# Navigating Interdependence:

## An ecosystem approach to visualizing complex systems

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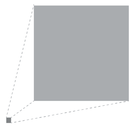
## Abstract

The visualization of complex systems can benefit from adopting an ecosystem model for design decisions. Considerations of tone, structure, user agency and content of the graphic depend on its primary purpose: whether to explain a concept or series of ideas, excite the user, or to use exploration of the data to enable discovery. Systematic analysis of these different criteria supports the creation of specific guidelines and informs the overall design of a coherent visualization system.

## The challenge of complexity

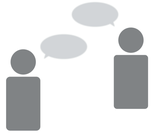
Complexity poses many interesting challenges for design. Complex systems share several basic properties. First, they are interdependent: synergies and feedback loops connect different components and determine how the whole system functions, making it difficult to study any one piece in isolation from the rest. This interdependence often spans multiple length and time scales, making it difficult to define a single problem for study. Differing definitions of a problem often lead to disagreements over the best approach to solve it. It can be particularly difficult to reach consensus when these disagreements are informed by different value systems or cultural framings.

1) inherent interdepence



2) issues of scale

3) questions of definition

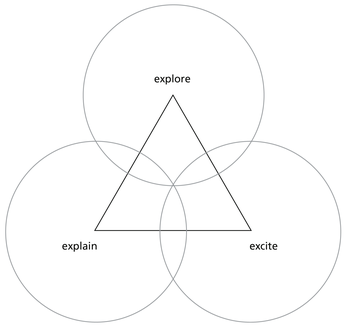


4) problems of communication

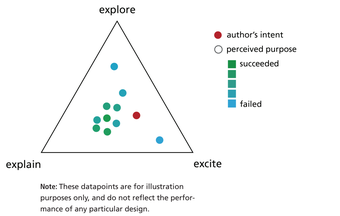
Designers can help by building infrastructures and methods to visualize interdependence, and by creating ecosystems that present data at different scales or from different perspectives. Introducing considerations of personal values and conceptual framings into the discussion of scientific data can also help to break the deadlock that results from faulty or incomplete communication.

## Purpose of a design

Identifying the specific purpose of a visualization can help to inform the design process and guide decisionmaking. Clarifying design purpose can inform thoughtful application and critique of graphical forms. Judging design decisions within the context of their original purpose and intended function moves the conversation beyond simplistic rules of thumb and creates opportunities to discuss when, why and how a particular solution might be used.




As an assessment technique, this approach can help to identify the strengths and weaknesses of a particular design. Comparing an author's intended purpose with the perceived purpose and efficacy reported by their audience can help to identify gaps and inconsistencies in the visualization, creating a more nuanced view of its success in the design space.




**Note:** These datapoints are for illustration purposes only, and do not reflect the performance of any particular design.

A user must move through different levels of engagement and detail to understand a complex system. Helping the user to navigate through many layers of information without becoming overwhelmed is a key challenge when designing for complex systems.


## Strategies

The tone and structure of the visualization, the degree of user agency that it grants, and the content it presents should all reflect the primary purpose of the design. These considerations can be further broken down into a series of choices that position a visualization within the design space and can be used to ensure construction of a coherent design.

**Tone**

formal — casual

reason — emotion

The tone of a visualization describes the kind of language and visual style used, as well as whether it appeals primarily to emotion or logic.

**Structure**

linear — nonlinear

exposition — narrative

Structure identifies the relationship between different components of the visualization. Linear forms are more likely to be used to support an expository argument or narrative, while nonlinear forms can allow for more open-ended exploration.

**Agency**

designer control — user control

explaining — exploring

conclusions — reasoning

Agency describes the balance of control between user and designer. A user might be allowed to explore and reach his or her own conclusions, or the design could be focused on explaining a particular approach to understanding the data. Conclusions might be presented as facts, or as a particular line of reasoning that invites the user to respond with their own perspective.

**Content**

certainty — ambiguity

sources cited — sources hidden

alternatives — single viewpoint

The content of a graphic refers to the level of information shown, and the level of certainty implied in the visualization. Standards for citations and the detail included about limitations and alternate interpretations of the data vary dramatically depending on the use case.

## Guidelines for design

The taxonomy above was used to articulate specific guidelines for a visualization ecosystem intended to present scientific information to the public.

### Tone

**1** Use wonder, aesthetic interest and curiosity to encourage engagement

### Structure

**2** Provide narratives to guide the user

**3** Support undirected exploration — use modular components, make multiple cross-references

**4** Show relationships and use transitions to preserve context

### Agency

**5** Provide opportunities to switch between narratives. Allow users to preview selections.

**6** Indicate user progress/history

### Content

**7** Clearly separate data from interpretation

**8** Explain limits of certainty and compare alternate interpretations; may be supported by a scenario-setting or experimental approach.

### Conversation

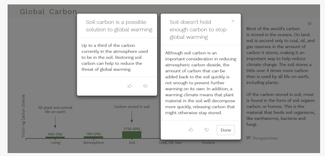
**9** Create tangible records of interaction

**10** Support action; incorporate the personal/local, allow user to contribute to information shown

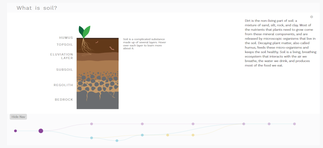
## Application

These guidelines structured the design of a website that served as a case study in science communication. The site should be approachable to even a casual user, support exploration, and convey the complex interrelationships between food consumption, land use, and soil health.


The navigation page serves as an overview of the site content, allows the user to select a narrative of interest, and serves as a foundation for the page navigation system.

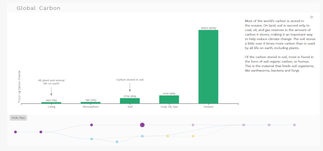



A modal popup presents different perspectives on the data and allows the user to agree/disagree with each. Votes could be tallied and visualized to create a personalized overview of reactions for each user. These overviews could then be used as tools to support further conversation.



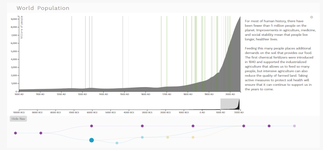



Icons represent aspects of the soil ecosystem and introduce the user to general concepts, focusing on the interdependence of the system and the services that it provides. The framing is positive, with a focus on inspiring wonder rather than fear.



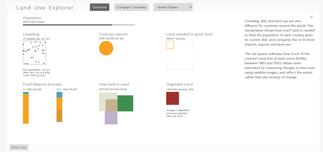



Simple summary graphics introduce the user to broad trends and important information about the soil ecosystem.

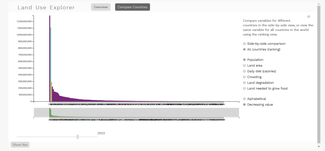





Interactive and linked graphics help the user to make connections between ideas, and encourage them to begin querying the system.








Exploratory graphics allow the user to set filter criteria and visualize statistical data in different ways, allowing users to query the system, and hopefully form and test their own hypotheses.