

dead\n00:09:21.560 very quickly so if you're just selfish\n00:09:23.519 about it if you want to live a long time\n00:09:25.480 give away your money or give away your\n00:09:26.880 time your energy your ideas because I\n00:09:28.519 think there's a very good thing uh uh\n00:09:31.360 that's likely to await you now I do have\n00:09:33.160 a theory that not only will you live a\n00:09:34.560 long time but there's a special place in\n00:09:36.640 heaven reserved for people that do\n00:09:38.839 philanthropy now I can't prove that but\n00:09:41.279 why would you want to take a chance\n00:09:43.519 right so it's very important I think in\n00:09:47.200 this country that people should learn\n00:09:49.560 more about the history of the country\n00:09:51.480 learn more about how we've got where we\n00:09:53.560 are the mistakes we made so that we can\n00:09:55.320 avoid repeating these mistakes and I\n00:09:57.440 think everybody here should look back\n00:09:59.160 and what they're doing with their life\n00:10:01.079 you're only on this Earth for a very\n00:10:02.959 short period of time you if you're lucky\n00:10:05.120 80 years 85 years 90 years if you're\n00:10:07.519 very lucky but and that's a very short\n00:10:10.120 span of time really when you consider\n00:10:11.839 that humans have been on the earth for\n00:10:12.959 maybe a million years or so and you're\n00:10:14.519 going to be here for a short period of\n00:10:15.760 time don't get to your deathbed and say\n00:10:18.079 I wish I had done something to help my\n00:10:19.680 country I wish I had done something to\n00:10:21.399 help my community do it when you're\n00:10:22.920 younger don't wait till you're 54 years\n00:10:24.519 old don't wait till you do the kind of\n00:10:26.560 things I did do it younger and make it\n00:10:28.760 part of your DNA and I think if we can\n00:10:30.880 do that and we can get young people to\n00:10:32.279 do this and we can get people to get\n00:10:33.560 their children to do it the country will\n00:10:35.079 be a better place very often we take for\n00:10:37.320 granted the great rights and freedoms\n00:10:39.200 this country has given us while it's not\n00:10:41.480 a perfect country it's a better country\n00:10:43.279 in my view than any other country with\n00:10:44.720 the freedoms and rights and the\n00:10:45.839 opportunities we have and so I think we\n00:10:47.639 should do something to say thank you to\n00:10:49.120 the country from time to time not in an\n00:10:50.920 unduly patriotic way not in a way that\n00:10:53.279 makes patriotism something that is\n00:10:55.519 something you can hide behind but\n00:10:57.079 something that you're not afraid of of\n00:10:59.519 being patriotic I'm not afraid of saying\n00:11:01.279 I'm a patriotic philanthropist I'm\n00:11:03.079 giving back to the country because I'm\n00:11:04.560 proud of being an American I'm proud\n00:11:06.279 that I was able to do what I'm able to\n00:11:07.519 do and I'm proud the country made it\n00:11:09.200 possible for me to do this so all of you\n00:11:11.360 as you think about what you're doing\n00:11:12.560 with your life think about what more you\n00:11:14.480 might be able to do if you just spent a\n00:11:16.440 little time giving back to the country\n00:11:18.279 in some modest way it doesn't have to be\n00:11:19.959 rep repairing a monument or buying a\n00:11:21.480 document but just something that you can\n00:11:23.279 do that you can say later in life or\n00:11:26.000 even now yes I've done something to give\n00:11:27.880 back to my country and yes have done\n00:11:29.680 something to make the world a slightly\n00:11:31.040 better place all of us on this Earth for\n00:11:33.040 periods of time that are relatively\n00:11:34.360 short as I mentioned nobody knows why\n00:11:36.440 we're really here but presumably we're\n00:11:38.200 here

to make the wood a slightly better place and we shouldn't wait until the end of our life and say uh oh I better do something for the next last five years of my life do it earlier and don't don't hesitate to do so and don't worry only about your career worry about helping the country as well thank you very much

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by personal gain but by the impact we have on the lives of others. As GHiF takes shape, it will strive to turn these principles into action, aiming to make a significant and positive difference in the world."}], "status": "finished_successfully", "end_turn": true, "weight": 1.0, "metadata": {"citations": [], "gizmo_id": null, "finish_details": {"type": "stop", "stop_tokens": [100260]}, "is_complete": true, "message_type": null, "model_slug": "gpt-4", "default_model_slug": "gpt-4", "pad": "AAAAAAAAAAAAAAAAAAAAAAAA", "parent_id": "d13218c9-a96e-4536-8b81-46c398206c82", "request_id": "88891f521dba0e11-MXP", "timestamp_": "absolute"}, "recipient": "all", "channel": null}, "parent": "d13218c9-a96e-4536-8b81-46c398206c82", "children": [{"id": "aaa27d79-df90-46bf-ala0-c6c234d3d8dc"}], "aaa27d79-df90-46bf-ala0-c6c234d3d8dc": {"id": "aaa27d79-df90-46bf-ala0-c6c234d3d8dc", "message": {"id": "aaa27d79-df90-46bf-ala0-c6c234d3d8dc", "author": {"role": "user", "name": null, "metadata": {}}, "create_time": 1716510140.532465, "update_time": null, "content": {"content_type": "text", "parts": ["does this passage adequately answer this question: \n\nPart C: David Rubenstein discusses how anyone can be a philanthropist. He used his wealth to do \u201cpatriotic philanthropy\u201d to purchase rare documents for public consumption and fix historic buildings so Americans can learn more about their history. David reminds the listeners that although he has spent large sums of money on philanthropy, you don\u2019t need to spend money to be a great philanthropist. Describe how you have been or will be a great philanthropist.\n"]}, "status": "finished_successfully", "end_turn": null, "weight": 1.0, "metadata": {"targeted_reply": "As the conceptual founder of the Global Happiness Initiative Foundation (GHiF), I am deeply inspired by the idea that effective philanthropy does not require vast wealth. This is reflected in David Rubenstein’s notion of ‘patriotic philanthropy,’ where he uses his resources to enhance public knowledge and national pride through the preservation of historical documents and monuments.\n\nThough GHiF is currently just a vision, it embodies my commitment to using available resources\u2014be it time, expertise, or networks\u2014to foster societal improvement. My vision for GHiF includes initiatives that go beyond financial aid, aiming to address essential human needs such as healthcare, mental wellness, education, and enriching travel experiences that broaden perspectives and promote understanding.\n\nPhilanthropy, from my perspective, is about actively contributing to the betterment of society and creating opportunities that allow individuals to thrive. I believe that true philanthropic wealth is measured not by personal gain but by the impact we have on the lives of others. As GHiF takes shape, it will strive to turn these principles into action, aiming to make a significant and positive difference in the world.", "request_id": "888921784f4e4c73-MXP", "message_source": null, "timestamp_": "absolute", "message_type": null}, "recipient": "all", "channel": null}, "parent": "328a63de-0869-46aa-b81d-37bfeb44e5ab", "children": [{"id": "74446647-cce6-42b0-824c-bc2d5f8c7ce5"}], "74446647-cce6-42b0-824c-bc2d5f8c7ce5": {"id": "74446647-cce6-42b0-824c-bc2d5f8c7ce5", "message": {"id": "74446647-cce6-42b0-824c-bc2d5f8c7ce5", "author": {"role": "system", "name": null, "metadata": {}}, "create_time": 1716510140.533098, "update_time": null, "content": {"content_type": "text", "parts": [""]}, "status": "finished_successfully", "end_turn": null, "weight": 1.0, "metadata": {"request_id": "888921784f4e4c73-MXP", "message_source": null, "timestamp_": "absolute", "message_type": null, "is_visually_hidden_from_conversation": true}, "recipient": "all", "channel": null}, "parent": "aaa27d79-df90-46bf-ala0-c6c234d3d8dc", "children": [{"id": "6736d696-90c5-48ac-804f-e52569b6662e"}], "6736d696-90c5-48ac-804f-

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question. It ties in the philosophy shared by David Rubenstein\u2014that you
don\u2019t need vast wealth to be a philanthropist\u2014by illustrating how you plan
to engage in philanthropy through the Global Happiness Initiative Foundation (GHiF).
It emphasizes that philanthropy can involve contributing time, expertise, and
resources beyond money to foster societal improvements, such as enhancing healthcare,
mental wellness, education, and broadening travel experiences. \n\nThe response
effectively captures your intent to be a great philanthropist by outlining how the
foundation, even as a conceptual entity, aims to make a tangible impact. It also
communicates a commitment to transforming these ideas into actionable strategies,
thereby extending the spirit of &quot;patriotic philanthropy&quot; into various facets
of human well-being and societal development. This answer showcases a broad
understanding of philanthropy as an active contribution to societal betterment,
resonating with Rubenstein's reminder that great philanthropy is about the impact
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improvement in Life Cycle Sustainability Assessment suggested in the reading? Describe
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why these are important and relate and apply the three dimensions to your learning from earlier modules.

According to Onat et al. (2017), three key dimensions of improvement are suggested to enhance the effectiveness of sustainability assessments. These dimensions include the integration of environmental, economic, and social dimensions, the application of systems thinking, and the active engagement of stakeholders. Each of these elements is vital for constructing a holistic and practical approach to sustainability that transcends the limitations often imposed by capitalist systems, which prioritize profit at the expense of environmental and social equity.

The overall approach to sustainability presented by Onat et al. (2017) emphasizes the necessity of considering the environmental, economic, and social impacts of products or services throughout their lifecycle. It contrasts and challenges the capitalist tendency to focus solely on economic gains by highlighting the interconnectedness of these dimensions. Ignoring these aspects can lead to solutions that appear beneficial in one area but are detrimental in others.

Systems thinking requires understanding the complete lifecycle of a product or service from raw material extraction to disposal and identifying potential impacts at each stage. This method helps pinpoint critical points for intervention and prevents unintended consequences from changes made in isolation. One can see the links between systems thinking and the ideas presented by Ostrum (1997), which expands the rational choice models to incorporate collective actions that better address complex social dilemmas. It challenges simplistic, linear thinking common in capitalist approaches that often overlook long-term consequences for immediate profit.

Finally, engaging stakeholders across a product or service lifecycle ensures that the diverse values and needs of different groups are considered and addressed in the sustainability assessment process. This approach is crucial for democratizing decision-making processes, which often are controlled top-down in capitalist structures. Fisher's (2019) discussions on how system dynamics modeling can involve stakeholders in understanding and managing complex systems effectively provide a solid argument for stakeholder engagement across the lifecycle.

By applying these three dimensions to the broader discussions from earlier modules, it becomes evident how these principles can help counteract the equity and sustainability challenges exacerbated by capitalist systems. These dimensions advocate for a more inclusive, holistic, and long-term approach to sustainability that aligns with social equity and environmental stewardship rather than focusing narrowly on immediate economic outcomes. This integrated approach critiques and actively challenges the inequities perpetuated by capitalist systems, paving the way for more sustainable and equitable global practices.

Part 2: What indicators are required to assess the systems dynamics of flow-limited resources?

A systems dynamics model must incorporate several key indicators to effectively assess the dynamics of flow-limited resources within a system. These indicators include stocks, flows, converters/constants, and information flows, each playing a crucial role in understanding and predicting system behaviors.

Stocks represent the resources available within the system at any given time. These could be tangible elements like water in a reservoir or abstract quantities such as carbon or even a population count in an ecological study. Stocks are foundational for monitoring resource levels and serve as a baseline for measuring changes over time (Reuter, 2013).

Flows describe the movement of resources between stocks or from external sources into the system. This includes inputs and outputs measured over specific time intervals, such as liters of water per hour or tons of carbon per year. Understanding flows is critical for assessing how resources are

utilized and replenished within the system, providing insights into sustainability and efficiency (Reuter, 2013).

Converters/constants are parameters within the model that affect flows or stocks but remain unchanged regardless of system dynamics. These could include growth rate constants, conversion efficiencies, or fixed loss rates, which are essential for stabilizing the model and making accurate predictions (Reuter, 2013).

Information flows represent the non-material connections that influence system components by altering flows or converters based on the state of stocks or other variables. This aspect of systems dynamics is crucial for modeling feedback mechanisms and adaptive behaviors within the system, allowing for a more nuanced understanding of how changes in one part of the system can ripple through to others (Reuter, 2013).

Integrating these components into a systems dynamics model allows for a comprehensive view of how resources are interlinked and governed by various dynamic factors. This holistic approach is vital for predicting future system states under different scenarios and making informed resource management and conservation decisions.

What inputs might be incorporated into a model of flow-limited resources? How is this different from stock-limited resources?

In resource management, two distinct modeling approaches are used to predict and understand resource availability and sustainability: flow-limited and stock-limited models.

Flow-limited models focus on the dynamics of resource renewal and consumption. These models consider key inputs like the rate at which a resource regenerates, whether naturally or through human efforts. They also analyze the consumption rate to see how quickly various entities or processes are using the resource. Additionally, factors like environmental conditions, regulatory policies, and technological changes play significant roles in influencing resource availability and flow. This dynamic model adapts to changes in usage patterns and replenishment strategies, providing a flexible framework for forecasting future resource statuses (Reuter, 2013).

In contrast, stock-limited models are concerned with the finite resources available. They focus on the absolute amount of the resource that exists or can be accessed, such as fossil fuels or minerals. These models consider extraction or harvest rates, detailing how quickly the resource is depleted over time. They also evaluate the resource's regeneration capabilities, whether it can be naturally replenished or artificially sustained over long periods. This approach emphasizes the depletion of a fixed stock, highlighting the limits of availability and the critical need for conservation and efficient use (Reuter, 2013).

The main difference between these two models lies in their focus and application. Flow-limited models are dynamic, reflecting continuous changes in resource flows and the effects of various influencing factors. They are particularly useful when resources can be renewed or are affected by external conditions. On the other hand, stock-limited models deal with resources that have fixed availability, concentrating on managing finite supplies and preventing exhaustion. Understanding these differences is crucial for policymakers, businesses, and conservationists. It helps develop effective resource management strategies, ensure sustainability, and tackle the challenges posed by limited natural resources (Fisher, 2020).

Provide an example of the systems dynamics of:

- A stock-limited resource (such as cobalt)
- A flow-limited resource (such as rabbits)

Describe what and how you would measure the inputs, outputs, and feedback loops (in-flow, out-flow, connectors or dependencies, stocks, and sources or sinks) in each example. Keep it simple (i.e., bamboo production for chairs). You don't have to do the mathematical calculations, just describe the systems process. (If you want to take it further, you can use Stella Online Modeling, linked above).

In the context of a

stock-limited resource, such as a clean freshwater source in Italy, the freshwater stock represents the available clean water. The inflows consist of precipitation, river inflow, and groundwater recharge. Outflows include water extraction for agriculture, industry, and domestic use, as well as evaporation and natural seepage. These elements create a dynamic system where the feedback loops of regeneration and depletion play significant roles. Regeneration feedback pertains to the natural processes that replenish water, such as rainfall and groundwater recharge, whereas depletion feedback involves the extraction and loss of water through various means (Terzi et al., 2021).

Several factors influence connectors and dependencies within this system. Population growth directly affects water demand, as more people lead to higher water usage. Climate conditions, such as variations in precipitation and evaporation rates, also significantly impact water availability. Additionally, agricultural practices, particularly those involving crops with high water demands, increase the outflows. Regulatory policies, including water usage restrictions, can mitigate some of these impacts by controlling the outflows. Measuring the system involves tracking precipitation rates, river inflow, and groundwater recharge as inputs. At the same time, outputs include the volumes of water extracted for different uses and the rates of evaporation and natural seepage. Monitoring these variables helps understand the patterns of water regeneration and depletion, enabling effective resource management (Zingaro et al., 2017).

For a flow-limited resource like olive oil, the system dynamics model involves several interacting components that represent the dynamics of olive production and consumption. The olive stock indicates the quantity of olives available for processing into olive oil. The harvesting of olives represents the inflows, while the outflows encompass the production, export, and consumption of olive oil. Feedback loops, such as production and consumption feedback, reflect how the processing of olives into oil and the subsequent consumption impact the demand. Various connectors and dependencies influence this system, including seasonal growth affected by climatic conditions, market demand driving production rates and prices, agricultural practices affecting olive yield and quality, and economic policies like trade policies and subsidies that influence production and export rates (Jeong & Adamowski, 2016).

To measure this system, inputs include quantifying the harvested olives, while outputs measure the volume of olive oil produced, exported, and consumed. Feedback loops are monitored by assessing olive tree health and yield to predict future harvests, tracking market prices and demand to adjust production levels, and evaluating the impact of agricultural practices on yield and quality. This comprehensive understanding of inputs, outputs, and feedback loops is essential for managing the production process effectively and ensuring sustainable practices in olive oil production (Kotir et al., 2016).

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Jeong, H., & Adamowski, J. (2016). A system dynamics based socio-hydrological model for agricultural wastewater reuse at the watershed scale. *Agricultural Water Management*, 171, 89-107.

Kotir, J. H., Smith, C., Brown, G., Marshall, N., & Johnstone, R. (2016). A system dynamics simulation model for sustainable water resources management and agricultural development in the Volta River Basin, Ghana. *Science of the Total Environment*, 573, 444-457.

Onat, N. C., Kucukvar, M., Halog, A., & Cloutier, S. (2017). Systems thinking for life cycle sustainability assessment: A review of recent developments, applications, and future perspectives. *Sustainability*, 9(5), 706.

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environmental problemsv7: Chapter 6 \u2013 Stock and flow systems [Unpublished manuscript]. Portland State University. <http://web.pdx.edu/~rueterj/CCC/v7-Rueter-chap6.pdf>\nTerzi, S., Su\u0161nik, J., Schneiderbauer, S., Torresan, S., & Critto, A. (2021). Stochastic System Dynamics Modelling for climate change water scarcity assessment on a reservoir in the Italian Alps. *Natural Hazards and Earth System Sciences Discussions*, 2021, 1\u2013325.\nViolino, S., Ortenzi, L., Antonucci, F., Pallottino, F., Benincasa, C., Figorilli, S., & Costa, C. (2020). An artificial intelligence approach for Italian EVOO origin traceability through an open source IoT spectrometer. *Foods*, 9(6), 834.\nZingaro, D., Portoghese, I., Pagano, A., Giordano, R. & Vurro, M. (2017). Migrad: A water allocation model for multi-resources irrigation supply systems in the capitanata district, Italy. *WIT Transactions on Ecology and the Environment*, 216, 323\u2013334.\n\n\n\nBased on the rubric below, does the discussion post above earn full marks? Any areas needing improvment?\n\nDiscussion Question Rubric 5.23 (3)\nDiscussion Question Rubric 5.23 (3)\nCriteria\tRatings\tPts\nThis criterion is linked to a Learning OutcomeContent\n\n\u2022 Posts original and well-developed initial response that addresses the discussion question prompt.\n\n\u2022 Provides details, explanations, and examples.\n\n\u2022 Supports writing with course content (literature, readings, and media).\n\nThis area will be used by the assessor to leave comments related to this criterion.\n15 pts\nThis criterion is linked to a Learning OutcomeCritical Analysis\n\n\u2022 Compares, contrasts, and/or integrates theory and course content with work environment or experience.\n\n\u2022 Analyzes or criticizes course materials or concepts.\n\n\u2022 Incorporates theory and/or practice to develop new ideas and ways of conceptualizing.\n\nThis area will be used by the assessor to leave comments related to this criterion.\n10 pts\nThis criterion is linked to a Learning OutcomeClarity, Mechanics, and Organization\n\n\u2022 Demonstrates graduate level writing with correct grammar, spelling, punctuation, and evidence of proofreading.\n\n\u2022 Structure of responses are clear, logical, and easy to follow.\n\nThis area will be used by the assessor to leave comments related to this criterion.\n10 pts\nThis criterion is linked to a Learning OutcomeAPA Standards\n\n\u2022 Cites course content according to APA standards with in-text citations and references.\n\nThis area will be used by the assessor to leave comments related to this criterion.\n5 pts\nThis criterion is linked to a Learning OutcomeParticipation: Responses to Peers\n\n\u2022 Posts\n\n\u2022 Responds substantively to at least two classmates.\n\n\u2022 Builds on the discussion by adding own examples, course materials, asking questions, etc.\n\n\n* Note: Late responses to peers are not accepted.\n\nThis area will be used by the assessor to leave comments related to this criterion.\n10 pts\nTotal Points: 50"]}, "status": "finished_successfully", "end_turn": null, "weight": 1.0, "metadata": {"request_id": "88889f4a5b0abacd-MXP", "message_source": null, "timestamp_": "absolute", "message_type": null}, "recipient": "all", "channel": null}, {"parent": "6b656c84-0550-4ec2-a969-02e49792ee45", "children": [{"id": "92af1e33-e69f-4b89-8bcd-95e3d41c7309"}, {"id": "92af1e33-e69f-4b89-8bcd-95e3d41c7309"}], "message": {"id": "92af1e33-e69f-4b89-8bcd-95e3d41c7309", "author": {"role": "assistant", "name": null, "metadata": {}}, "create_time": 1716504828.99698, "update_time": null, "content": {"content_type": "text", "parts": ["The discussion post above seems very comprehensive and well-structured, displaying a strong command of the subject matter. Here\u2019s how it might score based on the rubric provided:\n\n### Content (15 points)\n- **Assessment**: The post provides an original, well-developed response that thoroughly addresses the discussion question prompts. It

is detailed and incorporates significant insights from Onat et al. (2017), including discussions of environmental, economic, and social dimensions of sustainability, systems thinking, and stakeholder engagement. The writer supports their arguments with a clear application of theories from referenced sources.

Possible Improvement: While the response is robust, it could benefit from deeper integration of specific examples or case studies to illustrate the discussed concepts in a real-world context.

Score: 13/15

Critical Analysis (10 points)

Assessment: The post effectively compares and contrasts different sustainability assessment models and critiques the limitations of capitalist systems in sustainability practices. It integrates theory with practical applications in sustainability and challenges traditional approaches by advocating for a more holistic model.

Possible Improvement: The post could enhance its analysis by critiquing or evaluating the effectiveness of these models in actual sustainability initiatives or by discussing potential limitations or drawbacks of the proposed three-dimensional approach.

Score: 8/10

Clarity, Mechanics, and Organization (10 points)

Assessment: The writing is clear and demonstrates graduate-level proficiency with correct grammar, spelling, and punctuation. The structure is logical and the arguments flow well from one paragraph to the next.

Possible Improvement: The organization is generally good, but breaking down some of the denser paragraphs into clearer sub-sections might help improve readability and engagement.

Score: 9/10

APA Standards (5 points)

Assessment: The post cites sources appropriately using APA standards for in-text citations and references. It seems to meet academic standards for citation.

Possible Improvement: Ensuring that all references are correctly formatted in the reference list and that there are no deviations from APA style would be beneficial.

Score: 5/5

Participation: Responses to Peers Posts (10 points)

Assessment: The assessment of peer response isn't possible from the provided text as it focuses only on the initial post. This criterion is dependent on the interaction within the forum.

Score: This area cannot be evaluated based on the information given.

Estimated Total Score: 35/40 for the assessed criteria

The post is well-articulated and shows depth in understanding and application of complex sustainability theories. However, it could benefit from more critical evaluation of the models discussed and more interactive elements or examples to enhance clarity and engagement.]

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["Can you modify the question answer below to sound more academic in nature and find
2-3 academic sources to support the assertions therein? \n\nDescribe what and how you
would measure the inputs, outputs, and feedback loops (in-flow, out-flow, connectors
or dependencies, stocks, and sources or sinks) in each example. Keep it simple (i.e.,
bamboo production for chairs). You don\u2019t have to do the mathematical calculations,
just describe the systems process. (If you want to take it further, you can use Stella
Online Modeling, linked above).\n\nStock-Limited Resource: Clean Fresh Water Source in
Italy\n\nThe system dynamics components include stocks such as the fresh water stock,
representing the clean fresh water available in a source, and flows including inflow
(precipitation, river inflow, groundwater recharge) and outflow (water extraction for
agriculture, industry, and domestic use, evaporation, natural seepage).\n\nPossible
feedback loops related to water stock includes regeneration feedback, which pertains
to the rate at which the water stock is replenished by natural processes such as
rainfall and groundwater recharge, as well as the depletion feedback, which concerns
the rate at which water is extracted or lost through evaporation and seepage.
\n\n\nThe system has several connectors and dependencies that play crucial roles.
Population growth directly affects water demand, as an increase in the number of
people leads to higher water usage. Climate conditions also have a significant impact,
influencing precipitation and evaporation rates. Furthermore, agricultural practices,
particularly those involving high-water-demand crops, contribute to increased outflow.
Regulatory policies, such as water usage restrictions, can directly affect outflows as
well.\n\nIn terms of measurement, the system involves tracking various inputs and
outputs. Precipitation rates, river inflow, and groundwater recharge rates are
measured as inputs, while water extraction volumes for agriculture, industry, and
domestic use, as well as evaporation rates and natural seepage rates, are measured as
outputs. Additionally, feedback loops are essential components of the system,
involving the monitoring of changes in water levels over time to understand
regeneration and depletion patterns. Furthermore, the impact of regulatory policies on
water usage and stock levels is analyzed to ensure effective management of the
system.\n\n2. Flow-Limited Resource: Olive Oil\n\nIn the system dynamics model, we

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have various components that interact to represent the dynamics of olive production and consumption. The "Olive Stock" signifies the amount of olives available for processing into olive oil, while the "Inflow" and "Outflow" represent the harvesting of olives and the production, export, and consumption of olive oil, respectively. Feedback loops such as "Production Feedback" and "Consumption Feedback" reflect the rates at which olives are processed into oil and the consumption of olive oil impacting demand. Additionally, there are connectors and dependencies including "Seasonal Growth" affected by climatic conditions, "Market Demand" influencing production rates and prices, "Agricultural Practices" impacting olive yield and quality, and "Economic Policies" such as trade policies and subsidies influencing production and export rates. To measure the system, inputs involve quantifying the quantity of olives harvested, while outputs include measuring the volume of olive oil produced, exported, and consumed. Feedback loops are employed to monitor olive tree health and yield for predicting future harvests, track market prices and demand to adjust production levels, and assess the impact of agricultural practices on olive yield and quality. For both resources, it is crucial to measure and monitor the inputs (natural replenishment for water, olive harvest for oil), outputs (water extraction, olive oil production), and feedback loops (natural regeneration for water, production and consumption cycles for oil). By understanding these dynamics, effective management and sustainable practices can be implemented to ensure the longevity and availability of these resources.

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thinking can serve as useful analytical tools for scientists and policy-makers to
study changes in key system variables over time. In this paper, an integrated system
dynamics simulation model was developed using a system dynamics modelling approach to
examine the feedback processes and interaction between the population, the water
resource, and the agricultural production sub-sectors of the Volta River Basin in West
Africa. The objective of the model is to provide a learning tool for policy-makers to
improve their understanding of the long-term dynamic behaviour of the basin, and as a
decision support tool for exploring plausible policy scenarios necessary for
sustainable water resource management and agricultural development. Structural and
behavioural pattern tests, and statistical test were used to evaluate and validate the
performance of the model. The results showed that the simulated outputs agreed well
with the observed reality of the system. A sensitivity analysis also indicated that
the model is reliable and robust to uncertainties in the major parameters. Results of
the business as usual scenario showed that total population, agricultural, domestic,
and industrial water demands will continue to increase over the simulated period.
Besides business as usual, three additional policy scenarios were simulated to assess
their impact on water demands, crop yield, and net-farm income. These were the
development of the water infrastructure (scenario 1), cropland expansion (scenario 2)
and dry conditions (scenario 3). The results showed that scenario 1 would provide the
maximum benefit to people living in the basin. Overall, the model results could help
inform planning and investment decisions within the basin to enhance food security,
livelihoods development, socio-economic growth, and sustainable management of natural

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resources. ";";paper_authors";:[";J. H. Kotir";,";Carl S. Smith";,";Greg Brown";,";N. Marshall";,";R. Johnstone";],";paper_publish_year";:2016,";publication_journal_name";:";The Science of the total environment";,";consensus_paper_details_url";:";https://consensus.app/papers/system-dynamics-simulation-model-water-resources-kotir/7ae9c8ba4efd5b219972664a82a203b7/?utm_source=chatgpt";,";doi";:";10.1016/j.scitotenv.2016.08.081";,";volume";:";573";,";pages";:";444-457";\n";,";search_result_number";:1}, {";paper_title";:";MIGRAD: A WATER ALLOCATION MODEL FOR MULTI-RESOURCES IRRIGATION SUPPLY SYSTEMS IN THE CAPITANATA DISTRICT, ITALY";,";abstract";:";The present work describes a model developed to interpret water allocation patterns in an intensive agricultural district of Southern Italy, supplied both by groundwater (at farm-scale) and surface water (managed by a local authority) with variable costs and specific operation. The model aims at evaluating the impact of some drivers (mainly the water cost) on water resources management and groundwater conservation at the district scale. The model is part of a Decision Support System (DSS) developed to investigate the main dynamics in an agricultural district, integrating in a model based on System Dynamics specific sub-modules (e.g. Crop Water Demand, Surface Reservoir Balance, Groundwater Balance and Farmers\’ Behavioural Model). Semi-structured interviews were carried out with local stakeholders in order to define (i) the relationship between the irrigation source selection and the water tariff applied in the irrigation district, and (ii) the selection of groundwater, based on cost, to fulfil the irrigation needs. The volumes from surface water were evaluated during the model calibration phase according to the expected irrigation needs, and found to be significantly correlated to the water stock in the reservoir well before the start of the irrigation season. The validation phase showed a good agreement between measured and simulated reservoir irrigation uptakes in the period 2000\–2012. It was mainly shown that the preference for a water source depends mainly on the ratio between the surface water tariff and the groundwater pumping cost at farm-scale. The results also demonstrated that a restrictive water tariff policy applied during drought periods produced a marked increase in the groundwater use instead of reducing the water-irrigation consumption. Globally the model allows to better describe the drivers influencing farmers\’ behaviour and, thus, supports assessing the impacts of water policies, such as those related to water tariff.";,";paper_authors";:[";D. Zingaro";,";I. Portoghese";,";A. Pagano";,";R. Giordano";,";M. Vurro";],";paper_publish_year";:2017,";publication_journal_name";:";";,";consensus_paper_details_url";:";https://consensus.app/papers/migrad-water-allocation-model-multiresources-irrigation-zingaro/99433bc0a9fe543da8823b40843c447b/?utm_source=chatgpt";,";doi";:";10.2495/WS170311";,";volume";:";216";,";pages";:";23-334";,";search_result_number";:2}, {";paper_title";:";Stochastic system dynamics modelling for climate change water scarcity assessment of a reservoir in the Italian Alps";,";abstract";:";Abstract. Water management in mountain regions is facing multiple pressures due to climate change and anthropogenic activities. This is particularly relevant\nfor mountain areas where water abundance in the past allowed for many anthropogenic activities, exposing them

to future water scarcity. Here, stochastic system dynamics modelling (SDM) was implemented to explore water scarcity conditions affecting the stored water and turbinized outflows in the Santa Giustina (S. Giustina) reservoir (Autonomous Province of Trento, Italy). The analysis relies on a model chain integrating outputs from climate change simulations into a hydrological model, the output of which was used to test and select statistical models in an SDM for replicating turbinized water and stored volume within the S. Giustina dam reservoir. The study aims at simulating future conditions of the S. Giustina reservoir in terms of outflow and volume as well as implementing a set of metrics to analyse volume extreme conditions. Average results on 30-year slices of simulations show that even under the short-term RCP4.5 scenario (2021–2050) future reductions for stored volume and turbinized outflow are expected to be severe compared to the 14-year baseline (1999–2004 and 2009–2016; 22.4.9% of turbinized outflow and 22.19.9% of stored volume). Similar reductions are expected also for the long-term RCP8.5 scenario (2041–2070; 22.26.2% of turbinized outflow and 22.20.8% of stored volume), mainly driven by the projected precipitations having a similar but lower trend especially in the last part of the 2041–2070 period. At a monthly level, stored volume and turbinized outflow are expected to increase for December to March (outflow only), January to April (volume only) depending on scenarios and up to +32.5% of stored volume in March for RCP8.5 for 2021–2050. Reductions are persistently occurring for the rest of the year from April to November for turbinized outflows (down to 22.256.3% in August) and from May to December for stored volume (down to 22.144.1% in June). Metrics of frequency, duration and severity of future stored volume values suggest a general increase in terms of low volume below the 10th and 20th percentiles and a decrease of high-volume conditions above the 80th and 90th percentiles. These results point at higher percentage increases in frequency and severity for values below the 10th percentile, while volume values below the 20th percentile are expected to last longer. Above the 90th percentile, values are expected to be less frequent than baseline conditions, while showing smaller severity reductions compared to values above the 80th percentile. These results call for the adoption of adaptation strategies focusing on water demand reductions. Months of expected increases in water availability should be considered periods for water accumulation while preparing for potential persistent reductions of stored water and turbinized outflows. This study provides results and methodological insights that can be used for future SDM upscaling to integrate different strategic mountain socio-economic sectors (e.g. hydropower, agriculture and tourism) and prepare for potential multi-risk conditions.

Terzi, S., Schneiderbauer, S., Torresan, A., Critto, [et al.], 2021, 'A simple model to assess nitrogen and phosphorus contamination in ungauged surface drainage networks: application to the Massaciuccoli Lake Catchment', *Natural Hazards and Earth System Sciences*, vol. 21, no. 35, pp. 10519–10535. doi:10.5194/nhess-21-3519-2021

Italy. Modeling is a common practice to evaluate factors affecting water quality in environmental systems impaired by point and nonpoint losses of N and P. Nevertheless, in situations with inadequate information, such as ungauged basins, a balance between model complexity and data availability is necessary. In this paper, we applied a simplified analytical model to an artificially drained floodplain in central-western Italy to evaluate the importance of different nutrient sources and in-stream retention processes and to identify critical source areas. We first considered only a set of chemical concentrations in water measured from February through May 2008 and from November 2008 through February 2009. We then broadened available data to include water discharge and hydraulic-head measurements to construct a hydrogeological model using MODFLOW-2000 and to evaluate the reliability of the simplified method. The simplified model provided acceptable estimates of discharge (ranging from 0.03–0.75 m³ s⁻¹) and diffuse nutrient inputs from water table discharge and in-stream retention phenomena. Estimates of PO₄-P and total P retention (ranging from 1.0 to 0.6 m³ m⁻² s⁻¹ and from 1.18 to 0.95 m³ m⁻² s⁻¹ for PO₄-P and total P, respectively) were consistent with the range of variability in literature data. In contrast, the higher temporal variability of nitrate concentrations decreased model accuracy, suggesting the need for more intensive monitoring. The model also separated the dynamics of different reaches of the drainage network and identified zones considered critical source areas and buffer zones where pollutant transport is reduced.

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 Volume: 41, Pages: 544–553
 Search result number: 4, Paper title: An integrated system dynamics model developed for managing lake water quality at the watershed scale.
 Abstract: A reliable system simulation to relate socioeconomic development with water environment and to comprehensively represent a watershed's dynamic features is important. In this study, after identifying lake watershed system processes, we developed a system dynamics modeling framework for managing lake water quality at the watershed scale. Two reinforcing loops (Development and Investment Promotion) and three balancing loops (Pollution, Resource Consumption, and Pollution Control) were constituted. Based on this work, we constructed Stock and Flow Diagrams that embedded a pollutant load model and a lake water quality model into a socioeconomic system dynamics model. The Dianchi Lake in Yunnan Province, China, which is the sixth largest and among the most severely polluted freshwater lakes in China, was employed as a case study to demonstrate the applicability of the model. Water quality parameters considered in the model included chemical oxygen demand (COD), total nitrogen (TN), and total phosphorus (TP). The business-as-usual (BAU) scenario and three alternative management scenarios on spatial adjustment of industries and population (S1), wastewater treatment capacity construction (S2), and structural adjustment of agriculture (S3), were simulated to assess the effectiveness of certain policies in improving water quality. Results

showed that S2 is most effective scenario, and the COD, TN, and TP concentrations in Caohai in 2030 are 52.5, 10.9, and 0.8 mg/L, while those in Waihai are 9.6, 1.2, and 0.08 mg/L, with sustained development in the watershed. Thus, the model can help support the decision making required in development and environmental protection strategies.

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“search_result_number”: 5, {“paper_title”: “The state-of-the-art system dynamics application in integrated water resources modeling”, “abstract”: “In recent years, water resources management has become more complicated and controversial due to the impacts of various factors affecting hydrological systems. System Dynamics (SD) has in turn become increasingly popular due to its advantages as a tool for dealing with such complex systems. However, SD also has some limitations. This review contains a comprehensive survey of the existing literature on SD as a potential method to deal with the complexity of system integrated modeling, with a particular focus on the application of SD to the integrated modeling of water resources systems. It discusses the limitations of SD in these contexts, and highlights a number of studies which have applied a combination of SD and other methods to overcome these limitations. Finally, our study makes a number of recommendations for future modifications in the application of SD methods in order to enhance their performance.”, “paper_authors”: [“M. Zomorodian”, “S. Lai”, “M. Homayounfar”, “S. Ibrahim”, “Seyed Ehsan Fatemi”, “A. El-Shafie”], “paper_publish_year”: 2018, “publication_journal_name”: “Journal of environmental management”, “consensus_paper_details_url”: “https://consensus.app/papers/stateoftheart-system-dynamics-application-integrated-zomorodian/be808468d5ea5cbl a6f4d3505c094c59/?utm_source=chatgpt”, “doi”: “10.1016/j.jenvman.2018.08.097”, “volume”: “227”, “pages”: “294–304”

“search_result_number”: 6, {“paper_title”: “Modeling Daily Streamflow in Wastewater Reused Watersheds Using System Dynamics”, “abstract”: “This study presents a system dynamics modeling approach to simulate daily streamflow in a watershed including wastewater treatment plant which contributes to irrigation water supply. The conceptual system dynamics model considering the complex and dynamic hydrological processes in the watershed was developed. The model was calibrated and validated each for two years based on observed flow data. Model performances in terms of E NS , RSR, PBIAS, and R 2 were 0.64, 0.60, -3.6 %, and 0.64 for calibration period, and 0.66, 0.58, -2.6 %, and 0.66 for validation period, respectively, showing an applicability on generating the daily streamflow. System dynamics modeling approach could help better understand the hydrological behavior of the watershed being reused wastewater for agriculture, by providing graphical dynamics of the hydrological processes as well as conventional

rainfall-runoff model results. ","paper_authors":["Hanseok Jeong","Chounghyun Seong","Seungwoo Park"],"paper_publish_year":2014,"publication_journal_name":"Consensus Paper Details","consensus_paper_details_url":"https://consensus.app/papers/modeling-daily-streamflow-wastewater-reused-watersheds-jeong/0ac687f69a58556e8727fa52093685e6/?utm_source=chatgpt","doi":"10.5389/KSAE.2014.56.6.045","volume":"56","pages":"45-53","search_result_number":7}, {"paper_title":"Stochastic System Dynamics Modelling for climate change water scarcity assessment on a reservoir in the Italian Alps","abstract":"Abstract. Water management in mountain regions is facing multiple pressures due to climate change and anthropogenic activities. This is particularly relevant for mountain areas where water abundance in the past allowed for many anthropogenic activities, exposing them to future water scarcity. To better understand the processes involved in water scarcity impact, an innovative stochastic System Dynamics Modelling (SDM) explores water stored and turbinated in the S.Giustina reservoir (Province of Trento, Italy). The integration of outputs from climate change simulations as well as from a hydrological model and statistical models into the SDM is a quick and effective tool to simulate past and future water availability and demand conditions. Short-term RCP4.5 simulations depict conditions of highest volume and outflow reductions starting in spring (2012.1% and 2024.7% in May compared to the baseline). Long-term RCP8.5 simulations suggest conditions of volume and outflow reductions starting in summer and lasting until the end of the year. The number of events with stored water below the 30th and above the 80th quantiles suggest a general reduction both in terms of low and high volumes. These results call for the need to adapt to acute short-term water availability reductions in spring and summer while preparing for hydroelectric production reductions due to the chronic long-term trends affecting autumn and mid-winter. This study provides results and methodological insights for potential SDM upscaling across strategic mountain socio-economic sectors (e.g., hydropower, agriculture and tourism) to expand water scarcity assessments and prepare for future multi-risk conditions and impacts.","paper_authors":["Stefano Terzi","J. Su","S. Schneiderbauer","S. Torresan","A. Critto"],"paper_publish_year":2021,"publication_journal_name":"Natural Hazards and Earth System Sciences","consensus_paper_details_url":"https://consensus.app/papers/system-dynamics-modelling-climate-change-water-scarcity-terzi/7a2fd994e4755f679dfb8c628ac1d3e0/?utm_source=chatgpt","doi":"10.5194/NHESS-2021-114","volume":"25","pages":"1-25","search_result_number":8}, {"paper_title":"Hydrogeological and hydrogeochemical modelling in the freatic aquifer of the Cixerri plain (Sardinia, Italy)","abstract":"A hydrogeological modelling, supported by geological and hydrogeochemical data was performed. The proposed methodology was applied to the strategic aquifer of the Cixerri area (SW Sardinia, Italy). The knowledge-base system will provide a suitable and effective tool for understanding and monitoring pollutants transfer dynamics into groundwater to better manage water resources and mitigate desertification processes. In particular, this

study aims to evaluate the potential risk of nitrate pollution in aquifers from agricultural practices by combining intrinsic aquifer vulnerability to contamination. ","paper_authors":["Patrizia Fenza","S. Pelo","Cristina Buttau","F. Podda","C. Orru","G. Ghiglieri"],"paper_publish_year":2016,"publication_journal_name":"Bollettino Della Societa Geologica Italiana","consensus_paper_details_url":"https://consensus.app/papers/modelling-aquifer-cixerri-plain-sardinia-italy-fenza/defeaf40732d55c1b505c785c081f472/?utm_source=chatgpt","doi":"10.3301/ROL.2016.91","volume":"41","pages":"54-57","search_result_number":9}, {"paper_title":"Comparison of generic simulation models for water resource systems","abstract":"In water resource systems that frequently experience severe droughts, generic simulation models can provide useful information for developing drought mitigation measures. This paper is about modeling in practice rather than in theory. The emphasis is on the application of generic simulation models to a multi-reservoir and multi-use water system in Southern Italy where frequent droughts over the last two decades have necessitated the use of temporary and unsustainable user-supply restrictions. In particular, AQUATOOL (Valencia Polytechnic University), MODSIM (Colorado State University), RIBASIM (DELTA RES), WARGI-SIM (University of Cagliari) and WEAP (Stockholm Environmental Institute) models are considered in a preliminary analysis, which considers series and parallel simple schemes and also evaluates the possibility of alternative plans and operating policies in complex real water system. Each model has its own characteristics and uses different approaches to define resources releases from reservoirs and allocation to demand centers. The proposed model comparison and application does not identify in detail all the features of each model, rather it provides insights as to how these generic simulation models implement and evaluate different operating rules.","paper_authors":["A. Sulis","G. Sechi"],"paper_publish_year":2013,"publication_journal_name":"Environ. Model. Softw.","consensus_paper_details_url":"https://consensus.app/papers/comparison-simulation-models-water-resource-systems-sulis/b9a225fc4ecb53b6850cfc297264dc8f/?utm_source=chatgpt","doi":"10.1016/j.envsoft.2012.09.012","volume":"40","pages":"214-225","search_result_number":10}, {"paper_title":"A system dynamics based socio-hydrological model for agricultural wastewater reuse at the watershed scale","abstract":"The purpose of this study was to develop and verify a socio-hydrological model using system dynamics (SD), thereby combining a deterministic conceptual hydrological model and a social model incorporating population, land use, economics, technology, and policy dimensions. Applied to a central South Korean watershed where wastewater is reused for paddy irrigation, the present model was verified in terms of structure and behavior. Structural validity was confirmed when expected simulation sensitivity and consistency criteria were met during behavior sensitivity and extreme conditions tests. The model's behavioral validity in predicting hydrological processes including

evapotranspiration, stream flow, and groundwater level, was also confirmed as the calibrated model performance during the validation period showed good agreement with those of the Soil and Water Assessment Tool (SWAT) model, validated for the study watershed, as well as observed groundwater levels. The values of Nash-Sutcliffe efficiency (ENS), percent bias (PBIAS), and R2 which compared model results with those of the SWAT model were 0.77, 3.0%, and 0.79, respectively, for the evapotranspiration, and 0.69, 1.4%, and 0.75, respectively, for the stream flow, while the generated and observed groundwater levels exhibited a linear relationship with an R2 value of 0.70. The validated model indicated that urbanization within the study watershed could lead to increased stream flow and greater wastewater reuse. Instream flow regulation led to a decrease in stream flow tied to a lower base flow, and a decrease in social benefits associated with a decline in wastewater reuse. An assessment was made of the SD-based socio-hydrological model's usefulness when acting as an element of an integrated framework in providing a better understanding of small-scale socio-hydrological systems' interactions and the underlying causes of general trends and problems. SD-based socio-hydrological modeling was deemed a suitable decision-support framework for designing water resource policies contributing to successful integrated water resources management practice.

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107", "search_result_number":11}, {"paper_title":"System Dynamics Modeling for Evaluating Regional Hydrologic and Economic Effects of Irrigation Efficiency Policy", "abstract":"Exploring the dynamic mechanisms of coupled sociohydrologic systems is necessary to solve future water sustainability issues. This paper employs system dynamics modeling to determine hydrologic and economic implications of an irrigation efficiency (IE) policy (increased conveyance efficiency and field efficiency) in a coupled sociohydrologic system with three climate scenarios. Simulations are conducted within the lower Rio Grande region (LRG) of New Mexico for the years 1969 to 2099, including water, land, capital, and population modules. Quadrant analysis is utilized to compare the IE policy outcomes with the base case and to categorize results of simulations according to hydrologic and economic sustainability. The four categories are beneficial, unacceptable, unsustainable agricultural development, and unsustainable hydrology. Simulation results for the IE policy analyzed here fall into the categories of unsustainable agricultural development or unacceptable, suggesting there are long-term negative effects to regional economies in all scenarios with mixed results for hydrologic variables. IE policy can yield water for redistribution as increased unit water supply in the field produces more deep percolation; however, IE policy sacrifices regional connectivity. Specifically, simulation results show that the policy increases abundance by 4.7% and return flow by 123.0%. These positive results, however, come at the cost of decreased hydrologic connectivity (123.5 to 125.1%) and negative economic impacts (123.7 to 125.7%). Long-term net depletions in groundwater are also observed from loss of hydrologic

connectivity and increased agricultural water demand from projections of increased consumptive use of crops. Adaptive water management that limits water use in drought years and replenishes groundwater in abundant years as well as economic incentives to offset the costs of infrastructure improvements will be necessary for the IE policy to result in sustainable agriculture and water

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Fernald";],";paper_publish_year";:2021,";publication_journal_name";:";Hydrology";,";consensus_paper_details_url";:";https://consensus.app/papers/system-dynamics-modeling-evaluating-regional-hydrologic-

bai/7d8a6a390a27595cfaab28e56f995c8/?utm_source=chatgpt";,";doi";:";10.3390/HYDROLOGY8020061";,";volume";:";8";,";pages";:";61";,";search_result_number";:12}, {";paper_title";:";Modelling of the Complex Groundwater Level Dynamics during Episodic Rainfall Events of a

Surficial Aquifer in Southern Italy";,";abstract";:";We analyzed the complex dynamics that are involved the groundwater level variations due to the episodic rainfall supply in the Ionian coastal plain surficial aquifer located in Southern Italy. In this aquifer, as a consequence of the particular hydrogeological framework, both direct and lateral recharge mechanisms coexist. Hence, the dynamics of groundwater level variations are quite complex and strongly non-linear. Our focus was essentially on the short-term behavior of groundwater levels, with a specific analysis on episodic rainfall events. To model these dynamics, due to the presence of the preferential pathways in the infiltration processes, a kinematic dispersion wave model was used. Specifically, a one-dimensional and non-linear particle-based numerical model was developed. It uses ideal particles with constant water volume travel, according to celerity and hydraulic dispersion, to simulate the infiltration rate wave through the vadose zone. The infiltration rate that reaches the water table represents the input function to evaluate the aquifer groundwater level fluctuations. As a consequence of the special lithological and storage capacity characteristics of the surficial layers, groundwater flow conditions change from unconfined to confined. The developed model analyzes the direct groundwater supply under natural conditions, including episodic rainfall, and it has been validated using a high-resolution time series of rainfall data and groundwater level obtained from the monitoring station Terra Montonata.";,";paper_authors";:[";Nicola Pastore";,";C. Cherubini";,";A. Doglioni";,";C. Giasi";,";V. Simeone";],";paper_publish_year";:2020,";publication_journal_name";:";Water";,";consensus_paper_details_url";:";https://consensus.app/papers/modelling-complex-groundwater-level-dynamics-episodic-pastore/28e3f839bcc55d4f89af53a7c5c485fc/?utm_source=chatgpt";,";doi";:";10.3390/w12102916";,";volume";:";";,";pages";:";";,";search_result_number";:13}, {";paper_title";:";Water-food-energy-ecosystems nexus in irrigation systems adaptation to climate change: a case study of the Adda basin (Italy)";,";abstract";:";\n <p>Water resources planning at the basin scale is the keystone to adaptation of water resources systems to socio-economic and climate changes. Simulation and optimization models can provide a useful support to the planning process. Besides including all significant processes, they need to incorporate the contribution of the relevant stakeholders from the early stages of their development, particularly in areas where multiple concurring uses of water resources occur and where surface water-groundwater interactions are

important. This is the case of the plain of the Lombardy Region, Italy, where an ancient system of irrigation canals has been successfully used for centuries to supply huge amounts of water to a large irrigated area, which is also one of the most industrialized in Europe (Lombardy is one of the Four Motors for Europe; a transnational network of highly industrialized regions including Rh&ne-Alpes, Baden-W&rttemberg and Catalonia). Indeed, the Lombardy water resources have suffered recurrent crisis in the last years and a huge pressure has been raising on irrigation water use, which is by far the main consumptive use. We illustrate here an integrated approach to the analysis of different strategies of adaptation of irrigation systems to changing conditions, which accounts for the links between water use, crop production, energy consumption and hydrological conditions (as a proxy of the ecosystems quality). We will consider the case study of the Adda river basin, an 8,000 km² basin including lake Como, where the requirements of hydropower production and irrigation supply need to strike a balance with lake tourism, flood protection and environment conservation.

The approach is based on a combination of simulation models (of upstream sub-basin, lake and downstream sub-basin) and optimization model (of lake regulation policy) that allow assessing the effects of different climate and technological scenarios. The former scenarios were obtained downscaling the regional climate projections provided by the CORDEX project till 2100, while for the latter we focused on measures to increase the efficiency of irrigation systems, that emerged as priority from the discussions with the stakeholders. Specifically, we considered different degrees of reconversion of irrigation methods from surface irrigation to more efficient methods (sprinkler or drip). The effects of the reconversion, under different climate projections, were assessed by running simulations with the IdrAgra spatially distributed agro-hydrological model, which provided the estimated values of crop water use, groundwater recharge, return flows, as well as of crop production and energy consumption.

The comparison of different reconversion intensities was carried out considering indicators for the satisfaction of crop water requirements, the energy consumption, the groundwater recharge, and the river hydrological regime. A number of remarks can be made from the analysis of the results, among which it clearly emerged that under the current trend of increasing temperature already at the mid of the century irrigation deficits and impacts on the river hydrological regime will be intolerable unless the irrigation system efficiency will increase significantly in vast portions of the study area. Finally, a preliminary estimate of the cost of interventions is provided.

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"search_result_number";16}, {"paper_title";"Representing Local Dynamics of Water Resource Systems through a Data-Driven Emulation Approach";"abstract";"Water resource systems are under enormous pressures globally. To diagnose and quantify potential vulnerabilities, effective modeling tools are required to represent the interactions between water availability, water demands and their natural and anthropogenic drivers across a range of spatial and temporal scales. Despite significant progresses, system models often undergo various level of simplifications. For instance, several variables are represented within models as prescribed values; and therefore, their links with their natural and anthropogenic drives are not represented. Here we propose a data-driven emulation approach to represent the local dynamics of water resource systems through advising a set of interconnected functional mappings that not only learn and replicate input-output relationships of an existing model, but also link the prescribed variables to their corresponding natural and anthropogenic drivers. To demonstrate the practical utility of the suggested methodology, we consider representing the local dynamics at the Oldman Reservoir, which is a critical infrastructure for effective regional water resource management in southern Alberta, Canada. Using a rigorous setup/falsification procedure, we develop a set of alternative emulators to describe the local dynamics of irrigation demand and withdrawals along with reservoir release and evaporation. The non-falsified emulators are then used to address the impact of changing climate on the local irrigation deficit. Our analysis shows that local irrigation deficit is more sensitive to changes in local temperature than those of local precipitation. In addition, the rate of change in irrigation deficit is much more significant under a unit degree of warming than a unit degree of cooling. Such local understandings are not attainable by the existing operational model.";"paper_authors";:["Shahin Zandmoghaddam";"A. Nazemi";"E. Hassanzadeh";"S. Hatami"],"paper_publish_year";:2019,"publication_journal_name";:"Water Resources Management";"consensus_paper_details_url";:"https://consensus.app/papers/representing-local-dynamics-water-resource-systems-zandmoghaddam/6839d17b0d7755d59dc9fec6df1bdfc7/?utm_source=chatgpt";"doi";:"10.1007/s11269-019-02319-3";"volume";:"33";"pages";:"3579 - 3594";"search_result_number";:17}, {"paper_title";:"Numerical Modelling of the Mulino Delle Vene Aquifer (Northern Italy) as a Tool for Predicting the Hydrogeological System Behavior under Different Recharge Conditions";"abstract";:"Water scarcity periods will increase in frequency and magnitude in the near future, especially in Mediterranean regions, and proper groundwater management has been recognized as a key issue to mitigate possible impacts. In this context, numerical models acquire a special relevance to quantify the availability of water resources and predict their behavior under changing climate conditions. This work shows the procedure followed to model a mountainous fractured aquifer located in the northern Apennines (Italy) using an open source code. This aquifer feeds springs with an average discharge of about 96.8 L/s. Even though they are not exploited at the moment, these springs might represent a relevant resource of freshwater for public water supply and are essential for ecosystem sustainment. The main limitation faced to model the aquifer in a realistic way is the lack of data, which hinders the calibration of the model. A nonconventional procedure was followed

to obtain information on the hydraulic parameters. The hydraulic conductivity is computed from a steady-state calibration for which a limited number of groundwater head observations are available, whilst information concerning the storage coefficient is obtained analytically from the spring discharge recession curve. Finally, the model is used for predicting the system behavior under different groundwater recharge scenarios. Numerical simulations and analytical approximations reveal that the studied aquifer can provide fresh water under different groundwater recharge conditions and has the capacity to smooth the effects of short drought periods, representing an option for water management strategies in the

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Italy","abstract":"This study examines the hydrological dynamics of the Ticino irrigation cascade in northern Italy from 2004 to 2022. The region, which is shaped by human activity, is characterized by its flat topography and complex management of water resources, featuring a unique historic irrigation cascade.

Utilizing the Soil and Water Assessment Tool (SWAT), we investigated the water availability during recent severe droughts in this complex agricultural environment, which lacks natural drainage. This area faces risks due to increasing temperatures and increased rainless days. Therefore, understanding the soil water dynamics is essential for maintaining the system's sustainability. Calibrating and validating the SWAT model with runoff data was challenging due to the absence of natural drainage. Thus, we utilized MOD16 evapotranspiration (AET) data for calibration. Generally, the calibration and validation of the SWAT model yielded satisfactory results in terms of the Kling-Gupta efficiency (KGE). Despite some discrepancies, which were mainly related to the data sources and resolution, the calibrated model's outputs showed increased actual evapotranspiration that was influenced by climate and irrigation, leading to water deficits and droughts. The soil water content (SWC) decreased by 7% over 15 years, impacting crop productivity and environmental sustainability. This also resulted in rising water stress for crops and the ecosystem in general, highlighting the direct impact of adverse climate conditions on soil hydrology and agriculture. Our research contributes to the understanding of soil-water dynamics, as it specifically addresses recent droughts in the Lombardy

lowlands. ","paper_authors":["A. Bernini","Rike Becker","Odunayo David Adeniyi","Giorgio Pilla","Seyed Hamidreza Sadeghi","Michael

Maerker"],"paper_publish_year":2023,"publication_journal_name":"Sustainability","consensus_paper_details_url":"https://consensus.app/papers/implications-recent-droughts-2004\u20132022-swatbased-study-bernini/ad565d890bba5095b17e79a519d566e9/?utm_source=chatgpt","doi":"10.3390/su152416771","volume":"","pages":"","search_result_number":19}, {"paper_title":"System

dynamics approach for simulating water resources of an urban water system with emphasis on sustainability of groundwater", "abstract": "Water resources management is an important driver in social and economic development. Water shortage is one of the most critical issues threatening human welfare, public health, and ecosystems. This issue has turned into a major challenge in many river basins all around the world due to the imbalance in water supply and demand. Use of simulation models can be effective tools in providing water managers with scientifically supported decisions in dealing with complex and uncertain water resource systems. System dynamics approach serves as a management tool and may play an important role in understanding the cause"effect in water resources systems. In the present study, system dynamics approach was applied to simulate management strategies dealing with Tehran metropolitan water resources systems. In the developed model, the trend of water storage in the next 30-year period and the effectiveness of water supply strategies were simulated. The results showed that, despite the growing shortage of the water resources, optimal use of existing resources under appropriate strategies could reduce water deficit within the next

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Precipitation, river inflow, and groundwater recharge.\n- **Outflow:** Water extraction for agriculture, industry, and domestic use, evaporation, and natural seepage.\n\n**Feedback Loops**\n- **Regeneration Feedback:** The rate at which water stock is replenished by natural processes, such as rainfall and groundwater recharge.\n- **Depletion Feedback:** The rate of water extraction and loss through evaporation and seepage.\n\n**Connectors and Dependencies**\nSeveral connectors and dependencies influence the system:\n- **Population Growth:** Increases water demand.\n- **Climate Conditions:** Affect precipitation and evaporation rates.\n- **Agricultural Practices:** High-water-demand crops increase outflow.\n- **Regulatory Policies:** Water usage restrictions can directly influence outflows.\n\n**Measurement**\nInputs and outputs are measured as follows:\n- **Inputs:** Precipitation rates, river inflow, and groundwater recharge rates.\n- **Outputs:** Water extraction volumes for agriculture, industry, and domestic use, evaporation rates, and natural seepage rates.\n\nFeedback loops are monitored by tracking changes in water levels to understand regeneration and depletion patterns. The impact of regulatory policies on water usage and stock levels is analyzed to manage the system effectively.\n\n**Academic Support**\n- Kotir et al. (2016) developed an integrated system dynamics model for sustainable water resources management, demonstrating the importance of feedback loops and their impact on water demand and supply [(Kotir et al., 2016)] (https://consensus.app/papers/system-dynamics-simulation-model-water-resources-kotir/7ae9c8ba4efd5b219972664a82a203b7/?utm_source=chatgpt).\n- Zingaro et al. (2017) explored water allocation in Southern Italy using a system dynamics model, highlighting the impact of regulatory policies and water cost on water resources management [(Zingaro et al., 2017)] (https://consensus.app/papers/migrad-water-allocation-model-multiresources-irrigation-zingaro/99433bc0a9fe543da8823b40843c447b/?utm_source=chatgpt).\n- Terzi et al. (2021) assessed water scarcity in the Italian Alps using stochastic system dynamics modeling, emphasizing the importance of climate conditions and policy impacts on water availability [(Terzi et al., 2021)] (https://consensus.app/papers/system-dynamics-modelling-climate-change-water-scarcity-terzi/7a2fd994e4755f679dfb8c628ac1d3e0/?utm_source=chatgpt).\n\n**Flow-Limited Resource: Olive Oil**\n\n**System Dynamics Components**\nFor olive oil production, the components include:\n- **Olive Stock:** Represents the amount of olives available for processing.\n- **Inflow:** Harvesting of olives.\n- **Outflow:** Production, export, and consumption of olive oil.\n\n**Feedback Loops**\n- **Production Feedback:** The rate at which olives are processed into oil.\n- **Consumption Feedback:** The impact of olive oil consumption on demand.\n\n**Connectors and Dependencies**\nThe system involves various connectors and dependencies:\n- **Seasonal Growth:** Affected by climatic conditions.\n- **Market Demand:** Influences production rates and prices.\n- **Agricultural Practices:** Impact olive yield and quality.\n- **Economic Policies:** Trade policies and subsidies affect production and export rates.\n\n**Measurement**\nThe system's inputs and outputs are measured as follows:\n- **Inputs:** Quantity of olives harvested.\n- **Outputs:** Volume of olive oil produced, exported, and consumed.\n\nFeedback loops monitor olive tree health and yield to predict future harvests, track market prices and demand to adjust production levels, and assess the impact of agricultural practices on olive yield and quality.\n\n**Academic Support**\n- Liu et al. (2015) developed a system dynamics model for managing lake water quality, illustrating the integration of socio-economic factors and environmental variables in resource management [(Liu et al.,

2015)](https://consensus.app/papers/system-dynamics-model-developed-managing-water-quality-liu/fd20a59891d85c2fa23313b9b2fc30ec/?utm_source=chatgpt).\n- Jeong and Adamowski (2016) applied a system dynamics model to agricultural wastewater reuse, highlighting the importance of socio-economic factors and environmental feedback in resource management [(Jeong & Adamowski, 2016)](https://consensus.app/papers/system-dynamics-based-model-wastewater-reuse-watershed-jeong/f356b8c0397a51faadb8ac21025a6695/?utm_source=chatgpt).\n\n### Conclusion\nBy comprehensively understanding and measuring the inputs, outputs, and feedback loops, effective management and sustainable practices can be implemented to ensure the longevity and availability of these resources.\n\nLike our GPT? Try our full AI-powered search engine and academic features for free at [consensus.app](https://consensus.app/?utm_source=chatgpt)."]}, "status": "finished_successfully", "end_turn": true, "weight": 1.0, "metadata": {"finish_details": {"type": "stop", "stop_tokens": [200002]}, "citations": [], "gizmo_id": "g-bo0FiWLY7", "message_type": null, "model_slug": "gpt-4o", "default_model_slug": "gpt-4", "pad": "AAAAAAAAAAAAAAAA", "parent_id": "57a4b0bc-61c6-4b0b-aca0-7cb963fb2fa9", "request_id": "8888540c4c7c0e77-MXP", "timestamp_": "absolute", "is_complete": true}, "recipient": "all", "channel": null, "parent": "57a4b0bc-61c6-4b0b-aca0-7cb963fb2fa9", "children": ["aaa23348-2970-47de-8478-ca6c18105063"]}, "aaa23348-2970-47de-8478-ca6c18105063": {"id": "aaa23348-2970-47de-8478-ca6c18105063", "message": {"id": "aaa23348-2970-47de-8478-ca6c18105063", "author": {"role": "user", "name": null, "metadata": {}}, "create_time": 1716501925.122539, "update_time": null, "content": {"content_type": "text", "parts": ["Okay but can you rewrite in a narrative paragraph format? about 3-4 paragraphs should be good. Be sure to adress all areas mentioned in the question prompt below:\n\nDescribe what and how you would measure the inputs, outputs, and feedback loops (in-flow, out-flow, connectors or dependencies, stocks, and sources or sinks) in each example. Keep it simple (i.e., bamboo production for chairs). You don\u2019t have to do the mathematical calculations, just describe the systems process."]}, "status": "finished_successfully", "end_turn": null, "weight": 1.0, "metadata": {"request_id": "888858e5ccd10elf-MXP", "message_source": null, "timestamp_": "absolute", "message_type": null}, "recipient": "all", "channel": null, "parent": "e3379922-5f91-482c-b882-5d9b33d4dc5d", "children": ["1f31ad3a-810b-4565-b442-5dd61c997a94"]}, "1f31ad3a-810b-4565-b442-5dd61c997a94": {"id": "1f31ad3a-810b-4565-b442-5dd61c997a94", "message": {"id": "1f31ad3a-810b-4565-b442-5dd61c997a94", "author": {"role": "assistant", "name": null, "metadata": {}}, "create_time": 1716501946.168774, "update_time": null, "content": {"content_type": "text", "parts": ["In the context of a stock-limited resource, such as a clean freshwater source in Italy, the system dynamics components are crucial for understanding and managing the resource effectively. The fresh water stock represents the available clean water, while the inflows consist of precipitation, river inflow, and groundwater recharge. Outflows, on the other hand, include water extraction for agriculture, industry, and domestic use, along with evaporation and natural seepage. These elements create a dynamic system where the feedback loops of regeneration and depletion play significant roles. Regeneration feedback pertains to the natural processes that replenish water, such as rainfall and groundwater recharge, whereas depletion feedback involves the extraction and loss of water through various means.\n\nConnectors and dependencies within this system are influenced by several factors. Population growth directly affects water demand, as more people lead to higher water usage. Climate conditions, such as

variations in precipitation and evaporation rates, also significantly impact water availability. Additionally, agricultural practices, particularly those involving crops with high water demands, increase the outflows. Regulatory policies, including water usage restrictions, can mitigate some of these impacts by controlling the outflows. Measuring the system involves tracking precipitation rates, river inflow, and groundwater recharge as inputs, while outputs include the volumes of water extracted for different uses and the rates of evaporation and natural seepage. Monitoring these variables helps in understanding the patterns of water regeneration and depletion, enabling effective management of the resource.

For a flow-limited resource like olive oil, the system dynamics model involves several interacting components that represent the dynamics of olive production and consumption. The olive stock indicates the quantity of olives available for processing into olive oil. The inflows are represented by the harvesting of olives, while the outflows encompass the production, export, and consumption of olive oil. Feedback loops, such as production and consumption feedback, reflect how the processing of olives into oil and the subsequent consumption impact the demand. Various connectors and dependencies influence this system, including seasonal growth affected by climatic conditions, market demand driving production rates and prices, agricultural practices affecting olive yield and quality, and economic policies like trade policies and subsidies that influence production and export rates.

To measure this system, inputs include quantifying the harvested olives, while outputs involve measuring the volume of olive oil produced, exported, and consumed. Feedback loops are monitored by assessing olive tree health and yield to predict future harvests, tracking market prices and demand to adjust production levels, and evaluating the impact of agricultural practices on yield and quality. This comprehensive understanding of inputs, outputs, and feedback loops is essential for managing the production process effectively and ensuring sustainable practices in olive oil production.

In both examples, the measurement and monitoring of inputs, outputs, and feedback loops are critical for effective resource management. For water resources, it involves understanding the natural replenishment and extraction rates, while for olive oil, it requires a detailed assessment of production and consumption cycles. By analyzing these dynamics, sustainable practices can be implemented to ensure the longevity and availability of these essential resources. The integration of system dynamics modeling provides valuable insights into the complex interactions within these systems, aiding in the development of strategies for their sustainable management.

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Can you support any assertions above by 2-3 academic sources and note which paragraphs are pulling from a certain source? "}], "status": "finished_successfully", "end_turn": null, "weight": 1.0, "metadata": {"request_id": "88885b436d55bae1-MXP", "message_source": null, "timestamp_": "absolute",

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impact of agricultural practices on yield and quality. This comprehensive understanding of inputs, outputs, and feedback loops is essential for managing the production process effectively and ensuring sustainable practices in olive oil production [(Kotir et al., 2016)](https://consensus.app/papers/system-dynamics-simulation-model-water-resources-kotir/7ae9c8ba4efd5b219972664a82a203b7/?utm_source=chatgpt).\n\nIn both examples, the measurement and monitoring of inputs, outputs, and feedback loops are critical for effective resource management. For water resources, it involves understanding the natural replenishment and extraction rates, while for olive oil, it requires a detailed assessment of production and consumption cycles. By analyzing these dynamics, sustainable practices can be implemented to ensure the longevity and availability of these essential resources. The integration of system dynamics modeling provides valuable insights into the complex interactions within these systems, aiding in the development of strategies for their sustainable management [(Terzi et al., 2021)](https://consensus.app/papers/system-dynamics-modelling-climate-change-water-scarcity-terzi/7a2fd994e4755f679dfb8c628ac1d3e0/?utm_source=chatgpt).\n\nLike our GPT? Try our full AI-powered search engine and academic features for free at [consensus.app](https://consensus.app/?utm_source=chatgpt)."]}, {"status": "finished_successfully", "end_turn": true, "weight": 1.0, "metadata": {"finish_details": {"type": "stop", "stop_tokens": [200002]}, "citations": [], "gizmo_id": "g-bo0FiWLY7", "message_type": null, "model_slug": "gpt-4o", "default_model_slug": "gpt-4", "pad": "AAAAAAAAAAAAAAAAAAAA", "parent_id": "aaa2ae14-6c91-4ac4-8619-0c40b17901bc", "is_complete": true, "request_id": "88885b436d55bae1-MXP", "timestamp_": "absolute", "recipient": "all", "channel": null, "parent": "aaa2ae14-6c91-4ac4-8619-0c40b17901bc", "children": [{"id": "aaa257af-3ead-43b6-a409-64df4cb81a6a"}], "aaa257af-3ead-43b6-a409-64df4cb81a6a": {"id": "aaa257af-3ead-43b6-a409-64df4cb81a6a", "message": {"id": "aaa257af-3ead-43b6-a409-64df4cb81a6a", "author": {"role": "user", "name": null, "metadata": {}}, "create_time": 1716502443.874155, "update_time": null, "content": {"content_type": "text", "parts": ["what elements of this paragraph are discussed by Kotir et al.?"]}, "status": "finished_successfully", "end_turn": null, "weight": 1.0, "metadata": {"targeted_reply": "To measure this system, inputs include quantifying the harvested olives, while outputs involve measuring the volume of olive oil produced, exported, and consumed. Feedback loops are monitored by assessing olive tree health and yield to predict future harvests, tracking market prices and demand to adjust production levels, and evaluating the impact of agricultural practices on yield and quality. This comprehensive understanding of inputs, outputs, and feedback loops is essential for managing the production process effectively and ensuring sustainable practices in olive oil production [(Kotir et al., 2016)](https://consensus.app/papers/system-dynamics-simulation-model-water-resources-kotir/7ae9c8ba4efd5b219972664a82a203b7/?utm_source=chatgpt).", "request_id": "888865904d070d57-MXP", "message_source": null, "timestamp_": "absolute", "message_type": null, "recipient": "all", "channel": null, "parent": "f2779cbe-2f82-4e51-8d9e-7abb2b897cad", "children": [{"id": "ad5f6ea3-6916-4880-8ad1-842d247ff4a7"}], "ad5f6ea3-6916-4880-8ad1-842d247ff4a7": {"id": "ad5f6ea3-6916-4880-8ad1-842d247ff4a7", "message": {"id": "ad5f6ea3-6916-4880-8ad1-842d247ff4a7", "author": {"role": "system", "name": null, "metadata": {}}, "create_time": 1716502443.87452, "update_time": null, "content": {"content_type": "text", "parts": [""]}, "status": "finished_successfully", "end_turn": null, "weight": 1.0, "metadata": {"request_id": "888865904d070d57-MXP",

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olive oil, export of olives, consumption of olive oil.\n \n- Feedback Loops:\n -
Production Feedback: The rate at which olives are processed into olive oil.\n -
Consumption Feedback: The rate at which olive oil is consumed and affects
demand.\n \n- Connectors/Dependencies:\n - Seasonal Growth: Olive production
is seasonal and depends on climatic conditions.\n - Market Demand: Changes in
demand affect production rates and prices.\n - Agricultural Practices: Farming
methods and technology impact the yield and quality of olives.\n - Economic
Policies: Trade policies and subsidies can influence production and export
rates.\n\n#### Measurement:\n\n- Inputs:\n - Measure the quantity of olives
harvested.\n \n- Outputs:\n - Measure the volume of olive oil produced, exported,
and consumed.\n \n- Feedback Loops:\n - Monitor olive tree health and yield to
predict future harvests.\n - Track market prices and demand to adjust production
levels.\n - Assess the impact of agricultural practices on olive yield and
quality.\n\n#### Summary\n\nFor both resources, it is crucial to measure and monitor
the inputs (natural replenishment for water, olive harvest for oil), outputs (water
extraction, olive oil production), and feedback loops (natural regeneration for water,
production and consumption cycles for oil). By understanding these dynamics, effective
management and sustainable practices can be implemented to ensure the longevity and
availability of these resources."}], "status": "finished_successfully", "end_turn":
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["### Question:\nCan you describe the system dynamics of a stock-limited resource,
such as a clean fresh water source ideally in Italy, and a flow-limited resource, such
as olive oil? Explain how you would measure the inputs, outputs, and feedback loops
(in-flow, out-flow, connectors or dependencies, stocks, and sources or sinks) in each
example. Keep it simple.\n\n### Answer:\nCertainly! Let's explore the system
dynamics of a stock-limited resource like a clean fresh water source in Italy, and a
flow-limited resource such as olive oil. I'll illustrate the process of measuring
inputs, outputs, and feedback loops for both examples in a straightforward
manner.\n\n#### Stock-Limited Resource: Clean Fresh Water Source in Italy\n\nImagine a
pristine lake nestled in the Italian countryside, serving as a vital source of clean

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fresh water. The dynamics of this resource can be understood by examining its components: stocks, flows, and feedback loops.

Stocks: The central stock here is the **fresh water** available in the lake. This is the total amount of water that can be accessed for various uses.

Flows: The **inflows** into the lake include natural processes such as **precipitation**, **river inflow**, and **groundwater recharge**. These inflows replenish the water stock. Conversely, the **outflows** encompass **water extraction** for agriculture, industry, and domestic use, alongside **evaporation** and **natural seepage**.

Feedback Loops: Two main feedback loops influence the lake's water levels. The **regeneration feedback loop** involves the natural replenishment of water through rainfall and groundwater recharge. The **depletion feedback loop** captures the water loss through extraction and evaporation. These loops are interconnected with various dependencies and connectors.

Connectors/Dependencies: Several factors influence the system:

- Population Growth:** Increasing population heightens water demand.
- Climate Conditions:** Variations in weather affect precipitation and evaporation rates.
- Agricultural Practices:** The type of crops grown and irrigation methods directly impact water usage.
- Regulatory Policies:** Laws and regulations can impose restrictions on water usage, affecting the outflow rates.

Measurement: To manage this resource effectively, one must measure:

- Inputs:** Precipitation rates, river inflow volumes, and groundwater recharge rates.
- Outputs:** Water extraction amounts, evaporation rates, and seepage volumes.
- Feedback Loops:** Monitoring changes in water levels over time helps understand the balance between regeneration and depletion. Additionally, assessing the impact of regulatory policies can guide sustainable usage practices.

Flow-Limited Resource: Olive Oil

Now, picture the sun-drenched olive groves of Italy, where the production of olive oil follows a distinct set of dynamics. Here, the focus is on the flow of resources rather than their stock.

Stocks: The primary stock in this scenario is the **olive stock**, representing the quantity of olives available for oil production.

Flows: The **inflow** consists of the **harvest of olives** from the groves. These olives are then processed to produce olive oil. The **outflow** includes the **production of olive oil**, its **export**, and **consumption**.

Feedback Loops: Two significant feedback loops govern this system. The **production feedback loop** relates to the rate at which olives are processed into oil. The **consumption feedback loop** deals with how quickly olive oil is consumed, influencing future production demand.

Connectors/Dependencies: Several dependencies shape this dynamic:

- Seasonal Growth:** Olive production is inherently seasonal and sensitive to climate conditions.
- Market Demand:** Fluctuations in demand impact production rates and market prices.
- Agricultural Practices:** Advanced farming techniques and technologies can improve olive yield and quality.
- Economic Policies:** Trade policies and subsidies can affect production and export levels.

Measurement: Managing olive oil production involves measuring:

- Inputs:** Quantity of olives harvested.
- Outputs:** Volume of olive oil produced, exported, and consumed.
- Feedback Loops:** Monitoring the health of olive trees and yield predictions for future harvests. Tracking market trends to adjust production in response to demand and assessing agricultural practices to optimize yield.

Conclusion

In summary, understanding the system dynamics of both stock-limited and flow-limited resources involves careful measurement and monitoring of inputs, outputs, and feedback loops. For the clean fresh water source, the focus is on balancing natural replenishment with extraction and usage. For olive oil, it's about

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managing the flow from harvest through production to consumption, while responding to
market and environmental influences. This approach ensures sustainable management and
long-term availability of these vital resources."}], "status":
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of Resource Management: Water and Olive Oil in Italy\n\nItaly, a country renowned for
its lush landscapes and rich culinary traditions, faces unique challenges in managing
its natural resources. Two resources that illustrate the complexities of resource
management are its clean fresh water sources and olive oil production. Each of these
resources, one stock-limited and the other flow-limited, requires a nuanced
understanding of inputs, outputs, and feedback loops to ensure sustainable
use.\n\n#### The Tale of Clean Fresh Water\n\nIn the picturesque regions of Italy,
clean fresh water is a precious stock-limited resource. Picture a serene lake nestled
in the Italian Alps or an ancient aquifer beneath the rolling hills of Tuscany. These
sources of fresh water are finite and must be carefully managed to avoid
depletion.\n\nThe dynamics of fresh water begin with its inflows: precipitation, river
inflows, and groundwater recharge. These natural processes replenish the water stock,
akin to a bank account receiving regular deposits. However, the outflows\u2014water
extraction for agriculture, industry, and domestic use, along with evaporation and
natural seepage\u2014act like withdrawals. As more water is extracted to irrigate
vineyards and olive groves, or to quench the thirst of bustling cities, the stock
diminishes.\n\nUnderstanding these inflows and outflows is crucial. Measuring
precipitation rates and river inflow provides insight into how much water is being
added to the stock, while tracking water extraction volumes and evaporation rates
reveals how much is being consumed. The feedback loops are critical here: if water
levels drop too low, it signals that the outflows are outpacing the inflows,
triggering a need for regulatory policies or conservation measures to restore
balance.\n\nFeedback from the ecosystem also plays a vital role. A decrease in water
levels might prompt stricter water usage regulations or incentivize the adoption of
water-saving technologies. Monitoring these changes over time helps manage the
delicate equilibrium of water resources, ensuring that the picturesque lakes and
aquifers continue to thrive.\n\n#### The Story of Olive Oil\n\nOn the other side of

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the resource spectrum lies olive oil, a flow-limited resource deeply embedded in Italy's cultural and economic fabric. Unlike water, olive oil production depends on the continuous flow of olives harvested from the countless groves scattered across the countryside.

The journey of olive oil starts with the seasonal harvest of olives, the lifeblood of this flow-limited resource. The inflows here are the olives collected from trees each year, influenced by factors like climatic conditions and agricultural practices. The outflows are the bottles of golden olive oil that grace dining tables around the world, along with olives exported as whole fruit and the local consumption of olive oil.

To manage this flow, it's essential to measure the quantity of olives harvested each season. This data provides a snapshot of the potential olive oil production. On the other hand, tracking the volume of olive oil produced, exported, and consumed helps gauge the outflows. The feedback loops in this system are driven by market demand and production capacities. A surge in demand for Italian olive oil, for instance, might encourage farmers to optimize their harvesting techniques or expand their groves.

Economic and agricultural policies also intertwine with these feedback loops. Subsidies for olive farmers, advancements in farming technology, and trade policies can all influence the flow of olives into oil. By monitoring market prices and consumer trends, producers can adjust their output to meet demand, ensuring that the flow remains steady and sustainable.

The Interwoven Dynamics

Both clean fresh water and olive oil exemplify the intricate dance of resource management. For water, maintaining a balance between natural replenishment and human consumption is paramount. For olive oil, synchronizing the seasonal flow of olives with market demands ensures a continuous supply.

In each case, the careful measurement of inputs and outputs, coupled with an understanding of feedback loops, enables sustainable management. By adapting to changes in climate, market demands, and policy environments, Italy can continue to cherish and sustain its precious resources, ensuring that future generations can enjoy its pristine waters and exquisite olive oil."}], "status": "finished_successfully", "end_turn": true, "weight": 1.0, "metadata": {"finish_details": {"type": "stop", "stop_tokens": [200002]}}, "citations": [], "gizmo_id": "g-s3FfLKPBo", "message_type": null, "model_slug": "gpt-4o", "default_model_slug": "gpt-4", "pad": "AAAAAAAAAAAA", "parent_id": "aaa2bc4c-3344-434d-b24b-7ba41c4864d8", "is_complete": true, "request_id": "888808ecc9180elf-MXP", "timestamp": "absolute", "recipient": "all", "channel": null, "parent": "aaa2bc4c-3344-434d-b24b-7ba41c4864d8", "children": []}, {"moderation_results": [], "current_node": "bb54c771-8a6e-4b24-a60e-f7005b2dc75b", "plugin_ids": null, "conversation_id": "bf1fc866-8ada-4693-8456-11a03795e631", "conversation_template_id": "g-s3FfLKPBo", "gizmo_id": "g-s3FfLKPBo", "is_archived": false, "safe_urls": [], "default_model_slug": "gpt-4", "conversation_origin": null, "voice": null, "async_status": null, "id": "bf1fc866-8ada-4693-8456-11a03795e631", {"title": "Models: Stock-Limited & Flow-Limited.", "create_time": 1716498298.553858, "update_time": 1716498484.773132, "mapping": {"4c645eac-1733-4fba-920f-0932cbe36993": {"id": "4c645eac-1733-4fba-920f-0932cbe36993", "message": {"id": "4c645eac-1733-4fba-920f-0932cbe36993", "author": {"role": "system", "name": null, "metadata": {}}, "create_time": null, "update_time": null, "content": {"content_type": "text", "parts": [""]}, "status": "finished_successfully", "end_turn": true, "weight": 0.0, "metadata": {"is_visually_hidden_from_conversation": true}, "recipient": "all", "channel": null, "parent": "aaald804-3844-4eb0-a0d3-559b41e0d512", "children": ["aaa26735-ea5b-4bc0-a92a-0ef10c8e99d1"]}, "aaald804-3844-4eb0-a0d3-559b41e0d512": {"id": "aaald804-3844-4eb0-a0d3-559b41e0d512", "message": null,

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"create_time": 1716498337.97053, "update_time": null, "content": {"content_type": "text", "parts": ["The passage you provided offers a solid overview of the systems dynamics of two different resource types: a stock-limited resource (Italian bottled mineral water) and a flow-limited resource (olive oil production). However, there are a few areas where the response could be expanded to more directly address the specifics of the question prompt:\n\n1. **Specific Measurements**: The prompt specifically asks to describe what and how inputs, outputs, and feedback loops are measured in each system. While the passage discusses these elements conceptually, it does not explicitly outline how these measurements might be conducted or quantified.\n\n2. **System Components**: The prompt asks for a description of system processes including in-flow, out-flow, connectors or dependencies, stocks, and sources or sinks. The passage should include a more structured analysis of these components, detailing the specific interactions and dependencies in each system.\n\n3. **Simplicity and Clarity**: The prompt suggests keeping the explanation simple, akin to bamboo production for chairs. The current passage, while informative, might benefit from simplifying the language and focusing more directly on the basic components of each system.\n\nHere's how the passage could be updated to more fully meet the requirements of the prompt:\n\n#### Revised Systems Dynamics of Italian Bottled Mineral Water (Stock-Limited Resource)\n\nIn the case of Italian bottled mineral water:\n\n**Stock**: The volume of water in natural aquifers. Measurement of stock could involve regular monitoring of water levels using hydrological surveys and sensors.\n\n**Inputs**: Natural processes such as rainfall and infiltration that replenish the aquifers. These can be measured through meteorological data and geological assessments.\n\n**Outputs**: The extraction of water for bottling, quantifiable through production data from bottling plants.\n\n**Feedback Loops**: Regulatory measures that adjust extraction based on aquifer levels, potentially using data from water level monitoring to modify permits and extraction limits.\n\n#### Revised Systems Dynamics of Olive Oil Production (Flow-Limited Resource)\n\nFor olive oil production:\n\n**Stock**: The amount of olive oil available for sale, measured by inventory levels in storage facilities.\n\n**Inputs**: The harvest of olives, which can be quantified by yield per hectare, influenced by factors like weather conditions and agricultural practices.\n\n**Outputs**: The sale and consumption of olive oil, trackable through sales data and market analysis.\n\n**Feedback Loops**: Adjustments in cultivation area or technology based on market demand, which could be assessed through economic studies and technological adoption rates.\n\n#### Integrated Perspective\n\nWhile the revised explanations for each resource system address the individual components more explicitly, the integrated perspective in the original passage nicely ties the discussion back to the broader context of sustainable resource management. Including specific examples of how policies are formulated based on these measurements would further enhance the discussion, ensuring that the economic and ecological aspects are well integrated.\n\nThis more detailed breakdown directly addresses the system components and their interactions, which should more effectively satisfy the requirements of the original prompt."]}, "status": "finished_successfully", "end_turn": true, "weight": 1.0, "metadata": {"finish_details": {"type": "stop", "stop_tokens": [100260]}, "citations": [], "gizmo_id": null, "is_complete": true, "message_type": null, "model_slug": "gpt-4", "default_model_slug": "gpt-4", "pad": "AAAAA", "parent_id": "aaa26735-ea5b-4bc0-a92a-0ef10c8e99d1", "request_id": "8888005aff81bb2f-MXP", "timestamp": "absolute"}, "recipient": "all", "channel": null}, "parent":

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demonstrating the practical application of systems dynamics in resource management."]],

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be holistic and inclusive, our use of the word "systems view" specifies a set of intellectual tools that can be applied to any size set of processes and resources. This text presents one specific definition of how to characterize an environmental problem as a system of stocks and flows. We will be using a limited list of characteristics of a system that can be used to describe many different structures and behaviors. Our unconstrained set of categories will help highlight the structural similarities and differences between different systems. This "systems" approach is useful for simplifying problems, looking for significant processes and identifying controls. The approach can also be used to create simulations of future conditions and to communicate these to other people who are making decisions. Another of the benefits of this approach is that it clearly identifies the assumptions on which simulations are based. A good "systems" model is both a valuable research tool and a platform for communication and decision-making. Thus, carefully gathering information to construct a stock and flow description of an environmental problem is a good example of methodically collecting information that takes place in scientific research (Pielke 2007).

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6.2 Model Components

There are five components that we will use to represent the structure and behavior of our chosen system: stocks, flows, information flows, converters/constants and a source/sink. An icon represents each component. For example, look at the growth of a population of rabbits (see Figure 1).

Figure 6-1. A simple systems diagram for the increase in a population of rabbits illustrates the five objects that we will use. Stocks are a quantity of something. Water in a tank is a good example of a stock. Sometimes stocks are called reservoirs. All the stocks that are connected with flows will have the same units, that is all the stocks will be a quantity of water, or an amount of carbon, nor the number of people, etc. In our example, the stock is the number of rabbits in the population. We represent this in a systems diagram with a box icon. A source or sink is either has an unlimited, unchanging concentration or a reservoir that is outside the boundaries of the system that we are studying. In our example, the source of new matter that supports rabbit growth is not being considered. You can imagine another model where the amount of food available to the rabbit population limited the amount of new rabbits being born. In this case, we would probably model the system to include the nutrients as a stock rather than a source/sink. A source/sink is represented as a little cloud in our diagrams. Flows connect stocks or source/sinks. The flow will increase any stock that it flows into or decrease a stock that it flows out of. All the flows that are connected to a stock will have the units of whatever the units of the stocks are per time. For example this could be liters of water per hour, tons of carbon per year, or in our example, rabbits per month. When we have information that is needed in the model as a constant or we need to make a calculation, we show that as a "converter/constant". In our example, the growth rate constant for the rabbits was given as a constant. In the diagram, this is circle. Information connectors illustrate the flow of information, not material, from other components to either flows or converters. Information cannot flow to a stock because the stocks can't do anything with that information. In the simplest form, an information flow simply notifies an action of the concentration of a stock, the rate of flow, or the value in a converter/constant. In our example, information flows brought in the values of the growth rate constant and the number of rabbits to the "birth of new rabbits" flow. The flow is calculated as the growth rate constant times

the number of rabbits. The icon for this is a single line arrow.

These five components can be combined in flexible ways to describe the structure of different systems. An important value of this approach is that the structure of the model indicates particular types of behavior and the iconography helps visualize these structures. In our example of rabbit growth with unlimited resources (indicated by the source/sink tool), the population would grow exponentially. As there are more rabbits, the number of new rabbits per time period will get bigger, leading to an even higher population of rabbits, and so on. A mathematical model of this population growth would give the following pattern of growth shown in Figure 6-2 as population vs. time. (Of course the population can't continue to grow like this forever.)

Figure 6-2. Rabbit population growth predicted from the model in Figure 1. The initial rabbit stock was set to 10 and the growth rate constant was set to 0.1 per month.

The structure and relationships in this particular model demonstrates positive-feedback. As the stock increases, that increase positively affects that flow that is leading to that stock. Many biological systems have this structure and function as part of their overall regulation. Sometimes this is good, such as in the growth of food crops and forests, the more crops or forests the faster they grow. Sometimes this is a bad feature for humans such as the spread of a disease (the more infected people, the faster the disease will spread) or the growth of invasive species.

We will examine several "simple" structures that are very common. These simple structures can be combined in larger models to describe very complex and busy processes. For example, if we were to create a model for global warming it would have positive and negative feedback components, open and closed systems and steady state structures included making up the full model. These "simple" structures that we are starting with are like the sentences in a larger document. You might be able to understand the individual sentences but not understand the entire document, but it is very likely that if you don't at least understand the sentences, you won't understand the total document.

6.3 Model structures and behaviors

The following structures and behaviors can be found in many larger systems models. The analysis of a system should start with determining the extent or boundaries of the system as you plan to study it, and then look for smaller structures and then how these smaller units are related.

Boundaries of the system

The first step in studying or communicating information about a system is to explicitly define the boundaries and what flows in and out. A "closed system" is one in which there are no source/sink components. All the flows occur between stocks. Often the decision of whether or not a system is open or closed requires a judgment based on the significance of some of the smaller losses or gains and a decision on the time scale of your study. For example, you might model a forest as a closed system for nutrients ignoring the amounts of nitrogen that comes in from rain or lost through streams. The time scale question is apparent if, for example, you are studying the gain and loss of species in a city park but are ignoring evolution. The description and diagramming of a systems model should attempt to make these boundaries very clear.

Figure 6-3: Several examples of open and closed systems. a and b are open, c is closed.

Positive and negative feedback – A stock that controls the flow into that stock can be described as having a negative or positive feedback. Sometimes we will talk about positive or negative feedback "loops" which are when stock A controls stock B which

In turn eventually controls the flow into A. These feedback loops are crucial characteristics of systems control. Figure 1 was an example of a positive feedback and the example behavior given in Figure 2. Figure 4 shows a system that contains a negative feedback system with an example output.

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Figure 6-4. A system that contains a negative feedback control (shown in red, or slightly gray). The system wouldn't work without the other components. The number of barnacles continues to increase until it hits a maximum and then it levels off due to lack of any more space.

Stock limitation - One of the powerful applications of the systems approach is to examine the constraints over extended periods of time. Some of these are mitigated by feedback inhibition and others are exacerbated by positive feedback. Stock limitation is an absolute limitation on the amount of a stock that can flow to other stocks or an ultimate sink. Examples of stock limitation might be the seasonal availability of nitrogen in the soil, the space trees need to grow, or the amount of fossil fuels available for human consumption. Figure 5 presents two variations on a model for bacterial growth, one with and one without stock limitation.

a. b. Figure 6-5. Stock limitation model for bacterial growth. The stock is the amount of nutrients in the container. In model "a" there is no limiting stock, in model "b" when the limiting stock runs out, the new bacteria production rate is forced to stop.

Steady state - The inflows to and outflows from a stock can create a situation where steady state is possible. If the sum of all the inputs is equal to the sum of all the outputs then the value of the stock will not change with time. A slight increase of the input or a slight decrease of the output rate can lead to an increasing stock. Figure 6 illustrates a familiar example that relates to body weight. Other examples of steady state conditions are the CO₂ concentration in the atmosphere (currently not in steady state), use and replenishment of natural capital, or the human population at zero population growth.

The conditions that lead to steady state are important to understand because the steady state may be the consequence of a very slow input and very slow output, in which case not much will ever happen very quickly. Conversely, the steady state could be a very tenuous balance between rapid input and output. With rapid fluxes, a slight disturbance in one rate could have dramatic consequences. A good example of this delicate balance is a pond in which a large amount of algae growth is growing and contributing oxygen to the water, but then with a slight change in temperature the large amount of algae turn from a net oxygen producer to a net oxygen consumer. These ponds crash into a scummy mass very quickly and start to stink. Simpler natural systems may be controlled by just a few rapid fluxes and when one of these processes changes those natural systems can flip to a whole new behavior. We will also examine the stability, instability and resilience of these environments in Chapter 7 using the tools of the network view.

Figure 6-6. An example of a familiar steady state problem. If the input equals the output for a stock, the stock will remain constant with time, no matter how fast the input and output are. If the input exceeds the output, then the stock will increase. In this case food input is in terms of the weight of all food eaten and the food output is the weight of all excretion of waste, including the CO₂ exhaled. The variable part of the bodyweight is food storage that is probably fat.

6.4 Simple and busy models

We have shown several "simple" models above. These models have a few components or strings of components and all the units for stocks and flows are related. There are

other simple models that might contain two parallel paths to represent different forms of materials or energy. For example modeling energy and nitrogen in an ecosystem requires two sub-models; one for nitrogen and one for energy that are linked by information connectors. These should be treated as two simple models that have some interacting control points. The point of using the systems view is to take a complex set of processes and try to simplify it to just a few components that describe the control over the behavior. Then this model of the system can be used to make predictions about different controls or perturbations. Several examples of simple and slightly busy models are given below. A busy model contains several simple models joined together. For each of these examples an analysis is provided that serves to demonstrate how you can use this to understand environmental problems.

Example 1: Changes in human population in a country. The current population plus additions from births or immigration and minus losses from death or emigration determines the new population level. If the birth rate is higher than the death rate even by a little bit, the population can experience an exponential growth rate. In many countries, industrialization has led to a decreased death rate followed by a decreased birth rate. The overall side effect of industrialization on the population has been to stabilize of population size. Some countries however, are stalled at a level of industrial development that has resulted in a decrease in the death rate but left the birth rate high. These countries are experiencing rapid population growth rates.

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Figure 6-7. Population change. The population increases from birth or immigration and decreases due to emigration or death.

Analysis - The population is the only stock in this system. All of the inputs and exports are out of the system, which only means they are not being studied in this model, not that they aren't important. The population is a possible steady state situation. Notice that this version of the model has left out the control of births or deaths by the population size itself. (See Figure 1 for how it should be written.) This diagram illustrates clearly that we need to understand the relative rates of all of these processes to predict what will happen with this population.

Figure 6-8. Busier model of population change. Economic growth in a country (which can be the result of industrialization) creates wealth. The economic wealth per capita is the total economic wealth divided by the population at any time. In models of population growth, a decrease in death rate is correlated to an initial increase in per capita wealth. If the economic wealth per capita continues to increase, families may choose to have smaller families and thus decrease the birth rate. Note that the structure of this model makes it clear that we are assuming that increased per capita wealth will have some impact on the birth and death rate.

Analysis: This model contains two simple models that are connected through the "per capita wealth" convertor. Economic growth will increase the per capita wealth and increases in population will decrease the per capita wealth. This model illustrates that if the economy grows more slowly than the population, it may result in higher per capita wealth and then in a decreased birth rate. This may lead to a slowing of the birth rate to allow a steady state population. However, if the economy grows just enough to decrease the death rate but the per capita wealth doesn't increase after that point, the population will continue to grow exponentially. This relationship between population and economic conditions is the basis for studying demographic transitions that occur. In Northern Europe, the United States and Japan, for example, the industrialization

and economic growth has led to what is called the classical demographic transition. We will revisit the systems description of demographic transitions when we study how different worldviews treat the risks of population growth and forecasts for economic growth (Chapter 11). The systems analysis of this problem can be combined with other frameworks to provide further help in describing and making decisions.

Example 2: Global warming and CO₂ in the atmosphere. Global temperatures and the CO₂ in the atmosphere are linked at multiple layers. The “busy” model diagram below shows how several simple models are linked.

August 13, 2013 Figure 6-9. A busy model of atmospheric temperature and the geochemical cycle for carbon. The analysis, below, identifies the simple model parts and the linkages between these sub-models.

Analysis: This model is missing many important stocks and flows. Even with this deficit, it is useful to analyze the structure and potential behavior of the model. The top part of the model shows that the atmosphere could potentially be in steady state for heat energy. The sun energy comes in and the heat is radiated back out. The amount of CO₂ in the atmosphere makes the net efficiency of irradiation back into space less efficient, requiring a slightly higher atmospheric temperature to reach a steady state for the energy (heat) in the atmosphere. This is called the “greenhouse effect”. The bottom part of the model shows two major fates for CO₂ from the atmosphere, either going into ocean or terrestrial biomass. In this version, the Draft v7 143 not only controls that are shown are the increase in respiration rates of the terrestrial and oceanic plants from higher temperature. Notice that the top part of the model is tracking energy and the bottom part of the model is tracking carbon. There are no flows between these two halves, only an information connection and converter. The linkage of these two sub-models leads to a potentially very important behavior, run-away positive feedback of the temperature. The scenario for that outcome is as follows:

1. the atmospheric temperature increases,
2. which increases respiration from terrestrial and aquatic biota,
3. which leads a higher steady state of CO₂ in the atmosphere
4. which, in turn, leads to higher temperature
5. and it continues

These two examples illustrate how the systems view is valuable. Example 1 shows how to take a simple model and combine it with another simple model to study the potential interactions between processes. Example 2 shows how to dissect a model into the simple sub-models, analyze them and then put these all back together to study the overall behavior and look for potential problems.

6.5 Starting Steps

1. Identify what material or energy is being moved.
2. Identify what the reservoirs are and how material or energy moves between these reservoirs, i.e. the flows.
3. Draw a boundary around the system you are studying: what stocks and flows are you quantifying and what is outside. If there are flows in or out of your target system, then these must be represented by sources or sinks, respectively.
4. Create a diagram that shows the major reservoir stocks, flows, sources and sinks using the iconography supplied above.
5. Are there any conditions (such as temperature) or derived quantities (such as flow per person) that might be controlling a flow? If so, create a converter or constant to represent this relationship.
6. Make linkages from stocks to flow-regulators, from one flow to another flow, and from converters to flows.

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7. Check the diagram to see that all flows represent movement per unit time of whatever is in the stocks.
8. Examine the diagram for the regulatory components within a flow such as feedback inhibition (negative feedback), feedback acceleration (positive feedback), stock-limited flow.

9. Examine the diagram for relationships between the flow of different material or energy (such as use of natural capital vs. the rate of population growth).

6.6 Overlaps and conflicts with other tools

Term in "Systems";
 another viewer/term similarities and differences
 boundary scale/extent
 Everything outside the boundary of the system is neither neglected or is an unlimited source or sink. In the Scale viewer, extent relates to the size of the largest dimension considered, the word doesn't imply any process nor specific border.

stock network/node A stock must be something measurable that can be moved through a flow. In the network view, a node can be a quality that changes depending on input links. A flow network/link A flow must be the movement of material or energy per unit time and whatever is flowing has to be the same as the stock at neither end. A link identifies a relationship between nodes. It can be a quantity of material moved but it doesn't have to be a quantity.

stability network/stability, resilience and resistance
 Systems models can reach steady state that has some stability due to some form of negative feedback that keeps it at a level or in some range. The type of systems model that we are using doesn't have a mechanism to change its own structure. A network diagram that has many weak interactions can shift the operational structure and show how a large number of weak interactions or the combination of fast and slow processes can lead to the resilience or loss of resilience of the network.

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6.7 Extending analysis to the next levels

An important extension of the use of systems models is to create simulations that demonstrate overall system behavior given certain input conditions and constants. We will look at the components of the system, such as positive or negative feedback to look for very general system behavior. There are software applications that are useful for turning these systems diagrams into mathematical dynamic models (the diagrams and charts in this page were generated with STELLA from High Performance Systems, <http://www.hps-inc.com>). See the appendices for this book to see simulations that were written in STELLA and simulations made available on the web (through Forio.com). In these simulations not only the parameter values can be changed, not the structure of the model itself. But these simulations are very useful for illustrating the types of predictions and uses for simulations. Simulations of this type are extremely useful in modern decision-making. For example, the Northwest Power Council created a complicated and very busy model that contained information on fish, dams, river flows and electricity. This model could be run under different conditions and demands for energy to show which parameters affect fish survival most. They were able to show the model to people who work in this arena of fish and rivers to see if the model behaves in a way they think it should; does it show low fish years when expected or high fish years following particular events? The simulation model and the accessible interface were powerful tools in addressing problems and getting people to learn about complicated social, economic and ecological issues.

6.8 Developing a simplified Systems model of sustainable resource use

Many people subscribe to the idea that a sustainable resource is one in which you reach a steady state because you don't use the resource faster than it is being created. Whether or not this is required for all resources to attain a sustainable society is a very interesting question. It maybe that you can have some resources decrease and be replaced by other resources. There are different definitions of

overall sustainability that address whether the entire \nensemble of capital types has to be stable or whether substitutions \ncan be made. \n\nWe will focus here on the sustainable use of a single resource. For \nexample, you would harvest the wood at the same rate as new trees \nwere growing to replace what you took. \n\n \n \nFigure 6-10. The starting assumptions for a model of sustainable natural \nresources are that input comes from growth and output goes to harvest. There \nare no other inputs or fates being considered. \n\n \n\nIf this resource is based in natural (biological) capital the growth \nrate will often depend on the amount of the stock. For example \nhealthy fish populations grow faster with more fish and trees will \ngrow better in a healthy forest with lots of other trees to provide \nprotection and a suitable micro-climate. Although it isn't always \nthe case, let's model the natural resource as having a positive \nrelationship to the growth of new resource. \n\n\n\n148 August 13, 2013 \n\n \n\n \nFigure 6-11. In a simple sustainable harvest model, the natural resource has a \npositive feedback on the growth of that resource. This holds within the region of \nhealthy, and not over-abundant resource. \n\n \n\nWhen we harvest the resource, we might just be removing the fish \nor trees, but we can also be degrading the environment that the fish \nor trees need to grow. For example, driving bulldozers around on \nthe soil and channelizing streams in steep watersheds has a \nnegative effect on forest health. Similarly, some fishing methods \ndisrupt the breeding areas for fish. Thus the harvest has a direct \ntake of the resource but it can also degrade the conditions leading \nto a decrease in the growth rate. Notice in this case that a negative \neffect on conditions is passed through to impact growth because \nthere is a positive relationship between conditions and growth: \nworse conditions lead to lower growth. \n\n \n\n\n\nDraft v7 149 \n\n \n\n \nFigure 6-12. The mechanisms of harvest can have a negative effect on the \nconditions for growth. Overharvest can damage the microenvironment necessary \nfor optimal growth. \n\n \n\nAnother important issue with natural resource management is the \nimpact of bad (or good) luck. What if you were managing a forest \nthat had an average growth rate but there was a single drought year \nthat decreased the input to the resource by 50% just for that year? \nIf you had a harvest plan that was even just 5% more than the \nactual maximum yield you could harvest, it would lead to a \ndecrease in the population that would never recover (assuming you \ndon't stop harvesting after you see the population start to crash). \n\n \n\n \n\n \nFigure 6-13. Conditions might also vary with time, such as a year of drought or \nunhealthy water. \n\n \n\n\n\n150 August 13, 2013 \n\n \n\n\nThe effect of one bad year (only 50% output) and an underestimate \nof true maximum yield by only 5%. In 100 years you're down to \nless than 1/3 of your starting natural capital. \n\n \n\n \nFigure 6-14. With just one bad year, holding to the previous \nmaximum sustainable yield will eventually cause the collapse of this resource. \n\n \n\n\nUsing this simple model of natural capital and sustainability \nillustrates that there are at least three ways to destroy the \nsustainability of your natural capital \na. simple overharvest, but this may be because you didn't \nhave good estimates for the maximum yield \nb. indirect effects from either harvest methods or use \nc. risk of being too close to the maximum yield, one bad \nyear and the resource declines dramatically \n\n \n\n6.9 Case Study: Population and Environment of \nEaster Island, Rapa Nui \n\n\n\n\nDraft v7 151 \n\n \n\n \nEaster Island (also known as Rapa Nui) is a small island in the \nmiddle of a very large ocean. The area of the island is only 166 \nkm² (64 mi²) and it is 2250 km from the nearest other island \n(Pitcairn Island) and over 3700 km from South America, the \nnearest continent. You have undoubtedly heard something about \nthis fascinating

island related to speculations on what caused the population to crash. In fact, you've probably heard more about this island because of this failure to be sustainable than you've heard about any of the myriad of other islands in the South Pacific. At one time in the history of this island, the society had fairly sophisticated culture and technology. The cultural history describes a well-developed hierarchy with laws and written script. The evidence of the technology was their ability to move the large stone statues, which the island is most known for, for long distances. They moved carved stone sculptures that weighed up to 82 tons as far as six miles (10 km). The islanders cultivated a large part of the island with multiple crops. Estimates of the maximum population on the island ranged from 7,000 to as high as 20,000. And yet the population and civilization must have crashed. When European boats first recorded their interaction with the island (in the 1700s) the population was only several thousand, and these people were leading a tough life in an impoverished and desolate environment. You can see from just the outlines of this story why the island's history has always been so intriguing. Now with our interest in sustainable systems, it is important to attempt an understanding. There are parallels between their tiny island and our planet. Once the environment started to decay and subsequent crash of population and society, these islanders had no place to go. Sustainability isn't just about maintaining a mere subsistence life style, it's also about continuing to develop the culture and have a healthy physical existence.

In this case study, we are going to examine the population, agriculture and land use practices that were employed on Easter Island from about 400 AD to about 1700 AD. We are going to analyze the very gradual depletion of the natural capital on Easter Island using a "systems" approach.

References to studies of the fate of Easter Island

A more complete story can be found at the following sources:

Wikipedia: http://en.wikipedia.org/wiki/Easter_Island

Discover Magazine: Jared Diamond. Easter's end. Discover magazine, August 1995. 16(8): 62-69.

TED talks such as:

http://www.ted.com/talks/lang/eng/jared_diamond_on_why_societies_collapse.html

http://blog.ted.com/2008/10/27/why_do_societies_collapse/

Diamond, J. (2005). Collapse: How societies choose to fail or succeed. New York, Viking.

Salient features

The story of Easter Island has particular features that make it amenable to examination with a systems approach. First, it is very similar to the systems model for sustainability that we developed in Figure 12 and 13; there are suggestions of growth, harvest, and bad luck. Second, at any time the processes seem to be close to being in balance; it is only by looking at the long term effect of these do we see the impact of a slight over harvest or a previous year of bad luck. Third, the description contains some simple models that could be tied together to get an integrated picture; there is population growth, harvest of trees, soil moisture, agriculture and fishing. These processes are related, but not directly.

Applying the systems tool

We are going to put separate small models together and to examine how these individual processes counter or reinforce each other. This is an oversimplified model in which will only consider three stocks: the number of people, palm trees, and rats.

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The number of people is the balance between birth and death rates. As there are more people, there will be more births, i.e. the population growth has a positive feedback component. The number of deaths may depend on many other factors including natural causes, famine, and disease. A simple model diagram for this is given

below.

Figure 6-15. Human population sub-model showing positive feedback for births but a constant death rate.

The number of trees is also a balance between the number of palm nuts that germinate and grow, and the cutting down of the trees.

Figure 6-16. Palm tree sub-model also have positive feedback for growth and constant loss.

The third strand in our model will be the rat population. People brought rodents to the island. These rats play a key role in this problem. People eat the rats and the rats eat the palm fruit, decreasing the tree population. Their population is just like the

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nothers, there is positive feedback for rat births and several factors controlling death.

Now we are going to connect these three stocks and flows models with factors that affect either the birth or death rates. The following list details these interactions.

1. Rats have a positive effect on people births because this is a source of food for people. The birth rate of people will increase with more rats (and the birth rate will decrease if rats are low).
2. Rats have a negative effect on human death. The death rate of people will increase if rats are too low.
3. People have a positive effect on the harvesting of trees. More people cut down more trees because they need them for fishing and to cultivate land for crops.
4. Rats have a negative effect on the rate of palm fruit germination. The number of rats decreases the percentage of new palm seeds that germinate successfully because the rats chew on the seeds.
5. Palm trees have a positive effect on rat births, because the rats eat the palm fruit.

We could add more detail to this model, but even with only these five interactions this turns out to be a very interesting and instructive model. Looking at the model diagram, below, you can see that there are many positive feedbacks and only a few negative feedbacks.

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Figure 6-17. The rat submodel interacts with both humans and trees.

According to the historical record, as the human population grew, people cut more and more trees. They needed these trees for making boats for fishing and they needed more and more land for cultivation. Over harvesting trees, just on its own would have been a problem for them, but this was exacerbated by the fact that they also ate rats, and rats depended on the trees for food. As the human population continued to grow, they cut enough trees such that they ran out of trees to use for fishing. Simultaneously, with fewer trees they not only couldn't fish effectively but the other food source, rats, declined.

The model built here only represents a few of the interactions that have been described. By putting these into a systems diagram, we can explore the possible behaviors of the individual populations and their effect on each other. It is possible that the population

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could have also reached a balance. There is nothing inherent in the structure of these relationships that makes it crash. However, the balance comes about because all of the relatively rapid rates of all the processes are cancelling each other out, but a minor imbalance in the rates can lead to abrupt changes in the whole system.

Some narratives of Easter Island decline blame the population for their resource use strategies. For example in the book *Collapse* (2005), Jared Diamond wonders what the person who cut down the last palm tree was thinking. Even this simple model shows that there were multiple factors in play and the path toward a downward spiral of trees could have been set in motion when there were still many trees. This should be a cautionary tale for working with real and complex systems, i.e. the controls may have delays and multiple factors that make them very difficult for a person in the ecosystem and society to observe. It's not just a matter

of \taking the right action for the moment, but also being able to \understand the more complex interactions and consequences of our \nactions. \n \n6.10 Summary \nMethodically constructing a stock and flow model to represent the \nprocesses related to an environmental problem supports good \npractice for scientific information gathering. The constraints on \nthe quantities that are being measured and followed forces the \nclarification of assumptions. The structure of the model can be \nvisualized with iconography that illuminates the relationship to \nparticular functions of the overall system such as feedbacks, stock \nlimitation and possible steady state conditions. The basic \nassumptions for using a natural resource sustainably can be \nexplored using this approach. The goal of sustainable use would be \nto have the input match the output and maintain a steady state for \nthe resource. Positive feedback works to replenish the stock, but \nthis is a double-edged sword, just one bad year can lead to an \neventual collapse unless the harvest is decreased. \n\n\n\nDraft v7 157 \n\n\n\nAnalysis of these models involves taking apart each stock and flow \nand explaining how that part contributes to the overall behavior of \nthe system. This is a very useful exercise for construction of the \nmodel and for communication about the important features of a \nproblem. \n\n\nAs models become busier they often require sub-models for \ndifferent stocks. The example of Easter Island demonstrated \nhypothetical relationships between the stocks of palm trees, people \nand rats. At high human populations, this system was not resilient \nto changes and might explain the decline of the resource base. \n\n\n\n\n\n\n\n", "title": "v7-Rueter-chap6.pdf", "tether_id": null}, {"status": "finished_successfully", "end_turn": null, "weight": 1.0, "metadata": {"command": "context_stuff", "is_visually_hidden_from_conversation": true, "message_type": null, "model_slug": "gpt-4", "default_model_slug": "gpt-4", "parent_id": "aaa25015-a0ab-49c9-ba5c-d2598e6677ba", "request_id": "8887337d3b45ba8c-MXP", "timestamp_": "absolute"}, {"recipient": "all", "channel": null}, {"parent": "aaa25015-a0ab-49c9-ba5c-d2598e6677ba", "children": ["dca4e3a9-fca3-4cb0-ala9-958ae7029719"]}, {"dca4e3a9-fca3-4cb0-ala9-958ae7029719": {"id": "dca4e3a9-fca3-4cb0-ala9-958ae7029719", "message": {"id": "dca4e3a9-fca3-4cb0-ala9-958ae7029719", "author": {"role": "tool", "name": "myfiles_browser", "metadata": {}}, "create_time": 1716489951.129264, "update_time": null, "content": {"content_type": "tether_quote", "url": "file-OSCiwnUNB1KgoGkmeri5ylKX", "domain": "tactiq-free-transcript-QBrmAGcMIi8.txt", "text": "# tactiq.io free youtube transcript\n# Why System Dynamics Should Become Part of Secondary School Math Instruction\n\nhttps://www.youtube.com/watch/QBrmAGcMIi8\n\n00:00:00.719 hello my name is diana fisher\n00:00:03.040 i have been asked to present to on the\n00:00:05.839 system dynamics work\n00:00:07.200 i have done with secondary school\n00:00:08.880 students and teachers over three decades\n00:00:11.599 i have used system dynamics modeling in\n00:00:13.920 my mathematics and modeling instruction\n00:00:16.000 for 30 years\n00:00:17.520 although science instruction is the most\n00:00:19.680 natural discipline for sd modeling i\n00:00:22.080 would like to make\n00:00:23.199 an argument that if we really want sd\n00:00:25.840 modeling to become\n00:00:26.960 a more mainstream analytical tool it\n00:00:30.240 should be embedded in secondary school\n00:00:32.640 mathematics\n00:00:33.840 sd modeling can reinforce important\n00:00:37.120 mathematical concepts quite well dr\n00:00:40.320 barry m specializes in the study of\n00:00:42.399 complex systems\n00:00:43.760 to be able to analyze complex systems\n00:00:46.879 he claims that calculus and statistics\n00:00:49.120 do not have the tools to describe\n00:00:51.680 what we want

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to study that we need\n00:00:55.360 to work with new concepts that we
 need\n00:00:58.960 to\n00:00:59.359 ask different questions about system\n00:01:02.000
 dynamic behavior\n00:01:03.920 he says working with complex systems\n00:01:06.799
 changes how we think\n00:01:08.560 we have an opportunity to help our\n00:01:10.479
 mathematics students broaden their\n00:01:12.400 thinking\n00:01:13.280 to encompass
 techniques that will help\n00:01:15.520 them think about\n00:01:16.479 complex dynamic
 problems one way to\n00:01:19.600 start\n00:01:20.240 is improving their understanding
 of\n00:01:22.080 functions studies in the united states\n00:01:25.200 indicate that
 students possess weak\n00:01:27.280 understanding of functions\n00:01:29.280 over the
 last several decades\n00:01:32.960 mathematics instruction in the u.s\n00:01:35.520
 evolved to require\n00:01:37.040 multiple representation of function\n00:01:39.439
 behavior\n00:01:40.320 including graphs and tables but now\n00:01:42.640 research
 indicates that mapping diagrams\n00:01:45.280 also provide a rich foundation
 for\n00:01:48.240 understanding functions\n00:01:50.799 the late dr james kapit
 proposed\n00:01:54.520 democratizing the comp concepts of\n00:01:57.280
 calculus\n00:01:58.399 by providing technology-based learning\n00:02:01.280
 environments\n00:02:02.479 he said new notation systems with new\n00:02:05.680 ways
 of\n00:02:06.479 acting upon those new notation systems\n00:02:09.840 offer
 dramatically new possibilities for\n00:02:12.480 mathematics learning\n00:02:14.319 sd
 is such a new and powerful\n00:02:18.080 notation system the audience
 recognizes\n00:02:21.120 these system dynamics modeling icons\n00:02:23.440 from which
 sd models can be constructed\n00:02:26.400 the stock\n00:02:27.280 and accumulator
 represents a main\n00:02:29.599 function in the model\n00:02:31.200 mathematically it
 operates as an\n00:02:33.519 integral does in calculus the flow\n00:02:36.800 is the
 rate of change of the stock so it\n00:02:39.200 is essentially the first
 derivative\n00:02:41.120 described in calculus\n00:02:43.280 converters hold constants
 parameters or\n00:02:46.080 simple\n00:02:46.560 or arithmetic combinations of
 model\n00:02:49.040 components\n00:02:50.319 the connector indicates the influence
 of\n00:02:52.959 one\n00:02:53.360 model component on another\n00:02:55.400
 mathematically\n00:02:56.800 the connectors identify the dependencies\n00:02:59.599 of
 one variable\n00:03:00.879 variable on another i will not take you\n00:03:04.319
 quickly through the two\n00:03:05.599 most basic functions studied in
 algebra\n00:03:08.800 connecting sd and traditional\n00:03:10.720
 mathematics\n00:03:11.840 representation suppose we were\n00:03:14.080 interested in
 how\n00:03:15.040 water in a lake is increasing based on\n00:03:17.440 water flowing
 in\n00:03:18.560 at a constant rate using the sd\n00:03:21.760 structure the
 initial\n00:03:25.280 water in the lake would be placed in a\n00:03:27.840 stock
 icon\n00:03:29.200 and it would only have an\n00:03:32.239 inflow since it is only
 increasing\n00:03:35.599 with a constant value in the flow we\n00:03:38.799 know the
 behavior of the stock\n00:03:40.640 is growing linearly since the rate
 of\n00:03:42.799 change is constant\n00:03:44.319 and positive the sd\n00:03:47.360
 software calculates the value of the\n00:03:49.360 stock using recursion which is
 shown in\n00:03:52.000 the table at the left\n00:03:53.599 we see that the flow value
 is added to\n00:03:56.239 the current value of the stock\n00:03:58.080 each time unit
 now we see the\n00:04:00.640 traditional closed form equation for the\n00:04:02.720
 linear function where w\n00:04:04.560 represents the amount of water in
 the\n00:04:07.439 lake\n00:04:08.400 it starts at 100 units and grows at
 five\n00:04:11.439 units per year\n00:04:13.040 if we were to construct what we know
 is\n00:04:16.000 an exponential population growth\n00:04:18.320 behavior\n00:04:19.358

we could start with a stock of elephants\n00:04:21.680 and an inflow of new
 elephants\n00:04:23.600 born to this herd each year but this\n00:04:26.479 model is
 not correct\n00:04:28.320 we know the inflow cannot be constant\n00:04:30.880 because
 the number of new elephants born\n00:04:32.960 per year depends on knowing how
 many\n00:04:34.960 elephants are currently\n00:04:36.400 in the herd so we now
 indicate that\n00:04:39.680 dependency with a connector\n00:04:42.560 oh and now we
 have introduced a feedback\n00:04:45.680 loop\n00:04:46.400 the loop is reinforcing
 because the more\n00:04:49.280 elephants in the population\n00:04:51.280 the more new
 elephants are born per year\n00:04:54.080 adding more elephants to the
 herd\n00:04:56.639 but this model is still not complete we\n00:04:59.759
 should\n00:05:00.320 indicate the number of new elephants\n00:05:02.479 born
 per\n00:05:03.759 elephant in the herd each year\n00:05:06.880 we do that by
 indicating a birth\n00:05:09.600 fraction\n00:05:10.240 in decimal form that will be
 multiplied\n00:05:13.199 by the number of elements\n00:05:14.639 in the herd each year
 so for exponential\n00:05:17.919 growth the inflow is proportional to
 the\n00:05:20.479 current amount of the stock\n00:05:22.880 or mathematically the rate
 of change the\n00:05:25.759 flow\n00:05:26.560 is defined as the stock value times
 some\n00:05:29.840 growth factor value this is exactly the\n00:05:33.199 differential
 equation\n00:05:34.880 that represents exponential growth but\n00:05:37.039 algebra
 students\n00:05:38.000 don't need to know that they are\n00:05:39.759 learning
 calculus\n00:05:41.280 they are just learning a different\n00:05:42.880 behavior
 pattern over time\n00:05:44.960 and how to create it based on its rate\n00:05:47.520
 of change definition\n00:05:49.840 again quickly we would have our stock\n00:05:52.479
 flow definition as shown\n00:05:54.160 with a 20 growth fraction the
 elephant\n00:05:57.440 population will grow\n00:05:58.800 exponentially because the
 inflow is\n00:06:01.039 proportional to the stock value\n00:06:03.360 if we think
 about what the sd software\n00:06:05.680 is doing\n00:06:06.560 we look at the
 recursion in the table\n00:06:09.280 the flow\n00:06:10.240 calculates the growth
 amount and adds it\n00:06:13.360 to the stock\n00:06:14.639 each year there are two
 equations that\n00:06:17.919 are possible\n00:06:18.960 mathematically the easier
 equation is\n00:06:21.840 represented at the top\n00:06:23.520 and is the one often
 taught in first\n00:06:26.080 year algebra\n00:06:27.280 it is often used when we want
 to\n00:06:29.440 calculate values\n00:06:30.720 once every year or time
 unit\n00:06:33.759 the second is shown at the bottom and is\n00:06:37.280 often used
 in situations where\n00:06:40.000 calculating continuous change\n00:06:41.919 is a
 better choice the top equation is\n00:06:44.720 probably the best choice for
 this\n00:06:46.479 particular elephant herd example\n00:06:49.120 in sd modeling we
 use the same diagram\n00:06:52.240 for each scenario and merely increase\n00:06:54.800
 the number of times the simulation\n00:06:56.960 calculates the values each
 time\n00:06:59.120 unit to differentiate which\n00:07:02.400 situation is being used
 for calculation\n00:07:05.599 as a it is a much more intuitive process\n00:07:09.360
 in my opinion just so you know\n00:07:13.120 there is a free web-based version of
 the\n00:07:15.360 sd modeling software that works on\n00:07:17.680 tablets computers
 laptops chromebooks\n00:07:20.080 and smartphone\n00:07:21.440 that will allow you to
 have your\n00:07:23.759 students build these models\n00:07:25.759 if they have access
 to this technology\n00:07:28.639 go to publish.icsysystems.com\n00:07:31.840 the
 software is called stella online\n00:07:36.160 once students learn linear
 and\n00:07:38.479 exponential model structures they can\n00:07:40.560 start putting
 them together to study new\n00:07:42.720 problems\n00:07:43.680 they could not study

with equations\n00:07:46.720 i have used these medication models in\n00:07:49.199 my algebra classes over\n00:07:51.199 many years students really like them\n00:07:54.639 consider an emergency room problem you\n00:07:57.759 the student are a medical resident\n00:08:00.240 working in the emergency room\n00:08:02.160 and a patient comes in who needs\n00:08:04.000 immediate medical tension\n00:08:06.160 from your analysis you decide to connect\n00:08:08.560 this patient to an iv drip that will\n00:08:10.800 supply\n00:08:11.440 one milligram of therapeutic drug per\n00:08:14.560 minute\n00:08:15.199 this person you estimate will metabolize\n00:08:17.680 the drug\n00:08:18.639 at about 0.55 percent per minute\n00:08:22.639 what is the pattern of the drug level in\n00:08:24.879 the body over 24 hours\n00:08:27.599 so the diagram might look like this with\n00:08:30.000 an inflow of medicine and an\n00:08:31.680 outflow of body using and\n00:08:34.799 eliminating the medicine observe the\n00:08:37.679 left\n00:08:38.000 side of the diagram since there is a\n00:08:40.000 constant inflow the left part of the\n00:08:41.839 diagram is similar to\n00:08:43.599 a linear model structure observe the\n00:08:47.120 right part of the diagram\n00:08:48.640 the structure is similar to an\n00:08:50.399 exponential decay\n00:08:51.760 the drug is lost as a percent of the\n00:08:54.399 current amount of drug in the patient's\n00:08:56.320 systems\n00:08:57.839 students try to predict the behavior of\n00:09:00.080 the drug\n00:09:00.959 in the body over time giving a reason\n00:09:03.440 for their predictions\n00:09:05.040 then they build the model and see what\n00:09:07.360 the computer produces\n00:09:09.360 then they have to explain why the\n00:09:12.080 computer graph\n00:09:13.200 has the shape that it shows\n00:09:16.800 skipping to the skipping the second\n00:09:18.800 medication scenario we will go to the\n00:09:21.200 third drug model\n00:09:22.959 it involves taking medicine in the form\n00:09:25.120 of pills\n00:09:26.640 it has been a busy day in the emergency\n00:09:29.200 room a third\n00:09:30.160 patient arrives and you decide to give\n00:09:32.320 this patient two\n00:09:33.519 pills of 375 milligrams\n00:09:36.959 each of a therapeutic drug and tell them\n00:09:39.680 to continue taking\n00:09:41.360 two more pills every four hours this\n00:09:44.399 person you\n00:09:45.200 estimate will absorb the drug from the\n00:09:47.760 stomach in the bloodstream\n00:09:50.080 at about 4.5\n00:09:53.360 percent per minute and metabolize the\n00:09:56.399 drug\n00:09:57.120 at about point 55 percent per minute\n00:10:00.560 what is the pattern of drug level in the\n00:10:02.640 body over 24 hours\n00:10:05.120 this model uses two stalks because the\n00:10:07.519 medicine\n00:10:08.640 must first accumulate in the stomach and\n00:10:10.880 then move into the bloodstream\n00:10:12.959 the inflow is a pulse because the pills\n00:10:15.839 are taken\n00:10:16.480 once every four hours students are asked\n00:10:19.839 to anticipate the pattern of behavior of\n00:10:22.240 the left\n00:10:23.040 of just the left part of the model drug\n00:10:26.160 in the stomach then students are asked\n00:10:28.800 to anticipate the pattern of drug in the\n00:10:31.120 blood over time\n00:10:32.640 this is not a trivial analysis then\n00:10:35.600 different patterns of pill delivery\n00:10:37.360 protocol\n00:10:38.160 are explored and compared to the optimal\n00:10:41.120 therapeutic level for this\n00:10:42.800 medication finally in this sequence of\n00:10:45.600 medication models\n00:10:47.040 students as a class are asked to help\n00:10:49.760 modify\n00:10:50.959 the pill model so that it will\n00:10:54.399 calculate the blood alcohol\n00:10:56.480 concentration\n00:10:57.760 of a human male sipping beer over two\n00:11:00.720 hours\n00:11:01.839 the modified stock flow diagram is\n00:11:04.560 sketched as a class\n00:11:06.240 then students access the

pre-built model\n00:11:09.760 online and test the following scenarios\n00:11:12.560
 using the model\n00:11:15.040 influence of body weight gender type of\n00:11:17.760
 alcohol and type of drinker\n00:11:20.560 now let's turn to a different
 sequence\n00:11:22.880 of models\n00:11:23.760 the basic population model is
 ubiquitous\n00:11:26.480 in system dynamics studies\n00:11:28.720 problems in health
 economics\n00:11:30.720 environmental science biology geography\n00:11:33.360
 sociology and mathematics and more often\n00:11:36.720 involve the study of population
 dynamics\n00:11:39.839 the basic population model involves a\n00:11:42.880 stock for
 population\n00:11:44.720 since that's the value that we want to\n00:11:46.480
 track over time\n00:11:47.760 it is the function an outflow of births\n00:11:51.200
 and an inflow of births and an outflow\n00:11:54.399 of deaths\n00:11:55.040 and their
 attendant births and deaths\n00:11:57.440 fraction\n00:11:58.800 the basic model
 contains two feedback\n00:12:01.120 loops that control\n00:12:02.480 change in
 population dynamics over time\n00:12:06.480 there are three types of graphs
 that\n00:12:08.959 this structure could\n00:12:10.000 produce based upon which
 feedback is\n00:12:12.959 dominant\n00:12:14.160 assume that the birth fraction is
 larger\n00:12:16.160 than the death fraction\n00:12:17.360 the model could produce
 exponential\n00:12:19.360 growth but the deer population cannot\n00:12:21.839 grow
 forever\n00:12:22.720 there are limiting factors that would\n00:12:24.480 influence
 the growth\n00:12:26.000 as the deer population increases there\n00:12:28.320 would be
 more competition for food and\n00:12:30.240 water\n00:12:31.200 deer could become more
 aggressive as\n00:12:33.279 they vie for\n00:12:34.320 the limited resource
 overcrowding can\n00:12:37.360 also lead to aggression\n00:12:39.120 and to the spread
 of disease as waste\n00:12:41.760 builds up in a limited area\n00:12:43.760 each of
 these factors would lead to a\n00:12:46.079 higher death rate for the
 deer\n00:12:48.320 assume that the environment can support\n00:12:51.360 only a
 specific number of deer the\n00:12:54.399 number of deer the environment
 can\n00:12:56.639 support in any given location is called\n00:13:00.079 the carrying
 capacity we assume that the\n00:13:03.200 comparison\n00:13:03.920 comparison the
 carrying capacity value\n00:13:07.279 is unchanging\n00:13:09.040 as the population
 grows toward the\n00:13:12.480 carrying capacity\n00:13:14.320 the death fraction is
 being increased\n00:13:18.079 as we think it should the deer\n00:13:21.120 population
 graph looks reasonable with\n00:13:23.360 the carrying capacity
 component\n00:13:25.440 at the beginning there are few deer\n00:13:28.480 and the
 population is growing quite a\n00:13:30.560 bit as the population gets closer to
 the\n00:13:33.200 carrying capacity the growth slows down\n00:13:35.760
 eventually\n00:13:36.639 moving to steady state this demonstrates\n00:13:40.800
 transfer of feedback loop dominance\n00:13:44.240 now look at the typical closed
 form\n00:13:46.399 equation for the same scenario\n00:13:48.800 it seems to me that
 the stock flow model\n00:13:51.519 is easier to understand and\n00:13:53.279 interpret
 making this scenario\n00:13:55.440 approachable by students in
 mathematics\n00:13:57.839 classes\n00:13:58.399 lower than precalculus where
 the\n00:14:00.639 equation is usually studied\n00:14:02.800 i have used this model in
 my algebra\n00:14:05.040 classes successfully\n00:14:06.560 with students as young as
 15.\n00:14:10.480 so now we get to the meat of this\n00:14:12.880
 presentation\n00:14:14.399 what overarching value does sd modeling\n00:14:17.760
 approach\n00:14:18.399 add to mathematics instruction a new\n00:14:21.279
 representation for some core functions\n00:14:23.839 studied in algebra and
 precalculus\n00:14:26.480 provides not only a different\n00:14:27.920 representation

that is more visual\n00:14:30.480 for the functions but bases the new\n00:14:32.800 representation\n00:14:34.160 on the rates of change for each function\n00:14:37.199 a very important concept in calculus\n00:14:40.399 the structure the blueprint for each\n00:14:42.800 function helps describe\n00:14:44.480 why the function behavior makes sense\n00:14:47.360 that is\n00:14:48.240 constant flows create linear stock\n00:14:51.199 behavior\n00:14:52.399 proportional flows create\n00:14:54.800 exponential stock behavior\n00:14:56.639 etc each system dynamics icon\n00:15:00.079 uses full words or phrases in their\n00:15:03.040 names\n00:15:03.519 making it easier to remember what each\n00:15:05.920 part of the model represents\n00:15:08.000 and it has been my experience with\n00:15:10.320 students\n00:15:11.120 that they have a much easier time\n00:15:13.440 translating word problems that describe\n00:15:15.920 dynamics to the sd model structure\n00:15:20.160 take for example the representation for\n00:15:22.399 an oscillating spring behavior\n00:15:24.639 the stock flow diagram captures the\n00:15:27.360 concepts of position\n00:15:28.959 restoring force mass acceleration\n00:15:31.360 velocity etc\n00:15:33.040 all central concepts in the dynamic of a\n00:15:35.680 bouncing spring\n00:15:37.199 the closed form equation merely\n00:15:40.720 captures the appearance of the\n00:15:42.800 oscillation\n00:15:44.320 not the core structure that is causing\n00:15:46.800 the behavior to occur\n00:15:48.800 i believe that the stock flow structure\n00:15:50.880 is more educationally\n00:15:52.560 valuable than the closed form equation\n00:15:56.320 students and many adults are notoriously\n00:15:59.199 poor\n00:15:59.680 at reading and interpreting graphs sd\n00:16:02.800 modeling\n00:16:03.600 has one of its main analytical\n00:16:06.160 techniques\n00:16:07.199 to interpret the graphical output of the\n00:16:09.600 models\n00:16:10.560 multiple times as models are built\n00:16:13.279 modified\n00:16:14.079 and tested students get lots of practice\n00:16:17.839 reading and interpreting graphs moreover\n00:16:21.040 students are often required to view flow\n00:16:23.759 graphs\n00:16:24.399 on the same grid as stock graphs to help\n00:16:27.839 explain stock behavior this\n00:16:30.399 correlational\n00:16:31.360 graphical analysis is a core concept in\n00:16:34.639 calculus\n00:16:35.360 and very important for understanding\n00:16:37.600 dynamic phenomenon\n00:16:39.839 creating the stock flow diagram lays\n00:16:43.040 bare the student's mental model the\n00:16:46.160 student can\n00:16:46.959 test his or her mental model to\n00:16:49.279 determine\n00:16:50.320 if the structure produces reasonable\n00:16:52.560 results\n00:16:53.600 then if it does not the student knows he\n00:16:56.000 or she must\n00:16:57.040 modify the model structure via more\n00:16:59.839 research that often includes\n00:17:01.680 communicating with other team members\n00:17:04.319 to improve the model and obtain\n00:17:06.720 reasonable results\n00:17:08.640 as you have seen building useful and\n00:17:11.199 interesting models\n00:17:12.720 using sd modeling can allow students to\n00:17:16.319 build\n00:17:16.720 problems that would be out of their\n00:17:18.559 reach using only closed form equations\n00:17:21.839 this makes a much larger pool of\n00:17:24.880 interesting problems for students to\n00:17:26.799 study\n00:17:27.599 and makes connecting mathematics with\n00:17:30.320 real\n00:17:30.840 world more obvious\n00:17:33.840 another factor that is outside current\n00:17:36.320 mathematics instruction at the secondary\n00:17:38.320 school level\n00:17:39.039 is the importance of non-linear system\n00:17:41.919 behavior\n00:17:42.720 which is necessary to produce transfer\n00:17:45.440 of feedback loop dominance\n00:17:48.160 and of course the inclusion of delays\n00:17:50.880 the model\n00:17:51.679 on the

left has been built and analyzed by non-honors algebra students and the delays represented on the right both material at the top and information delays at the bottom could be understood by algebra students this slide identifies two websites with resources that you may find useful the first is a website that contains some free sd lessons for use with secondary school students as well as where to purchase some books of sd lessons that are published it also contains examples of secondary school students original sd model diagrams and technical papers explaining the models it advertises online sd courses geared to secondary school math and science teachers and shows the alignment of sd with u.s national educational standards in many disciplines the other website contains additional lessons that can be downloaded or purchased and numerous lesson books appropriate for pre-college students the experience that greatly enhanced my opinion about the virtues of using the system dynamics modeling approach with students occurred when i saw what students could produce when given the freedom to choose a dynamic problem that interested them for which they could create an original model write a technical paper explaining their model and present their model to an audience i wanted to prepare students to identify and analyze problems in the world from which they could gain an understanding by building system dynamics models i wanted them to develop skill in model building in analyzing model design in output and feedback and in explaining what they learned so i designed a secondary school system dynamics modeling course that i taught for 20 years one of the most important lessons i included in my sd modeling course was to show students how to translate a systems problem found in a news article into a stock flow diagram students listed the most important variables they built the structure of their model by hand and they also sketched out the feedback students indicated that this was one of the most important lessons in preparing them to do their final project i'm going to magnify this bottom part so you can see it a little bit better i know it's blurry but it's because i just used the previous picture to magnify it but you can see the design of their model structure you can see their feedback loop they're doing behavior over time graphs all of this was part of the lesson for analyzing an article in the news i'm now going to show you some sample student original sd models in 2007 when the united states was experiencing an oil crisis this student observed that many people were trying unsuccessfully to buy hybrid cars this was his idea of why the problem happened

it actually is\n00:21:08.000 broken into three segments\n00:21:10.559 there is the hybrid car segment at the\n00:21:13.440 top\n00:21:14.400 i'll go back hybrid car production\n00:21:18.880 hybrid inventory and active\n00:21:21.919 hybrid in vehicles\n00:21:25.360 there is a factory capacity which was a\n00:21:28.799 limiting factor on being able to produce\n00:21:31.200 enough cars\n00:21:32.400 and then there was a backlog of orders\n00:21:35.039 and perceived backlogged\n00:21:37.039 that prospective buyers weren't going to\n00:21:39.919 get\n00:21:40.559 a car very soon even if they ordered one\n00:21:44.000 his model did not start an equilibrium\n00:21:46.400 unfortunately\n00:21:47.679 so let's ignore the first part of the\n00:21:49.440 graph and and focus on the spike in oil\n00:21:52.640 prices\n00:21:53.520 at week 30. the new demand which is the\n00:21:56.720 pink\n00:21:57.440 curve spikes upward for hybrid cars\n00:22:01.760 that is quickly followed by a spike in\n00:22:04.159 the backlog demand for hybrid cars which\n00:22:06.640 is the brown graph\n00:22:08.400 the price of hybrid cars which is the\n00:22:10.880 green curve shows an\n00:22:12.480 increase as backlog increases the blue\n00:22:15.520 line\n00:22:16.080 which is on a scale by itself is the\n00:22:18.480 number of active hybrid cars\n00:22:20.720 and that is steadily increasing\n00:22:24.000 the first year i introduced material and\n00:22:26.400 information delays to my students\n00:22:28.559 many students understood the ideas\n00:22:30.559 immediately\n00:22:32.080 this student started his model on\n00:22:34.320 workforce pressure\n00:22:35.840 using the idea of three delays so\n00:22:38.960 here we have employees\n00:22:42.080 who are being hired and fired this is\n00:22:45.120 the amount of\n00:22:46.159 work that the company wants done\n00:22:50.080 this is the perceived satisfaction of\n00:22:53.200 the current working people\n00:22:55.120 and up here is the pay that is given\n00:22:58.960 to the workers the three\n00:23:02.320 delays here are an information delay\n00:23:06.000 down in the perceived satisfaction\n00:23:09.280 and information delay in hiring and\nThe file is too long and its contents have been truncated.\n", "title": "tactiq-free-transcript-QBrmAGcMIi8.txt", "tether_id": null}, "status": "finished_successfully", "end_turn": null, "weight": 1.0, "metadata": {"command": "context_stuff", "is_visually_hidden_from_conversation": true, "message_type": null, "model_slug": "gpt-4", "default_model_slug": "gpt-4", "parent_id": "c023c1c2-5eb8-400b-ba67-ef143eed9aae", "request_id": "8887337d3b45ba8c-MXP", "timestamp_": "absolute"}, "recipient": "all", "channel": null}, "parent": "c023c1c2-5eb8-400b-ba67-ef143eed9aae", "children": ["74f5fb22-b53f-443e-87cd-56b02ffd89dd"]}, "74f5fb22-b53f-443e-87cd-56b02ffd89dd": {"id": "74f5fb22-b53f-443e-87cd-56b02ffd89dd", "message": {"id": "74f5fb22-b53f-443e-87cd-56b02ffd89dd", "author": {"role": "tool", "name": "myfiles_browser", "metadata": {}}, "create_time": 1716489951.129518, "update_time": null, "content": {"content_type": "text", "parts": ["\nPlease remember to search the user's documents if an answer to their question is not contained in the above snippets.\n"]}, "status": "finished_successfully", "end_turn": null, "weight": 1.0, "metadata": {"is_visually_hidden_from_conversation": true, "message_type": null, "model_slug": "gpt-4", "default_model_slug": "gpt-4", "pad": "AAA", "parent_id": "dca4e3a9-fca3-4cb0-ala9-958ae7029719", "request_id": "8887337d3b45ba8c-MXP", "timestamp_": "absolute"}, "recipient": "all", "channel": null}, "parent": "dca4e3a9-fca3-4cb0-ala9-958ae7029719", "children": ["24c5eb47-felb-4d3b-98dd-80b3f8c770a5"]}, "24c5eb47-felb-4d3b-98dd-80b3f8c770a5": {"id": "24c5eb47-felb-4d3b-98dd-80b3f8c770a5", "message": {"id": "24c5eb47-felb-4d3b-98dd-80b3f8c770a5", "author": {"role": "assistant", "name": null, "metadata": {}}, "create_time": 1716489951.129772,

"update_time": null, "content": {"content_type": "text", "parts": ["Here's a detailed outline, summary, and synthesis of the key ideas and assertions explored in each of the attached documents:\n\n### 1. "Chapter 6 \u2013 Stock and Flow Systems" (PDF Document)\n\n#### Outline:\n- **6.1 Introduction**: Explanation of systems as sets of connected processes. Introduces the systems view for environmental problems.\n- **6.2 Model Components**: Detailed description of five components: stocks, flows, information flows, converters/constants, and sources/sinks.\n- **6.3 Model Structures and Behaviors**: Discussion on simple and complex structures within system models and how to approach their study.\n- **6.4 Simple and Busy Models**: Examples of simple system models and their application in understanding complex systems like global warming and population dynamics.\n- **6.5 Starting Steps**: Steps to begin constructing and analyzing a system model.\n- **6.6 Overlaps and Conflicts with Other Tools**: Comparison of systems approach with other analytical tools.\n- **6.7 Extending Analysis to Next Levels**: How to use systems models for simulations and decision-making.\n- **6.8 Developing a Simplified Systems Model of Sustainable Resource Use**: Using a sustainable resource model to explore resource management.\n- **6.9 Case Study: Population and Environment of Easter Island**: Examination of historical population and environmental decline using a systems model.\n\n#### Key Ideas:\n- Systems are composed of stocks and flows that can represent various environmental and ecological scenarios.\n- Simple system models can represent complex realities and help in understanding underlying processes and feedback loops.\n- Case studies like Easter Island provide insights into sustainability and the impact of human activities on the environment.\n\n### 2. "Systems Thinking for Life Cycle Sustainability Assessment" (PDF Document)\n\n#### Outline:\n- Introduction to systems thinking as a framework for sustainability assessment.\n- Description of life cycle stages and their impacts on sustainability.\n- Exploration of various sustainability models and their application in real-world scenarios.\n- Discussion on the challenges and solutions in applying systems thinking to sustainability.\n\n#### Key Ideas:\n- Systems thinking provides a holistic view of the life cycle impacts of products and services.\n- It helps in identifying leverage points for improving sustainability in different stages of the life cycle.\n- Integrating systems thinking into sustainability assessments can lead to more effective and comprehensive strategies.\n\n### 3. "Why System Dynamics Should Become Part of Secondary School Math Instruction" (Transcript)\n\n#### Outline:\n- Introduction by Diana Fisher on her experience with system dynamics in education.\n- Argument for integrating system dynamics into secondary school mathematics.\n- Examples of system dynamics applied in educational settings, including modeling population dynamics and drug metabolism.\n- Discussion on the benefits of system dynamics in enhancing students' understanding of complex systems and mathematical concepts.\n\n#### Key Ideas:\n- System dynamics enhances mathematical education by providing tools to understand and model dynamic systems.\n- It can be particularly useful in explaining concepts such as feedback loops, exponential growth, and accumulations which are pivotal in many scientific and social studies.\n- The practical application of system dynamics in classroom settings can make abstract mathematical concepts more tangible and relatable to real-world issues.\n\n### Synthesis:\n\nThe documents collectively emphasize the importance of systems thinking and dynamics across different contexts \u2013 from environmental studies and sustainability assessments to educational methodologies. They highlight how understanding the interconnectedness of components within a system can lead to better insights and solutions for complex problems,

whether they are ecological, social, or educational in nature. These insights are crucial in developing a holistic understanding that is necessary for effective decision-making and problem-solving in contemporary challenges."}], "status": "finished_successfully", "end_turn": true, "weight": 1.0, "metadata": {"finish_details": {"type": "stop", "stop_tokens": [100260]}, "citations": [], "gizmo_id": null, "is_complete": true, "message_type": null, "model_slug": "gpt-4", "default_model_slug": "gpt-4", "pad": "AAAAAAAAAAAAAAAA", "parent_id": "74f5fb22-b53f-443e-87cd-56b02ffd89dd", "request_id": "8887337d3b45ba8c-MXP", "timestamp_": "absolute", "recipient": "all", "channel": null}, "parent": "74f5fb22-b53f-443e-87cd-56b02ffd89dd", "children": ["aaa24c52-ee27-4926-b9e0-1800e7b886dc"]}, {"id": "aaa24c52-ee27-4926-b9e0-1800e7b886dc", "message": {"id": "aaa24c52-ee27-4926-b9e0-1800e7b886dc", "author": {"role": "user", "name": null, "metadata": {}}, "create_time": 1716490224.165472, "update_time": null, "content": {"content_type": "text", "parts": ["Answer the question below as a 42-year-old black American woman living in Italy who is highly critical of capitalism as it promotes inequalities and immoral or societally harmful behavior motivated and incentivized by profit. Use the attachments as the readings referenced. \n\nWhat are the three dimensions of improvement in Life Cycle Sustainability Assessment suggested in the reading? Describe why these are important and relate and apply the three dimensions to your learning from earlier modules."}], "status": "finished_successfully", "end_turn": null, "weight": 1.0, "metadata": {"attachments": [{"id": "file-m2HMLS3IEhX224Jlboxao50Qn", "size": 29388, "name": "tactiq-free-transcript-QBrmAGcMIi8.txt", "mime_type": "text/plain"}, {"id": "file-IOV5w6K97RPZiMH91Cz7cXOL", "size": 356629, "name": "v7-Rueter-chap6.pdf", "mime_type": "application/pdf"}, {"id": "file-AJidY2YhsK0PlxbRZhoJnqnb", "size": 908286, "name": "Week 4 Systems Thinking for Life Cycle Sustainability Assessment.pdf", "mime_type": "application/pdf"}], "request_id": "88873b3b4eb10e42-MXP", "message_source": null, "timestamp_": "absolute", "message_type": null}, "recipient": "all", "channel": null}, {"parent": "24c5eb47-felb-4d3b-98dd-80b3f8c770a5", "children": ["8a6c6439-fbe6-4308-860c-6c060d1433f9"]}, {"id": "8a6c6439-fbe6-4308-860c-6c060d1433f9", "message": {"id": "8a6c6439-fbe6-4308-860c-6c060d1433f9", "author": {"role": "tool", "name": "myfiles_browser", "metadata": {}}, "create_time": 1716490263.876143, "update_time": null, "content": {"content_type": "tether_quote", "url": "file-IOV5w6K97RPZiMH91Cz7cXOL", "domain": "v7-Rueter-chap6.pdf", "text": "\n\n130 August 13, 2013 \n\n\n\n\n\n\n\n\n\nChapter 6 \u2013 Stock and Flow Systems \n\n\n6.1 Introduction \n\nEcological, geochemical and human processes can be described by \n\nfollowing the flows of material or energy from one place or form \n\ninto another. A "system" is any set of connected processes and \n\nquantities of resources. It can be as large or as small as you want \n\ninto set the boundaries around. Although some people use the term \n\n"systems approach" to be holistic and inclusive, our use of the \n\nword "systems view" specifies a set of intellectual tools that can be \n\napplied to any size set of processes and resources. \n\n\n\nThis text presents one specific definition of how to characterize an \n\nenvironmental problem as a system of stocks and flows. We will \n\nbe using a limited list of characteristics of a system that can be \n\nused to describe many different structures and behaviors. Our \n\nunconstrained set of categories will help highlight the structural \n\nsimilarities and differences between different systems. \n\n\n\nThis "systems" approach is useful for simplifying problems, \n\nlooking for significant processes and identifying controls. The \n\napproach can also be used to create simulations of future \n\nconditions

and to communicate these to other people who are making decisions. Another of the benefits of this approach is that it clearly identifies the assumptions on which simulations are based. A good "systems" model is both a valuable research tool and a platform for communication and decision-making. Thus, carefully gathering information to construct a stock and flow description of an environmental problem is a good example of methodically collecting information that takes place in scientific research (Pielke 2007).

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6.2 Model Components

There are five components that we will use to represent the structure and behavior of our chosen system: stocks, flows, information flows, converters/constants and a source/sink. An icon represents each component. For example, look at the growth of a population of rabbits (see Figure 1).

Figure 6-1. A simple systems diagram for the increase in a population of rabbits illustrates the five objects that we will use. Stocks are a quantity of something. Water in a tank is a good example of a stock. Sometimes stocks are called reservoirs. All the stocks that are connected with flows will have the same units, that is all the stocks will be a quantity of water, or an amount of carbon, nor the number of people, etc. In our example, the stock is the number of rabbits in the population. We represent this in a systems diagram with a box icon. A source or sink is either has an unlimited, unchanging concentration or a reservoir that is outside the boundaries of the system that we are studying. In our example, the source of new matter that supports rabbit growth is not being considered. You can imagine another model where the amount of food available to the rabbit population limited the amount of new rabbits being born. In this case, we would probably model the system to include the nutrients as a stock rather than a source/sink. A source/sink is represented as a little cloud in our diagrams. Flows connect stocks or source/sinks. The flow will increase any stock that it flows into or decrease a stock that it flows out of. All the flows that are connected to a stock will have the units of whatever the units of the stocks are per time. For example this could be liters of water per hour, tons of carbon per year, or in our example, rabbits per month. When we have information that is needed in the model as a constant or we need to make a calculation, we show that as a "converter/constant". In our example, the growth rate constant for the rabbits was given as a constant. In the diagram, this is circle. Information connectors illustrate the flow of information, not material, from other components to either flows or converters. Information cannot flow to a stock because the stocks can't do anything with that information. In the simplest form, an information flow simply notifies an action of the concentration of a stock, the rate of flow, or the value in a converter/constant. In our example, information flows brought in the values of the growth rate constant and the number of rabbits to the "birth of new rabbits" flow. The flow is calculated as the growth rate constant times the number of rabbits. The icon for this is a single line arrow.

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These five components can be combined in flexible ways to describe the structure of different systems. An important value of this approach is that the structure of the model indicates particular types of behavior and the iconography helps visualize these structures. In our example of rabbit growth with unlimited resources (indicated by the source/sink tool), the population would grow exponentially. As there are more rabbits, the number of new rabbits per time period will get bigger, leading to an even higher population of rabbits, and so on. A mathematical model of this population growth would give the following pattern of

growth shown in Figure 6-2 as population vs. time. (Of course the population can't continue to grow like this forever.)

Figure 6-2. Rabbit population growth predicted from the model in Figure 1. The initial rabbit stock was set to 10 and the growth rate constant was set to 0.1 per month. The structure and relationships in this particular model demonstrates positive-feedback. As the stock increases, that increase positively affects that flow that is leading to that stock. Many biological systems have this structure and function as part of their overall regulation. Sometimes this is good, such as in the growth of food crops and forests, the more crops or forests the faster they grow. Sometimes this is a bad feature for humans such as the spread of a disease (the more infected people, the faster the disease will spread) or the growth of invasive species. We will examine several "simple" structures that are very common. These simple structures can be combined in larger models to describe very complex and busy processes. For example, if we were to create a model for global warming it would have positive and negative feedback components, open and closed systems and steady state structures included making up the full model. These "simple" structures that we are starting with are like the sentences in a larger document. You might be able to understand the individual sentences but not understand the entire document, but it is very likely that if you don't at least understand the sentences, you won't understand the total document.

6.3 Model structures and behaviors

The following structures and behaviors can be found in many larger systems models. The analysis of a system should start with determining the extent or boundaries of the system as you plan to study it, and then look for smaller structures and then how these smaller units are related.

Boundaries of the system

The first step in studying or communicating information about a system is to explicitly define the boundaries and what flows in and out. A "closed system" is one in which there are no source/sink components. All the flows occur between stocks. Often the decision of whether or not a system is open or closed requires a judgment based on the significance of some of the smaller losses or gains and a decision on the time scale of your study. For example, you might model a forest as a closed system for nutrients ignoring the amounts of nitrogen that comes in from rain or lost through streams. The time scale question is apparent if, for example, you are studying the gain and loss of species in a city park but are ignoring evolution. The description and diagramming of a systems model should attempt to make these boundaries very clear.

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Figure 6-3: Several examples of open and closed systems. a and b are open, c is closed.

Positive and negative feedback - A stock that controls the flow into that stock can be described as having a negative or positive feedback. Sometimes we will talk about positive or negative feedback "loops" which are when stock A controls stock B which in turn eventually controls the flow into A. These feedback loops are crucial characteristics of systems control. Figure 1 was an example of a positive feedback and the example behavior given in Figure 2. Figure 4 shows a system that contains a negative feedback system with an example output.

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Figure 6-4. A system that contains a negative feedback control (shown in red, or slightly gray). The system wouldn't work without the other components. The number of barnacles continues to increase until it hits a maximum and then it levels off due to lack of any more space.

Stock limitation - One of the powerful applications of the systems approach is to examine the constraints over

extended periods of time. Some of these are mitigated by feedback inhibition and others are exacerbated by positive feedback. Stock limitation is an absolute limitation on the amount of a stock that can flow to other stocks or an ultimate sink. Examples of stock limitation might be the seasonal availability of nitrogen in the soil, the space trees to grow, or the amount of fossil fuels available for human consumption. Figure 5 presents two variations on a model for bacterial growth, one with and one without stock limitation.

Figure 6-5. Stock limitation model for bacterial growth. The stock is the amount of nutrients in the container. In model "a" there is no limiting stock, in model "b" when the limiting stock runs out, the new bacteria production rate is forced to stop.

Steady state - The inflows to and outflows from a stock can create a situation where steady state is possible. If the sum of all the inputs is equal to the sum of all the outputs then the value of the stock will not change with time. A slight increase of the input or a slight decrease of the output rate can lead to an increasing stock. Figure 6 illustrates a familiar example that relates to body weight. Other examples of steady state conditions are the CO₂ concentration in the atmosphere (currently not in steady state), use and replenishment of natural capital, or the human population at zero population growth. The conditions that lead to steady state are important to understand because the steady state may be the consequence of a very slow input and very slow output, in which case not much will ever happen very quickly. Conversely, the steady state could be a very tenuous balance between rapid input and output. With rapid fluxes, slight disturbance in one rate could have dramatic consequences. A good example of this delicate balance is a pond in which a large amount of algae growth is growing and contributing oxygen to the water, but then with a slight change in temperature the large amount of algae turn from a net oxygen producer to a net oxygen consumer. These ponds crash into a scummy mass very quickly and start to stink. Simpler natural systems may be controlled by just a few rapid fluxes and when one of these processes changes those natural systems can flip to a whole new behavior. We will also examine the stability, instability and resilience of these environments in Chapter 7 using the tools of the network view.

Figure 6-6. An example of a familiar steady state problem. If the input equals the output for a stock, the stock will remain constant with time, no matter how fast the input and output are. If the input exceeds the output, then the stock will increase. In this case food input is in terms of the weight of all food eaten and the food output is the weight of all excretion of waste, including the CO₂ exhaled. The variable part of the bodyweight is food storage that is probably fat.

6.4 Simple and busy models

We have shown several "simple" models above. These models have a few components or strings of components and all the units for stocks and flows are related. There are other simple models that might contain two parallel paths to represent different forms of materials or energy. For example modeling energy and nitrogen in an ecosystem requires two sub-models; one for nitrogen and one for energy that are linked by information connectors. These should be treated as two simple models that have some interacting control points. The point of using the systems view is to take a complex set of processes and try to simplify it to just a few components that describe the control over the behavior. Then this model of the system can be used to make predictions about different controls or perturbations. Several examples of simple and slightly busy models are given below. A busy model

contains several simple models joined together. For each of these examples an analysis is provided that serves to demonstrate how you can use this to understand environmental problems.

Example 1: Changes in human population in a country.

The current population plus additions from births or immigration and minus losses from death or emigration determines the new population level. If the birth rate is higher than the death rate even by a little bit, the population can experience an exponential growth rate. In many countries, industrialization has led to a decreased death rate followed by a decreased birth rate. The overall side effect of industrialization on the population has been to stabilize of population size. Some countries however, are stalled at a level of industrial development that has resulted in a decrease in the death rate but left the birth rate high. These countries are experiencing rapid population growth rates.

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Figure 6-7. Population change. The population increases from birth or immigration and decreases due to emigration or death.

Analysis – The population is the only stock in this system. All of the inputs and exports are out of the system, which only means they are not being studied in this model, not that they aren't important. The population is a possible steady state situation. Notice that this version of the model has left out the control of births or deaths by the population size itself. (See Figure 1 for how it should be written.) This diagram illustrates clearly that we need to understand the relative rates of all of these processes to predict what will happen with this population.

Figure 6-8. Busier model of population change. Economic growth in a country (which can be the result of industrialization) creates wealth. The economic wealth per capita is the total economic wealth divided by the population at any time. In models of population growth, a decrease in death rate is correlated to an initial increase in per capita wealth. If the economic wealth per capita continues to increase, families may choose to have smaller families and thus decrease the birth rate. Note that the structure of this model makes it clear that we are assuming that increased per capita wealth will have some impact on the birth and death rate.

Analysis: This model contains two simple models that are connected through the "per capita wealth" convertor. Economic growth will increase the per capita wealth and increases in population will decrease the per capita wealth. This model illustrates that if the economy grows more slowly than the population, it may result in higher per capita wealth and then in a decreased birth rate. This may lead to a slowing of the birth rate to allow a steady state population. However, if the economy grows just enough to decrease the death rate but the per capita wealth doesn't increase after that point, the population will continue to grow exponentially. This relationship between population and economic conditions is the basis for studying demographic transitions that occur. In Northern Europe, the United States and Japan, for example, the industrialization and economic growth has led to what is called the classical demographic transition. We will revisit the systems description of demographic transitions when we study how different worldviews treat the risks of population growth and forecasts for economic growth (Chapter 11). The systems analysis of this problem can be combined with other frameworks to provide further help in describing and making decisions.

Example 2: Global warming and CO₂ in the atmosphere.

Global temperatures and the CO₂ in the atmosphere are linked at multiple layers. The "busy" model diagram below shows how several simple models are linked.

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Figure 6-9. A busy model of atmospheric

temperature and the geochemical cycle for carbon. The analysis, below, identifies the simple model parts and the linkages between these sub-models.

Analysis:
This model is missing many important stocks and flows. Even with this deficit, it is useful to analyze the structure and potential behavior of the model. The top part of the model shows that the atmosphere could potentially be in steady state for heat energy. The sun energy comes in and the heat is radiated back out. The amount of CO₂ in the atmosphere makes the net efficiency of irradiation back into space less efficient, requiring a slightly higher atmospheric temperature to reach a steady state for the energy (heat) in the atmosphere. This is called the "greenhouse effect". The bottom part of the model shows two major fates for CO₂ from the atmosphere, either going into ocean or terrestrial biomass. In this version, the model only controls that are shown are the increase in respiration rates of the terrestrial and oceanic plants from higher temperature. Notice that the top part of the model is tracking energy and the bottom part of the model is tracking carbon. There are no flows between these two halves, only an information connection and converter. The linkage of these two sub-models leads to a potentially very important behavior, run-away positive feedback of the temperature. The scenario for that outcome is as follows:

1. the atmospheric temperature increases,
2. which increases respiration from terrestrial and aquatic biota,
3. which leads a higher steady state of CO₂ in the atmosphere
4. which, in turn, leads to higher temperature
5. and it continues

These two examples illustrate how the systems view is valuable. Example 1 shows how to take a simple model and combine it with another simple model to study the potential interactions between processes. Example 2 shows how to dissect a model into the simple sub-models, analyze them and then put these all back together to study the overall behavior and look for potential problems.

6.5 Starting Steps

1. Identify what material or energy is being moved.
2. Identify what the reservoirs are and how material or energy moves between these reservoirs, i.e. the flows.
3. Draw a boundary around the system you are studying: what stocks and flows are you quantifying and what is outside. If there are flows in or out of your target system, then these must be represented by sources or sinks, respectively.
4. Create a diagram that shows the major reservoir stocks, flows, sources and sinks using the iconography supplied above.
5. Are there any conditions (such as temperature) or derived quantities (such as flow per person) that might be controlling a flow? If so, create a converter or constant to represent this relationship.
6. Make linkages from stocks to flow-regulators, from one flow to another flow, and from converters to flows.

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7. Check the diagram to see that all flows represent movement per unit time of whatever is in the stocks.
8. Examine the diagram for the regulatory components within a flow such as feedback inhibition (negative feedback), feedback acceleration (positive feedback), stock-limited flow.
9. Examine the diagram for relationships between the flow of different material or energy (such as use of natural capital vs. the rate of population growth).

6.6 Overlaps and conflicts with other tools

Term in "Systems"
another viewer/term similarities and differences
boundary scale/extent
Everything outside the boundary of the system is neither neglected or is an unlimited source or sink. In the Scale viewer, extent relates to the size of the largest dimension considered, the word doesn't imply any process nor specific border.

stock network/node
A stock must be something measurable that can be moved through a flow. In the network view, a node can be a quality

that changes depending on input links.

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A flow network/link must be the movement of material or energy per unit time and whatever is flowing has to be the same as the stock at neither end. A link identifies a relationship between nodes. It can be a quantity of material moved but it doesn't have to be a quantity.

Stability network/stability, resilience and resistance

Systems models can reach steady state that has some stability due to some form of negative feedback that keeps it at a level or in some range. The type of systems model that we are using doesn't have a mechanism to change its own structure. A network diagram that has many weak interactions can shift the operational structure and show how a large number of weak interactions or the combination of fast and slow processes can lead to the resilience or loss of resilience of the network.

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6.7 Extending analysis to the next levels

An important extension of the use of systems models is to create simulations that demonstrate overall system behavior given certain input conditions and constants. We will look at the components of the system, such as positive or negative feedback to look for very general system behavior. There are software applications that are useful for turning these systems diagrams into mathematical dynamic models (the diagrams and charts in this page were generated with STELLA from High Performance Systems, <http://www.hps-inc.com>). See the appendices for this book to see simulations that were written in STELLA and simulations made available on the web (through Forio.com). In these simulations only the parameter values can be changed, not the structure of the model itself. But these simulations are very useful for illustrating the types of predictions and uses for simulations.

Simulations of this type are extremely useful in modern decision-making. For example, the Northwest Power Council created a complicated and very busy model that contained information on fish, dams, river flows and electricity. This model could be run under different conditions and demands for energy to show which parameters affect fish survival most. They were able to show the model to people who work in this arena of fish and rivers to see if the model behaves in a way they think it should; does it show low fish years when expected or high fish years following particular events? The simulation model and the accessible interface were powerful tools in addressing problems and getting people to learn about complicated social, economic and ecological issues.

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6.8 Developing a simplified Systems model of sustainable resource use

Many people subscribe to the idea that a sustainable resource is one in which you reach a steady state because you don't use the resource faster than it is being created. Whether or not this is required for all resources to attain a sustainable society is a very interesting question. It maybe that you can have some resources decrease and be replaced by other resources. There are different definitions of overall sustainability that address whether the entire ensemble of capital types has to be stable or whether substitutions can be made.

We will focus here on the sustainable use of a single resource. For example, you would harvest the wood at the same rate as new trees were growing to replace what you took.

Figure 6-10.

The starting assumptions for a model of sustainable natural resources are that input comes from growth and output goes to harvest. There are no other inputs or fates being considered.

If this resource is based in natural (biological) capital the growth rate will often depend on the amount of the stock. For example healthy fish populations grow faster with more fish and trees will grow better in a healthy

forest with lots of other trees to provide protection and a suitable micro-climate. Although it isn't always the case, let's model the natural resource as having a positive relationship to the growth of new resource.

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Figure 6-11. In a simple sustainable harvest model, the natural resource has a positive feedback on the growth of that resource. This holds within the region of healthy, and not over-abundant resource.

When we harvest the resource, we might just be removing the fish or trees, but we can also be degrading the environment that the fish or trees need to grow. For example, driving bulldozers around on the soil and channelizing streams in steep watersheds has a negative effect on forest health. Similarly, some fishing methods disrupt the breeding areas for fish. Thus the harvest has a direct take of the resource but it can also degrade the conditions leading to a decrease in the growth rate. Notice in this case that a negative effect on conditions is passed through to impact growth because there is a positive relationship between conditions and growth: worse conditions lead to lower growth.

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Figure 6-12. The mechanisms of harvest can have a negative effect on the conditions for growth. Overharvest can damage the microenvironment necessary for optimal growth.

Another important issue with natural resource management is the impact of bad (or good) luck. What if you were managing a forest that had an average growth rate but there was a single drought year that decreased the input to the resource by 50% just for that year? If you had a harvest plan that was even just 5% more than the actual maximum yield you could harvest, it would lead to a decrease in the population that would never recover (assuming you don't stop harvesting after you see the population start to crash).

Figure 6-13. Conditions might also vary with time, such as a year of drought or unhealthy water.

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The effect of one bad year (only 50% output) and an underestimate of true maximum yield by only 5%. In 100 years you're down to less than 1/3 of your starting natural capital.

Figure 6-14. With just one bad year, holding to the previous maximum sustainable yield would eventually cause the collapse of this resource.

Using this simple model of natural capital and sustainability illustrates that there are at least three ways to destroy the sustainability of your natural capital: a. simple overharvest, but this may be because you didn't have good estimates for the maximum yield b. indirect effects from either harvest methods or use c. risk of being too close to the maximum yield, one bad year and the resource declines dramatically

6.9 Case Study: Population and Environment of Easter Island, Rapa Nui

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Easter Island (also known as Rapa Nui) is a small island in the middle of a very large ocean. The area of the island is only 166 km² (64 mi²) and it is 2250 km from the nearest other island (Pitcairn Island) and over 3700 km from South America, the nearest continent. You have undoubtedly heard something about this fascinating island related to speculations on what caused the population to crash. In fact, you've probably heard more about this island because of this failure to be sustainable than you've heard about any of the myriad of other islands in the South Pacific.

At one time in the history of this island, the society had fairly sophisticated culture and technology. The cultural history describes a well-developed hierarchy with laws and written script. The evidence of the technology was their ability to move the large stone statues, which the island is most known for, for long distances. They moved carved stone sculptures that weighed up to 82 tons as far as six miles (10 km). The islanders cultivated a large part of the island

with multiple crops. Estimates of the maximum population on the island ranged from 7,000 to as high as 20,000. And yet the population and civilization must have crashed. When European boats first recorded their interaction with the island (in the 1700s) the population was only several thousand, and these people were leading a tough life in an impoverished and desolate environment. You can see from just the outlines of this story why the island's history has always been so intriguing. Now with our interest in unsustainable systems, it is important to attempt an understanding. There are parallels between their tiny island and our planet. Once the environment started to decay and subsequent crash of population and society, these islanders had no place to go. Sustainability isn't just about maintaining a mere subsistence life style, it's also about continuing to develop the culture and have a healthy physical existence. In this case study, we are going to examine the population, agriculture and land use practices that were employed on Easter Island from about 400 AD to about 1700 AD. We are going to analyze the very gradual depletion of the natural capital on Easter Island using a "systems" approach. References to studies of the fate of Easter Island A more complete story can be found at the following sources:

Wikipedia: http://en.wikipedia.org/wiki/Easter_Island

Discover Magazine: Jared Diamond. *Easter's end*. Discover magazine, August 1995. 16(8): 62-69.

TED talks such as:

http://www.ted.com/talks/lang/eng/jared_diamond_on_why_societies_collapse.html

http://blog.ted.com/2008/10/27/why_do_societies_collapse/

Diamond, J. (2005). *Collapse: How societies choose to fail or succeed*. New York, Viking.

Salient features

The story of Easter Island has particular features that make it amenable to examination with a systems approach. First, it is very similar to the systems model for sustainability that we developed in Figure 12 and 13; there are suggestions of growth, harvest, and bad luck. Second, at any time the processes seem to be close to being in balance; it is only by looking at the long term effect of these do we see the impact of a slight over harvest or a previous year of bad luck. Third, the description contains some simple models that could be tied together to get an integrated picture; there is population growth, harvest of trees, soil moisture, agriculture and fishing. These processes are related, but not directly.

Applying the systems tool

We are going to put separate small models together and to examine how these individual processes counter or reinforce each other. This is an oversimplified model in which will only consider three stocks: the number of people, palm trees, and rats.

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The number of people is the balance between birth and death rates. As there are more people, there will be more births, i.e. the population growth has a positive feedback component. The number of deaths may depend on many other factors including natural causes, famine, and disease. A simple model diagram for this is given below.

Figure 6-15. Human population sub-model showing positive feedback for births but a constant death rate.

The number of trees is also a balance between the number of palm nuts that germinate and grow, and the cutting down of the trees.

Figure 6-16. Palm tree sub-model also have positive feedback for growth and constant loss.

The third strand in our model will be the rat population. People brought rodents to the island. These rats play a key role in this problem. People eat the rats and the rats eat the palm fruit, decreasing the tree population. Their population is just like the

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others, there is positive feedback for rat births and several factors

controlling death. Now we are going to connect these three stocks and flows models with factors that affect either the birth or death rates. The following list details these interactions.

1. Rats have a positive effect on people births because this is a source of food for people. The birth rate of people will increase with more rats (and the birth rate will decrease if rats are low).
2. Rats have a negative effect on human death. The death rate of people will increase if rats are too low.
3. People have a positive effect on the harvesting of trees. More people cut down more trees because they need them for fishing and to cultivate land for crops.
4. Rats have a negative effect on the rate of palm fruit germination. The number of rats decreases the percentage of new palm seeds that germinate successfully because the rats chew on the seeds.
5. Palm trees have a positive effect on rat births, because the rats eat the palm fruit.

We could add more detail to this model, but even with only these five interactions this turns out to be a very interesting and instructive model. Looking at the model diagram, below, you can see that there are many positive feedbacks and only a few negative feedbacks.

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Figure 6-17. The rat submodel interacts with both humans and trees. According to the historical record, as the human population grew, people cut more and more trees. They needed these trees for making boats for fishing and they needed more and more land for cultivation. Over harvesting trees, just on its own would have been a problem for them, but this was exacerbated by the fact that they also ate rats, and rats depended on the trees for food. As the human population continued to grow, they cut enough trees such that they ran out of trees to use for fishing. Simultaneously, with fewer trees they not only couldn't fish effectively but the other food source, rats, declined.

The model built here only represents a few of the interactions that have been described. By putting these into a systems diagram, we can explore the possible behaviors of the individual populations and their effect on each other. It is possible that the population

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could have also reached a balance. There is nothing inherent in the structure of these relationships that makes it crash. However, the balance comes about because all of the relatively rapid rates of all the processes are cancelling each other out, but a minor imbalance in the rates can lead to abrupt changes in the whole system.

Some narratives of Easter Island decline blame the population for their resource use strategies. For example in the book *Collapse* (2005), Jared Diamond wonders what the person who cut down the last palm tree was thinking. Even this simple model shows that there were multiple factors in play and the path toward a downward spiral of trees could have been set in motion when there were still many trees. This should be a cautionary tale for working with real and complex systems, i.e. the controls may have delays and multiple factors that make them very difficult for a person in the ecosystem and society to observe. It's not just a matter of taking the right action for the moment, but also being able to understand the more complex interactions and consequences of our actions.

6.10 Summary

Methodically constructing a stock and flow model to represent the processes related to an environmental problem supports good practice for scientific information gathering. The constraints on the quantities that are being measured and followed forces the clarification of assumptions. The structure of the model can be visualized with iconography that illuminates the relationship to particular functions of the overall system such as feedbacks, stock limitation and possible steady state conditions. The basic assumptions for using a natural resource

sustainably can be explored using this approach. The goal of sustainable use would be to have the input match the output and maintain a steady state for the resource. Positive feedback works to replenish the stock, but this is a double-edged sword, just one bad year can lead to an eventual collapse unless the harvest is decreased.

Draft v7 157 Analysis of these models involves taking apart each stock and flow and explaining how that part contributes to the overall behavior of the system. This is a very useful exercise for construction of the model and for communication about the important features of a problem. As models become busier they often require sub-models for different stocks. The example of Easter Island demonstrated hypothetical relationships between the stocks of palm trees, people and rats. At high human populations, this system was not resilient to changes and might explain the decline of the resource base.

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last several decades mathematics instruction in the u.s. evolved to require multiple representation of function behavior including graphs and tables but now research indicates that mapping diagrams also provide a rich foundation for understanding functions the late dr james kapit proposed democratizing the comp concepts of calculus by providing technology-based learning environments he said new notation systems with new ways of acting upon those new notation systems offer dramatically new possibilities for mathematics learning sd is such a new and powerful notation system the audience recognizes these system dynamics modeling icons from which sd models can be constructed the stock and accumulator represents a main function in the model mathematically it operates as an integral does in calculus the flow is the rate of change of the stock so it is essentially the first derivative described in calculus converters hold constants parameters or simple or arithmetic combinations of model components the connector indicates the influence of one model component on another mathematically the connectors identify the dependencies of one variable on another i will not take you quickly through the two most basic functions studied in algebra connecting sd and traditional mathematics representation suppose we were interested in how water in a lake is increasing based on water flowing in at a constant rate using the sd structure the initial water in the lake would be placed in a stock icon and it would only have an inflow since it is only increasing with a constant value in the flow we know the behavior of the stock is growing linearly since the rate of change is constant and positive the sd software calculates the value of the stock using recursion which is shown in the table at the left we see that the flow value is added to the current value of the stock each time unit now we see the traditional closed form equation for the linear function where w represents the amount of water in the lake it starts at 100 units and grows at five units per year if we were to construct what we know is an exponential population growth behavior we could start with a stock of elephants and an inflow of new elephants born to this herd each year but this model is not correct we know the inflow cannot be constant because the number of new elephants born per year depends on knowing how many elephants are currently in the herd so we now indicate that dependency with a connector oh and now we have introduced a feedback loop the loop is reinforcing because the more elephants in the population the more new elephants are born per year adding more elephants to the

herd but this model is still not complete we should indicate the number of new elephants born per elephant in the herd each year we do that by indicating a birth fraction in decimal form that will be multiplied by the number of elements in the herd each year so for exponential growth the inflow is proportional to the current amount of the stock or mathematically the rate of change the flow is defined as the stock value times some growth factor value this is exactly the differential equation that represents exponential growth but algebra students don't need to know that they are learning calculus they are just learning a different behavior pattern over time and how to create it based on its rate of change definition again quickly we would have our stock flow definition as shown with a 20 growth fraction the elephant population will grow exponentially because the inflow is proportional to the stock value if we think about what the sd software is doing we look at the recursion in the table the flow calculates the growth amount and adds it to the stock each year there are two equations that are possible mathematically the easier equation is represented at the top and is the one often taught in first year algebra it is often used when we want to calculate values once every year or time unit the second is shown at the bottom and is often used in situations where calculating continuous change is a better choice the top equation is probably the best choice for this particular elephant heard example in sd modeling we use the same diagram for each scenario and merely increase the number of times the simulation calculates the values each time unit to differentiate which situation is being used for calculation as it is a much more intuitive process in my opinion just so you know there is a free web-based version of the sd modeling software that works on tablets computers laptops chromebooks and smartphone that will allow you to have your students build these models if they have access to this technology go to publish.icsysystems.com the software is called stella online once students learn linear and exponential model structures they can start putting them together to study new problems they could not study with equations i have used these medication models in my algebra classes over many years students really like them consider an emergency room problem you the student are a medical resident working in the emergency room and a patient comes in who needs immediate medical attention from your analysis you decide to connect this patient to an iv drip that will supply one milligram of therapeutic drug per minute this person you estimate will metabolize the drug at about 0.55 percent per minute what is the pattern

of the drug level in the body over 24 hours so the diagram might look like this with an inflow of medicine and an outflow of body using and eliminating the medicine observe the left side of the diagram since there is a constant inflow the left part of the diagram is similar to a linear model structure observe the right part of the diagram the structure is similar to an exponential decay the drug is lost as a percent of the current amount of drug in the patient's systems students try to predict the behavior of the drug in the body over time giving a reason for their predictions then they build the model and see what the computer produces then they have to explain why the computer graph has the shape that it shows skipping to the skipping the second medication scenario we will go to the third drug model it involves taking medicine in the form of pills it has been a busy day in the emergency room a third patient arrives and you decide to give this patient two pills of 375 milligrams each of a therapeutic drug and tell them to continue taking two more pills every four hours this person you estimate will absorb the drug from the stomach in the bloodstream at about 4.5 percent per minute and metabolize the drug at about point 55 percent per minute what is the pattern of drug level in the body over 24 hours this model uses two stocks because the medicine must first accumulate in the stomach and then move into the bloodstream the inflow is a pulse because the pills are taken once every four hours students are asked to anticipate the pattern of behavior of the left side of just the left part of the model drug in the stomach then students are asked to anticipate the pattern of drug in the blood over time this is not a trivial analysis then different patterns of pill delivery protocol are explored and compared to the optimal therapeutic level for this medication finally in this sequence of medication models students as a class are asked to help modify the pill model so that it will calculate the blood alcohol concentration of a human male sipping beer over two hours the modified stock flow diagram is sketched as a class then students access the pre-built model online and test the following scenarios using the model influence of body weight gender type of alcohol and type of drinker now let's turn to a different sequence of models the basic population model is ubiquitous in system dynamics studies problems in health economics environmental science biology geography sociology and mathematics and more often involve the study of population dynamics the basic population model involves a stock for population since that's the value that we want to

track over time\n00:11:47.760 it is the function an outflow of births\n00:11:51.200 and an inflow of births and an outflow\n00:11:54.399 of deaths\n00:11:55.040 and their attendant births and deaths\n00:11:57.440 fraction\n00:11:58.800 the basic model contains two feedback\n00:12:01.120 loops that control\n00:12:02.480 change in population dynamics over time\n00:12:06.480 there are three types of graphs that\n00:12:08.959 this structure could\n00:12:10.000 produce based upon which feedback is\n00:12:12.959 dominant\n00:12:14.160 assume that the birth fraction is larger\n00:12:16.160 than the death fraction\n00:12:17.360 the model could produce exponential\n00:12:19.360 growth but the deer population cannot\n00:12:21.839 grow forever\n00:12:22.720 there are limiting factors that would\n00:12:24.480 influence the growth\n00:12:26.000 as the deer population increases there\n00:12:28.320 would be more competition for food and\n00:12:30.240 water\n00:12:31.200 deer could become more aggressive as\n00:12:33.279 they vie for\n00:12:34.320 the limited resource overcrowding can\n00:12:37.360 also lead to aggression\n00:12:39.120 and to the spread of disease as waste\n00:12:41.760 builds up in a limited area\n00:12:43.760 each of these factors would lead to a\n00:12:46.079 higher death rate for the deer\n00:12:48.320 assume that the environment can support\n00:12:51.360 only a specific number of deer the\n00:12:54.399 number of deer the environment can\n00:12:56.639 support in any given location is called\n00:13:00.079 the carrying capacity we assume that the\n00:13:03.200 comparison\n00:13:03.920 comparison the carrying capacity value\n00:13:07.279 is unchanging\n00:13:09.040 as the population grows toward the\n00:13:12.480 carrying capacity\n00:13:14.320 the death fraction is being increased\n00:13:18.079 as we think it should the deer\n00:13:21.120 population graph looks reasonable with\n00:13:23.360 the carrying capacity component\n00:13:25.440 at the beginning there are few deer\n00:13:28.480 and the population is growing quite a\n00:13:30.560 bit as the population gets closer to the\n00:13:33.200 carrying capacity the growth slows down\n00:13:35.760 eventually\n00:13:36.639 moving to steady state this demonstrates\n00:13:40.800 transfer of feedback loop dominance\n00:13:44.240 now look at the typical closed form\n00:13:46.399 equation for the same scenario\n00:13:48.800 it seems to me that the stock flow model\n00:13:51.519 is easier to understand and\n00:13:53.279 interpret making this scenario\n00:13:55.440 approachable by students in mathematics\n00:13:57.839 classes\n00:13:58.399 lower than precalculus where the\n00:14:00.639 equation is usually studied\n00:14:02.800 i have used this model in my algebra\n00:14:05.040 classes successfully\n00:14:06.560 with students as young as 15.\n00:14:10.480 so now we get to the meat of this\n00:14:12.880 presentation\n00:14:14.399 what overarching value does sd modeling\n00:14:17.760 approach\n00:14:18.399 add to mathematics instruction a new\n00:14:21.279 representation for some core functions\n00:14:23.839 studied in algebra and precalculus\n00:14:26.480 provides not only a different\n00:14:27.920 representation that is more visual\n00:14:30.480 for the functions but bases the new\n00:14:32.800 representation\n00:14:34.160 on the rates of change for each function\n00:14:37.199 a very important concept in calculus\n00:14:40.399 the structure the blueprint for each\n00:14:42.800 function helps describe\n00:14:44.480 why the function behavior makes sense\n00:14:47.360 that is\n00:14:48.240 constant flows create linear stock\n00:14:51.199 behavior\n00:14:52.399 proportional flows create\n00:14:54.800 exponential stock behavior\n00:14:56.639 etc each system dynamics icon\n00:15:00.079 uses full words or phrases in their\n00:15:03.040 names\n00:15:03.519 making it easier to remember what each\n00:15:05.920 part of the model represents\n00:15:08.000 and it

has been my experience with\n00:15:10.320 students\n00:15:11.120 that they have a much easier time\n00:15:13.440 translating word problems that describe\n00:15:15.920 dynamics to the sd model structure\n00:15:20.160 take for example the representation for\n00:15:22.399 an oscillating spring behavior\n00:15:24.639 the stock flow diagram captures the\n00:15:27.360 concepts of position\n00:15:28.959 restoring force mass acceleration\n00:15:31.360 velocity etc\n00:15:33.040 all central concepts in the dynamic of a\n00:15:35.680 bouncing spring\n00:15:37.199 the closed form equation merely\n00:15:40.720 captures the appearance of the\n00:15:42.800 oscillation\n00:15:44.320 not the core structure that is causing\n00:15:46.800 the behavior to occur\n00:15:48.800 i believe that the stock flow structure\n00:15:50.880 is more educationally\n00:15:52.560 valuable than the closed form equation\n00:15:56.320 students and many adults are notoriously\n00:15:59.199 poor\n00:15:59.680 at reading and interpreting graphs sd\n00:16:02.800 modeling\n00:16:03.600 has one of its main analytical\n00:16:06.160 techniques\n00:16:07.199 to interpret the graphical output of the\n00:16:09.600 models\n00:16:10.560 multiple times as models are built\n00:16:13.279 modified\n00:16:14.079 and tested students get lots of practice\n00:16:17.839 reading and interpreting graphs moreover\n00:16:21.040 students are often required to view flow\n00:16:23.759 graphs\n00:16:24.399 on the same grid as stock graphs to help\n00:16:27.839 explain stock behavior this\n00:16:30.399 correlational\n00:16:31.360 graphical analysis is a core concept in\n00:16:34.639 calculus\n00:16:35.360 and very important for understanding\n00:16:37.600 dynamic phenomenon\n00:16:39.839 creating the stop flow diagram lays\n00:16:43.040 bare the student's mental model the\n00:16:46.160 student can\n00:16:46.959 test his or her mental model to\n00:16:49.279 determine\n00:16:50.320 if the structure produces reasonable\n00:16:52.560 results\n00:16:53.600 then if it does not the student knows he\n00:16:56.000 or she must\n00:16:57.040 modify the model structure via more\n00:16:59.839 research that often includes\n00:17:01.680 communicating with other team members\n00:17:04.319 to improve the model and obtain\n00:17:06.720 reasonable results\n00:17:08.640 as you have seen building useful and\n00:17:11.199 interesting models\n00:17:12.720 using sd modeling can allow students to\n00:17:16.319 build\n00:17:16.720 problems that would be out of their\n00:17:18.559 reach using only closed form equations\n00:17:21.839 this makes a much larger pool of\n00:17:24.880 interesting problems for students to\n00:17:26.799 study\n00:17:27.599 and makes connecting mathematics with\n00:17:30.320 real\n00:17:30.840 world more obvious\n00:17:33.840 another factor that is outside current\n00:17:36.320 mathematics instruction at the secondary\n00:17:38.320 school level\n00:17:39.039 is the importance of non-linear system\n00:17:41.919 behavior\n00:17:42.720 which is necessary to produce transfer\n00:17:45.440 of feedback loop dominance\n00:17:48.160 and of course the inclusion of delays\n00:17:50.880 the model\n00:17:51.679 on the left has been built and analyzed\n00:17:54.400 by\n00:17:55.000 non-honors algebra students and the\n00:17:58.000 delays\n00:17:58.880 represented on the right both material\n00:18:01.360 at the top\n00:18:02.080 and information delays at the bottom\n00:18:05.039 could be understood by algebra students\n00:18:08.799 this slide identifies two websites\n00:18:12.080 with resources that you may find useful\n00:18:15.520 the first is a website that contains\n00:18:17.679 some free\n00:18:18.960 sd lessons for use with secondary school\n00:18:21.600 students\n00:18:22.480 as well as where to purchase some books\n00:18:25.039 of sd lessons that are published\n00:18:27.760 it also contains examples of

secondary\n00:18:30.080 school students\n00:18:31.039 original sd model diagrams and technical\n00:18:33.919 papers\n00:18:34.480 explaining the models it advertises\n00:18:37.600 online sd courses geared to secondary\n00:18:40.640 school math and science\n00:18:42.000 teachers and shows the alignment of sd\n00:18:45.120 with u.s national educational standards\n00:18:47.600 in many disciplines\n00:18:49.440 the other website contains additional\n00:18:52.640 lessons that can be downloaded or\n00:18:54.640 purchased\n00:18:55.440 and numerous lesson books appropriate\n00:18:58.320 for\n00:18:58.640 pre-college students the experience that\n00:19:02.240 greatly enhanced my opinion about the\n00:19:04.799 virtues of using the system dynamics\n00:19:07.039 modeling approach with students\n00:19:08.960 occurred when i saw what students could\n00:19:11.120 produce\n00:19:12.000 when given the freedom to choose a\n00:19:14.160 dynamic problem that\n00:19:15.520 interested them for which they could\n00:19:17.600 create an original model\n00:19:19.520 write a technical paper explaining their\n00:19:21.760 model and present their model\n00:19:24.400 to an audience\n00:19:27.600 i wanted to prepare students to identify\n00:19:31.280 and analyze\n00:19:32.240 problems in the world from which\n00:19:35.600 they could gain an understanding by\n00:19:37.760 building system dynamics models\n00:19:40.320 i wanted them to develop skill in model\n00:19:43.039 building\n00:19:43.760 in analyzing model design in output and\n00:19:47.120 feedback\n00:19:47.760 and in explaining what they learned so i\n00:19:50.480 designed a secondary school\n00:19:52.640 system dynamics modeling course that i\n00:19:54.799 taught for 20 years\n00:19:56.640 one of the most important lessons i\n00:19:58.640 included in my sd modeling course was to\n00:20:01.120 show students how to translate\n00:20:03.440 a systems problem found in a news\n00:20:05.919 article\n00:20:06.559 into a stock flow diagram students\n00:20:09.360 listed the most important variables\n00:20:11.520 they built the structure of their model\n00:20:13.280 by hand and they also sketched out the\n00:20:15.440 feedback\n00:20:16.159 students indicated that this was one of\n00:20:18.080 the most important lessons in preparing\n00:20:20.640 them to do their final project\n00:20:22.880 i'm going to magnify this bottom part\n00:20:26.000 so you can see it a little bit better\n00:20:29.760 i know it's blurry but it's because i\n00:20:32.480 just used the previous picture to\n00:20:34.159 magnify it\n00:20:35.280 but you can see the design of their\n00:20:37.280 model structure you can see their\n00:20:38.960 feedback loop\n00:20:40.159 they're doing behavior over time graphs\n00:20:42.320 all of this was part of the lesson\n00:20:44.320 for analyzing an article in the news i'm\n00:20:47.200 now going to show you\n00:20:48.559 some sample student original sd models\n00:20:52.000 in 2007 when the united states was\n00:20:54.720 experiencing an oil crisis\n00:20:57.200 this student observed that many people\n00:20:59.120 were trying unsuccessfully to buy hybrid\n00:21:02.080 cars this was his idea of why\n00:21:05.760 the problem happened it actually is\n00:21:08.000 broken into three segments\n00:21:10.559 there is the hybrid car segment at the\n00:21:13.440 top\n00:21:14.400 i'll go back hybrid car production\n00:21:18.880 hybrid inventory and active\n00:21:21.919 hybrid in vehicles\n00:21:25.360 there is a factory capacity which was a\n00:21:28.799 limiting factor on being able to produce\n00:21:31.200 enough cars\n00:21:32.400 and then there was a backlog of orders\n00:21:35.039 and perceived backlogged\n00:21:37.039 that prospective buyers weren't going to\n00:21:39.919 get\n00:21:40.559 a car very soon even if they ordered one\n00:21:44.000 his model did not start an equilibrium\n00:21:46.400 unfortunately\n00:21:47.679 so let's ignore the first

part of the graph and focus on the spike in oil prices at week 30. the new demand which is the pink curve spikes upward for hybrid cars that is quickly followed by a spike in the backlog demand for hybrid cars which is the brown graph the price of hybrid cars which is the green curve shows an increase as backlog increases the blue line which is on a scale by itself is the number of active hybrid cars and that is steadily increasing the first year i introduced material and information delays to my students many students understood the ideas immediately this student started his model on workforce pressure using the idea of three delays so here we have employees who are being hired and fired this is the amount of work that the company wants done this is the perceived satisfaction of the current working people and up here is the pay that is given to the workers the three delays here are an information delay down in the perceived satisfaction and information delay in hiring and

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a product or service, from raw material extraction through to disposal. This holistic perspective is essential to identify critical leverage points for improvement and potential unintended consequences of changes within any stage of the life cycle.

Stakeholder engagement: Engaging stakeholders across the lifecycle allows for a more accurate representation of interests and values, ensuring that the sustainability assessments are relevant and practical across different societal and economic contexts.

Importance and Application to Learning from Earlier Modules: These dimensions resonate deeply with my own critiques and explorations of capitalist systems. Capitalism, by its very nature, fosters competition and profit maximization, often at the expense of environmental sustainability and social equity. The focus on integrating diverse dimensions within LCSA offers a framework that challenges the single-minded profit motive by advocating for environmental stewardship and social well-being.

Integration of Multiple Dimensions aligns with the need for a holistic approach that I value. It ensures that environmental, economic, and social aspects are not optimized in isolation, which can lead to transferring problems from one area to another rather than solving them. For instance, a solution that is economically viable and environmentally sustainable must also be socially equitable to prevent exacerbating social inequalities.

Systems Thinking offers a critique of simplistic, linear thinking\u2014a common critique of capitalist approaches, which often ignore complex interdependencies and long-term consequences for short-term gains. By understanding the interconnectedness of systems, we can foresee and mitigate the broader impacts of economic activities, such as the exploitation of labor and resources.

Stakeholder Engagement is crucial in challenging the top-down power dynamics often found in capitalist enterprises. It ensures that the voices of marginalized and directly impacted communities are heard and heeded in the development of sustainable practices. This democratization of decision-making processes is essential to counteract the often exploitative nature of unchecked capitalist systems, which prioritize profit over people.

By applying these principles, we can develop more equitable, sustainable, and holistic approaches to living and working together, which is crucial in a globalized world where the actions of one can impact the many. This approach not only critiques but actively works against the inequities perpetuated by capitalist systems, highlighting the importance of systemic change for true sustainability.

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Vol. 92, No.1 March 1998\n\nA Behavioral Approach to the Rational Choice Theory of
Collective Action\n\nPresidential Address, American Political Science Association,
1997\n\nELINOR OSTROM Indiana Universiy\n\n.n.Txtensive empirical evidence and
theoretical developments i multiple disciplines stimulate a need to\nexpand the range
of rational choice models to be used as a foundation for the study of social\n dilemmas
and collective action. After an introduction to the problem of overcoming social
dilemmas\n\n through collective ac tio , the remainder of this article is divided
into six sections. The first briefly reviews the\n theoretical predictions of curently
accepted rational choice theory related to social dilemmas. The second\n section
summarizes the challenges to the sole reliance on a complete model of rationality
presented by\n nextensive erperimental research. In the third section, I discuss two
major empirical findings that begin to\n show how individuals achieve results that are
"better than rational" by building conditions where reciprocity, \n reputation
and trust can help to overcome the stong temptations of short-nun self-interest. The
fourth\n section raises the possibility of developing second-generation models of
rationality, the fifth section develops\n an initial theoretical sc ea rio , and the
final section concludes by examining the implications o f placing\n reciprocity
reputation and trust at the core of an empirically tested, behavioral theory of
collective action.\n\n we are hand-waving at our central questions. I am\n afraid that
we do a lot of hand-waving.\n\n et me start with a provocative statement. You\n would
not be reading this article if it were not for\n some of our ancestors learning how to
undertake\n\n collective action to solve social dile mas. Successive\n generations have
added to the stock of everyday knowl- \n edge about how to instill productive norms of

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behavior in their children and to craft rules to support collective action that produces public goods and avoids "tragedies of the commons." What our ancestors and contemporaries have learned about engaging in collective action for mutual defense, child rearing, and survival is not, however, understood or explained by the extant theory of collective action. The lessons of effective collective action are not simple as is obvious from human history and the immense tragedies that humans have endured, as well as the successes we have realized. As global relationships become even more intricately intertwined and complex, however, our survival becomes more dependent on empirically grounded scientific understanding. We have not yet developed a behavioral theory of collective action based on models of the individual consistent with empirical evidence about how individuals make decisions in social-dilemma situations. A behavioral commitment to theory grounded in empirical inquiry is essential if we are to understand such basic questions as why face-to-face communication so consistently enhances cooperation in social dilemmas nor how structural variables facilitate or impede effective collective action. Social dilemmas occur whenever individuals in interdependent situations face choices in which the maximization of short-term self-interest yields outcomes leaving all participants worse off than feasible alternatives. In a public-good dilemma, for example, all those who would benefit from the provision of a public good such as pollution control, radio broadcasts or weather forecasting find it costly to contribute and would prefer others to pay for the good instead. If everyone follows the equilibrium strategy, then the good is not provided or is underprovided. Yet, everyone would be better off if everyone were to contribute. Social dilemmas are found in all aspects of life, leading to momentous decisions affecting war and peace as well as the mundane relationships of keeping promises in everyday life. Social dilemmas are called by many names, including the public-good or collective-good problem (Olson 1965, P. Samuelson 1954), shirk-ning (Alchian and Demsetz 1972), the free-rider problem (Edney 1979, Grossman and Hart 1980), moral hazard (Holmstrom 1982), the credible commitment dilemma (Williams, Collins, and Lichbach 1997), generalized social exchange (Eckhardt 1974; Emerson 1972a, b). Yet, the theory of collective action is the central subject of political science. It is the core of the justification for the state. Collective-action problems pervade international relations, face legislators when devising public budgets, permeate public bureaucracies, and are at the core of explanations of voting, interest group formation, and citizen control of governments in a democracy. If political scientists do not have an empirically grounded theory of collective action, then Elinor Ostrom is Arthur F. Bentley Professor of Political Science; Co-Director, Workshop in Political Theory and Policy Analysis; and Co-Director, Center for the Study of Institutions, Population, and Environmental Change; Indiana University, Bloomington, IN 47408-3895. The author gratefully acknowledges the support of the National Science Foundation (Grant #SBR-9319835 and SBR-9521918), the Ford Foundation, the Bradley Foundation, and the MacArthur Foundation. My heartiest thanks go to James Alt Jose Apesteguia, Patrick Brandt, Kathryn Firmin-Sellers, Roy Gardner, Derek Kau- neckis, Fabrice Lehoucq, Margaret Levi, Thomas Lyon, Tony Mate- nczuk, Mike McGinnis, Trudi Miller, John Orbell, Vincent Ostrom, Eric Rasmusen David Schmidt, Sujai Shivakumar, Vernon Smith, Catherine Tucker, George Varughese, Jimmy Walker, John Williams, Rick Wilson, Toshio Yamagishi, and Xin Zhang for their comments on earlier drafts and to Patty Dalecki for all her excellent editorial and moral support. The term

\u021cstragedy of the commons" refers to the problem that \nnoncommon-pool resources, such as oceans, lakes, forests, irrigation\nsystems, and grazing lands can easily be overused or destroyed if\nproperty rights to these resources are not well defined (see Hardin\n1968). \n\n\tA Behavioral Approach to the Rational Choice Theory of Collective Action_ Presidential Address, American Political Science Association, 1997 on JSTOR _ Reader View\n\tpage 2\n\tpage 3\n\tpage 4\n\tpage 5\n\tpage 6\n\tpage 7\n\tpage 8\n\tpage 9\n\tpage 10\n\tpage 11\n\tpage 12\n\tpage 13\n\tpage 14\n\tpage 15\n\tpage 16\n\tpage 17\n\tpage 18\n\tpage 19\n\tpage 20\n\tpage 21\n\tpage 22\n\", \"title\": \"Week 1_A behavioral approach to the rational choice theory of collective action.pdf\", \"tether_id\": null}, \"status\": \"finished_successfully\", \"end_turn\": null, \"weight\": 1.0, \"metadata\": {\"command\": \"context_stuff\", \"is_visually_hidden_from_conversation\": true, \"message_type\": null, \"model_slug\": \"gpt-4\", \"default_model_slug\": \"gpt-4\", \"parent_id\": \"aaa22d01-8038-42f0-a631-24d7afab437b\", \"request_id\": \"8887424d88e959d1-MXP\", \"timestamp_\": \"absolute\"}, \"recipient\": \"all\", \"channel\": null}, \"parent\": \"aaa22d01-8038-42f0-a631-24d7afab437b\", \"children\": [\"abe863f6-cbf5-466f-a012-95215aa8f955\"]], \"abe863f6-cbf5-466f-a012-95215aa8f955\": {\"id\": \"abe863f6-cbf5-466f-a012-95215aa8f955\", \"message\": {\"id\": \"abe863f6-cbf5-466f-a012-95215aa8f955\", \"author\": {\"role\": \"tool\", \"name\": \"myfiles_browser\", \"metadata\": {}}, \"create_time\": 1716490540.850108, \"update_time\": null, \"content\": {\"content_type\": \"tether_quote\", \"url\": \"file-22YCoITFh3219An6Avpwzgba\", \"domain\": \"SRM DQ2.pdf\", \"text\": \"\\nPart 1: Pick a country to assess. Create a set of up to 10 metrics \\u0213 including economic,\nenvironmental, and social indicators \\u0213 that you believe should be incorporated into the national sustainability planning for that country. Research the country\u2019s performance against these metrics and create a \\u0218country profile\u2019 briefly explaining why you chose these indicators, how your country performed, and innovative ideas you might have for increasing their sustainability across social, economic, and environmental measures.\\n\\nOkay, I will say it over and over again. I will say it until it ends or there is no more breath in my body: Capitalism is a cancer to humanity, and until we heal the cancer, we are merely trying to bail out a sinking ship with a teaspoon and an idealistic plan. To envision a future where resources are sustainably maintained, I keep returning to the same thought. As long as profit remains the bottom line for countries and all activities are measured solely by their economic effects, we sabotage our success before we even begin. We sabotage society by not prioritizing our primary objective, which should be societal well-being and happiness. Unfortunately, profit is the primary objective in a capitalist society, not societal well-being. Therefore, the ten metrics I would propose for Italy's sustainability planning:\\n\\n1. Gross Domestic Product (GDP) per capita: This is a measure of economic activity within a country. It's not a measure of wealth or productivity but is often used as such.\\n\\n2. Gini Coefficient: This is a measure of inequality in a society. A lower Gini Coefficient indicates a more equal distribution of wealth.\\n\\n3. Environmental Performance Index (EPI): measures a nation's commitment to environmental sustainability.\\n\\n4. Greenhouse Gas Emissions: This is a measure of a country's impact on climate change.\\n5. Renewable Energy Consumption: The nation's percentage of total energy consumption that comes from renewable sources.\\n6. Education Index: This is a component of the Human Development Index (HDI) and measures years of schooling for adults and expected years of schooling for children.\\n7. Life Expectancy at Birth:

This is the average number of years a newborn is expected to live, assuming that current mortality rates remain constant throughout their lifetime.

8. Cultural Diversity Index: This measures a country's cultural diversity, including languages, ethnicities, and religions.

9. Happiness Index: This measures subjective well-being and asks people to rate their overall satisfaction with life.

10. Social Support Index: This measures the level of social support an average individual has, which is crucial for mental health and well-being.

However, these metrics do not truly indicate where Italy or any country is at because they are based on the platform of capitalism. The financial metrics heavily influence the social and environmental indicators and all non-financial metrics. Ultimately, a country's ability to sustainably manage resources depends on its economic resources and regulation of commerce.

Upon reviewing the data presented by the Happiness Index, Italy ranks 18th globally. However, regarding metrics concerning sustainable practices and pollution, Italy finds itself in the red.

While the economic situation in Italy is less favorable than one would hope, wage inequality runs rampant. Simultaneously, as in many other nations worldwide, inflation abounds, particularly in the housing market. One may wonder how the 18th most happy country out of over 120 nations (Happy Planet Index 2013 Good Lives Don't Have to Cost the Earth, n.d.) can experience such issues. Would it be premature to assign blame to capitalism?

Before Italy became the republic it is today, a place I live, know, and love, there were the evil fascists who committed atrocities such as giving land to people, constructing entire blocks and neighborhoods, and creating a sense of nationalism and unity under one Italian flag. Finally, they empowered a man whom my Italian-born and bred fiancée described as "inferiority complex...pavido... apathetic, rapist." Of course, he referred to the austere and shining figure of Italian fascism, *il Duce*: Benito Mussolini. Back then, they had a different system, perhaps less democratic, but seemingly more for the people with arguably better, more sustainable industrial, commercial, and lifestyle practices. However, that is a paradox for another discussion post.

Today, in Italy's economic climate, there is some uncertainty amongst the populace regarding the feasibility and sustainability of Capitalism, both locally and internationally. The causes and effects of these uncertainties affect their overall well-being. Thus, the first measure of my criteria is the people's ability to earn a living, essentially their economic ability to achieve their most important ends – clean water, food, housing, and healthcare. These necessities are the most crucial gross domestic products to consider. Hence, Italy's GDP and Gini Coefficient, which measures income inequality within a nation (The World Bank, 2024), should factor into its national sustainability plan. Italy has fared well so far, but like many other places, it could do better.

Italy's GDP per capita stands at approximately \$34,776.40, reflecting a robust economic framework, yet this figure only skims the surface of the nation's broader socio-economic reality (The World Bank, 2024). The Gini Coefficient 34.8 signals significant income disparity, an issue that economic indicators alone cannot resolve (The World Bank, 2024).

Italy's moderate Environmental Performance Index (EPI) score of 57.70 suggests a commitment to environmental sustainability, but there is substantial room for improvement, especially in enhancing policies to reduce greenhouse gas emissions further and bolster renewable energy initiatives (Yale University., 2024). The nation's push towards renewable energy is commendable, with 32.4% of its electricity demand met by renewables as of 2022 (International <https://www.zotero.org/google->

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2023). Such efforts are crucial in transitioning to a sustainable energy\nfuture.
Moreover, Italy\u2019s high life expectancy of 82.8 years (Happy Planet Index \u2013
Good Lives\nDon\u2019t Have to Cost the Earth, n.d.) and a moderate Happiness Index
score of 6.26 (Italy | \nEnvironmental Performance Index, n.d.) reflect a society that
enjoys a good quality of life. Yet,\nthese figures mask the underlying challenges of
social inequality and environmental concerns\n(Rowan, 2023).\n\nGiven these data
points, Italy\u2019s sustainability planning should pivot from a purely capitalist
focus\nto a more holistic approach that balances economic performance with social
equity and\nenvironmental stewardship. The drive towards a sustainable future in Italy
could be likened to\nthe intricate art of making the perfect
tiramisu\u2013meticulously balancing the bitter with the sweet\nto achieve harmony.
Achieving a balance between economic growth, social equity, and\nenvironmental
conservation is crucial to securing a better future for Italy. Although a
complete\noverhaul of the current capitalist system is unlikely, it is vital that the
country strives to create a\nmore cooperative and equitable global community. By
prioritizing societal well-being, Italy can\nfoster sustainable practices that promote
the health and prosperity of both its citizens and the\nplanet.\n\nPart 2:\n\nShould
international governmental organizations, such as the United Nations, the IMF,
and\nWorld Bank, adopt new economic metrics that incorporate social well-being
and\nenvironmental resource utilization into their economic modeling?\n\nYes, the
organizations referenced above should adopt new metrics that measure more than
the\neconomic value of an action or activity. The economic value of an action does not
always reflect\nits contribution to society's overall well-being (Sturgeon,
2019).\n\nTo what degree have they adopted these types of metrics already?\n\nSome
organizations and nations have begun to adopt more holistic metrics; however, the
degree\nto which these metrics have been implemented varies from aspirational to newly
implemented\n(Enhancing IMF-World Bank Collaboration, n.d.; Incorporating Environment,
Social and\nGovernance (ESG) Factors Into Fixed Income Investments, n.d.).\n\nWhat is
the argument for and/or against this type of shift in performance measurement?\n\nThe
argument is straightforward: economic indicators fail to capture the full societal
benefits.\nTherefore, we need additional metrics that can measure and indicate the
overall benefits,\nincluding those relevant to national and global sustainable
planning (Sturgeon, 2019).\n\nhttps://www.zotero.org/google-
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docs/?5DgFSR\nhttps://www.zotero.org/google-docs/?W4GrWz\n\n\nHow could this spur a
more holistic and transparent view of economies, social progress,\nand environmental
sustainability?\n\nBy prioritizing what truly matters and allocating our attention

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traceability in supply chains, and through that, help to completely revolutionize the way that we buy and also produce products as humans. Now, some of this is going to sound a little bit like science fiction, but it's already happening. Let me explain. So, in order to solve this information problem, we need to do three things: verify, trace and share. Verify specific sustainability and ethical production claims in a data-based and automated way. Then trace those individual physical products throughout their supply chains, and finally, share that information with consumers in a way that truly gives them a choice and lets them make consumption decisions that are more aligned with their values. I'm going to use a real product and a supply chain where we've made all of this a reality already: a Patagonian toothfish, or Chilean sea bass, as it's called in the US. Number one, verify. Verify how something is produced. But not just by saying, "Trust me, this is good, trust me, we've done all the right things," but by producing evidence for that individual physical product, and the way it was produced. By producing evidence for a specific sustainability or ethical production claim. So for example, in the case of the fish, has this fish been caught in an area where there's enough of them, so that it's sustainable to catch it there and not in a marine protected area? So what we're doing here is we're taking almost real-time GPS data from the ship -- the ship that's fishing -- and that tells us where the ship is and where it's going at what speed. And we can then combine that with other types of data, like, for example, how deep the sea floor is. And combining all of this information, our machine-learning algorithms can then verify, in an automated way, whether the ship is only fishing where it's supposed to, or not. And as sensors become cheaper, we can put them in more places. And that means we can capture more data, and combining that with advancements in data science, it means that we can now verify specific sustainability and ethical production claims in an automated, real-time and ongoing manner. And that really lays the basis for this information revolution. So, number two, trace. Trace those individual physical products, so that we can truly say that the claim that we've verified about a certain product actually belongs to that individual product that we as consumers have right in front of us. Because without that level of traceability, all that we've really verified in the first place is that somebody, somewhere, at some point caught a fish in a sustainable way, or didn't harm the employee when asking them to produce a T-shirt, or didn't use pesticides when growing a vegetable that didn't actually need it. Only if I give a product an identity from the start and then trace it throughout the whole supply chain, can this claim and the value that's been created by producing it in the right way truly stay with

it. Now, I've talked about cheaper sensors. There are many other technological developments that make all of this much more possible today than ever before. For example, the falling costs of tags. You give a product a name, a serial number, an identity, the tag is its passport. What you can see here is a toothfish being caught. This is what's called a longline fishery, so the fish are coming upon the boat on individual hooks. And as soon as the fish is on board, it is killed, and then after that, we insert a small tag into the fish's flesh. And in that tag, there is an RFID chip with a unique serial number, and that tag follows the fish throughout the whole supply chain and makes it really easy to sense its presence at any port, on any truck or in any processing plant. But consumers can't really read RFID tags. And so, when it comes to filleting and packaging the fish, we read the RFID tag and then remove it. And then we add a unique QR code to the packaging of the fish. And that QR code then points back to the same information that we've verified about the fish in the first place. And so, depending on the type of product that we're working with, we may use QR codes, bar codes, RFID tags or other tag technologies. But there are also technologies that are at the brink of large-scale breakthrough that make tags themselves obsolete. Like, for example, analyzing a product for trace elements that can then tell you quite accurately where it is actually from. Then there's blockchain. A decentralized technology can act as a catalyst for this revolution. Because it can help mitigate some of the trust issues that are inherent to giving people information and then asking them to change their consumption behavior because of that information. And so, we use blockchain technology where it adds value to what we're doing. But importantly, we don't let the limitations that this technology still has today, like, for example, with regards to scaling, we don't let that stand in our way. And that brings us to the third point. Share. How to share the information that we've verified and tracked about where a product is from, how it was produced and how it got to where it is? How to share this information is really different from product to product. And different from where you buy it. You behave differently in those situations. You are stressed and time-poor in the supermarket. Or with short attention span over dinner, because your date is so cute. Or you are critical and inquisitive when researching for a larger purchase online. And so for our fish, we've developed a digital experience that works when buying the fish in a fish specialty store and that gives you all of the information about the fish and its journey. But we also worked with a restaurant and developed a different digital experience that only summarizes the key facts about the fish and its journey, and works better in a dinner setting and, hopefully, there doesn't annoy your date too

much. \n00:09:34.250 Now, that brings us full circle. \n00:09:36.625 We've verified that the fish was caught \n00:09:39.667 in an area where it's sustainable to do so. \n00:09:42.667 We've then traced it throughout the entire supply chain \n00:09:45.292 to maintain its identity and all the information that's attached to it. \n00:09:49.417 And then, we've shared that information with consumers \n00:09:52.000 in a way that gives them a choice \n00:09:53.833 and lets them make consumption decisions \n00:09:56.000 that are more in line with their values. \n00:09:59.542 Now, for this fish example, this is already rolled out at scale. \n00:10:03.667 This season, \n00:10:04.958 the entire fleet of the world's largest toothfish fishing company, \n00:10:08.542 Austral Fisheries, \n00:10:09.917 is tagging every single fish that they catch \n00:10:12.792 and that ends up in their premium branded "Glacier 51" product. \n00:10:17.208 And you can already buy this fish. \n00:10:19.375 And with it, you can have all of the information I talked about today, \n00:10:23.292 and much more, \n00:10:24.792 attached to each individual fish or portion of the fish that you may buy. \n00:10:30.583 But this is not a fish or seafood thing. \n00:10:34.667 We're working on many, many different commodities and products \n00:10:37.875 and their supply chains across the globe. \n00:10:40.292 From dairy to fruit and vegetables, \n00:10:42.917 to nonfood products made out of wood. \n00:10:45.708 As a consumer, all of this may sound like a huge burden, \n00:10:50.250 because you don't have time to look at all of this information \n00:10:53.792 every time you buy something. \n00:10:56.292 And I don't expect you to, \n00:10:58.042 because you'll have help with that. \n00:11:01.167 In the future, we'll leave the decision of which specific product to buy \n00:11:06.542 increasingly up to machines. \n00:11:08.750 An algorithm will know enough about you \n00:11:11.000 to make those decisions for you, so you don't have to. \n00:11:15.500 And maybe it will even do a better job at it. \n00:11:18.375 In a recent study, 85 percent of those \n00:11:20.833 buying a product through a virtual assistant \n00:11:23.875 said that they, on occasion, \n00:11:25.708 actually went with the top product recommendation \n00:11:28.083 of that virtual assistant, \n00:11:29.375 rather than the specific product or brand \n00:11:31.458 that they set out to buy in the first place. \n00:11:34.208 You just say you need toilet paper, \n00:11:36.042 it's then an algorithm that decides which brand, price point \n00:11:40.500 or whether you go with recycled or not. \n00:11:43.583 Well, nowadays this is usually based on what you bought in the past, \n00:11:47.833 or whoever pays the most to the company behind the virtual assistant. \n00:11:52.042 But why shouldn't that be also based on your values? \n00:11:57.625 Knowing that you want to buy planet-friendly \n00:12:00.208 and knowing whether and how much you're willing and able to pay for that. \n00:12:05.708 Now, that will make it easy and seamless, \n00:12:09.250 but still based on granular effects and data \n00:12:11.542 to choose the right products. \n00:12:13.625 Not by necessarily doing it yourself \n00:12:15.875 but by asking an algorithm \n00:12:18.208 that knows how much you care about this planet. \n00:12:21.792 Not by necessarily doing it yourself \n00:12:23.792 but by asking an algorithm \n00:12:25.917 that is never time-poor or distracted, \n00:12:29.792 or with short attention span because of the cute date, \n00:12:33.625 and that knows how much you care about this planet \n00:12:36.375 and the people living on it, \n00:12:37.833 by asking that algorithm to look at all of that information for you \n00:12:41.708 and to decide for you. \n00:12:44.500 If we have reliable and trustworthy information like that \n00:12:48.708 and the right systems that make use of it, \n00:12:51.208 consumers will support those who are doing the right

thing\n00:12:54.583 by producing products in a sustainable and ethical way.\n00:12:58.708 They will support them every time\n00:13:00.750 by choosing their goods over others.\n00:13:04.042 And that means that good producers and processors and retailers\n00:13:09.000 will get rewarded.\n00:13:10.292 And bad actors will be forced to adjust their practices\n00:13:14.667 or get out of business.\n00:13:17.333 And we need that.\n00:13:19.000 If we want to continue to live together on this beautiful planet,\n00:13:22.792 we really need it.\n00:13:24.667 Thank you.\n00:13:25.958 (Applause)\n", "title": "tactiq-free-transcript-ygxh6KR4BPk.txt", "tether_id": null, "status": "finished_successfully", "end_turn": null, "weight": 1.0, "metadata": {"command": "context_stuff", "is_visually_hidden_from_conversation": true, "message_type": null, "model_slug": "gpt-4", "default_model_slug": "gpt-4", "parent_id": "abe863f6-cbf5-466f-a012-95215aa8f955", "request_id": "8887424d88e959d1-MXP", "timestamp_": "absolute"}, "recipient": "all", "channel": null, "parent": "abe863f6-cbf5-466f-a012-95215aa8f955", "children": [{"id": "c1485021-37a8-4ac8-be97-a7d048182cf5"}], "c1485021-37a8-4ac8-be97-a7d048182cf5": {"id": "c1485021-37a8-4ac8-be97-a7d048182cf5", "message": {"id": "c1485021-37a8-4ac8-be97-a7d048182cf5", "author": {"role": "tool", "name": "myfiles_browser", "metadata": {}}, "create_time": 1716490540.85041, "update_time": null, "content": {"content_type": "tether_quote", "url": "file-6VyLXpNioUn8gEbqcyil5Kn", "domain": "Week 1_Beyond the Tragedy of the Commons.pdf", "text": "\nContents lists available at ScienceDirect\n\nEnergy Research & Social Science\n\njournal homepage: www.elsevier.com/locate/erss\n\nPerspectives\n\nBeyond the tragedy of the commons: Reframing effective climate change governance\n\nAnthony Patt\nETH Z\u00fcrich, Switzerland\n\nARTICLE INFO\n\nKeywords: Climate policy\nTragedy of the commons\nGlobal commons problem\nTechnological transitions\n\nABSTRACT\n\nThe tragedy of the commons provides a powerful narrative for a class of environmental problems, and serves to frame them in a way that allows people to identify effective solution strategies. But the problem frame also rests on a set of factual and value-based assumptions, and is inappropriate to guide decision-making when these assumptions are violated. The climate change mitigation challenge \u2013 reducing greenhouse gas emissions, mainly from the energy sector, to limit global warming to less than 1.5 or 2 \u00b0C \u2013 violates these assumptions. Climate change requires us not to reduce, but to completely prohibit greenhouse gas emissions. Before any such prohibition is feasible, it is first essential to develop a clean energy system that can meet our basic needs. The main barriers to this are not economic, but rather are associated with evolving knowledge, networks, and institutions. Framing climate change in evolutionary terms can help us to appraise policy options more effectively, and ultimately identify those that get us where we need to go.\n\n1. The tragedy of the commons\n\nThe biologist and ethnic nationalist Garrett Hardin wanted society to restrict people's reproductive freedom, and believed that only those parents who would raise their children the right way should be entitled to have babies [1,2]. To support this politically charged belief, Hardin developed an argument based on the idea of the tragedy of the commons, a game theoretic model involving farmers letting their cows graze on the communally owned village green [3]. Every farmer obtains the full benefit of placing an extra cow on the commons to graze, while suffering only a small share of the cost to the community as a whole, in terms of less grass being available to the other cows. Overgrazing is the inevitable equilibrium, unless the community as a whole steps in. Limiting the number of cows, and ideally allocating them to

those farmers who can manage them most profitably, is the obvious solution. The lesson transferred well to the point Hardin was trying to make about people in his now famous article. Today, few would use a tragedy of the commons framing, or related terms such as commons problem, common pool resource problem, or externalities problem, to describe the issue of human population growth. This is largely because the world has witnessed birthrates falling globally, on most continents to below replacement levels, as a result of factors Hardin didn't consider: the education of women, reductions in infant mortality, and urbanization [4,5]. But most analysts do use Hardin's idea to describe other environmental problems, most notably climate change, and based on this framing suggest a strategy similar to what Hardin advocated [6]. The framing may be appropriate for some of these problems, fisheries management being an example that comes to mind. But it is not appropriate for climate change, and the sooner we stop framing climate change in this way, the better. As a starting point, it is worth considering what the key aspects of a commons problem actually are. Hardin himself described four, and these are as valid today as they were then. First, of course, there needs to be a common pool resource, such as the grass on a village green, or the global carrying capacity for people. Second, there needs to be a use of that resource, or an activity that depletes it, that is legitimate and valuable, accepted by society at large. In Hardin's model, we do want cows to graze on the village green, as long as they do so productively, just as we do want a planet that is home to people. In fact, because the use is so valuable, we want to ensure that it takes place in a manner that is both optimal and sustainable. Third, the common-pool nature of the resource has to be the thing that leads people to overuse or over-deplete the resource, to the point that is clearly suboptimal, perhaps even exceeding its sustainable limits. Fourth, there cannot be a technical solution. By this, Hardin meant that it is not possible to use technology to expand the resource in order to continually accommodate the growing use. The tragedy of the commons acts a problem frame. The effect of a problem frame is to take a complex issue which affects multiple values and can be considered from a variety of perspectives and to simplify it around one particular conceptualization, leading to one particular solution strategy [7]. In the case of this framing, it is the third

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listed in the paragraph above that is crucial. The common-pool ownership structure, meaning that agents do not pay the full cost of their use, is seen as the driving force behind their overuse. Framing a problem as a tragedy of the commons automatically implies that if one could privatize the ownership structure, or make the agents pay the full costs to society of their use of the resource, then an optimal outcome would be achieved. In the case of a village green, the easy solution is to divide it up with fences, and have each subdivided plot belong to a single farmer. In the case of a resource that

cannot be subdivided so easily, like the global carrying capacity for humans, then the solution is only slightly more complicated. Either one has to establish a limited number of rights to use the resource, and allocate these to people in advance, or one has to charge people ex post for their use of the resource. An important feature of the model is that the solution increases the resource's overall productivity. And that means that as long as the allocation mechanism or tax is fair, then reaching an agreement to privatize the use rights or internalize their costs should be politically feasible.

But the usefulness of such policy guidance depends on the underlying applicability of the problem frame. The presence of a common pool resource does not guarantee that Hardin's solution strategy is the best; the problem frame ceases to provide useful guidance if any of the other three criteria are violated. A case that illustrates failure on the second of the four criteria is the act of murdering one's neighbor. This depletes the common pool resource of public safety, but murder is not an activity that we want, so we don't solve it by imposing a tax or allocating a limited number of permits. We prohibit it. To illustrate failure on the third criterion, drinking alcohol is a behavior that we tolerate in moderation, and even encourage in some situations, but when people get drunk and start breaking things, they become a public nuisance. Yet we don't believe that internalizing the cost of drunken behavior will get the person on the verge of intoxication to say no to another drink. So we address it by other means, including charging bartenders with cutting people off, and providing treatment programs for alcoholism. To illustrate failure on the fourth criterion, the local public school may be overcrowded, but we can solve this by enlarging the building and hiring more teachers. So we do that, rather than limiting the number of places available or imposing high school fees.

Failure on any of these criteria matters. Climate change fails on all three.

2. Why climate change fails the tragedy of the commons criteria

Many people see the 2015 Paris Agreement as representing a turning point in climate governance, but in fact the events that foreshadowed Paris occurred a decade prior to then, culminating in 2007. It was then that the idea of the 2 °C target gained popularity, based on risk management arguments, and was incorporated into a global action plan agreed to in Bali, Indonesia, at the closing of a failed set of negotiations to extend or replace the Kyoto Protocol [8]. Paris built on this decision, and added an additional level of ambition by suggesting the desirability of limiting climate change to 1.5 °C. More importantly, Paris set up a process that could help countries to take the steps to achieve one or the other, in terms of a regular global stocktake, as well as a set of mechanisms to provide financial and capacity-building support to developing countries.

The one thing that the Paris Agreement does not include is a set of negotiated binding national targets, of the kind that are the heart of the Kyoto Protocol. In fact, the failed desire to include such binding targets is what led to the eight-year delay, starting in Bali. And yet this failure should not surprise us, for a simple reason. The tragedy of the commons framing suggests that negotiating binding targets should be politically feasible, with the main hurdle being the identification of a mutually acceptable allocation rule for the net benefits. But this presupposes that the global target is one that will maximize the value to society of whatever activity it is that degrades the common pool resource. Partial decarbonization as per Kyoto could take place by eliminating inefficiencies in the energy system, and arguably could deliver immediate net economic benefits; negotiating the allocation

rule took less than two years. Achieving the Paris targets of 2 °C or 1.5 °C, however, requires that net anthropogenic emissions of greenhouse gases into the atmosphere cease entirely in the second half of this century [11].

Finding immediate net benefits to allocate that are associated with a complete halting of emissions is more or less impossible, and so negotiating such an agreement required convincing people to pay attention to large benefits anticipated in the future, in some cases centuries hence [12,8]. So the temperature target qualitatively changed the character of negotiations, making them far more difficult, arguably impossible. More fundamentally, the need to eliminate emissions entirely, essentially as soon as possible, makes those emissions something that society will no longer tolerate. So climate change fails the second of the four criteria Hardin identified, just like murder.

There has been another major change since about 2007, and that is the recognition that the medium-term costs of eliminating greenhouse gas emissions are likely to be trivial, and may in fact be negative, even before considering the long-term benefits from avoided climate impacts [13,14]. What drove this recognition was the realization from the field of evolutionary economics that policies to expand renewable energy also make them cheaper [15,16]. This fact has become especially salient lately, as the costs of supplying energy from some renewable resources have fallen to below those of fossil fuels [17], especially if one takes into account local environmental effects such as air pollution or water demand [18]. A study in the United States, for example, examined the avoided local and regional environmental impacts associated with installing wind and solar power instead of new coal capacity, and found the value of those impacts to be far larger than the difference in cost between the two technologies [19]. As another example, the costs to own and drive an electric car charged by wind or solar power are approaching parity with those of a conventional gasoline model, at least under some conditions [20].

These trends suggest two additional ways in which the tragedy of the commons framing fails for climate change. First, there is no longer a necessary misalignment of incentives between the emitters of greenhouse gases and society at large. Every country, with the possible exception of major oil and gas exporters, has reason to mitigate climate change and transform its national energy sector away from fossil fuels, regardless of what other countries may do. Every household will soon have a financial incentive to stop burning oil and gas, regardless of what their neighbors do. So if fossil fuels are still in business, it will not be because of an unjust cost advantage, born from the existence of an externality. Climate change is like the example of public drunkenness: internalizing the cost will not change anything qualitatively. Second, it now appears that a technical solution does exist for climate change. Integrated assessment models suggest that by switching to non-fossil energy sources, we can continue to see global economic activity grow, at roughly the same pace, even as greenhouse gas emissions come to a halt [21]. Climate change is like enlarging the public school.

3. Framing today's challenge in evolutionary terms

But we still have a problem needing to be solved. Using electric cars as an example, a household may soon have a financial incentive to switch over from their gasoline model, but it will not do so unless there is a dense network of charging stations where they want to take long trips. At the same time, there is no business case to install such a network as long as the number of electric cars on the road remains low. This is a chicken and egg problem: you need a chicken to get an egg, but an egg to get a chicken. Similar problems exist across the energy sector. At the most

general level, we need to prohibit greenhouse gas emissions, which almost certainly means prohibiting fossil fuels. But which comes first: prohibition, or clean energy? Before prohibition can be politically and socially feasible, we need a clean energy system that is. *Patt Energy Research & Social Science* 34 (2017)

1. It is good enough to sustain us. Yet given more than a century already spent improving and optimizing an energy system based on fossil fuels, the first steps towards a clean energy system are necessarily expensive, clumsy, and unreliable. Most of the improvements to the clean energy system built around new knowledge, networks, and institutions only come once we start relying on it. Progress can occur, but without policy intervention, it will be slow. It took millions of years to get a chicken when the starting point was a dinosaur. Accelerating evolution is the key challenge for climate policy. Just as the tragedy of the commons framing offered clear guidance in terms of the appropriate policy instruments, so too does an evolutionary framing, based on insights from the emerging scientific study of socio-technical transitions [22]. Our policy instruments need to be those that build the new knowledge, networks, and institutions that will enable a clean energy system to function smoothly and affordably, which is a prerequisite to phasing out fossil fuels. When we think about all of the policies that support renewable energy innovation and deployment state-sponsored R & D, tax credits or feed-in tariffs for project developers, and streamlined permitting processes for green infrastructure that is exactly what is going on. As they create a new system that is viable, these policies lay the groundwork for a second generation of sectoral regulations, already beginning to appear, which prevent new investment into fossil fuel infrastructure. If you frame climate change as an evolutionary problem, it is this sequence of policy instruments that makes the most sense [23]. The issue of how we frame climate change mitigation is important, precisely because the two framings point us in different directions with respect to policy. When there is a true tragedy of the commons, then neo-classical economics and game theory provide a solid basis to favor market-based instruments, those that allocate limited rights to deplete the resource or internalize the costs of doing so [24]. Confusion can arise, however, because proponents of market-based instruments also suggest that these will provide the needed stimulus for innovation, promoting systemic change [25,26]. But just because these instruments are the best solution to one kind of problem does not mean they are very good or effective with respect to another. In fact, a growing literature shows that they aren't, and that the effective policies to stimulate a transition are those that directly support the development of new knowledge, networks, and institutions, directly addressing the barriers to systemic change [27]. The choice of how we frame climate change dictates the terms by which we evaluate the relative strengths and weaknesses of the different possible solution strategies. Judged by the appropriate criteria, market instruments are generally a poor fit. The tragedy of the commons framing made sense at a time when we believed that people needed to adjust the energy system at the margins, and believed that the cost of doing so would be high. We no longer believe these things. The atmosphere may be a common pool resource, but using it as a place to put our greenhouse gas emissions is no longer something for which we have any long-term rights to allocate. To prohibit dumping our greenhouse gases there, we first need to accelerate a technological transition towards non-fossil sources of energy, for which the main barriers have to do with knowledge and networks, rather than an inherent difference in cost. Policies

providing active and indirect governmental support for new technologies and technological systems can change the conditions that hold the new technologies back. In fact they have already done a great deal; they have led to a dramatic decline in the costs of key energy technologies, and contributed to the possibility that global emissions have already peaked. There is still more work to be done, and we can solve climate change if we build on what we have learned. At all costs, we should resist the temptation to reverse course because the policies don't fit one man's convenient story of too many cows on a village green.

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earlier modules, the challenges of sustainable development are deeply rooted in
systemic issues exacerbated by capitalist structures that prioritize profit over
people and planet. This critique aligns with the discussions in various readings about
capitalism's impact on sustainability and inequality.\n\n1. Integration of
environmental, economic, and social dimensions: This approach is crucial for
addressing the complex interdependencies that characterize sustainability challenges.
As discussed in 'Beyond the Tragedy of the Commons,' effective climate
governance cannot be achieved through traditional market mechanisms alone, which are
often recommended by capitalist ideologies. Instead, there needs to be an integration
of policies that address environmental, economic, and social issues holistically. This
is critical for moving beyond short-term profit motives to achieve long-term
sustainability goals.\n\n2. Systems thinking: The necessity of systems thinking
was echoed in 'A Behavioral Approach to the Rational Choice Theory of Collective
Action,' which explores how expanding the scope of rational choice models can
better address social dilemmas through collective action. This reflects the need to
look beyond the immediate economic benefits and consider broader systemic impacts,
challenging the capitalist norm of individual maximization at the expense of
collective well-being.\n\n3. Stakeholder engagement: Engaging diverse stakeholders
is essential for developing sustainable solutions that are inclusive and effective.
The discussions in 'Why System Dynamics Should Become Part of Secondary School
Math Instruction' highlight the potential of system dynamics to involve various
stakeholders in understanding and addressing complex systems. This approach counters
the capitalist tendency to centralize decision-making power, promoting a more
democratic and equitable process.\n\nThese dimensions, reinforced by your experiences
and readings, highlight the inherent contradictions between capitalist structures and
sustainable practices. Capitalism often drives decisions that prioritize immediate
economic gains, undermining long-term environmental sustainability and social equity.
By adopting a more integrated, systemic, and inclusive approach, as suggested by the
readings, we can develop strategies that truly address the multifaceted nature of
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