Modeling the Path to Nature-Positive Agriculture

Successfully navigating complex problems with dynamic system modeling

Our global community faces a confluence of challenges. Feeding a growing population of more than 8 billion while navigating a changing climate is arguably top of the list. Net-zero pledges are not enough. We need net-positive companies working to enrich the world around them.

The agriculture industry is uniquely positioned to meet this need. Nature-positive farming can enable thick, healthy topsoil that sequesters carbon dioxide while extracting feed, fuel, fiber and food. Yet, despite conservation commitments, this industry is one of the largest greenhouse gas contributors due to limitations with current technologies, practices, and commodity market structures and incentives.

Corporations, investors and policymakers alike are grappling with what changes will generate the greatest positive impacts with the fewest negative consequences. While businesses use Net Present Value (NPV) calculations to maximize future financial profits, no equivalent tool is used today to maximize sustainability impacts.

The good news: an approach exists which can be deployed for precisely this purpose.

Dynamic System Modeling (DSM) is a strategy tool that can be used to optimize returns across financial, human, social and environmental capital — guiding decisions to deliver benefits today and for generations to come. DSM was developed at the Massachusetts Institute of Technology to understand how hundreds of variables interact across complex systems. Over time, these many nonlinear relationships create the first, second, and third order effects of our decisions.

CASE STUDY

A Company Committed to a Nature-Positive Agriculture

Inari — the SEEDesign™ company — has made a bold commitment to become a net-positive company. This means its emissions, water and waste footprint will be far offset by the positive impacts created by driving nature-positive agriculture. Through a combination of predictive design and multiplex gene editing, the company aims to design seeds that exponentially increase yield while reducing environmental impacts from land, water and nitrogen use. To achieve net-positive, Inari is designing seeds with an understanding of their likely ripple effects across interdependent agricultural, ecological, biological and financial systems.

SSM simulation dashboards enable Inari to evaluate, for example, which plant characteristics would most improve greenhouse gasses, land use and water quality at the same time.

The value of dynamic system thinking and modeling is captured in its name. It's a whole system analysis. Our Earth's biome is composed of layered systems containing all living beings — human, plant, animal, microbe. Within these intertwined systems, changes we expect to be powerful might be "policy resistant" and unexpectedly weak. Meanwhile, small changes can create outsized effects. This well documented phenomenon is called "the butterfly effect."

To best simulate likely product impacts, Inari built a suite of dynamic **SEEDesign™ System Models (SSM)** to assess effects across key metrics. Inari uses SSM to identify the most effective products for a nature-positive agricultural system. SSM simulation dashboards enable Inari to evaluate, for example, which plant characteristics would most improve greenhouse gasses, land use and water quality at the same time. The company can also explore how likely product impacts change under future conditions that are different from historic ones.

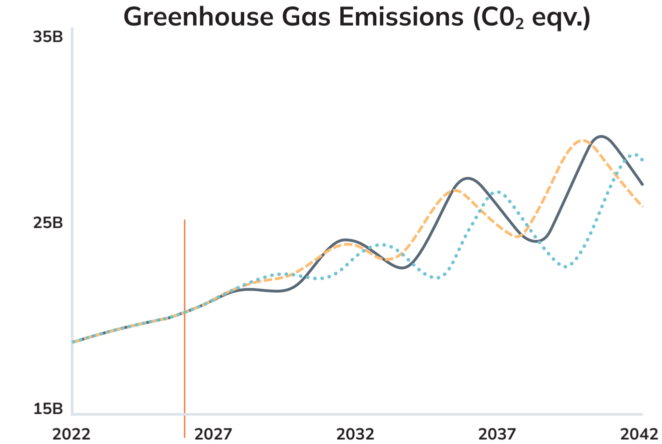
Inari embeds this systemic opportunity analysis into product ideation and development. For new corn and soybean seed ideas, the team reviews a quantitative impact scorecard alongside other key assessments such as market size and technical feasibility. And the models will become smarter as robust trial data is generated — offering more informed insights across the value chain.

The next page provides a simple hypothetical from Inari's SSM[1] to show what this modeling looks like in action. In this example, we consider how increasing market demand might affect U.S. soybean production, greenhouse gas emissions (GHG) and land use, and then explore the role step-change yield improvements with no additional input needs might have in mitigating negative trends.

LEGEND

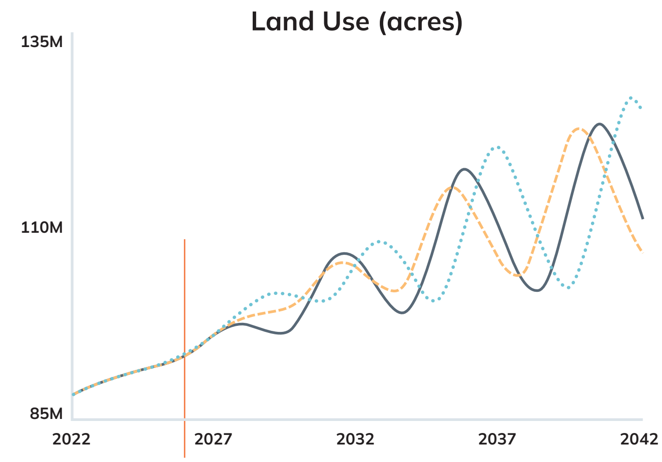
Future scenarios explored

- **Scenario 1:** *historic conditions continuing (market, climate, etc.)*
- **Scenario 2:** *a 6% one time increase in soybean market demand in 2026*
- **Scenario 3:** *6% demand increase plus rapid adoption of a 15% higher-yielding soybean plant with no additional fertilizer needs*
- *When the 6% market demand increase occurs*

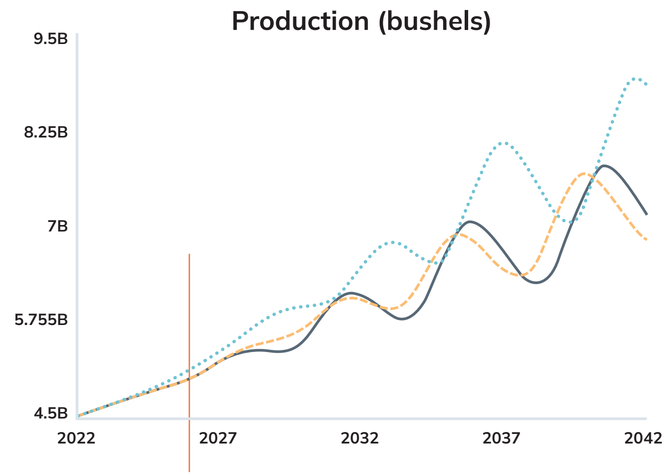


What can we learn from exploring these scenarios?

Scenario 1: Historic trends continue and overall production increases alongside the existing problems of rising GHGs and land use. Cyclic fluctuations reflect the commodity market interplay between corn and soybean supply and demand.



Scenario 2: Soybean market demand increases an additional 6% in 2026 as the effects of hundreds of millions in renewable biodiesel investment is realized and plants under construction across the U.S. come online. In this Scenario 2, higher prices incentivise planting soybeans and more production is achieved by more land use which continues well into the middle of the next decade. Net greenhouse gas emissions also rise as tractors drive across more acres, more fertilizers with their carbon intensive supply chains are applied, and trucks haul more soybeans off farm.



Scenario 3: The 6% demand increase remains and a 15% higher yielding soybean requiring no additional inputs enters the market in 2025. As it's adopted, perhaps unsurprisingly, production increases substantially. Interestingly, while overal land use remains similar to Scenario 2, net greenhouse gas emissions are significallly lower than in both Scenarios 1 and 2. In addition, although the CO_2 captured by plants photosynthesizing is not reflected in Graph 1, it is notable that higher biomass soybeans will also sequester more carbon dioxide.

[1] Note: SSM models are in late stage validation phases, results may be updated.

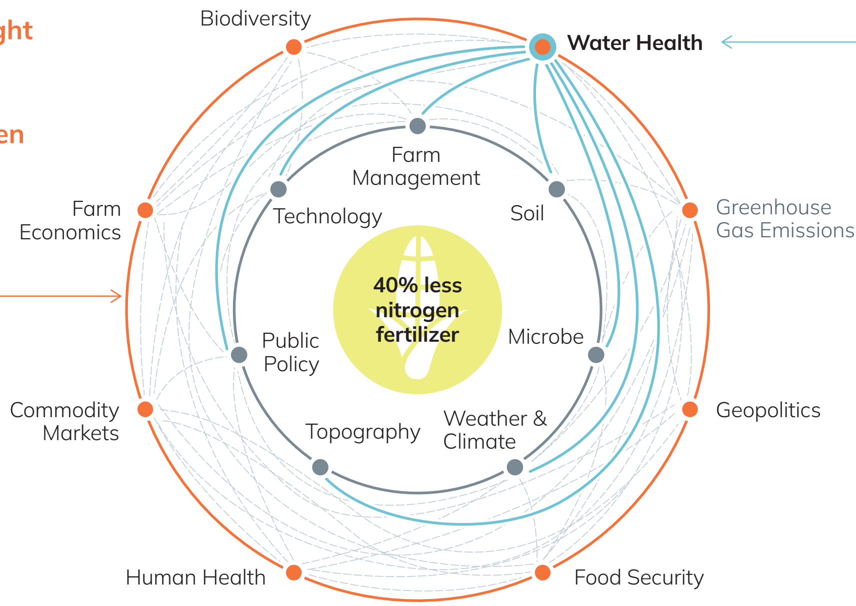
That 15% yield increase would take almost 15 years using traditional breeding methods. That is without factoring in likely increases in extreme heat, drought and flood events as climate change advances. New breeding technology innovations such as gene editing are critical to delivering much-needed step-change yield increases with a substantially smaller footprint in more challenging growing environments.

Assessing Water Pollution through System Interactions

To understand likely impacts, a system analysis starts with a broad question – opening the door to layered, more complex understanding beneath.

1

"What areas might be affected by corn that needs 40% less nitrogen fertilizer?"



2

"Honing in, how significantly might Water Health be affected?"

Intuitively, we might assume that when corn requires 40% less nitrogen, water pollution from fertilizer would be reduced by 40%. In reality, linear outcomes are rare in complex systems. Determining non-linear results requires understanding causal relationships between interdependent systems — as shown by the dashed grey lines to the left.

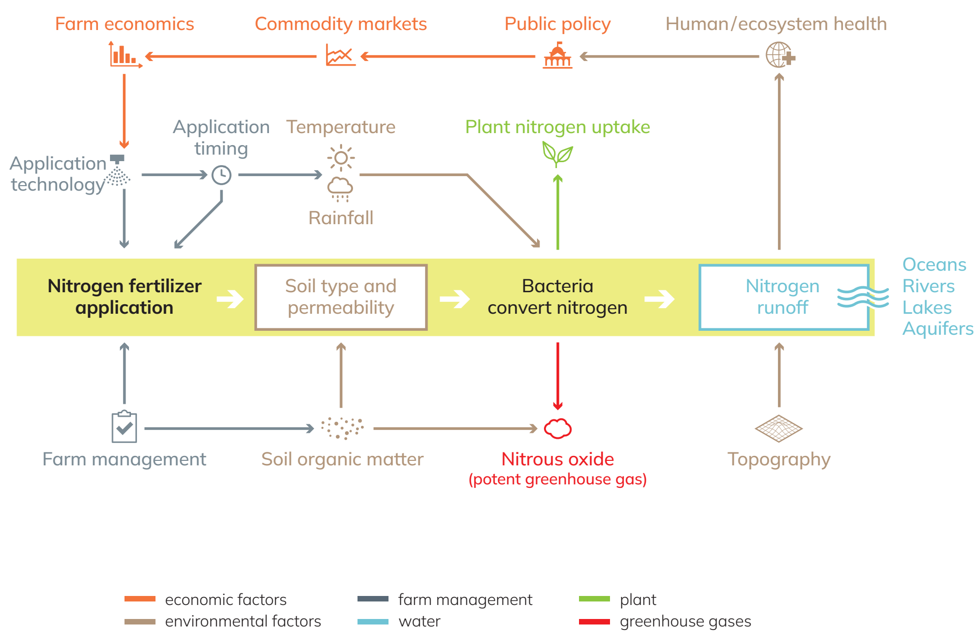
Digging Deeper

3

"Mapping the flow of nitrogen from application onwards highlights key system interactions that will determine rate and level of impact"

How and when fertilizer application occurs matters a great deal. For example, fertilizer injected into the soil in the spring instead of sprayed in the fall is less exposed to heavy rainfalls that can wash nitrogen off the field. Technology access and farm economics influence application approach.

Once fertilizer is in the soil system, bacteria begin conversions into nitrogen that plants can absorb, nitrogen that's released into the atmosphere as an inert gas or potent greenhouse gas, or soluble nitrogen that enters the water system. Bacteria move most quickly through these conversions when their soil habitat is warm, moist and well-aerated; conditions that change across soil type, rainfall (weather) and farm management practices like no-till and cover crops.



The illustrations on the prior page show just a few of the many interactions that will ultimately determine the significance (rate and level) of water pollution. Were we to follow nitrogen as it moves from tractor to soil, bacteria, plant, air, water in different chemical forms, we would find all of the systems on the first diagram either affecting or being affected by changes in corn fertilizer needs.

"Impact" is rarely intuitively linear. Instead, impacts emerge over time through a unique series of system interactions. By exploring these many interactions over time and under different assumptions, **dynamic system modeling has the capability to discover emergent trends and powerful levers of change.** This is critically important as science and recent events clearly indicate we cannot assume that the future will look and act like our present day.

CONCLUSION

A Strategic Advantage for Agriculture and Every Industry

A redesigned agriculture industry — technology, practices and market structure — has an unparalleled opportunity to replenish the natural world even as it extracts food, fiber, fuel and feed from it. But this redesign must be informed by an understanding of how actions cascade through complex, intertwined systems. Dynamic system modeling is a user-friendly strategy tool for optimizing impacts under future conditions.

This analysis only becomes more valuable over time. While agriculture's value chain is one of the closest to the natural world, ultimately every industry's value chain moves through a series of interdependent systems that begin with the natural world. The competitive advantages of optimizing for the natural, social and human capital that underpins all financial profits will increase exponentially as climate change advances. With a systems perspective, we can better invest in people, planet and profits for today and generations to come.

FREQUENTLY ASKED QUESTIONS

What are the inputs and outputs of a sustainability-focused system model?

Inari's SEEDesign™ System Models incorporate a swath of inputs — for example, product improvements (such as increased yield and resource use efficiency), climate factors and market factors. On the other end, measurable outputs include usage of natural resources (such as land and water), as well as air and water pollution.

Don't ESG ratings already help companies calculate their sustainability impacts?

Although ESG ratings are often thought of as a green impact assessment tool, they merely evaluate the risks to a firm's financial profit from external environmental, social and governance factors. They do not offer a roadmap to a more sustainable future.

Have dynamic system models been used for other applications?

Yes — they have been successfully deployed by organizations both public and private across industries, for example: the National Renewable Energy Laboratory, United States Department of Energy (DOE), Bioenergy Technologies Office, Italian Department of Sustainability of Livestock and Fisheries, Canadian National Research Council, Dartmouth College, University College London, Imperial College, Cornell University, and many others.