Resilience Analysis of Complex Systems

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Systems:

- Simple systems are those with very few state variables that behave in a readily understood and predictable manner.
- Complicated systems are those with many state variables. Once understood, they still behave in a predictable manner.
- Complex systems, because of internal interactions and feedback mechanisms between the state variables, they tend to generate surprises in behavior.

Complex System:

All human-environmental management problems which involve public health and public policy are complex systems.

Traditional Approach:

- Traditional environmental models are designed to control change in systems that are assumed to be stable.
- We can characterize this approach as the "Command-and-Control" approach.
- Examples are numerous and applications are in Simple and Complicated Systems.
- Premise is "the change is possible to control."

System Change:

- Human-environmental systems do not respond to change in a smooth and predictable way.
- A stressed system can suddenly shift from a seemingly steady state to a state that is difficult to reverse to the original state.
- Not only systems in nature (and society) change, but in long time periods they also change how they change.

System Change:

- This concept is in contrast to the perspective of a world that is in near equilibrium and/or in steady state as it is defined in our current models and applications.

- This distinction should be paid attention when human-environmental systems are studied.

Observation:

Studying the components of human-environmental systems in isolation from each other is no longer a meaningful approach.

Premise:

When a system is pushed by natural or social stresses to a tipping point the feedbacks from that abrupt change can be unpredictable.

Conclusion:

Without improved understanding of tipping points, we will remain unable to forecast the likelihood of disruptive abrupt changes, and we will remain ill prepared to mitigate their impacts.

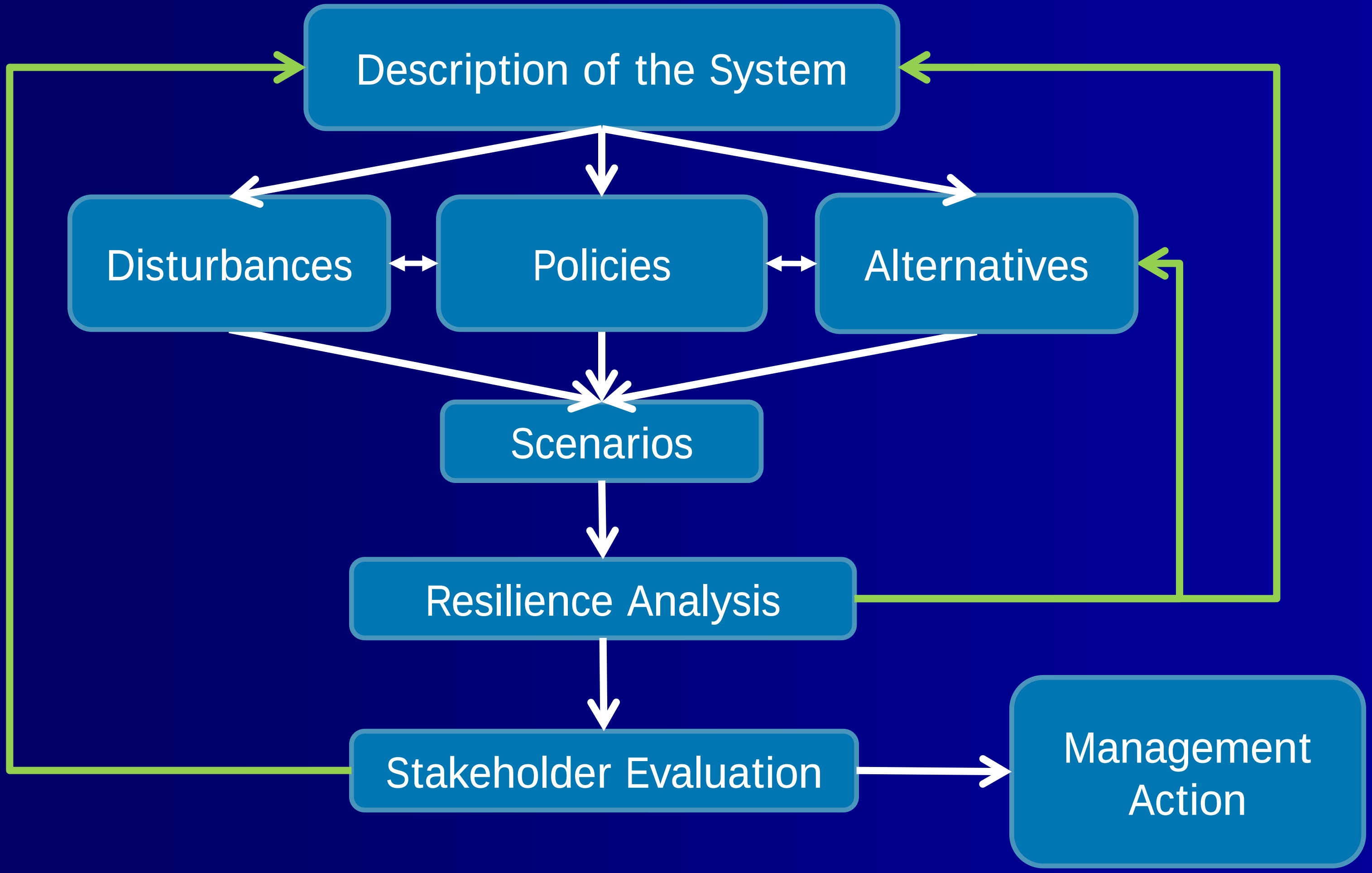
Resilience Terminology:

- It is important to understand and quantify the return to equilibrium concept – if at all the system does return to equilibrium.
- And question what happens if it does not?
- This brings about the concept of stability domains.
- Which is followed by the terms: Resilience and
  - Resistance, R.
  - Panarchy, Pa.
  - Latitude, L.
  - Precariusness, Pr.

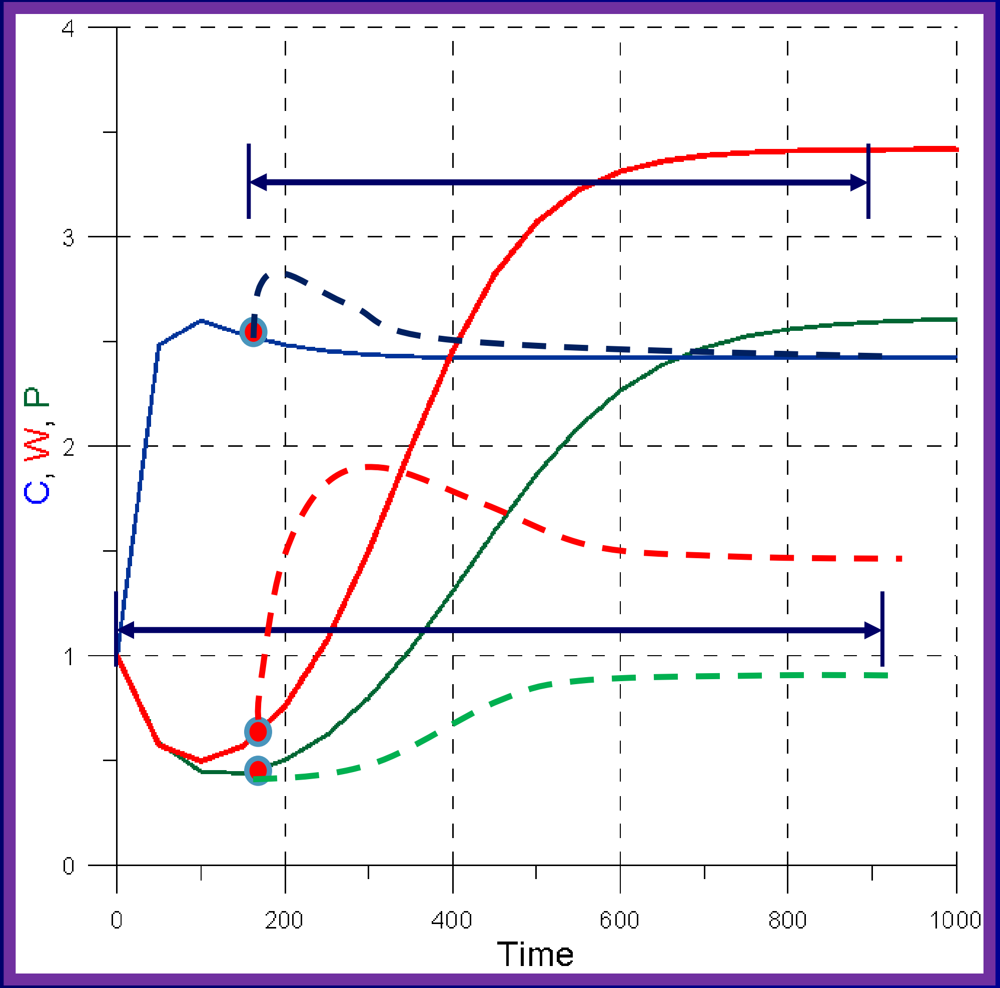
Components of Resilience:

- **Latitude** is defined as the maximum amount the system can be changed before it loses its ability to recover;
- **Resistance** is the ease or difficulty of implementing a change on the system;
- **Precariousness** is the current trajectory of the complex system, and how close it currently is to a threshold which, if breached, makes recovery difficult or impossible or moves the system to another state; and,
- **Panarchy** is an indicator to measure how the above three attributes are influenced by the states and dynamics of the other systems that comprise the overall **complex system** at scales above and below the scale of interest.

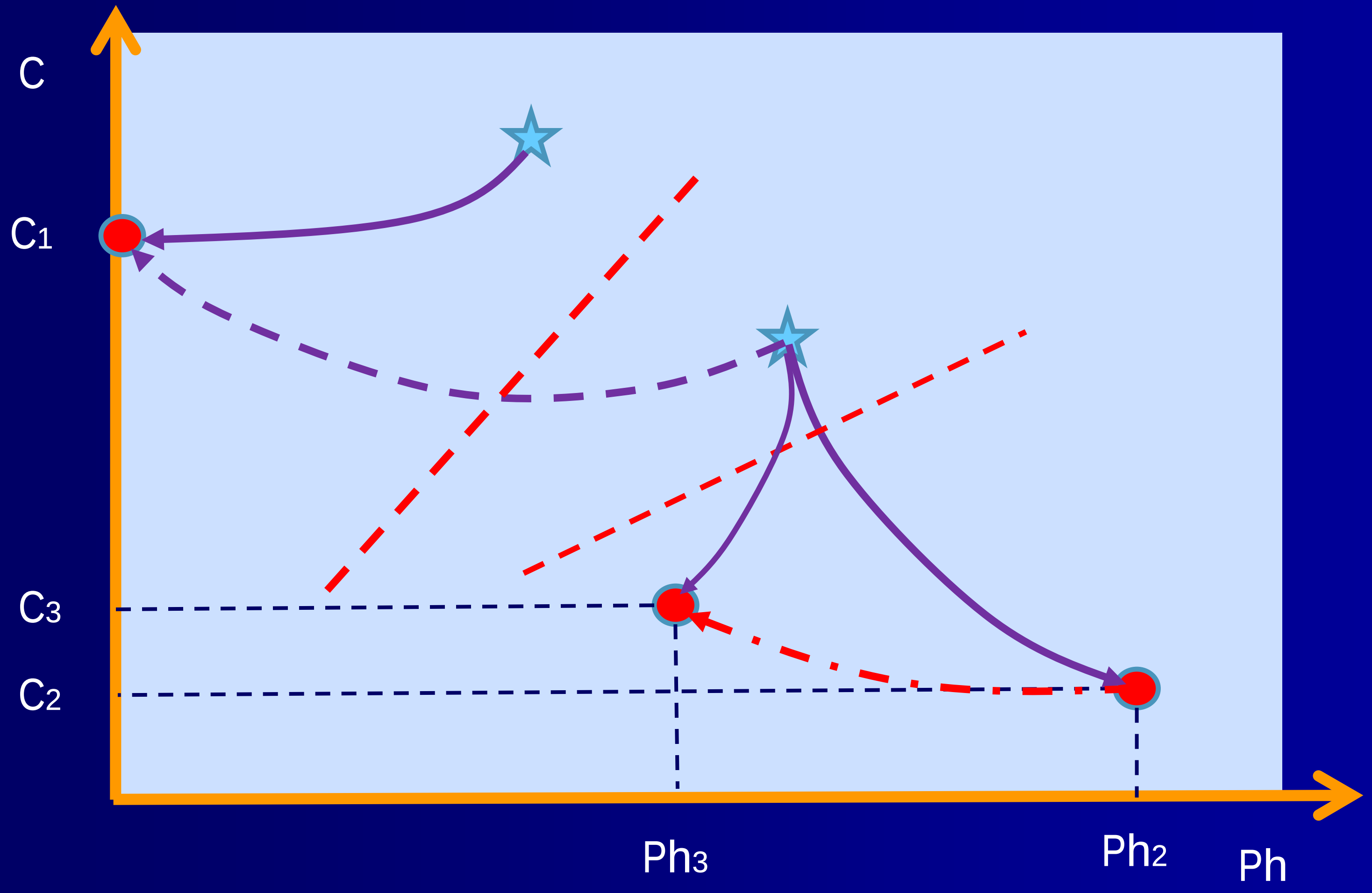
Resilience Analysis:



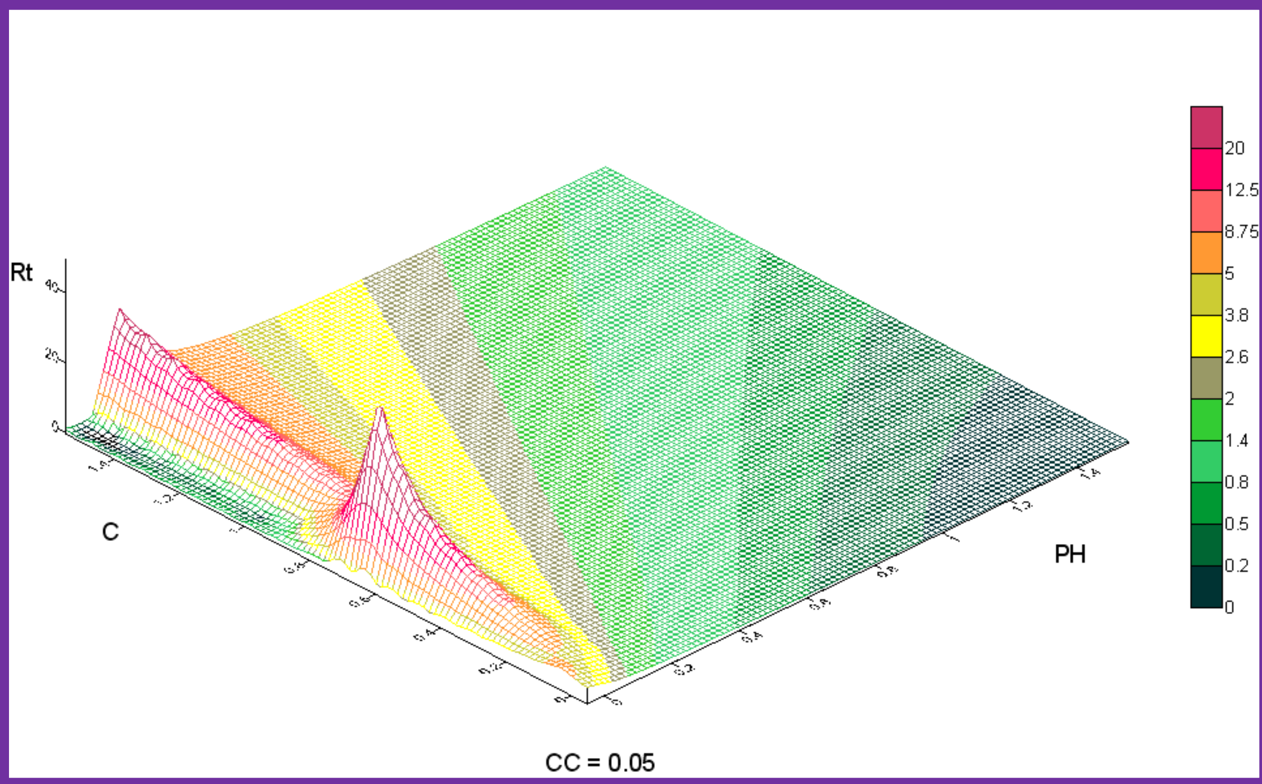
Example: Return time



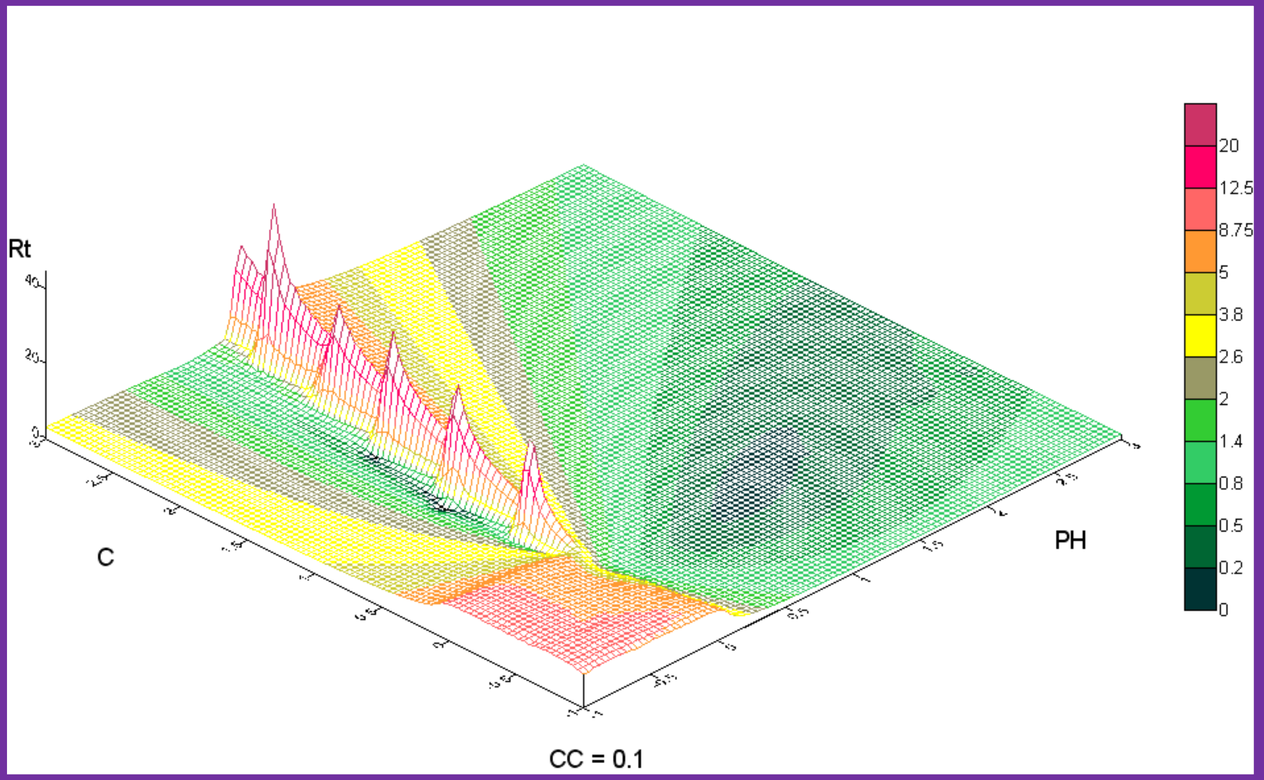
Example: Thresholds



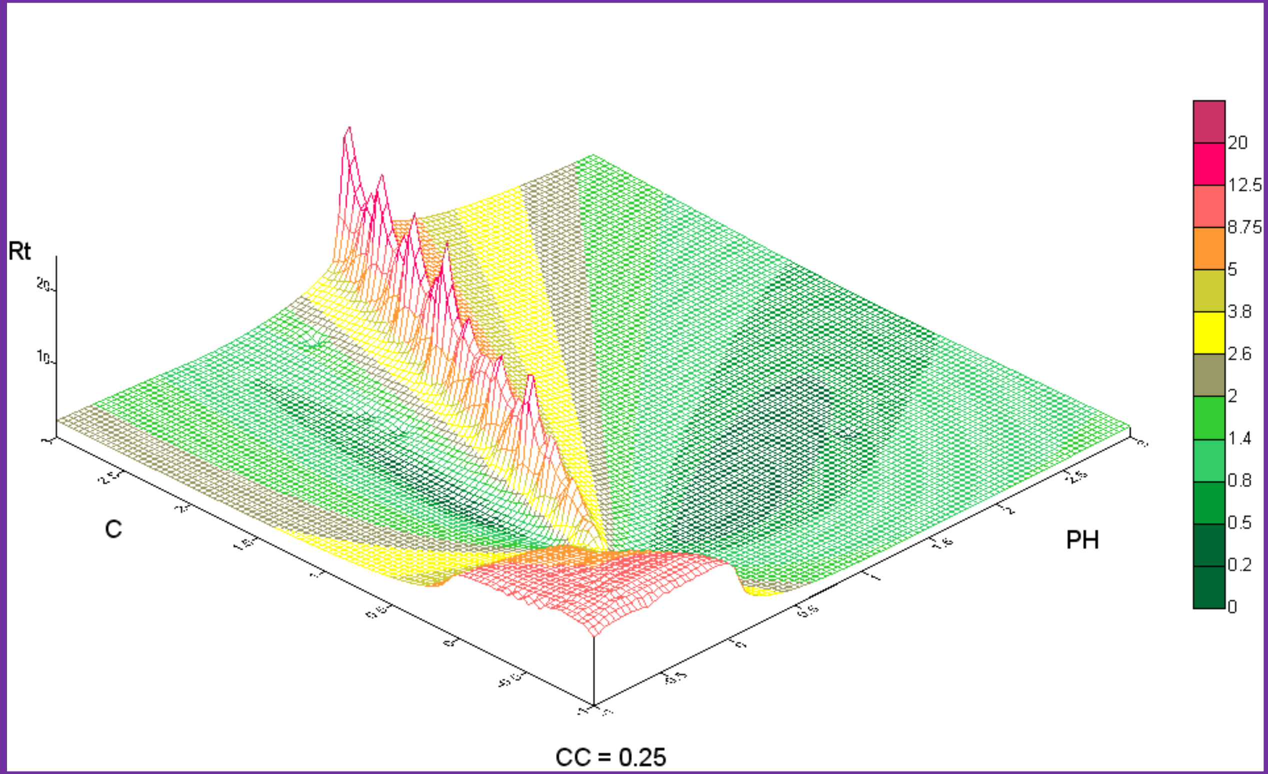
Phase Diagram: (CC = 0.05)



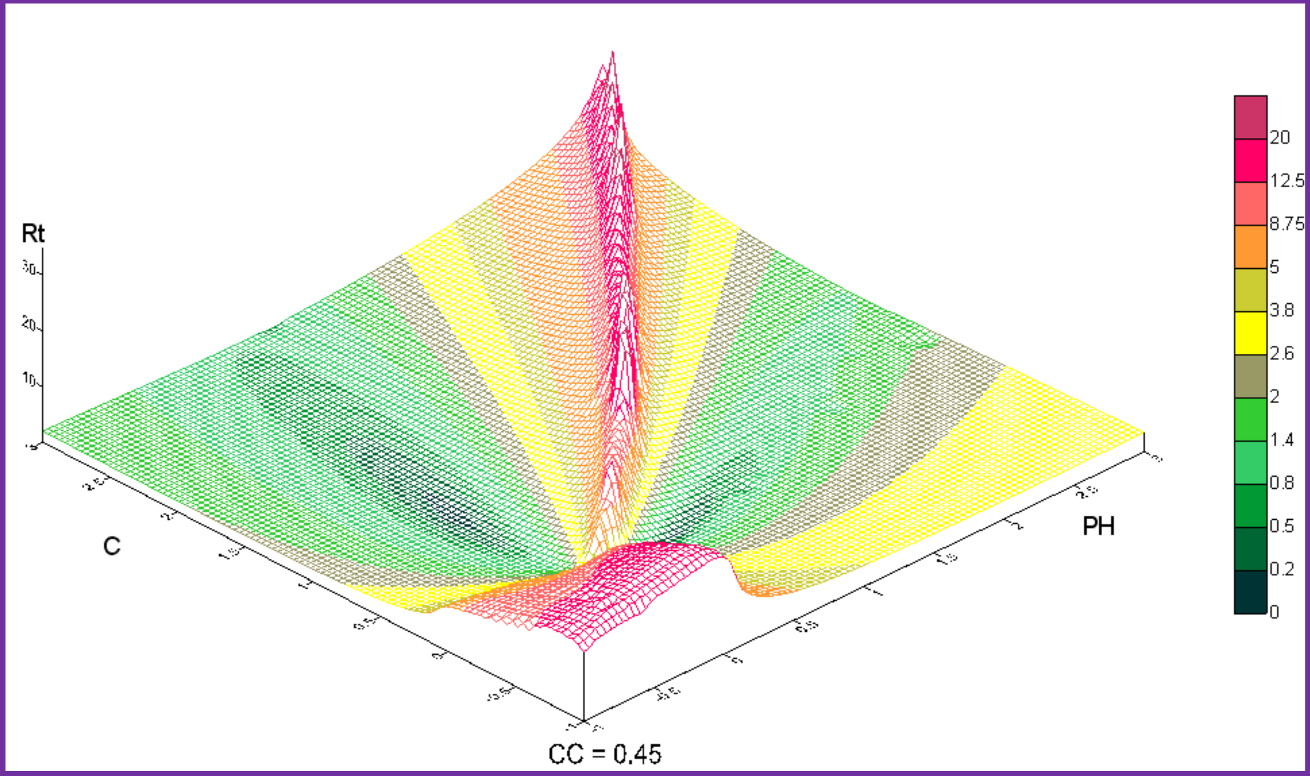
Phase Diagram: (CC = 0.1)



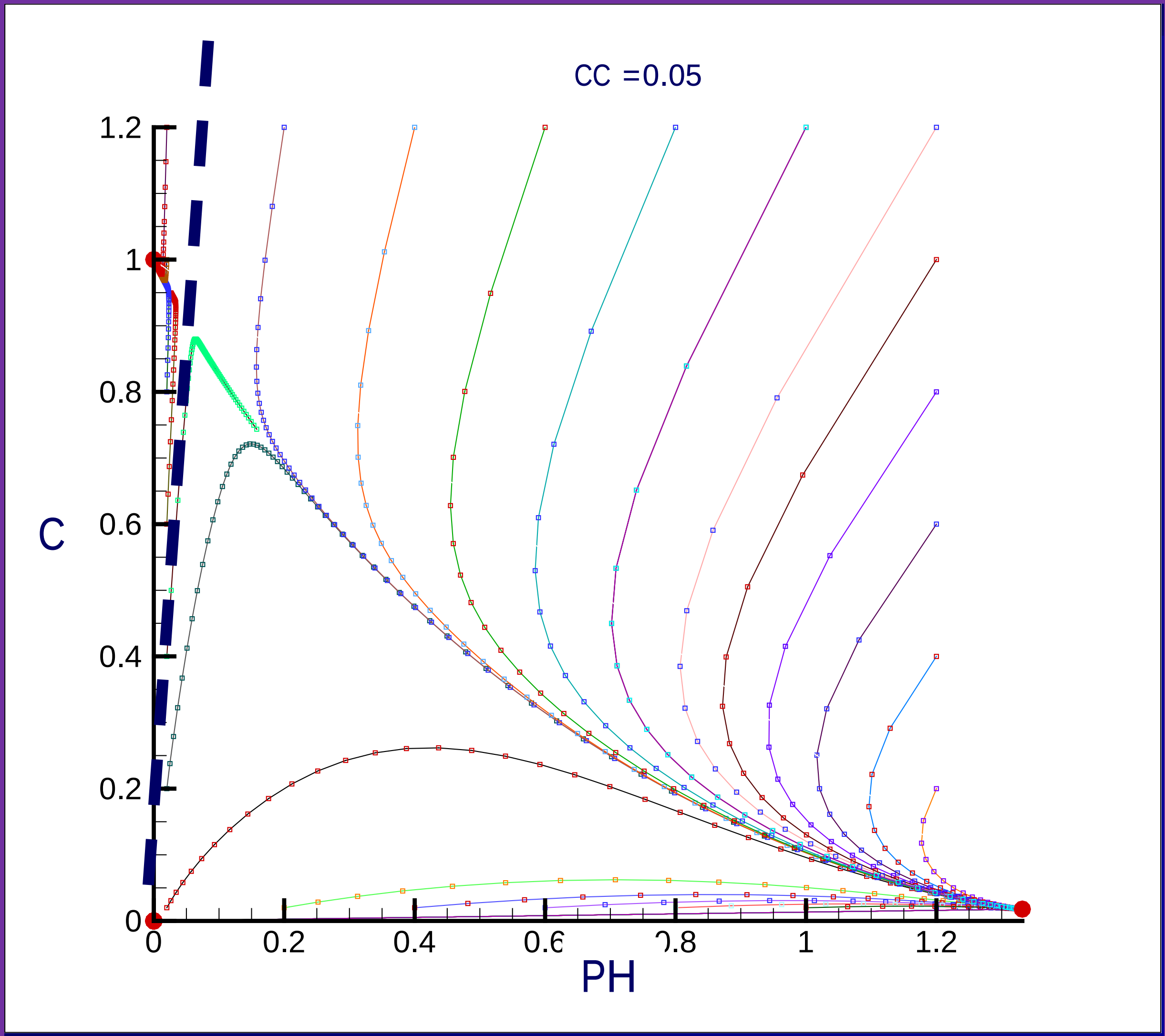
Phase Diagram: (CC = 0.25)



Phase Diagram: (CC = 0.45)



Scenario 1:



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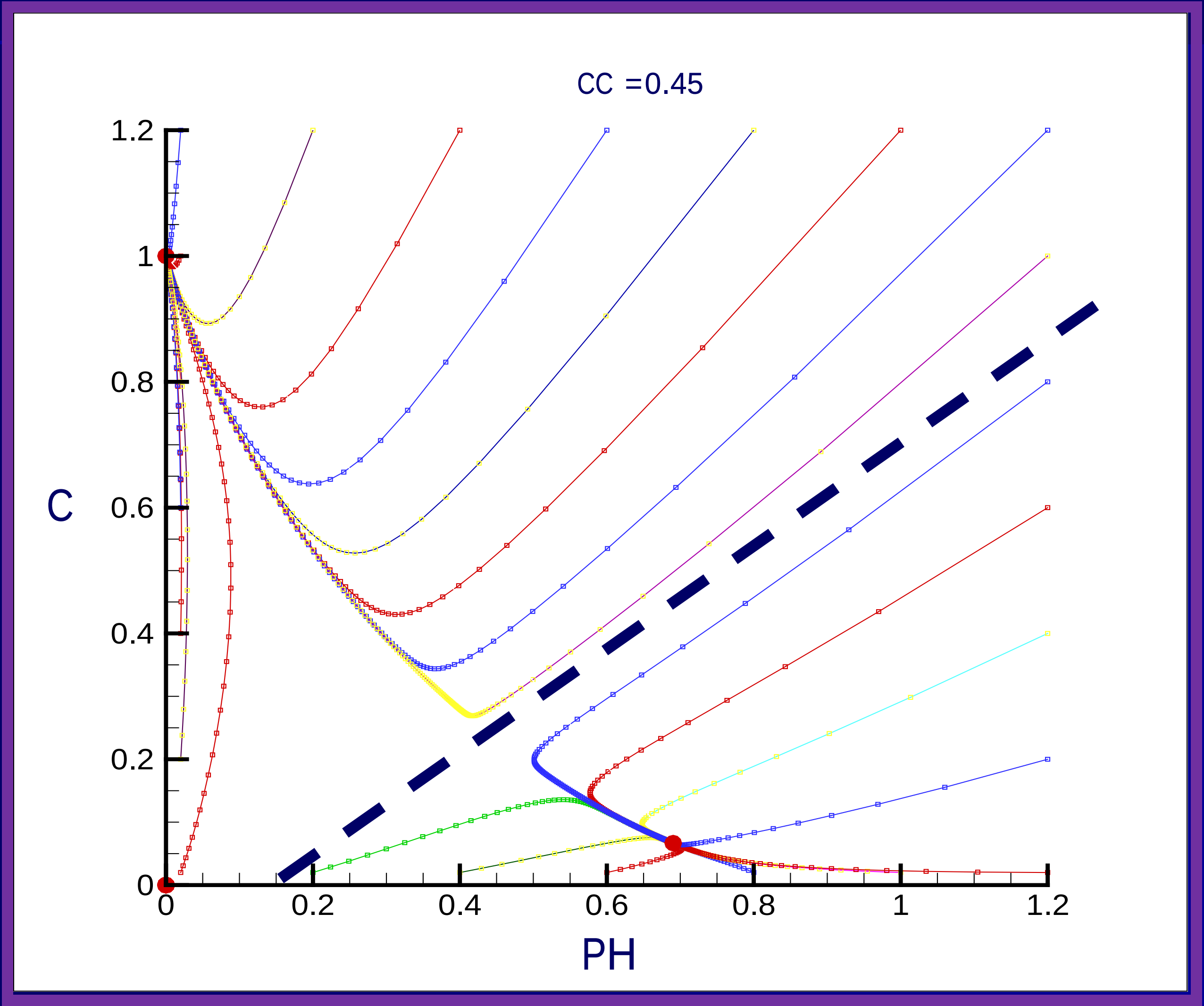

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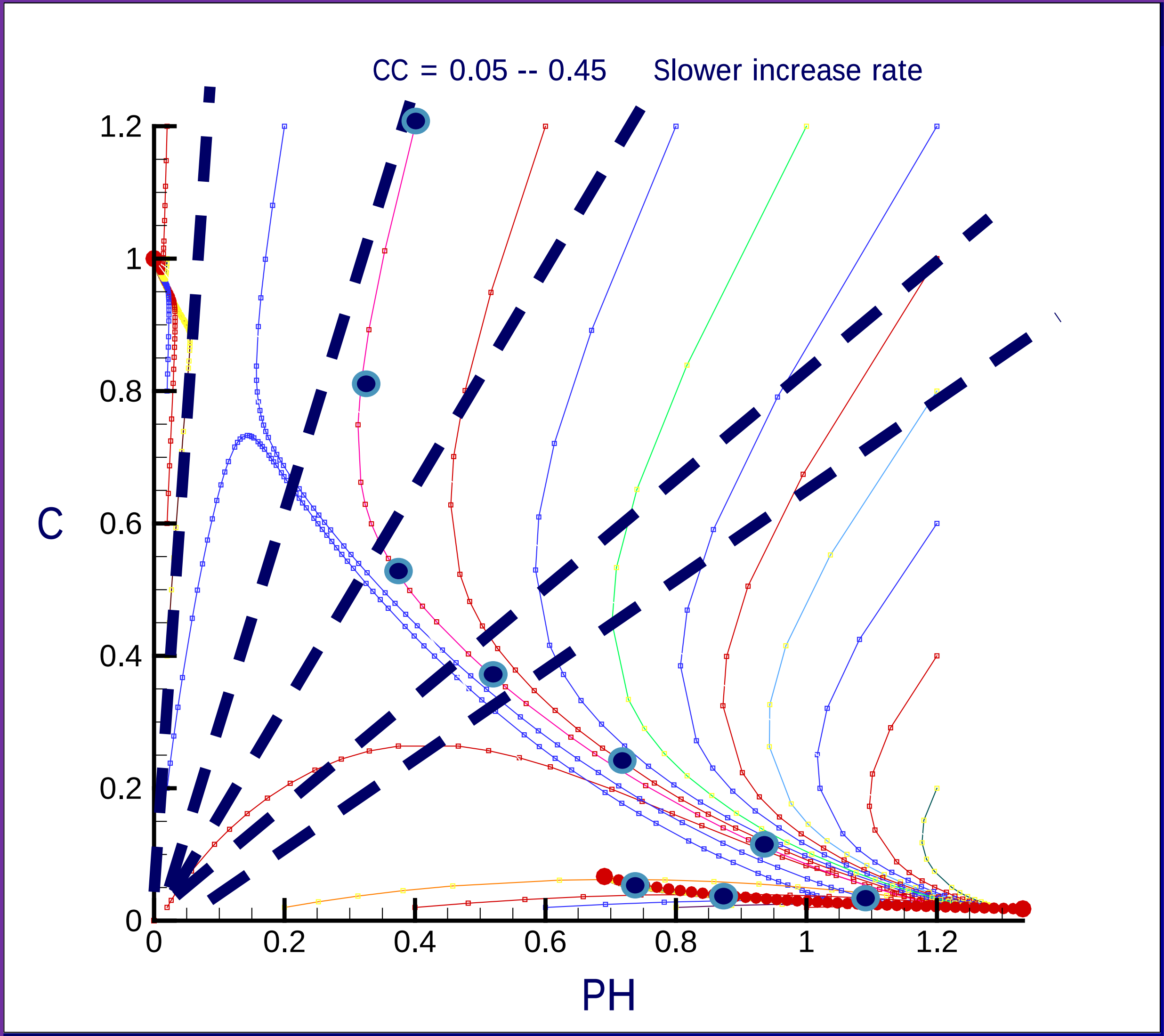

Environmental management is complex especially when it involves humans.

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