# Understanding the dynamics of nutrient management and runoff from plant farms in the Potomac watershed

**Take example of nitrogen management in corn planting of Frederick**

By

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# Appendix B

# 1. Sensitivity Test

We have use sensitivity test on the parameters that have important effects on structure or have much uncertainty. The sensitivity test results help to estimate reasonable range for parameters value, test the robustness of the structure and also give important indications for the analysis and policy.

1. Adjustment time for capital

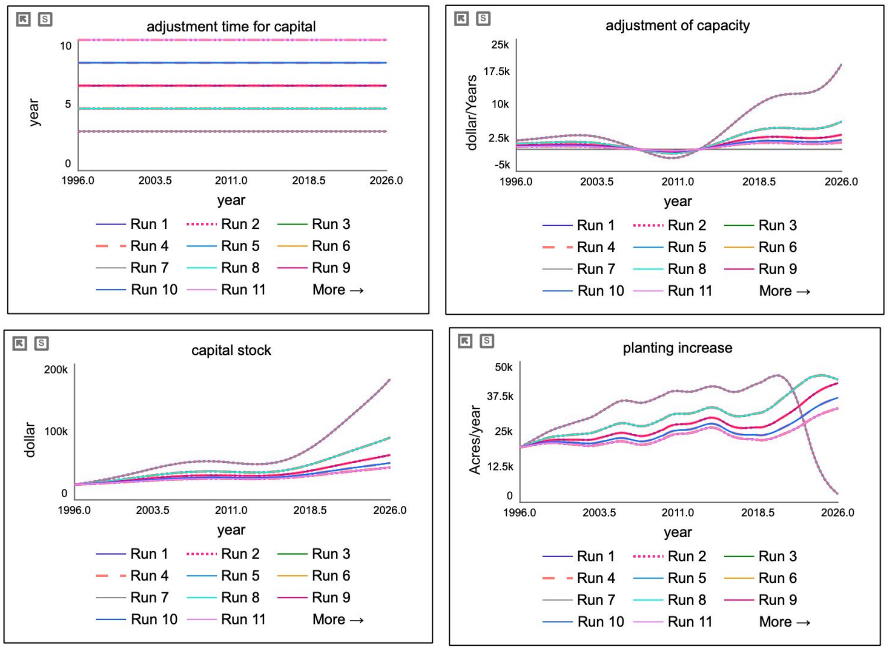



Figure 2 Sensitivity test on Adjustment time for capital

Adjustment time for capital shows how long time that capital level can be adjusted to desired level for capacity adjustment. Figure 2 shows when the adjustment time for capital is longer, the adjustment for capacity shows more gentle change and oscillation. As a result, capital stock shows similar trend and planting increase shows lower increase or decreasing trend. The whole system is less sensitive. When the adjustment time for capital is shorter, the adjustment capacity shows higher level, which indicates the capital in the industry has experienced frequent adjustment with shorter delay. Capital stock shows a general higher amount. As a result, planting acreage also shows higher increase every year.

The scenarios indicates that with a shorter adjustment time for capital would cause a larger amount of capital occupation in the production and push a higher planting acres. A longer capital adjustment is beneficial to prevent frequent and large oscillation in the commodity production system.

2. Utilization adjustment time

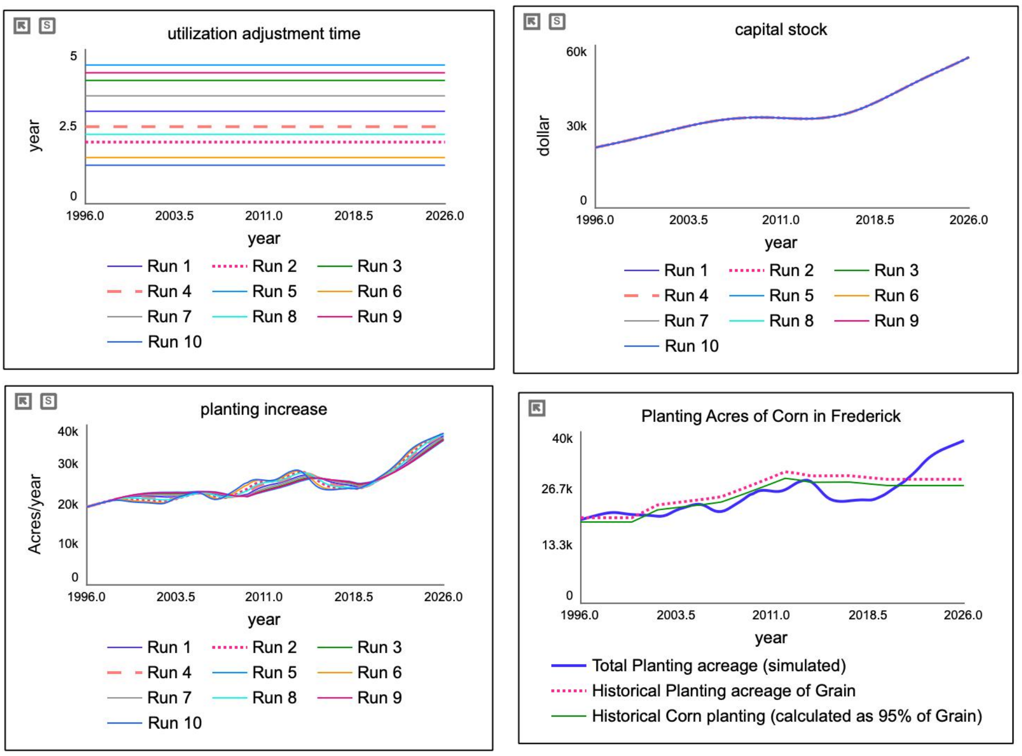
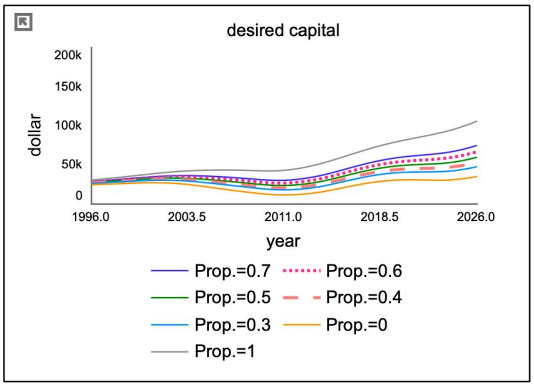



Figure 1 Sensitivity test on Capacity Utilization Adjustment Time

Utilization adjustment time is the most important delay for the utilization structure, which shows how long time farmers can adjust their utilization rate for existing capacity. Figure 1 shows, by adjusting it from 1 year to 5 years, the planting increase does not show high sensitivity. The change on planting increase is limited in 5000 acres between two extreme value: 1 year and 5 years. The most difference by parameter adjustment comes from the different delays for the oscillation. The main trend of planting acreage stays the same. It has no effect on capital level or capacity adjustment structure.

3. Different large farm proportion



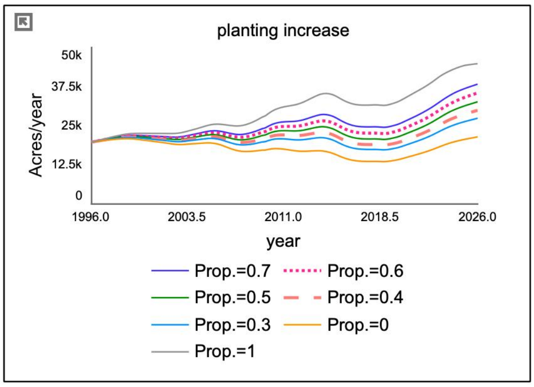




Figure 3 Sensitivity test on large farm proportion

Different large farm proportion represents for how much proportion of large farms existing in total farms. We have tested it from 03 to 0.7 (original value) and two extreme values as 0 and 1. We could see that with a lower proportion of large farms than 0.7, the desired capital level would be generally lower than original level. As a result, the planting increase also shows a decreasing to the change. However, we can find out that general changing trend of capital and planting increase rate is not changed. By the end of simulation horizon, scenarios from all proportion give an increasing trend. As a comparison, with a lower proportion of large farms, the graphs shows a more obvious falling during increasing years, while when there is higher proportion of large farms, it just shows more steady as approximate equilibrium, then in the increasing years, it rises up quickly.

This corresponds to the difference of sensitiveness to profitability between large farms and small farms. When expected profitability is lower, small producers would decrease investing willing , while larger producers could continue the normal investment. When expected profitability is falling to negative, small producers would withdraw capital and leave the market, while larger producers can just stop adding more investment to the industry but continue their production, because they have a higher production efficiency by more advanced technology and capital input as well as a better risk resistance by a closely cooperation with retailer company. Hence,the uncertainty on proportion of large farms would not bring unexpected effect to the trend of planting increase rate and the result meet our former assumptions and analysis.

4. Expected acquisition delay

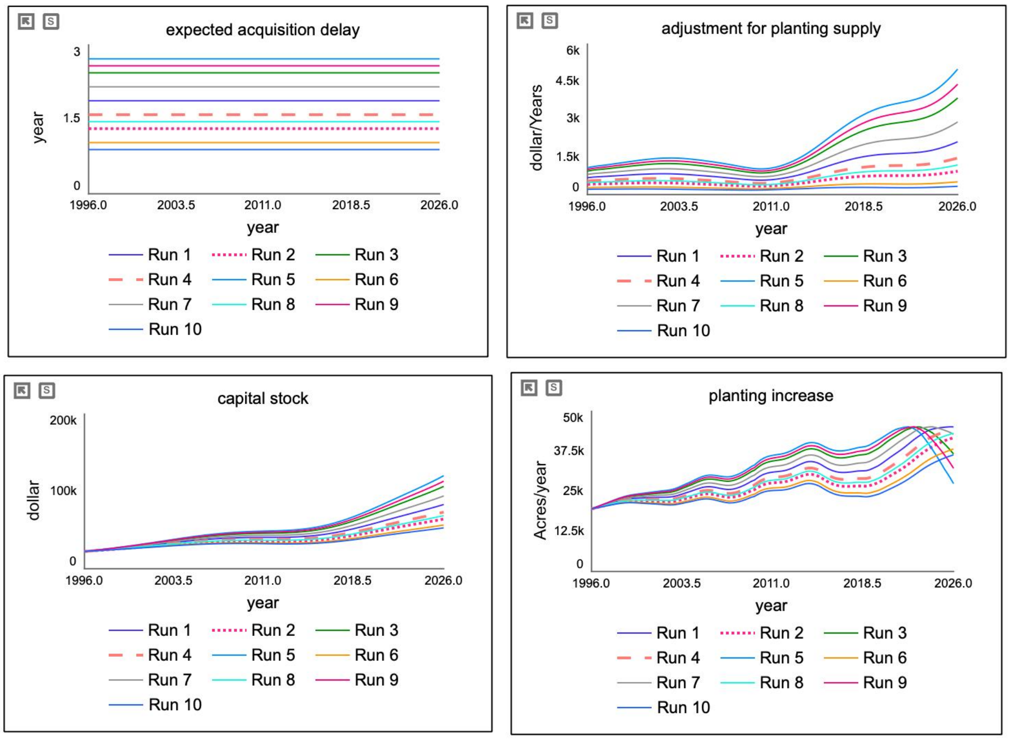



Figure 4 Sensitivity test for expected acquisition delay

The expected acquisition delay is assumed as the sum of growth period duration and some other adjustment time. This indicates the period that farmers need to estimate, adjust and acquire capacity. It usually consists the growth period of plant and other time for necessary resource to achieve new planing capacity. The sensitivity test starts as the 0.75 to 3 years, which represents for a very short adjustment time after the 0.5 year long time for planting growth to a very long adjustment time.

In Figure 4, we can find with a longer expected acquisition delay, adjustment for plants in line turns to be very high, which represents for a high capital demand with consideration for replacement of this large part of inventory in process (As long as the products moves from capital on order to capital stock, they are all seen as inventory in process as they are not transformed to capital). As the new orders also contains expected new acquisition rate, the final capital stock shows less sensitive than adjustment in land, but there is an obvious rising as well as in planting acreage. By contrast, a lower expected acquisition delay shows a faster speed for inventory in process turning to be capital, which gives less effect on capital stock and planting acreage.

5. Adjustment time for effect by expected profitability

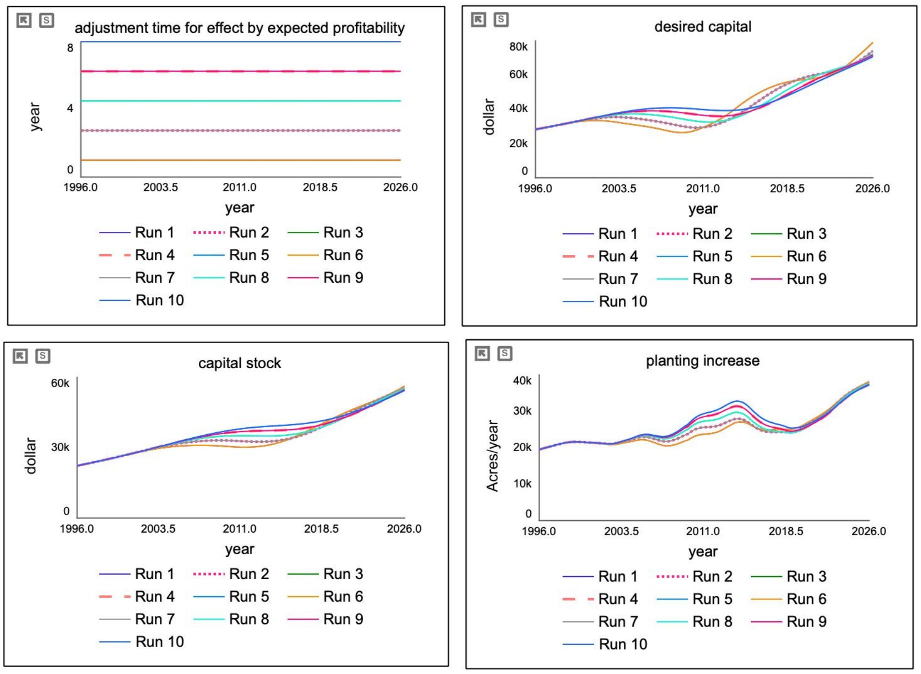



Figure 5 Sensitivity test for adjustment time for effect by expected profitability

Adjustment time for effect by expected profitability is the delay for producer or capital decision makers to accept the changing of profitability from former market data and shaped a new expected profitability. Figure 5 shows, when the adjustment time is very long to 5 years, desired capital level would increase more smooth to its final level, so does capital stock. Planting increase shows a higher level generally. This is because with a longer adjustment time, the producers or decision makers can capture a long-term change on profitability. They would be less effected by the short-term low value of profitability. As a contrast, with a shorter adjustment time, the desired capital shows more waves before it reaches the final level. The stock shows a steady low level before it suddenly shows higher increasing to its final level. These all indicates a very short adjustment time for expected profitability gives more oscillation for capital market. The planting acreage shows a higher level with a longer adjustment time for effect by expected profitability.This, to some extent, indicates with a longer smoothed market trend, the planting acreage would tend to show a rising trend.

6. Elasticity of soil erosion to humus change

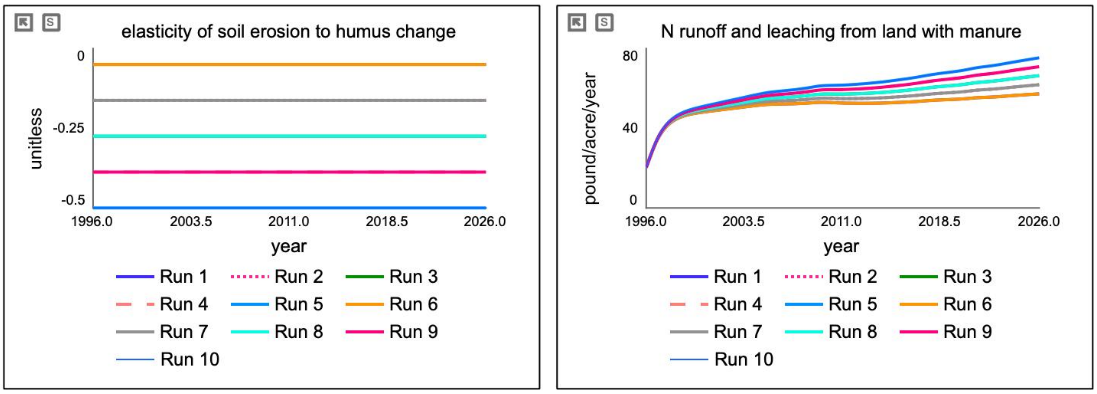



Figure 6 Sensitivity test on elasticity of soil erosion to humus change

Elasticity of soil erosion to humus shows how soil erosion would react by the changing soil/humus conditions. In the model, we have used -0.1. Here we adjust it from -0.05 to -0.3.

In Figure 6, we can see the elasticity has a great effect on the final effect on the N runoff and leaching. With elasticity value range of -0.05 (orange line) to -0.163 (gray line), the runoff changes from 57.3 lb/acre/year to 61.9 lb/acre/year. It would not largely effect the simulation validity for the structure. While when elasticity is changed to -0.3, the runoff increases to 75.4 lb/acre/year, which can give large departure from historical data. Seen from practice, the soil fading speed and effect on erosion is quite slow. A lower value range suits practice better. So we picked up -0.1.

7. Elasticity of fertilizer demand to fertilizer cost (price) change

The Elasticity of fertilizer demand to fertilizer cost shows how much effect the fertilizer application expectation would be restricted by a fertilizer cost. From the literature of Metaxoglow and Smith, they calculate the basic elasticity as -0.06, which indicates that demand of fertilizer has a low sensitivity to the fertilizer cost change. In our model, we have assume that fertilizer used in manure has a little lower elasticity (-0.1) than land without manure (-0.12), as the manure has taken up part of N source and they have saved some cost for fertilizer N. However, both the elasticity for two lands are larger than -0.06.

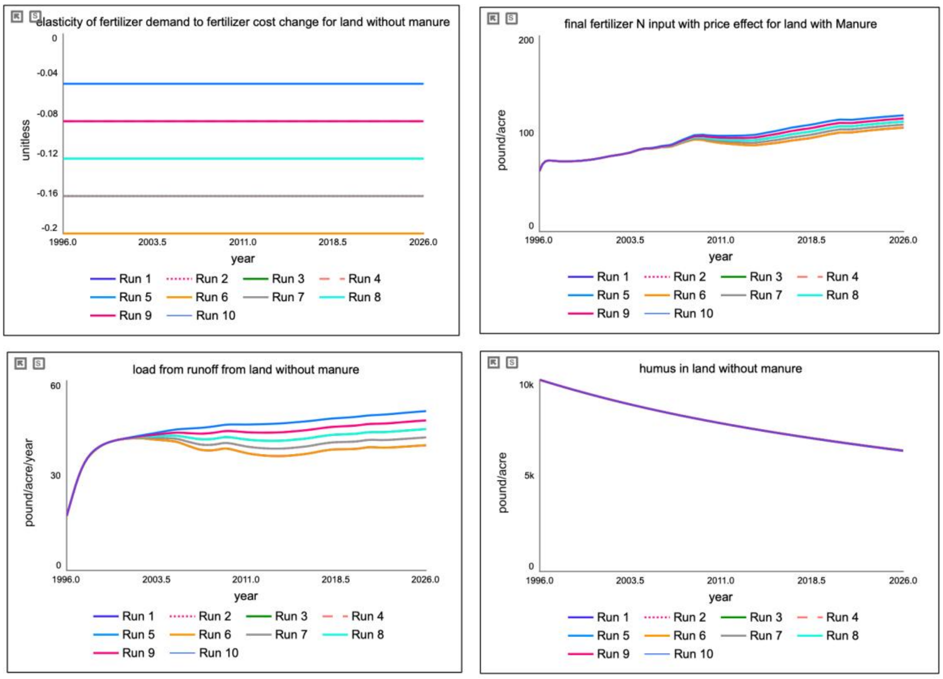



Figure 7 Sensitivity test for elasticity of fertilizer demand to fertilizer cost

In Figure 7, we can see that a larger absolute value on elasticity like -0.2 has a larger effect on the demand fertilizer and correspondingly a lower N load. It indicates that fertilizer price can be used as assistance methods to control the N application from fertilizer. The elasticity change does not show obvious change on humus changing as the slight effect from N application to humus.

8. Elasticity of N application to humus change

Elasticity of N application to humus change represents for how much N application would be effected to the humus condition change. It can reflects how much that farms observe the soil fading and how much they would like to input more N to guarantee the yield target.

In Figure 8, it shows an adjustment from -0.01 to -0.1, while original value is set as -0.05. The gap of N application between these two extreme elasticity is shown as 152-176 Ib/acre/year in land with manure and 132-146 Ib/acre/year in land without manure. As a result, N load from land with manure varies from 55 to 64 Ib/acre/year. In the estimated of reasonable range of elasticity, the system shows sensitive but will not effect final simulation results or conclusion.

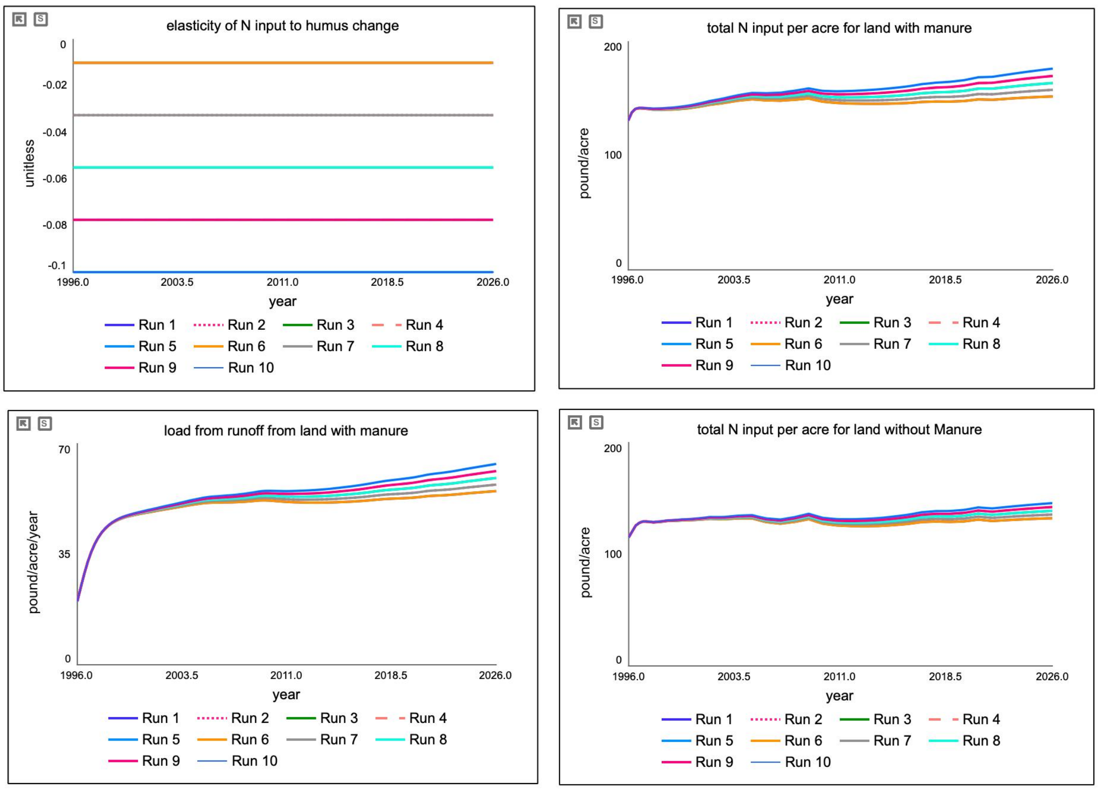



Figure 8 Sensitivity test for Elasticity of N application to humus change

9. Elasticity of humus change on yield

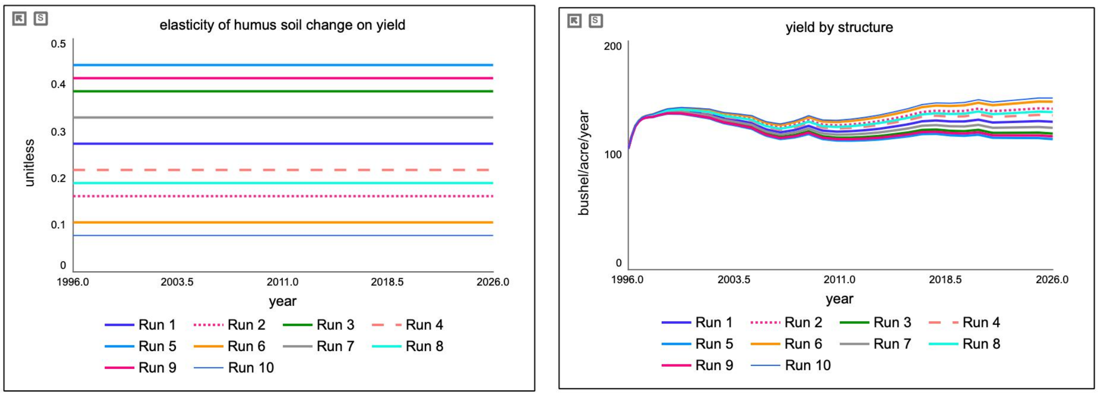
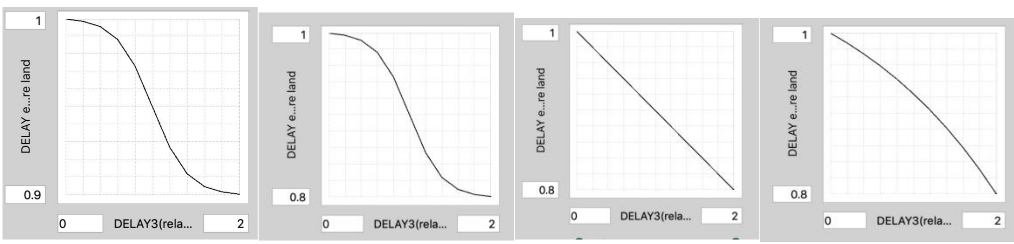



Figure 9 Sensitivity test on Elasticity of humus change on yield

Elasticity of humus change on yield represents for how other properties of soil quality without nutrient level has effect on final yield. The adjustment range if 0.05 to 0.5. The value is set as 0.1 in the model. Figure 9 shows, with the soil fading trend, a higher elasticity would leads to a larger yield falling. Combining the analysis in the paper on the burden-shifting structure, the effect of soil quality on yield is largely decreased in the past years as a result of large amount of fertilizer N input. Though we fail to find the exact elasticity of yield to humus change or the N application to humus change, in the model, we assume the former is larger than the latter on the absolute value: 0.1 for elasticity of yield to humus change and -0.05 for N application to humus change. We use this gap to assume that the effect of soil quality on yield cannot be 100% replaced by the adding of N application by fertilizer or manure.

10. Delay effect of N input on humification in manure land



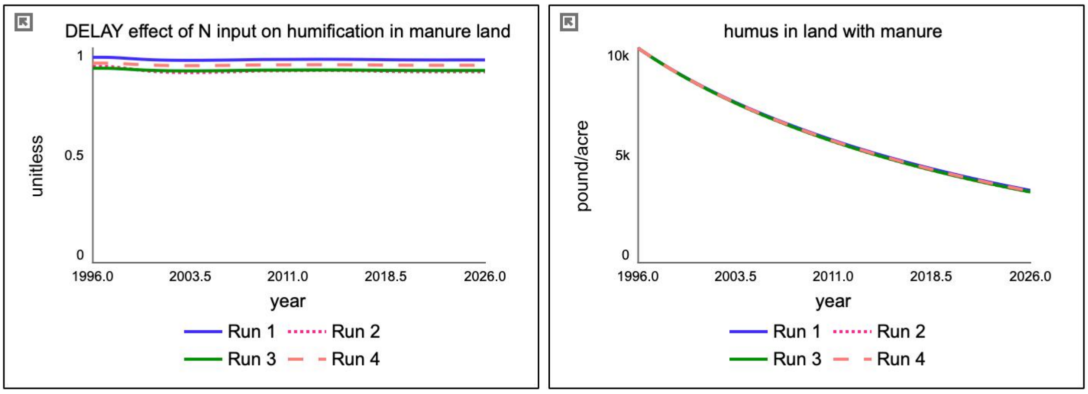



Figure 10 Sensitivity test on the table function of effect of N input on humification in land with manure

Figure 10 shows the shape of table function for effect of N input on humification in land with manure does not have big influence on the humus conditions as the change on effect is very limited.

11. Delayed effect by manure input on humification

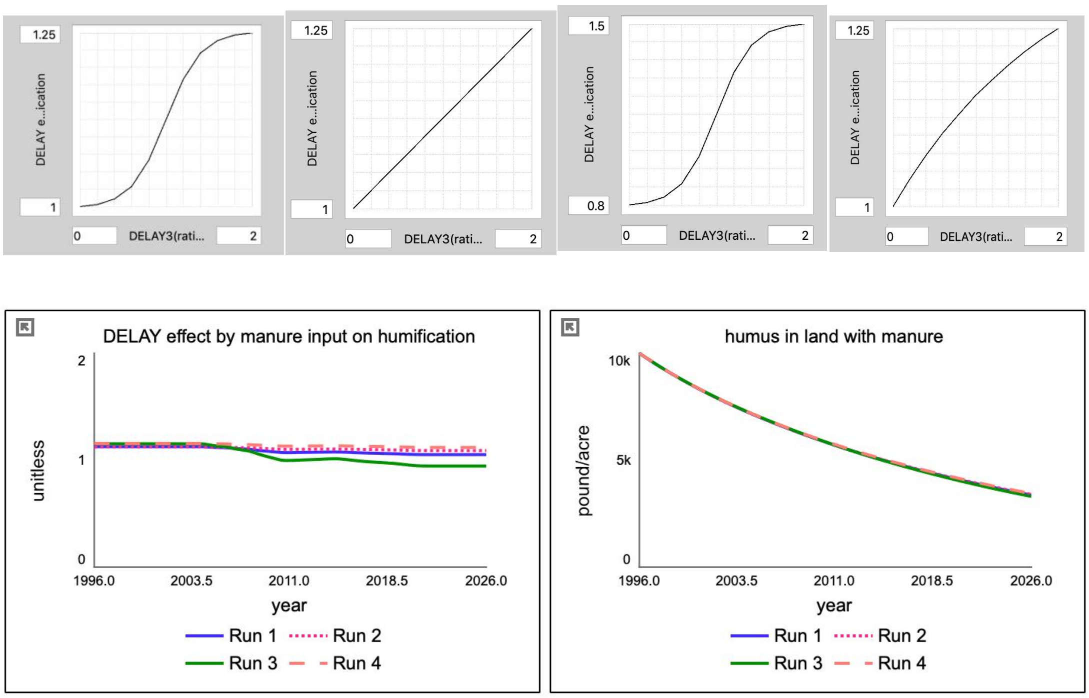
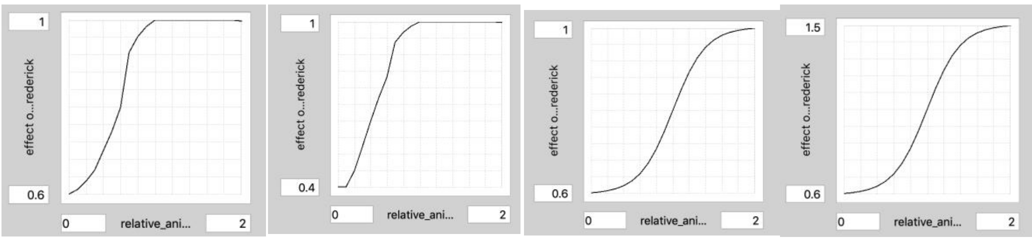



Figure 11 Delayed effect by manure input on humification

The Delayed effect by manure input on humification represents for how manure input can benefit the humufication rate. From Figure 11, we could see a shape change on table function or slight value change will not effect obviously on the humus in land with manure, as the effectiveness takes long time to accumulates to show an effect on humus shaping. This corresponds to the limit description in the paper. We have simplified the structure of humus as these elasticity or effects are quite slow to show effectiveness. In our simulation horizon of 20 years, they can be simplified or ignored compared with the change on N application and N load. Hence, in structure we have amplified these effects to show a faster simulation result.

12. Change on the effect of animal scale change on planting increase



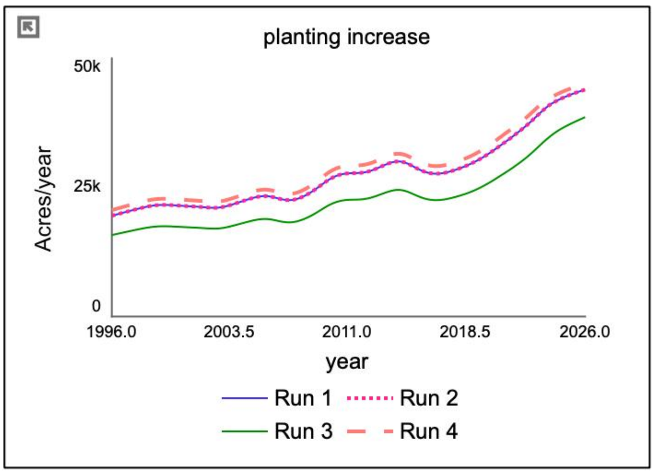



Figure 12 Sensitivity test on effect of animal scale change to planting increase

The effect of animal scale change to planting increase represents for how the change on animal scale would effect the corn planting increase. In Figure 12, graph 1 and graph 2 shows with a longer relative animal scale, the lowest effect is changing from 0.6 to 0.4. But this does not give big effect on our simulation result, as the relative animal scale does not show such a low level or there is not that large change on animal scale in the past twenty years. While in graph 3 when we assume if the relative ratio is over 1, the effect is still lower than 1, the final planting increase is decreased. It indicates the farmers would not use full capacity to plant corn even when the animal scale has reached reference level. The effect is restricted by graph 3, compared with graph 1. The graph 4 shows when the animal scale is larger than reference level, farmers can raise the utilization rate beyond capacity and plants more plantings than full capacity level. As a result the planting increase line is higher. However, this is the scenario we assume hardly happened in practice.

## 2. Optimization

In the commodity production structure, we have used optimization by Stella for optimization value for some delayed parameters. However, we rely more on literature, calculation from data and practical reference for the parameters. And the optimization suggestions are mostly close to the parameters we use in the model.

Starting optimization "Optimization 1" at 2023-May-24 12:04:08

| Method | additional starts | maxiter | init_step | tolerance |
|---|---|---|---|---|
| **Powell** | 5 | 5000 | 1 | 0.00001 |

| Payoff: | **Payoff** |
|---|---|
| Action | minimize |
| Kind | Calibration |
| Element | planting start rate |
| Weight | 1 |
| Comparison Variable | historical planting acre(soybean) |
| Comparison Run | -2 |
| Comparison Type | Squared Error |
| Comparison Tolerance | 0 |

| Parameter: | utilization adjustment time | adjustment time for capital | Time to adjust planting | expected acquisition delay | adjust time for effect by expected profitability |
|---|---|---|---|---|---|
| min_value | 1 | 1 | 0.5 | 0.5 | 3 |
| max_value | 3 | 10 | 3 | 5 | 8 |
| scaling | 0.1 | 0.1 | 0.1 | 0.1 | 0.5 |

| | utilization adjustment time | adjustment time for capital | Time to adjust planting | expected acquisition delay | adjust time for effect by expected profitability | **Payoff** |
|---|---|---|---|---|---|---|
| Starting at | 2 | 10 | 3 | 1 | 3 | |
| This pass gave | 3 | 10(max) | 3 | 2.65362018 | 3(min) | 1.99709266e+11 |
| Restarting at | 2 | 5.5 | 1.75 | 2.75 | 5.5 | |
| This pass | 3 | 10(max) | 3 | 2.65360432 | 3(min) | 1.99709266e+11 |

| | | | | | | |
|---|---|---|---|---|---|---|
| gave | | | | | | |
| Restarting at | 1.5 | 7.75 | 1.125 | 1.625 | 6.75 | |
| This pass gave | 3 | 10(max) | 3 | 2.65360424 | 3(min) | 1.99709266e+11 |
| Restarting at | 2.5 | 3.25 | 2.375 | 3.875 | 4.25 | |
| This pass gave | 3 | 10(max) | 3 | 2.65360441 | 3(min) | 1.99709266e+11 |
| Restarting at | 1.75 | 6.625 | 0.8125 | 3.3125 | 3.625 | |
| This pass gave | 3 | 10(max) | 3 | 2.65360461 | 3(min) | 1.99709266e+11 |
| Restarting at | 2.75 | 2.125 | 2.0625 | 1.0625 | 6.125 | |
| This pass gave | 3 | 10(max) | 3 | 2.65360392 | 3(min) | 1.99709266e+11 |
| After 258 runs | 3 | 10(max) | 3 | 2.65360424 | 3(min) | 1.99709266e+11 |

Finishing optimization at 2023-May-24 12:04:13

Generally we use optimization on Stella more for comparison rather than take the values directly. Having considered the factor beyond our hypothesis, we tend to leave the disparity between our simulation result and historical data.We estimate parameters to its approaching to most reasonable. Then the simulation could give best indications and most confidence on validity for our structure and further analysis.