Municipal, Large, (> 1 Mgal/day) | 50 | 250 | 12398 | 2,000,000 | 7570.82 | 5299.574 | 30.57041 |  |
| NC0050415 | Phillips Middle School | 36.00472 | -77.68639 | 100% Domestic (< 1 Mgal/day) | 52 | 204 | 64.35197 | 10,000 | 37.8541 | 26.49787 | 0.158676 |  |
| NC0047279 | Heritage Meadows WWTP | 36.38167 | -78.66167 | 25 | 62 | 234 | 64.35197 | 10,000 | 37.8541 | 26.49787 | 0.158676 |  |
| NC0025054 | Oxford WWTP | 36.27722 | -78.59111 | Municipal, Large, (> 1 Mgal/day) | 64 | 236 | 22641 | 3,500,000 | 13248.935 | 9274.2545 | 55.82712 |  |
| NC0048631 | Long Creek Court WWTP | 36.22278 | -78.45417 | 100% Domestic (< 1 Mgal/day) | 66 | 226 | 45.046379 | 7,000 | 26.49787 | 18.548509 | 0.111073 |  |
| NC0038610 | Pittman Elementary School WWTP | 36.26361 | -77.74417 | 100% Domestic (< 1 Mgal/day) | 72 | 228 | 61.7778912 | 9,600 | 36.339936 | 25.4379552 | 0.152329 |  |
| NC0025402 | Enfield WWTP | 36.15056 | -77.68806 | Municipal, Large, (> 1 Mgal/day) | 86 | 40 | 6469 | 1,000,000 | 3785.41 | 2649.787 | 15.95096 |  |
| NC0020231 | Louisburg WWTP | 36.08667 | -78.29222 | Municipal, Large, (> 1 Mgal/day) | 88 | 218 | 8862 | 1,000,000 | 3785.41 | 2649.787 | 21.85151 | Value assumed |
| NC0029131 | Kittrell Job Corps Center | 36.22556 | -78.45389 | 100% Domestic (< 1 Mgal/day) | 93 | 224 | 160.879925 | 25,000 | 94.63525 | 66.244675 | 0.39669 |  |
| NC0038644 | Dawson Elementary School WWTP | 36.16917 | -77.52306 | 100% Domestic (< 1 Mgal/day) | 95 | 220 | 46.9769381 | 7,300 | 27.633493 | 19.3434451 | 0.115834 |  |
| NC0069311 | Franklin County WWTP | 36.07000 | -78.41694 | Municipal, Large, (> 1 Mgal/day) | 110 | 214 | 19407 | 3,000,000 | 11356.23 | 7949.361 | 47.85288 |  |
| NC0050431 | North Edgecombe High School | 35.98056 | -77.59444 | 100% Domestic (< 1 Mgal/day) | 119 | 42 | 128.70394 | 20,000 | 75.7082 | 52.99574 | 0.317352 |  |
| NC0030317 | Tar River Regional WWTP | 35.98250 | -77.72028 | Municipal, Large, (> 1 Mgal/day) | 121 | 200 | 135139.137 | 21,000,000 | 79493.61 | 55645.527 | 333.2198 |  |
| NC0037885 | Southern Nash Middle School | 35.88194 | -78.08750 | 100% Domestic (< 1 Mgal/day) | 131 | 198 | 96.527955 | 15,000 | 56.78115 | 39.746805 | 0.238014 |  |
| NC0020061 | Spring Hope WWTP | 35.90528 | -78.11278 | Municipal (< 1 Mgal/day) | 132 | 212 | 2588 | 400,000 | 1514.164 | 1059.9148 | 6.38137 |  |
| NC0042510 | Lake Royale WWTP | 35.94889 | -78.19083 | 100% Domestic (< 1 Mgal/day) | 134 | 210 | 514.81576 | 80,000 | 302.8328 | 211.98296 | 1.269409 |  |
| NC0023337 | Scotland Neck WWTP | 36.11944 | -77.43389 | Municipal (< 1 Mgal/day) | 146 | 216 | 4367 | 675,000 | 2555.15175 | 1788.60623 | 10.76795 |  |
|  | City of Washington WWTP |  |  |  | 230 | 24 | 23611 | 3,650,000 | 13816.7465 | 9671.72255 | 58.2189 | These are 2 plants so combined the flow |
|  | GUC |  |  |  | 237 | 30 | 113206 | 17,500,000 | 66244.675 | 46371.2725 | 279.1381 |  |

**Sensitivity analysis**

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Description automatically generated**Parameter sensitivity analysis (a: CF\_ERA-5, b: CF\_gridMET, c: CF\_GPM IMERG, d: TP\_ERA-5, e:TP\_gridMET, f:TP\_GPM IMERG; \* indicates t\_stat<20; # indicates t\_stat>10).

**Parameters used for model optimization**

SWAT+ model optimization parameters details [bsn: Basin, sol: Soil, hru: Hydrological Response Unit, plt: Plant]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Parameter Range (Unit)** | **Resolution** | **Type of Change** | **Description** | **Initial range used for model calibration**  **(min, max)** | **Calibrated parameter value** |
| surlag | 0.05, 24.0  (days) | bsn | Absolute Value | Surlag Controls delay in surface runoff release | 0.05, 24 | 3.574 |
| cmn | 0.001, 0.003  (-) | bsn | Absolute Value | Rate factor for humus mineralization of organic nutrients | 0.001, 0.003 | 0.0018 |
| cdn | 0.0, 3.0  (-) | bsn | Absolute Value | Denitrification rate control | 0, 3 | 2.261 |
| sdnco | 0.0, 1.0  (-) | bsn | Absolute Value | Denitrification threshold water content | 0, 1 | 0.559 |
| nperco | 0.0, 1.0  (-) | bsn | Absolute Value | Nitrate percolation coefficient | 0.01, 1 | 0.080 |
| n\_updis | 0.0, 100.0  (-) | bsn | Absolute Value | Nitrogen uptake distribution parameter controlling depth distribution of nitrogen uptake in soil | 0, 100 | 49.233 |
| awc | 0.01, 1.0  (mm H2O mm-1) | sol | Absolute Change | The difference in soil water content between field capacity and permanent wilting point | -0.3, 0.3 | 0.081 |
| bd | 0.9, 2.5  (g cm-3) | sol | Absolute Change | Moist bulk density, representing soil's mass-to-volume ratio at or near field capacity. | -0.4, 0.8 | 0.271 |
| k | 0.0001, 2000.0 (mm hr-1) | sol | Percent Change | Saturated hydraulic conductivity, indicating the ease of water movement through soil | -30, 30 | -4.024 |
| z | 0.0, 3500.0  (mm) | sol | Percent Change | Depth from soil surface to bottom of layer | -30, 30 | 1.469 |
| esco | 0.0, 1.0  (-) | hru | Absolute Change | Soil evaporation compensation factor which allows modification of depth distribution to meet soil evaporative demand, considering capillary action, crusting, and cracks. | -0.3, 0.3 | -0.069 |
| epco | 0.0, 1.0  (-) | hru | Absolute Change | Plant uptake compensation factor which allows adjustment of water uptake depth distribution in response to plant transpiration demand and soil water availability. | -0.3, 0.3 | -0.114 |
| biomix | 0.0, 1.0  (-) | hru | Absolute Change | Biological mixing efficiency, determining redistribution of soil constituents by biota activity. | -0.3, 0.3 | -0.048 |
| latq\_co | 0.0, 1.0  (-) | hru | Absolute Change | Coefficient for the Plant ET curve number | -0.3, 0.3 | 0.101 |
| perco | 0.0, 1.0  (fraction) | hru | Absolute Change | Percolation coefficient, adjusting soil moisture for percolation to occur. | -0.3, 0.3 | -0.272 |
| cn2 | 35.0, 95.0  (-) | hru | Percent Change | Curve number for Condition II runoff potential. | -30, 30 | 12.283 |
| cn3\_swf | 0.0, 1.0  (-) | hru | Percent Change | Soil water factor for the curve number for condition III runoff potential | -30, 30 | -24.729 |
| ovn | 0.01, 30.0  (-) | hru | Percent Change | Manning's "n" value for overland flow velocity estimation | -30, 30 | 14.865 |
| canmx | 0.0, 100.0  (mm H2O) | hru | Percent Change | Maximum canopy storage, representing the maximum amount of water held in the canopy when fully developed. | -30, 30 | -0.189 |
| lat\_ttime | 0.5, 180.0  (days) | hru | Percent Change | Lateral flow travel time allows the model to calculate travel time based on soil hydraulic properties. | -30, 30 | -19.100 |
| revap\_min | 0.0, 50.0  (m) | aqu | Percent Change | Threshold depth of water in shallow aquifer for percolation to deep aquifer | -30, 30 | 7.659 |
| Lai\_pot | 0.5, 10  (m2 m-2) | Plt | Absolute Value | Potential maximum leaf area index | NA | Corn: 5  Cotton: 2.5  Soyb: 2.027 |
| Harv\_idx | 0.01, 1.25  (-) | plt | Absolute Value | Harvest index- crop yield/aboveground biomass | NA | Soyb: 0.418 |

SLR Plant database update

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