**N Model for Iowa Agricultural Systems**

**Learning Objectives**

1. Understand that by the Law of Conservation of Mass, the mass of an element is neither created nor destroyed. Thus, as nitrogen (N) cycles, it flows between stocks (= reservoirs, pools, stores, storages), but the sum of all stocks remains constant. This allows us to work with element budgets.

2. Learn how we can use simulation models to pose ‘What-if?’ questions about the effects about the effects of management on N cycling in agricultural system. This includes questions about cropping system, N fertilizer addition, tilled vs no-till, cover crops and riparian buffer strips.

3. Gain an understanding of how local management can influence soil health, and local and regional water and air pollution.

**Access the N Model**

To access and run the model on a laptop, follow the instructions at:

<https://www.nrem.iastate.edu/nmodel/how-run-model>

**Part A: Conservation of mass**

1. Open the model and use it in ‘Lab’ mode.
2. Set the parameters: Cropping system = Continuous corn; Fertilizer = 90 in spring; Management = Tilled; Randomness = Deterministic.
3. Open the Excel spreadsheet ‘N in IA Ag model worksheet’, **Part A** and note that values for the Initial stocks at the start of the run have been entered for you.
4. Run the model. When the model pauses at the end of the 10-year run, record the ‘Final’ stocks in the spreadsheet. It is set up to calculate the difference in stocks over time, i.e., the ‘Final’ amount at the end of the 10-yr model run, minus the ‘Initial’ amount.
5. Summarize the data collected in Table 1 below and then address these questions:
   1. Did the N stocks within a given pool, e. g., Soil Inorganic N, differ between the Initial and Final times?

Soil Inorganic and Organic N both decreased, while N in Crop Yield and the Stream increased. Atmospheric N did not change.

* 1. Determine whether Total N stocks, i.e., the sum of all the stocks in the whole system plus the fertilizer added, differed between the Initial and Final times. Was the difference in Total N stocks close to zero? ***Note:***Rounding errors might cause it not to be *exactly* zero.

The change in total N was close to zero (-1).

* 1. Do your data support the Law of Conservation of Mass? How does this Law enable us to construct element budgets in ecosystems?

Yes, assuming that the change in total N of -1 kg/ha in a pool of 15,218 kg/ha was simply the result of rounding errors. Although an element may move between pools as it undergoes chemical transformations, the total mass of it within a system remains constant – mass is neither created nor destroyed.

Table 1. N Stocks in an IA Agricultural System. ‘Total N’ is the sum across all stocks. ‘Initial’ and ‘Final’ refer to the timing of the measurements, at the start and end of the model run of 10 years.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Timing** | **Stock** (kg N/ha) | | | | | | |
|  | Atmosphere | Soil Inorganic N | Crop Yield | Soil Organic N | Stream | Buffer Strip | Total N |
| Initial | 8000 | 200 | 0 | 6300 | 0 | 0 | 15218 |
| Final | 8000 | 46 | 1054 | 5976 | 142 | 0 | 15218 |
| Difference in Stocks over time | 0 | -153 | 1054 | -324 | 142 | 0 | -1 |

**Part B: What-If questions about management factors**

1. Use the model, again in **‘Lab’** mode, to explore three scenarios by comparing output from a baseline run with a run in which you have changed only **one** parameter, e.g., fertilizer addition or management.
2. Develop a plan for how you will use the model to answer ‘What-If?’ questions under each of three Scenarios (stated below). Identify and record in Table 1 (Yellow shaded part) the:
3. Parameters for the baseline run for your scenario (i.e., Cropping System, Fertilizer, Management).
4. Single parameter that you need to change in the second run to be able to answer the ‘What-If?’ question.
5. Output data on stocks that you need to record to make comparisons that will allow you to address the ‘What-If?’ question (blue-shaded part of Table).
6. Other stocks you should look at to determine other, perhaps unintended effects of the change made in the parameter.
7. Fill in the data in the table below as you proceed.
8. Interpret your results.

**What-If questions to explore for three Scenarios:**

Scenario 1 – Effect of fertilizer: Does planting continuous corn with N fertilizer at 270 kg/ha in spring increase Yield?

Scenario 2 – Effect of perennial crop: Does planting perennial Alfalfa increase Soil Organic N stocks?

Scenario 3 – Effect of cover crop:  Does planting a corn-soybean rotation (N fertilizer = 180 in spring) with management of ‘Cover Crop’ reduce N stocks in ‘N Stream’? What is the significance of this?

**Table 2**. Parameters and stocks in model runs. For each Scenario, ‘a’ = baseline (initial) run; ‘b’ = experimental (final) run. ‘Sp’ = Spring.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Scenario** | **Parameter Settings** | | | **Final N Stocks in Model Run (All in kg/ha)** | | | | | |
|  | Cropping system | Fertilizer | Manage-ment | Atmo-sphere | Soil In-organic N | Yield | Soil Organic N | Stream (10-yr total) | Buffer Strip |
| 1a | CC | 90-Sp | Tilled | 8000 | 46 | 1054 | 5976 | 142 | 0 |
| 1b | CC | 270-Sp | Tilled | 8096 | 232 | 1519 | 6611 | 458 | 0 |
|  | | | | | | | | | |
| 2a | CC | 0 | Tilled | 8000 | 31 | 502 | 5810 | 72 | 0 |
| 2b | Alfalfa | 0 | Tilled | 4127 | 221 | 1775 | 7820 | 138 | 0 |
|  | | | | | | | | | |
| 3a | CS | 180-Sp | Tilled | 8043 | 286 | C: 1072  S: 1255 | 5447 | 246 | 0 |
| 3b | CS | 180-Sp | Cover Crop | 7361 | 128 | C: 1131  S: 1314 | 5544 | 210 | 0 |

**Results: Interpret the data collected from the** **modeled Scenarios:**

Scenario 1: Does planting continuous corn with N fertilizer at 270 in spring increase Yield?

Results: Yield increased from 1054 to 1519 kg/ha N when N fertilizer was increased from 90 to 270 kg/ha. N is an essential nutrient, and corn is a high-N-demanding crop, so N uptake and productivity, and thus yield, are linked. Is there a limit to the increase in yield that could be achieved by adding more and more N fertilizer? Could you address this question with more modeling runs?

Scenario 2: Does planting perennial Alfalfa increase Soil Organic N stock?

Results: Soil Organic N stocks were only 5810 kg/ha after 10 years under continuous corn, but increased to 7820 kg/ha after 10 years under alfalfa. Alfalfa is a perennial crop that has more root growth than corn. Thus, alfalfa contributes more organic matter to soil than does corn. Also, because alfalfa is not tilled, there is less soil disturbance, leading to less soil organic matter mineralization.

Scenario 3: Planting a corn-soybean rotation (N fertilizer = 180 in spring) with management of ‘Cover Crop’ reduces N stocks in ‘N Stream.’ What is the significance of this?

Results: N in streamflow over 10 years was 246 kg/ha without a cover crop and reduced to 210 kg/ha with a cover crop. Thus, planting a cover crop reduced N losses to streams. However, the reduction was only about 12.5%. A cover crop could take up inorganic N in the soil when the crop was not growing, reducing the pool of leachable Soil Inorganic N.

**Discussion: Simulation Modeling and Real-World Experiments**

1. Please check out this article for a brief explanation of the relationship between simulation modeling and real-world experiments: <https://www.energy.gov/ne/articles/role-modeling-and-simulation-scientific-discovery>. To summarize, simulation modeling is not intended to be a substitute for real-world experiments. Modeling is valued in scientific discovery however, because it complements actual experiments by providing insights that might be impossible or impractical to discover in real-world experiments.
2. Pretend that you’ve decided to conduct a real-world experiment to test any one of the above three hypotheses. State which hypothesis you will test and briefly describe the design of the experiment. *Hint*: Remember back to the beginning of the course and be sure to include the critical elements of design of an experiment.

H1: Planting continuous corn with N fertilizer at 270 in spring increases Yield.

Experimental Design: A field-based randomized complete block design with 4 blocks and 4 levels of N fertilizer added in spring, 0, 90, 180 and 270 kg/ha. The independent variable is the N Fertilizer level. The dependent variable is the Yield measured. One cannot control the weather, so repeat the experiment over several years to analyze the effect of that variability on the results. Repeat the experiment in various sites with different soil types to analyze the effect of soil on the results.

1. For the ‘Randomness’ setting, we ran the model in the ‘Deterministic’ mode, meaning that the climate factors (temperature and precipitation) were the same across all model runs. As such, there could not be any realistic replication by running the model multiple times. The ‘Stochastic’ setting incorporates the standard deviation and skewness of these climate variables on a monthly basis over a 20-year period.
2. Re-run any of the above scenarios using the ‘Stochastic’ mode. Did the Final values turn out the same as in your previous run?

No, the Final stocks were different than in the previous run.

1. Why would changing the ‘Randomness’ setting to ‘Stochastic’ allow for more realistic replication, and thus use of statistical tests across time?

The ‘Stochastic’ setting incorporates the observed variability in monthly temperature and precipitation, and this in turn would drive variability in N cycling and stocks of N. This would be more representative of temporal variation in real-world experiments. One could design statistical tests to evaluate of climate variability on output data.

1. What is the ‘Dead Zone’? How do management practices at the farm level in Iowa affect eutrophication (inputs of high levels of nutrients, mainly from industrialized agriculture and inadequate water treatment) and hypoxia (low oxygen levels) in the Gulf of Mexico? Check out these videos to address these questions.

<https://www.noaa.gov/media-release/average-dead-zone-for-gulf-of-mexico-predicted>

<https://www.youtube.com/watch?v=rK_mEHqx7rw>

Hypoxic or Dead Zones are areas of low to no oxygen that can kill fish and marine life. Low oxygen levels are caused by eutrophication, inputs of high levels of nutrients, mainly from industrialized agriculture and inadequate water treatment. High nutrient levels stimulate productivity of plankton, which die, sink to the ocean floor and decompose, consuming oxygen. Hypoxia occurs during the middle of summer when there is strong stratification: the pycnocline is a layer in an ocean in which water density increases rapidly with depth. Lack of mixing blocks oxygen above pycnocline from replenishing the O2 supply below, where aerobic respiration has consumed O2. Hypoxia occurs at <2 ppm O2. Most marine organisms in near-bottom waters cannot tolerate low-oxygen levels, so they either escape this habitat or die.