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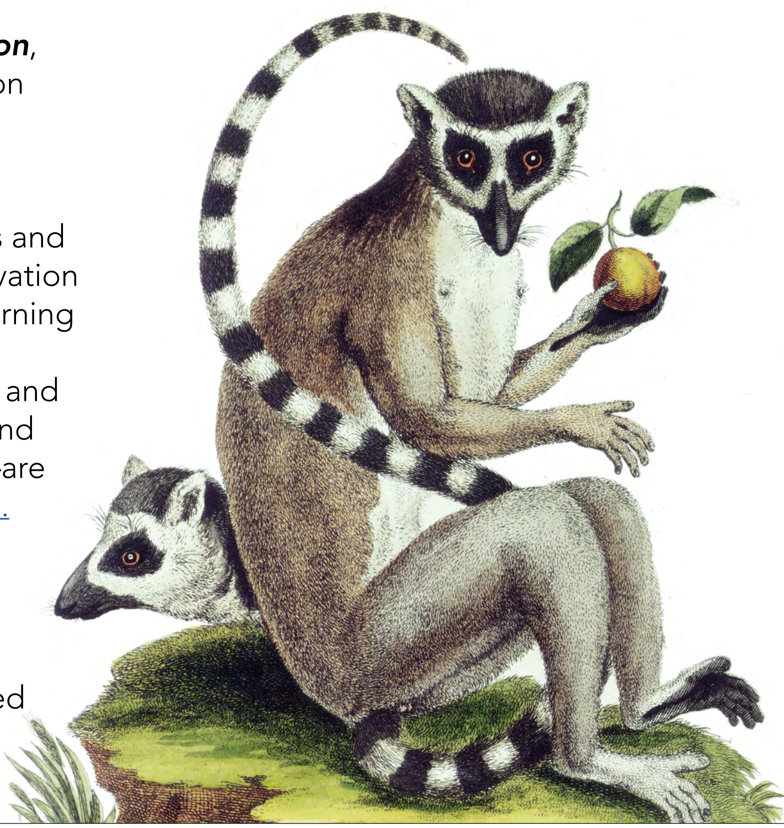

Modeling Links Between Corn Production and Beef Production in the United States: A Systems Thinking Exercise Using Mental Modeler

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LEARNING OBJECTIVES

After this exercise, students will be able to:

- Analyze complex problems within food systems and create responses that aim to promote systems-wide change, using systems thinking skills;
- Use the systems thinking tool Mental Modeler to represent the current dynamics of and links between corn and beef production in the United States, drawing from credible sources of evidence; and
- Create a model that can be used to explore key systems thinking concepts including boundaries, leverage points, and trade-offs in relation to industrial crop and animal production.

BACKGROUND

What are food systems? There are numerous definitions and different categorizations of the idea of food systems. Chase and Grubinger (2014) define food systems as "an interconnected web of activities, resources, and people that extends across all domains involved in providing human nourishment and sustaining health, including growing and production, processing, packaging, transportation, distribution, marketing, consumption, and disposal of food. The organization of food systems reflects and responds to social, cultural, political, economic, health, and environmental conditions and can be identified at multiple scales, from a household kitchen to a city, county, state, or nation." Parsons et al. (2019) differentiate the food system ("interconnected system of everything and everybody that influences and is influenced by the activities bringing food from farm to fork and beyond") from a food system (the food system in a specific place or context) from food systems (the totality of different types of food systems in different contexts). Other ways to conceptualize these systems are as 'foodscapes' and 'foodways' that encompass the dynamic and reciprocal relationships between people and the places and spaces where we acquire food, prepare food, talk about food, exchange food, or generally gather meaning from food (Sterling et al. In prep).

A complex and interlinked food system delivers approximately 135 pounds of red meat and poultry per person consumed in the United States every year (USDA 2019). In recent years, food journalists and activists have pointed to the links between corn production and beef production in this country and sought to further connect these to a host of social and environmental consequences.

In preparation for this exercise, students should review the following required and recommended articles and commentaries on food systems, and beef and corn production in the United States.

Required Readings

- Betley, E., et al. 2021. Introduction to Systems and Systems Thinking. Synthesis. Network of Conservation Educators and Practitioners, Center for Biodiversity and Conservation, American

Museum of Natural History, New York, NY. Available from https://ncep.amnh.org (17 reading pages).
- Foley, J. 2013. It's Time to Rethink America's Corn System. Available from https://ensia.com/voices/its-time-to-rethink-americas-corn-system/?viewAll=1 (9 reading pages).
- Pollan, M. 2002. Power Steer. New York Times, March 31, 2002. Available from http://www.nytimes.com/2002/03/31/magazine/power-steer.html (18 reading pages).

Recommended Readings

- Chase, L.C., and V. Grubinger. 2014. Chapter 1: Introduction to Food Systems. Food, Farms, and Community: Exploring Food Systems. University of New Hampshire Press, Durham, NH, USA (14 reading pages).
- Corah, L. 2008. ASAS Centennial paper: development of a corn-based beef industry. Journal of Animal Science 86:3635–3639. Available from https://doi.org/10.2527/jas.2008-0935 (4 reading pages).
- USDA and US HHS. 2015. About meats and poultry. Dietary Guidelines for Americans. Available from https://health.gov/dietaryguidelines/2015/guidelines/chapter-1/a-closer-look-inside-healthy-eating-patterns/#callout-meat-poultry (1 reading page).
- USDA. 2019. U.S. Per capita availability of red meat, poultry, and seafood on the rise. Available from https://www.ers.usda.gov/amber-waves/2019/december/us-per-capita-availability-of-red-meat-poultry-and-seafood-on-the-rise/ (1 reading page).

INSTRUCTIONS

This exercise uses a free, web-based systems thinking tool: Mental Modeler software (www.mentalmodeler.org). Prior to completing this exercise, you should review the educational materials available from www.mentalmodeler.org/#resources, in particular the videos listed on the Mental Modeler Instructors Guide, including "Introduction to Fuzzy Cognitive Maps" (5 minutes) and "Introduction to Mental Modeler" (13 minutes). These videos introduce the Mental Modeler software and its theoretical underpinning, and the various software capabilities used in this exercise on creating a model and running scenarios with the model. As you progress through the assignment, the videos "Evaluating and Improving Your Model 1" and "Evaluating and Improving Your Model 2" may also be helpful.

You will create a model using the Mental Modeler software (www.mentalmodeler.org, username: mentalmodeler, password: mentalmodeler) that represents your understanding of the current dynamics of and links between corn and beef production in the US (see Appendix 1). You will need to incorporate at least two environmental impact components[1] from the list below (or you can present an argument for an impact not listed) and at least three key "sustainability" components, with the option of two others listed below. You will submit your model (.mmp file) and a Word or text document with a written summary of your model, following the detailed instructions below.

Model (.mmp File)

Your model should include:

1. The components that comprise the relevant "parts" of the system. To ensure your model is not overly complicated and hard to interpret, do not use more than 25 components in your final model—be careful to include the most important ones.
   a. Corn production and beef production must be included.

   b. At least 2 components must be "impact" components (environmental impacts of agriculture from this list), or you can include your own choice for an impact, with written justification:
      - Climate Change
      - Water Pollution
      - Gulf of Mexico dead zone
      - Herbicide-tolerant weeds
   c. These 3 key "sustainability" components:
      - Human health: A state of complete physical, mental, and social well-being (as defined by the as defined by the World Health Organization; https://www.who.int/about/who-we-are/constitution).
      - Healthy environment: An environment is healthy when its physical, chemical, and biological components, and their interrelationships, are able to withstand stressors and maintain or achieve a desired state.
      - Economic health: Increases in economic growth and development, generally indicated through increased gross national product on a large scale or income on a small scale and individual and citizens' well-being.
   d. You may also choose to supplement with one or both of these additional "sustainability components" (optional):
      - Social equity: Equal opportunity in a safe and healthy environment. This can also include equality of outcome, for example, in relation to food justice, with four dimensions of equity: distributional, procedural, recognitional, and contextual (Friedman et al. 2018).
      - Cultural integrity: Ensuring that a group's values, norms, practices, systems of meaning, ways of life, and other social regularities are respected (adapted from Kreuter et al. 2003).
2. The directional relationships[2] between these components.
3. The degree of the positive or negative influence (using the sliding bars on the links between components in Mental Modeler) that one component has on another. See Tip #3 below.

Important tip: Be sure to periodically save your model to your computer as you go, downloading iterative versions of your work to your computer. One trade-off with a browser-based tool is that a mistakenly closed browser window with an unsaved model can delete ALL YOUR WORK. Don't let this happen to you!

As you begin to add components of the food system to the model, add their relationships to each other (positive or negative). Specifically, think about what parts of the food system impact, or are impacted by, the components you start with. As you complete this part of the exercise, where appropriate and particularly for critical or unusual relationships/components, enter the evidence (in the notes section of Mental Modeler on the left-hand side of the program) you are using to determine the components you choose and the relationships you define. For example, if you are citing a peer-reviewed paper, include at minimum the author(s) and date in the notes, and you should include the full citation in your model summary below. If you do not have any evidence from peer-reviewed publications, provide your reasoning for the chosen components and relationships/weights.

You will define the components that seem relevant to this issue based on your understanding. There are a few things to remember when you make your model:

Tip #1
"Defining Components" (e.g., boxes) need to be things that can increase or decrease in quality or quantity. For example, these may be things like (a) access to healthy food, (b) food prices, (c)

amount of cropland, or (d) greenhouse gas emissions. All of these things can increase or decrease. The components should not be things like (e) policy, since "policy" is not something that can increase or decrease (existence and enforcement of specific government regulations can increase or decrease). You can add as many components as you think is necessary to represent the system, by clicking on the "add component" button at the top of the modeling screen, up to a maximum of 25 components.

Tip #2
"Defining Relationships" between components can either be positive or negative. For example, as soil fertility increases, corn production may also increase. Therefore, you might draw a positive arrow from the component "soil fertility" to the component "corn production."

Tip #3
"Defining Degree of Influence" represents the weightings you give to the positive or negative relationships that you define between components. For example, a rainstorm may increase the amount of flooding slightly (represented by a small positive relationship defined between these two components) but a hurricane may increase the amount of flooding a great deal (represented by a high positive relationship defined between these two components). In general, it is best to assign relative strength of influence as high (value between 0.7–1), medium (value of 0.4–0.7), and low (0.1–0.4).

As you complete this part of the exercise, check each component and relationship. Are components able to increase and decrease in response to relationships with other components? If not, can you phrase the component in a different way so that it becomes something that increases or decreases? Reflect on the reasons for making the relationship. Is it fundamentally important to the model? Are the relationships sound? Are there missing intermediary/mediating components[3] that should be added to create direct relationships? Be sure to think about what drives the system and how all the different parts of the system interact with and relate to each other.

Next, refine your model. Start by examining your model and identifying 2 or 3 components that have a disproportionate impact on the overall sustainability of the food system (as measured by changes in your 3 required components of human health, healthy environment, and economic health; and social equity, and cultural integrity if you chose those as well). *Make sure Mental Modeler Scenario Tab is set to hyperbolic tangent* (*not sigmoid, which may be the default*). Navigate to the scenarios tab and play with increasing or decreasing the value (between -1 and 1) of these components one at a time. The impact on other components in the model as a result of the scenario will appear in the interface to the right. Next, evaluate how these changes affect other components of your model—this is called scenario analysis. If scenario analysis delivers illogical results, refine your model and continue an iterative process of adjusting the model, running the scenario, adjusting the model, etc. This process of refinement may also involve adjusting or removing relationships for several reasons: the evidence for the relationship mismatches with the scenario analysis results, the relationship is not direct (if it is indirect, you may add a component to better illustrate the relationship), or you were able to refine your model to focus ONLY on what you feel are the most important components and relationships. Recall that this model is your vision of how the system works, based on high-quality evidence for components and relationships. This step is where you test whether or not the model reflects your understanding of the system and its function.

Once you feel your model structure is robust and not in need of further refinement, again conduct the scenario analysis process described above, focusing on increasing or decreasing high leverage points[4] that may make the system more sustainable, as measured by impacts on your 3 required components from this list: human health, healthy environment, economic health, social equity, and cultural integrity. Recall from the video "Introduction to Systems Thinking and Modeling," high leverage points are places within the system where a relatively small amount of force can be applied strategically to make a relatively large change to a system. Simply, you want to find components within your model where a small change results in large desired changes for your sustainability components (human health, healthy environment, economic health, social equity, and cultural integrity). These leverage components can be ones that are either directly connected to the sustainability components, or indirectly connected. Once you have identified possible high leverage points, think about possible interventions[5] (represented by components) that you can insert into your model in places that will have an impact on the overall system. Then run scenarios with your interventions and your leverage points in an attempt to increase the overall system sustainability.

Calculating Network Properties of Your Model

After you have made your model and are happy with it, you can assess its network properties through an automated process in the Mental Modeler software. To see the metrics, navigate to the "Preferred State and Metrics" tab. On the left, you will see how many components you have in your model, how many connections, the density[6], # connections/component, # of driver components[7], # of receiver components[8], # of ordinary components[9], and your complexity score[10]; and on the right you will see your components listed along with their scores for indegree[11], outdegree[12], and centrality[13], along with their type (see Glossary below defining all these terms).

Model Summary (Word or Text Document)

The Model Summary will have 4 parts:

1. A screenshot of your model (take a screenshot or use the "camera" tool in the modeling screen)
2. A short narrative summary of your model (1/2 page, single-spaced, on what you included in your model and why, including why you chose your 3 sustainability components).
3. Your answers to the following questions:
    a. Reflect on the boundaries you have set for your model. What was your reasoning for components you decided to include or exclude?
    b. Based on the notes that you entered into your model, what sources of evidence did you draw on to determine your components and define your relationships?
    c. Describe in detail your scenario analysis process.
        – First, did any scenarios prompt you to refine your model by adjusting components, relationships, or degree of influence? If so, which scenarios and how was your model refined?
        – Second, once your model was not in need of further refinement, identify the scenarios you ran on the 2 or 3 components with a disproportionate impact on the overall sustainability of the system (as measured by impacts on your 3 required components from this list: human health, healthy environment, economic health, social equity, and cultural integrity). Evaluate how these changes affected other components of your model (feel free to use screenshots of your scenarios for these answers).
    d. Based on your model, what components disproportionately influence and/or are disproportionately influenced by corn production and beef production in the US? How did you determine the influence of these particular components?
    e. In terms of approaches that might address issues related to corn and beef production in

the US in the future, identify any leverage points that already existed in your model or that you added to your model as a result of your scenario analysis, and identify any interventions that you added to exert force on the leverage points and cause components to increase or decrease in order to make the food system more sustainable (i.e., a preferred state).

f. Referring explicitly to your model, what are the trade-offs involved in the leverage points in your model? Which components increased or decreased and by how much, and what does this lead you to conclude about the feasibility of the interventions you have suggested?

g. Reflecting on the process of creating your model, did this process change the way you think about or approach future food system scenarios? Why or why not?

4. A literature cited section, reflecting all the evidence you entered as notes in your model to support your choices of components and relationships.

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APPENDIX 1

Additional prompts for current dynamics of and links between corn and beef production in the US, drawing from articles and commentaries as preparation for exercise:

- Corn production
  - Versatility of the corn crop: high yield, processed into numerous food and non-food products include biofuels and animal feed

  - Corn fed to cattle results in meat and dairy products for human consumption
  - Significant environmental impacts due to expansive cropland devoted to growing corn monoculture; inputs including soil, water, and fertilizer
  - Health impacts of processed foods made with corn
  - Economic impacts of consolidated corn production supply chain
  - Labor impacts, livelihoods, debt, loss/atrophy of localized knowledge, impacts on farm communities in terms of population decrease and decrease in tax base and social services
- Beef production
  - Efficiency of industrial animal production system, as narrowly defined in terms of economic cost of production
  - Significant environmental impacts due to high concentration of animals prior to slaughter
  - Health impacts of diets high in red meats and processed meats, extensive use of antibiotics
  - Economic impacts of consolidated beef production supply chain
  - Dangerous, dirty, and demeaning jobs in slaughterhouse and meat packing plants, migrant labor
  - Animal welfare issues

GLOSSARY

1. **Component**: a box in the mental model representing a part of a system that can measurably increase or decrease. The five starting components we have given you vary in our ability to adequately measure them.
2. **Relationships/connections**: directional connections (can be one-way or feedback) between two components, also including the weight of the relationship. Relationships can be direct, between two components, or indirect, which means they have mediating components that help to explain the connections.
3. **Mediating/intermediate component**: a component that mediates between two other components, helping to explain the connection in a measurable way.
4. **Leverage point**: the place in a system or model where an intervention will be more powerful (i.e., create more change) and be at a lower cost than it would at other points. Some systems thinkers distinguish high leverage points where the change is outsized in comparison to the intervention from low leverage points, where the system impact is relatively minor.
5. **Intervention**: pressure or action (i.e., policy creation or grassroots action, changes in social norms) that can be applied at an intervention point to create change.
6. **Density**: ratio of components to relationships/connections.
7. **Driver component**: component with arrows out and no arrows in.
8. **Receiver component**: component with arrows in and no arrows out.
9. **Ordinary component**: component that is not a driver component or a receiver component.
10. **Complexity score**: degree of receiver to driver variables present across the model. Intended to account for feedback loops.
11. **Indegree**: metric calculated on the basis of the number of arrows in.
12. **Outdegree**: metric calculated on the basis of number of arrows out.
13. **Centrality score**: metric calculated by summing indegree plus outdegree.

Additional terms:
- **Central component**: component with the highest centrality scores.
- **Intervention point**: places in the system where a change can be made. The change could have a small or large impact on the system.