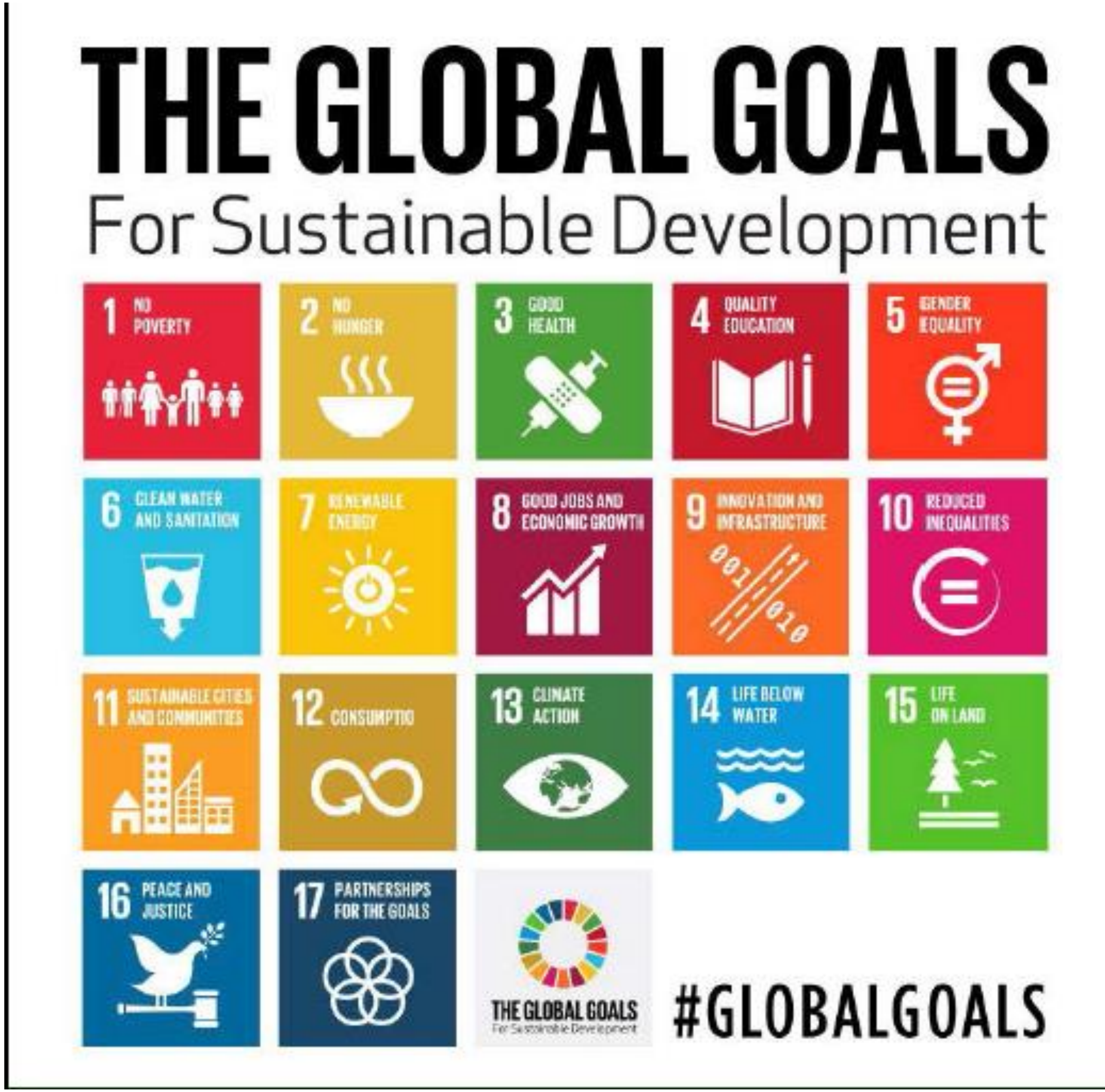
Lecture 15

UN
Sustainable Development Goals



REVIEW ARTICLE
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nature sustainability

Nexus approaches to global sustainable development

Jianguo Liu[1]*, Vanessa Hull[2], H. Charles J. Godfray[3,4], David Tilman[5], Peter Gleick[6], Holger Hoff[7,8], Claudia Pahl-Wostl[9], Zhenci Xu[1], Min Gon Chung[1], Jing Sun[1,10] and Shuxin Li[1]

Table 1 | Nexus examples and direct relationships to SDGs

Nexus example	SDGs
Food-energy-water nexus[32]	2, 7, 6
Water-food-energy-climate nexus[128]	6, 2, 7, 13
Food-energy nexus[129]	2, 7
Food-water nexus[130]	2, 6
Energy-water nexus[131]	7, 6
Energy-economic growth-CO_2 nexus[132]	7, 8, 13
Water- energy-land nexus[67]	6, 7, 2
Energy-water-food-education nexus[133]	7, 6, 2, 4
Water-energy-people nexus[134]	6, 7
Women-water nexus[135]	5, 6
Energy-poverty-climate nexus[136]	7, 1, 13
Food, energy, water, and health nexus[137]	2, 7, 6, 3
Tourism growth-water security nexus[138]	9, 6

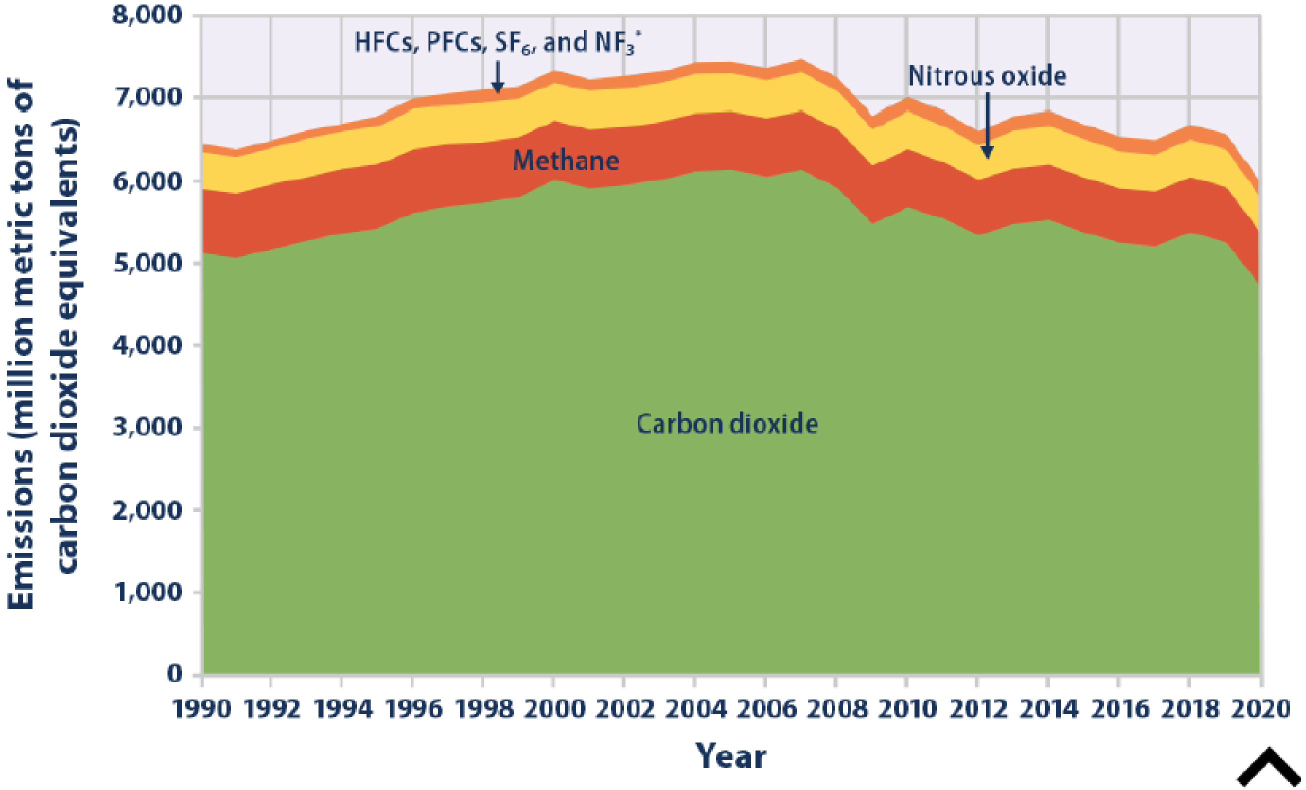
SDG PYRAMID

SUSTAINABLE DEVELOPMENT GOALS

United in Diversity Creative Campus @ Kura Kura Bali

Sustain Resource Availability
Strengthen Institutions and Collaborations
Preserve Terrestrial Biodiversity
Reduce Inequities
Build Partnerships
Preserve Aquatic Biodiversity
Reduce Poverty
Food
Water
Energy
Enhance Food Production and Security
Enhance Water Security
Innovations to Expand Industry and Jobs
Promote SMEB Innovations and Industry
Reduce Greenhouse Gas Emissions
Increase Energy Security
Expand SMEB Literacy
Boost Equal Gender Access to Resources
Lower Consumption And Production Costs
Enhance Health And Well-Being

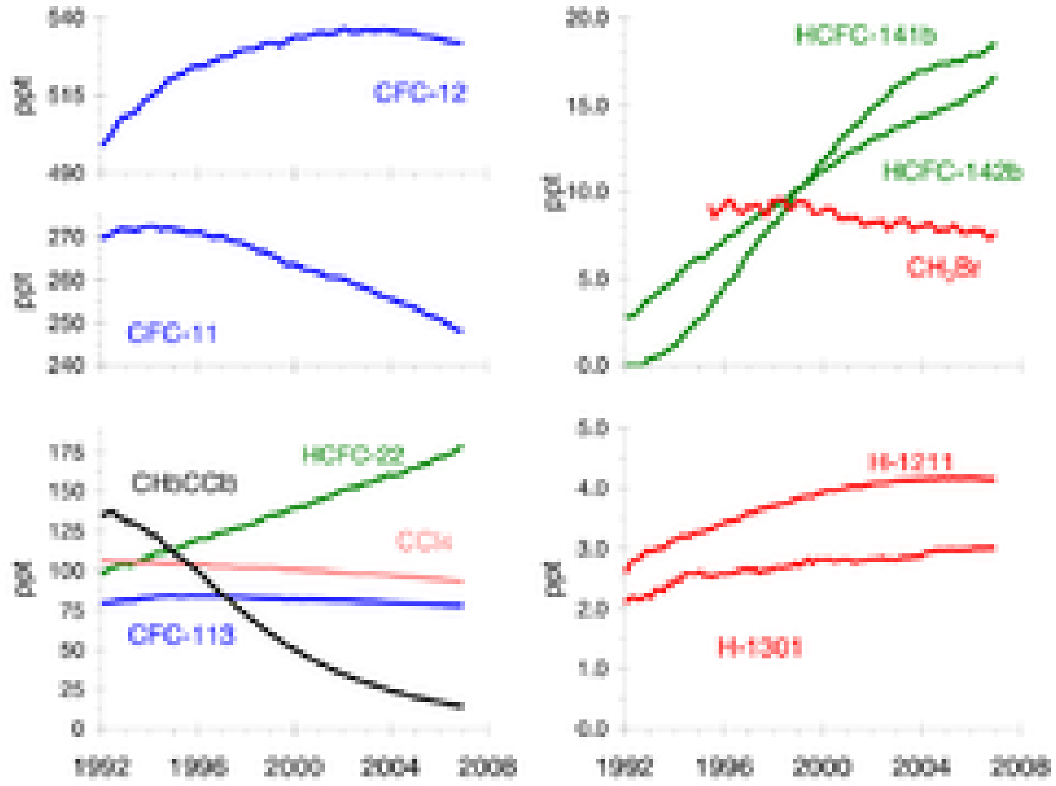
Figure 1. U.S. Greenhouse Gas Emissions by Gas, 1990–2020

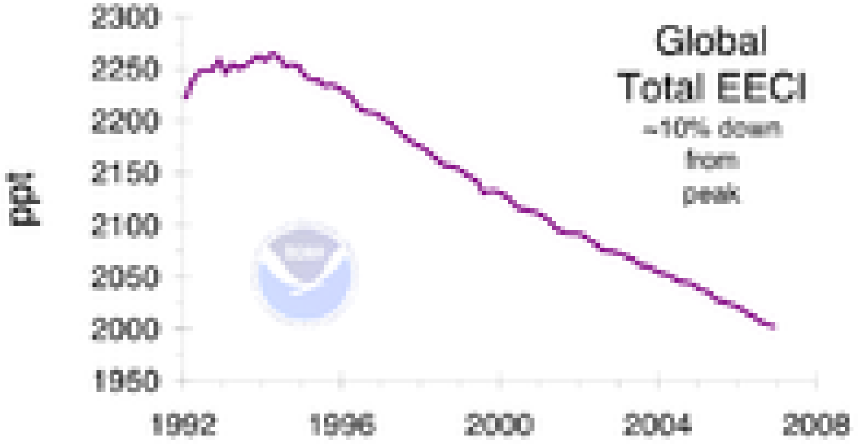


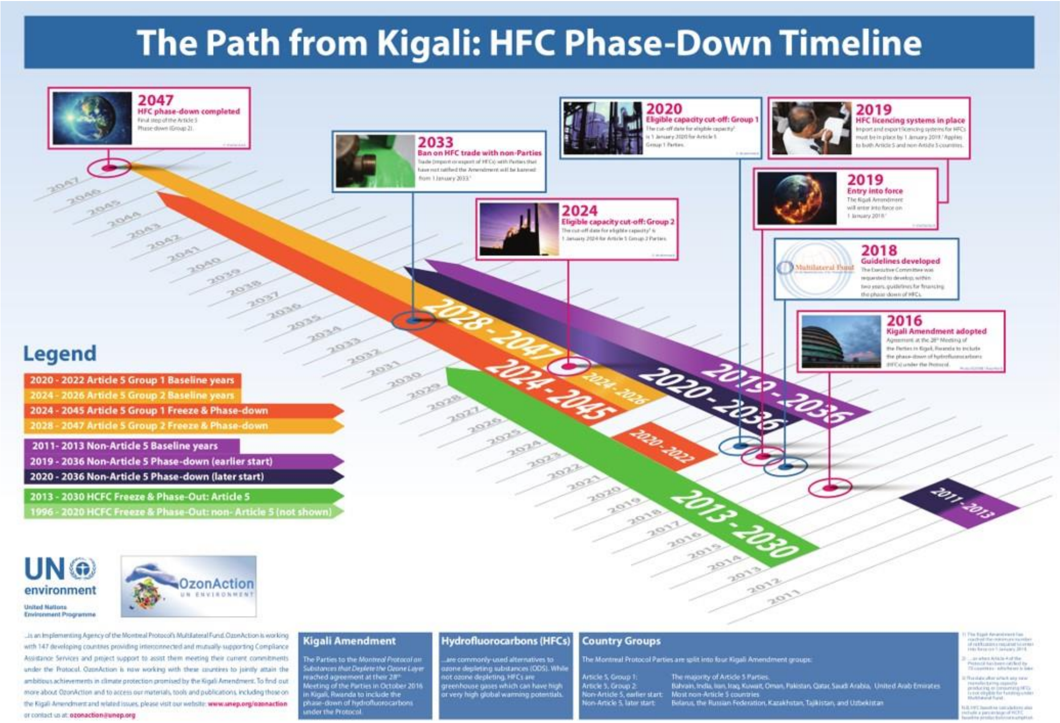
<https://epa.gov/system/files/other-files/2022-07/us-ghg-emissions_fig-1.csv> <https://epa.gov/system/files/images

MONTREAL PROTOCOL
CONTRIBUTES TO THE

SUSTAINABLE DEVELOPMENT GOALS







Nexus of climate change, water and food security, energy and social justice[142]

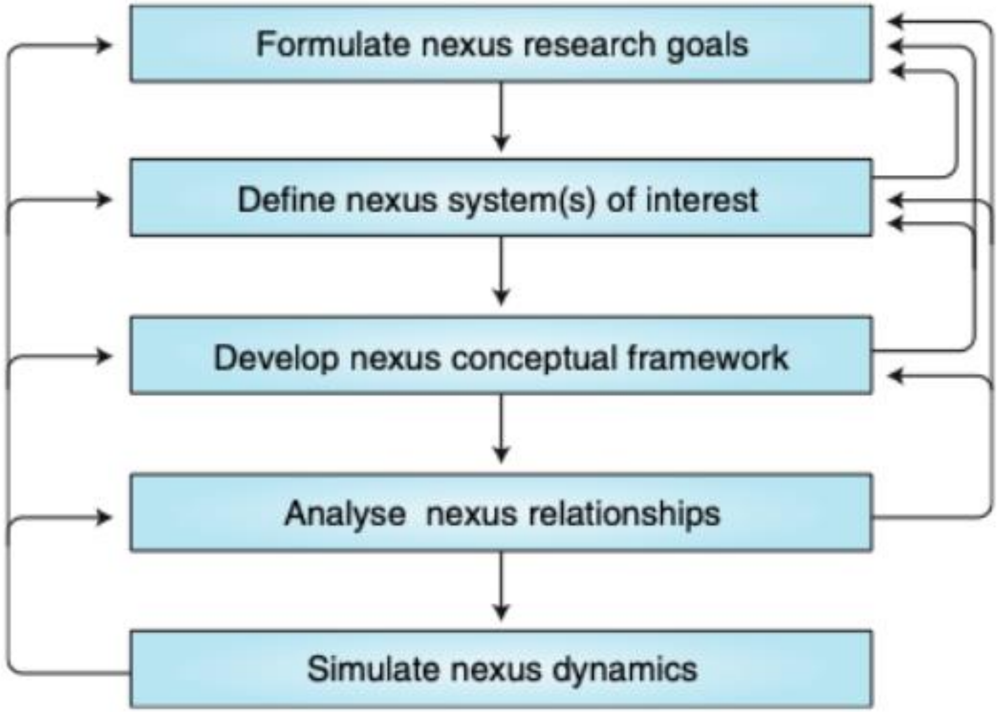


Fig. 2 | Five major steps involved in implementing nexus approaches. Stakeholders may be engaged throughout all the steps.

Liu et al. (2018) *Nature Sustainability*

How do we Measure Progress?

Nexus of climate change, water and food security, energy and social justice[142]

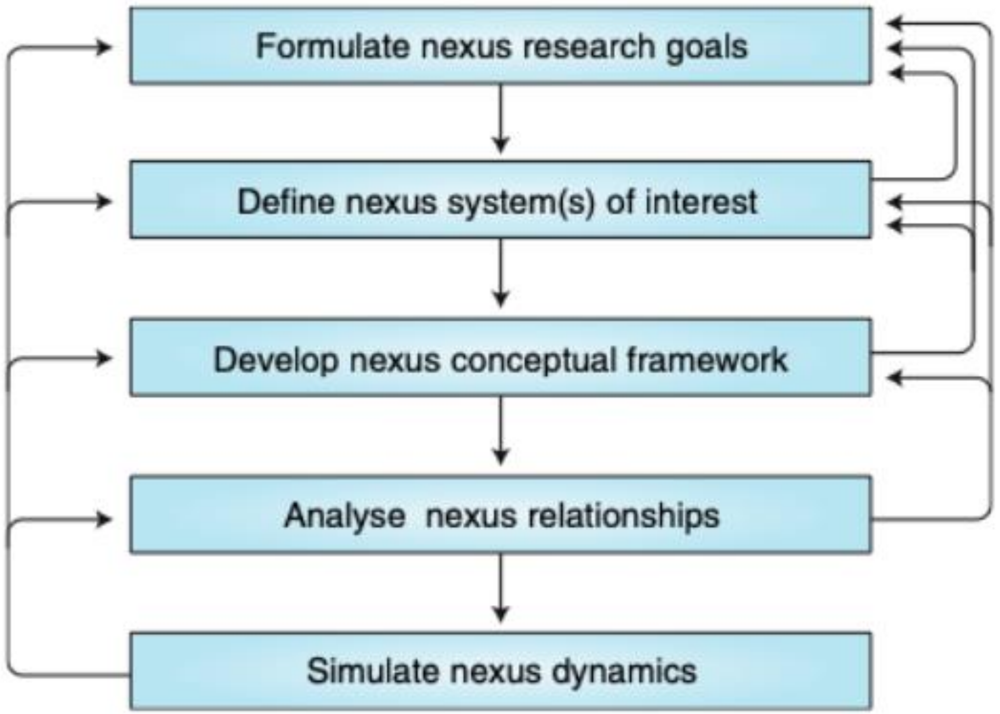


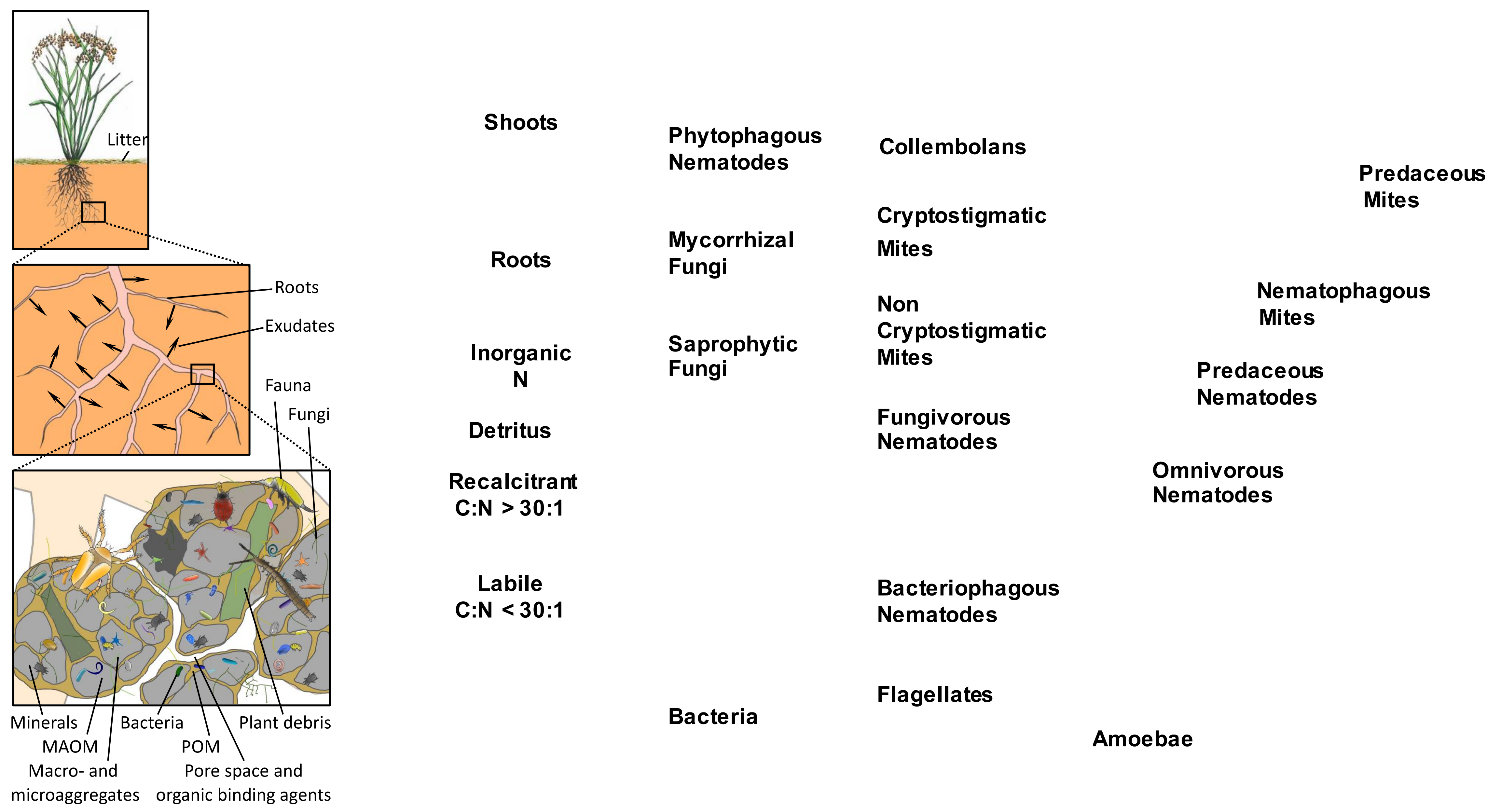
Fig. 2 | Five major steps involved in implementing nexus approaches.
Stakeholders may be engaged throughout all the steps.

Liu et al. (2018) *Nature Sustainability*

What is a System?

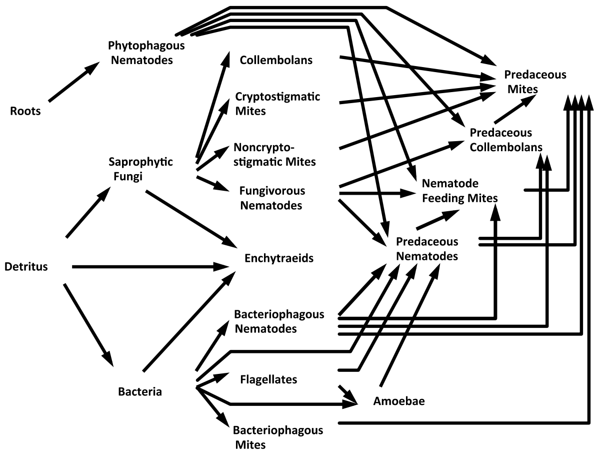
A set of interacting or interdependent components forming an integrated whole

Etymology Greek *σύστημα* systēma Latin word *systēma* "Composition"

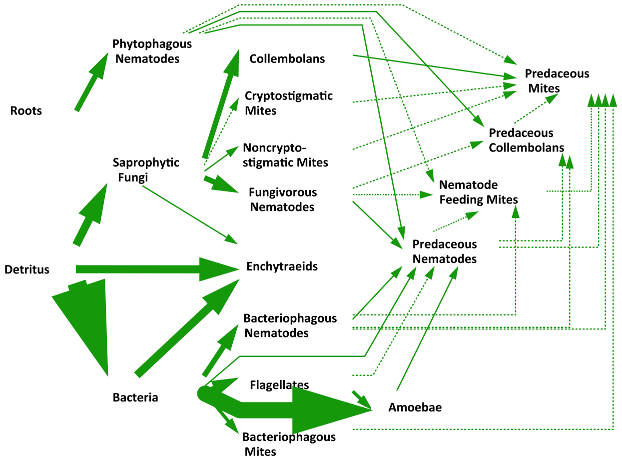

Litter
Roots
Exudates
Fauna
Fungi
Minerals
MAOM
Macro- and
microaggregates
Bacteria
POM
Pore space and
organic binding agents
Plant debris
Shoots
Roots
Inorganic
N
Detritus
Recalcitrant
C:N > 30:1
Labile
C:N < 30:1
Phytophagous
Nematodes
Mycorrhizal
Fungi
Saprophytic
Fungi
Bacteria
Collembolans
Cryptostigmatic
Mites
Non
Cryptostigmatic
Mites
Fungivorous
Nematodes
Bacteriophagous
Nematodes
Flagellates
Amoebae
Predaceous
Mites
Nematophagous
Mites
Predaceous
Nematodes
Omnivorous
Nematodes

System Characteristics
Entities and Components

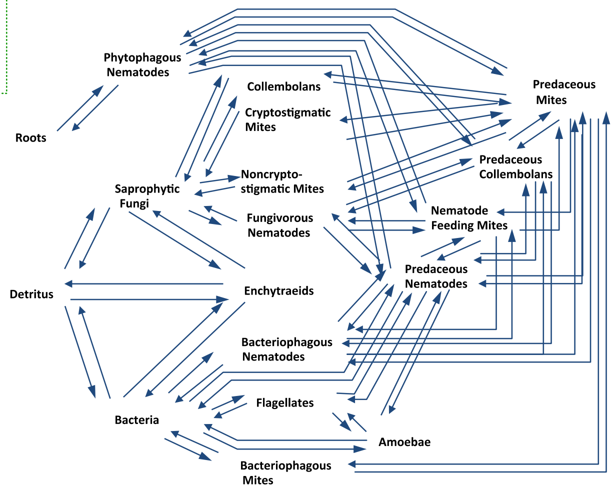
Structure



Function



Dynamics



- Structure
- Function
- Dynamics

Structure

Systems are comprised entities/components that interact amongst themselves within defined boundaries in reaction to external drivers.

Many systems are organized as “nested” hierarchies wherein subsystems at a smaller scale are combined to form a system at a larger scale.

For ecosystems the structural hierarchy extends from molecules and cells to individual organisms, populations, and communities (i.e., ecosystem components).

The densities and interactions among individuals and nonliving components of the environment are important components for understanding structure at the ecosystem scale.

Function

Processes and their outcomes that result from the activities of and interactions among system components define system functions.

The transformations of energy and matter through biological and physical processes (e.g., photosynthesis, decomposition, nutrient transformations and cycling, soil formation) within ecosystems define ecosystem functions in a general sense, and ecosystem services in a social-ecological context.

Dynamics

Dynamics refers to **changes** that the **structure** and **function** undergo across space and through time, the changes in the **rates of processes** that occur within the system, and the **behavior and rates** that characterize how the system responds to changes in the underlying environmental conditions.

Natural open system: a Forest

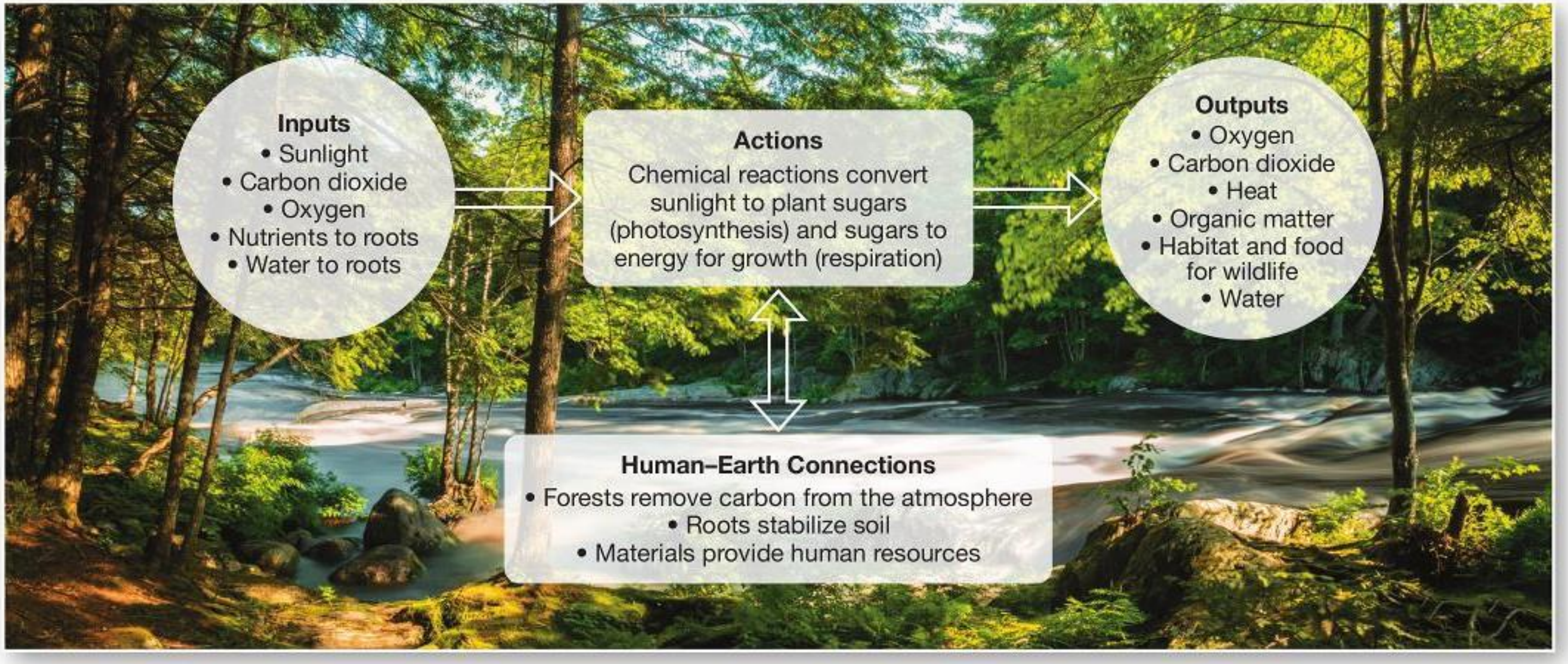
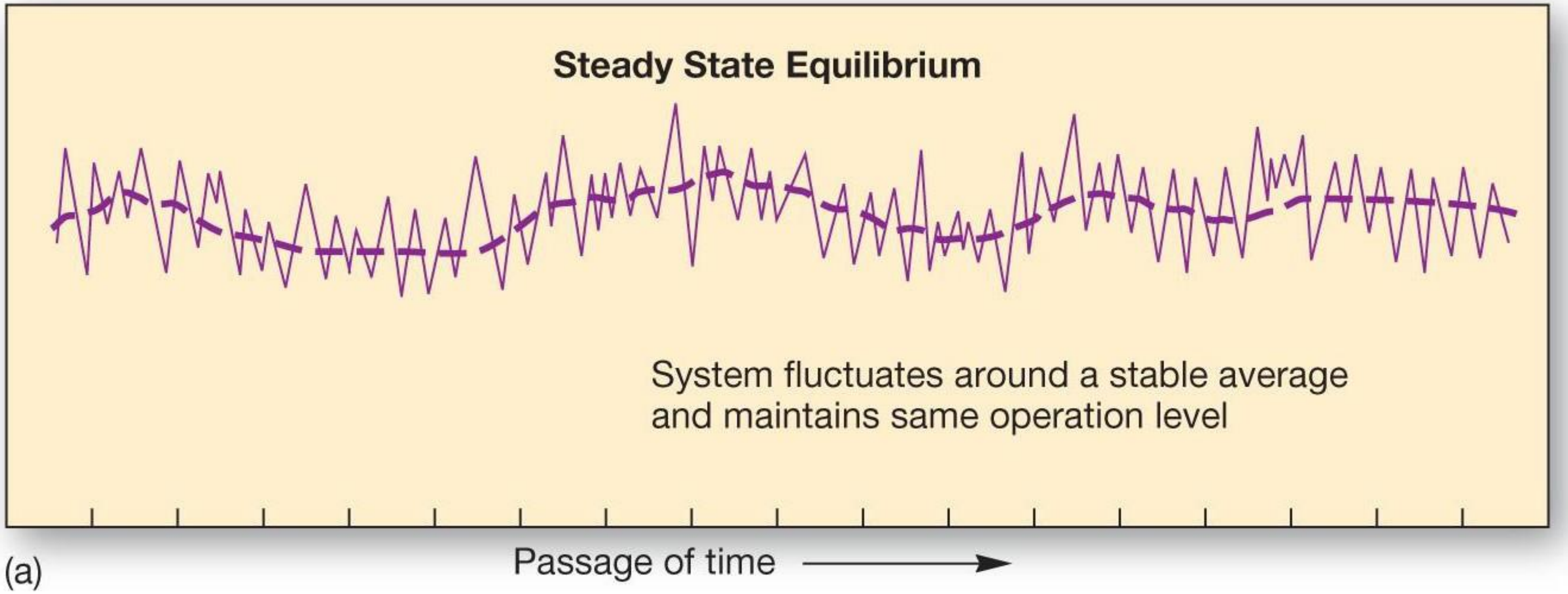


Figure 1.7

Steady-State/Equilibrium

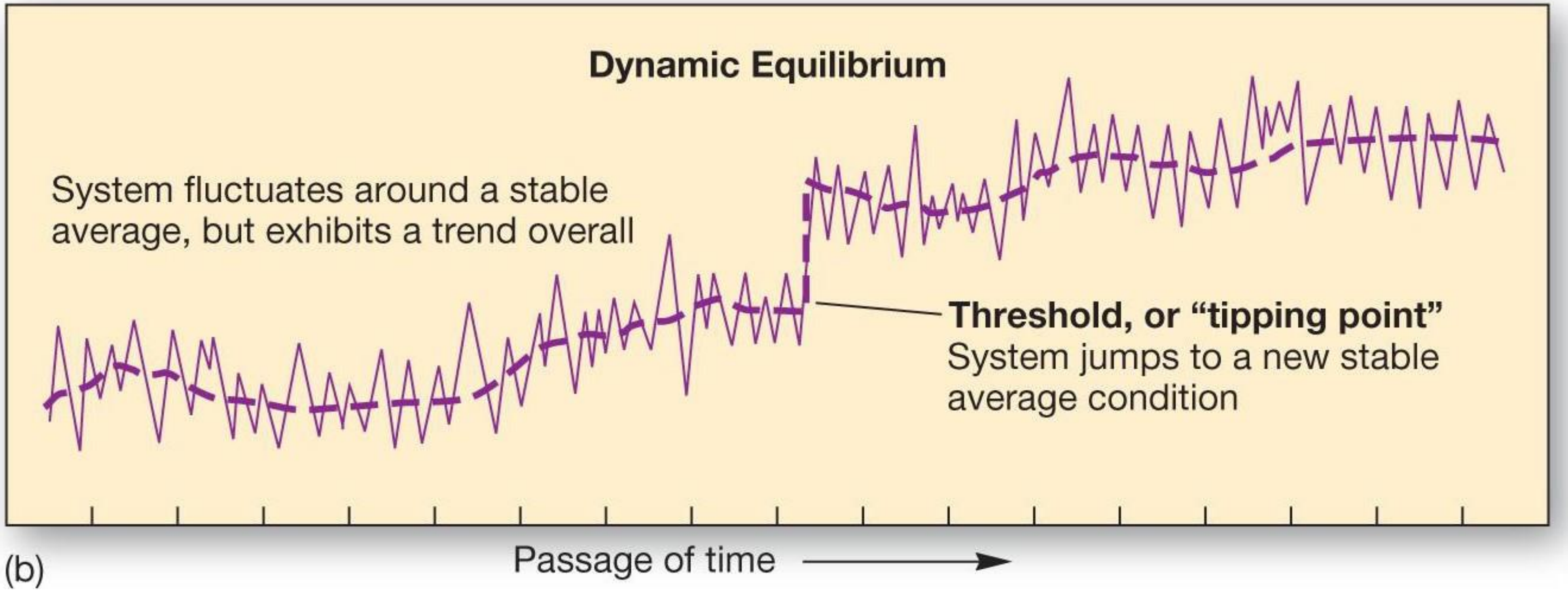
Steady-State/Equilibrium: when the rates of inputs and outputs in the system are equal and the amounts of energy and matter in storage within the system are constant (or fluctuate around a stable average).



(a)

Dynamic Equilibrium

Some systems are in a condition of **dynamic equilibrium** with an increasing or decreasing trend. A dynamic equilibrium system may change to a new operation level as it reaches a threshold called *tipping point*.



(b)

https://en.wikipedia.org/wiki/Phase_space#/media/File:Pendulum_phase_portrait_illustratio
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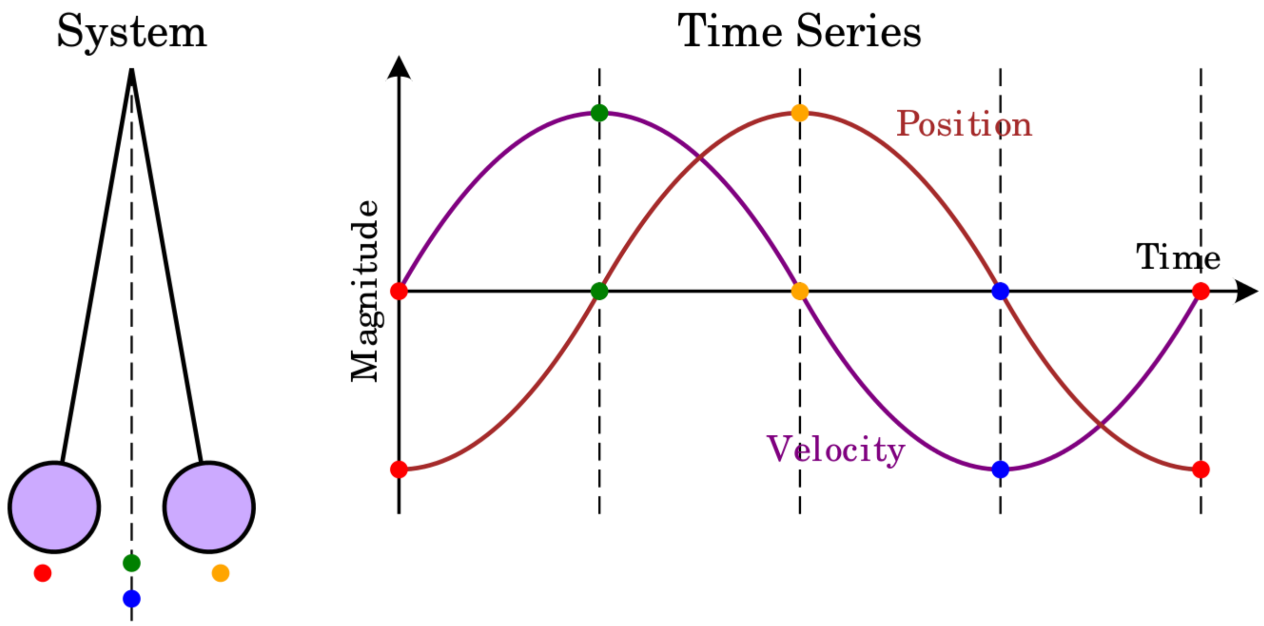

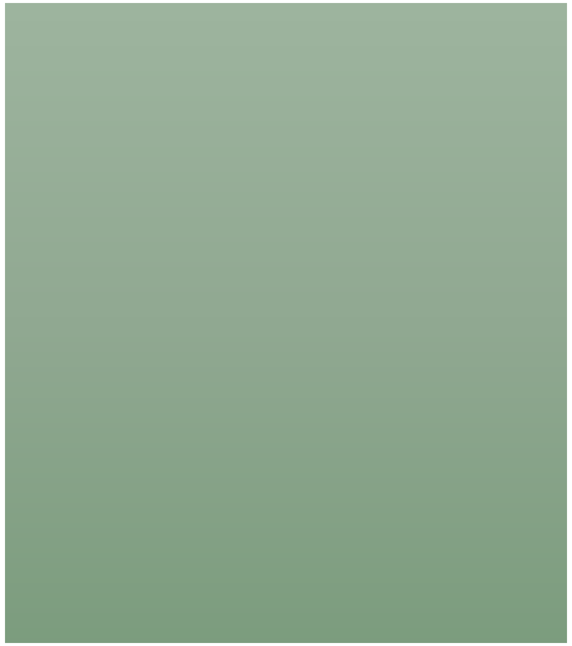

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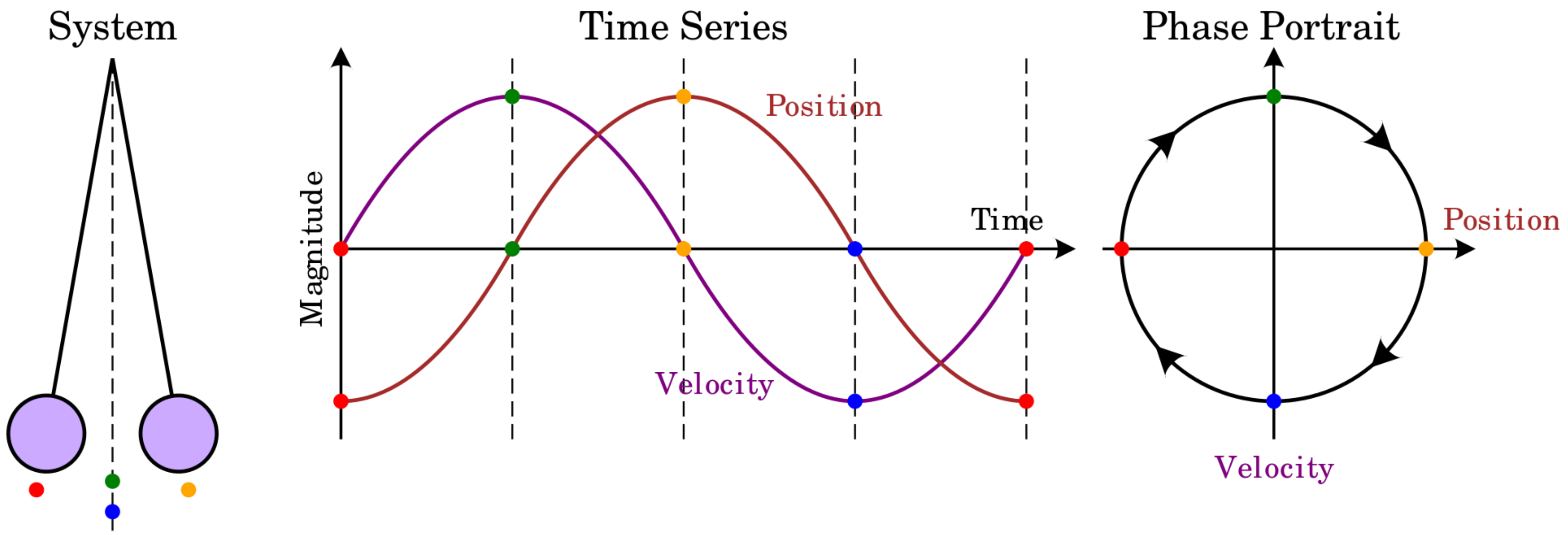
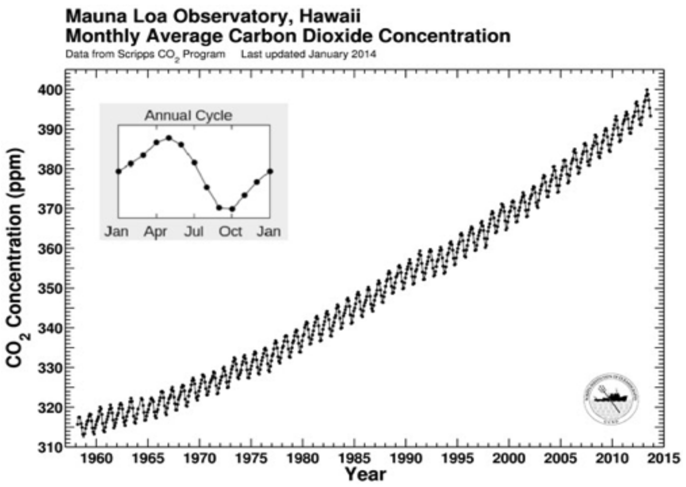
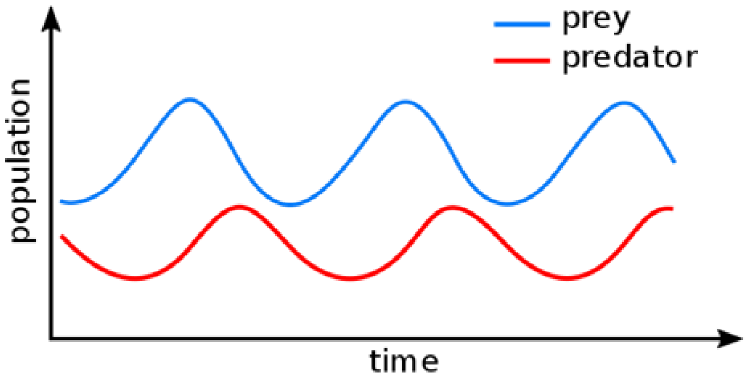


https://en.wikipedia.org/wiki/Phase_space#/media/File:Pendulum_phase_portrait_illustration.svg

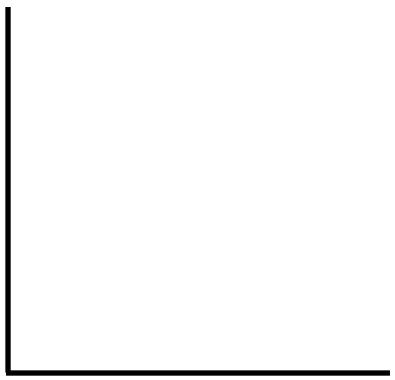
Time Series



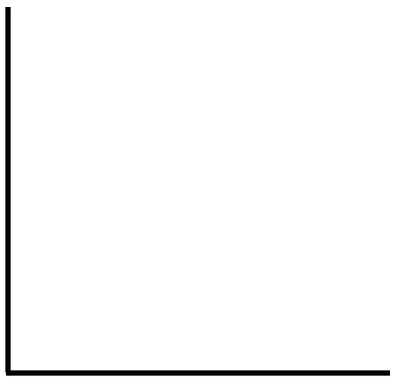


Phase Portrait

Annual Cycle



1960 - 2015



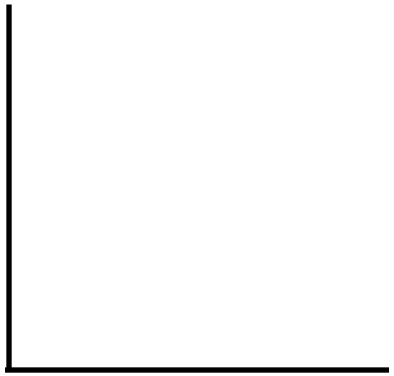
Prey $_{(t)}$

Pred $_{(t)}$

Prey $_{(t+1)}$

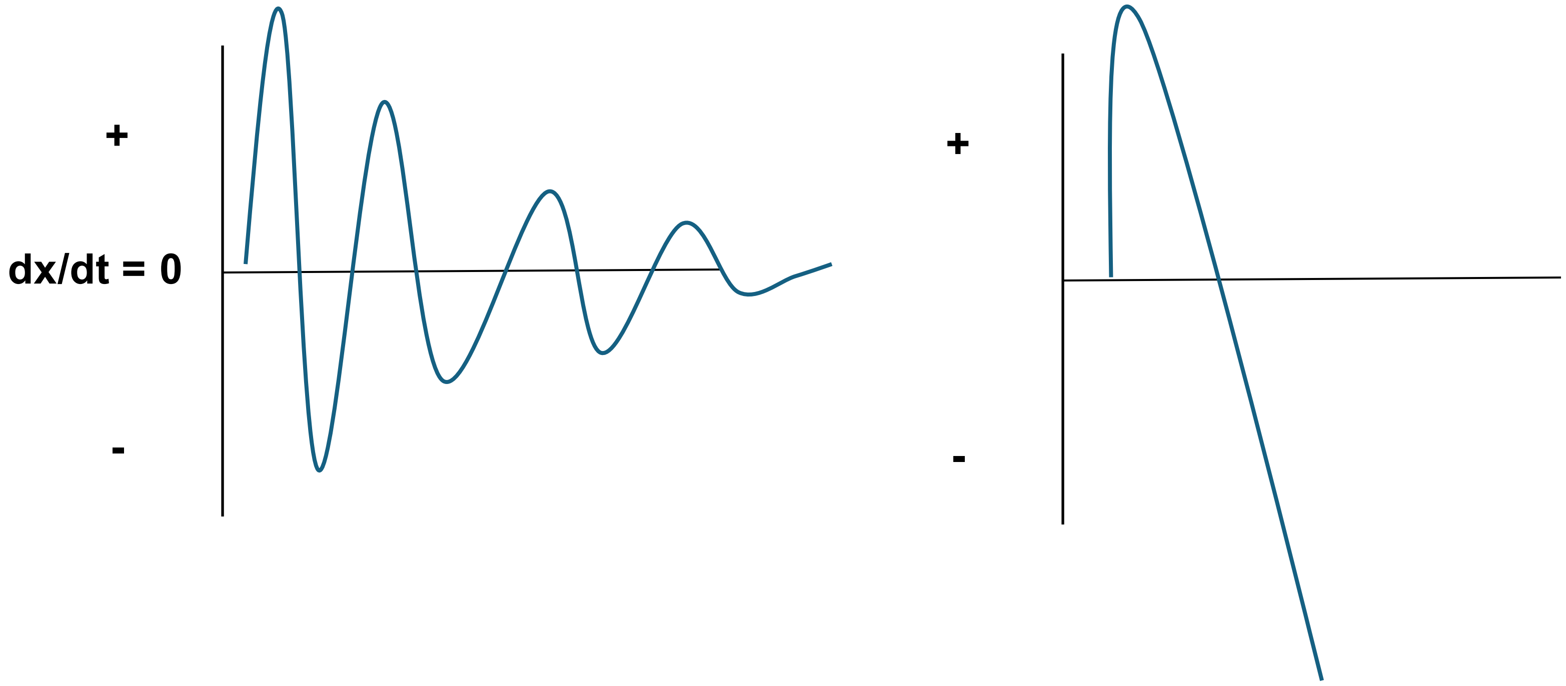
Pred $_{(t+1)}$

Prey



Pred

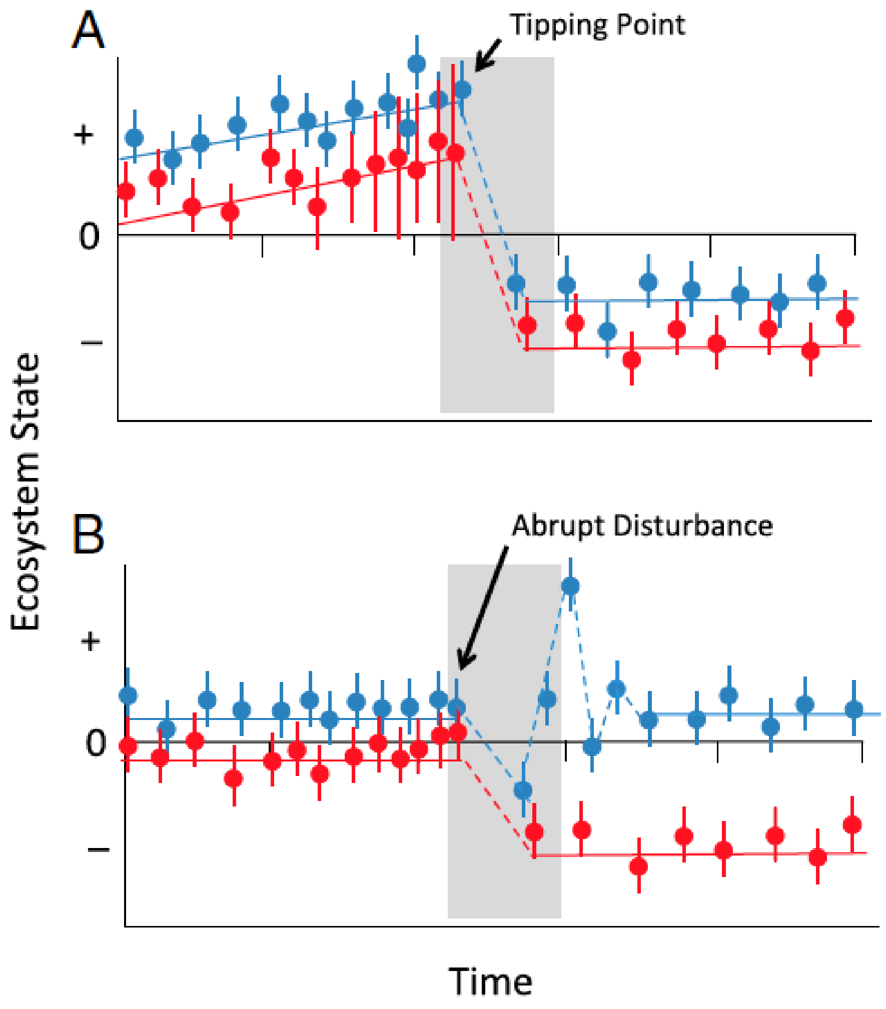
Stability & Resilience

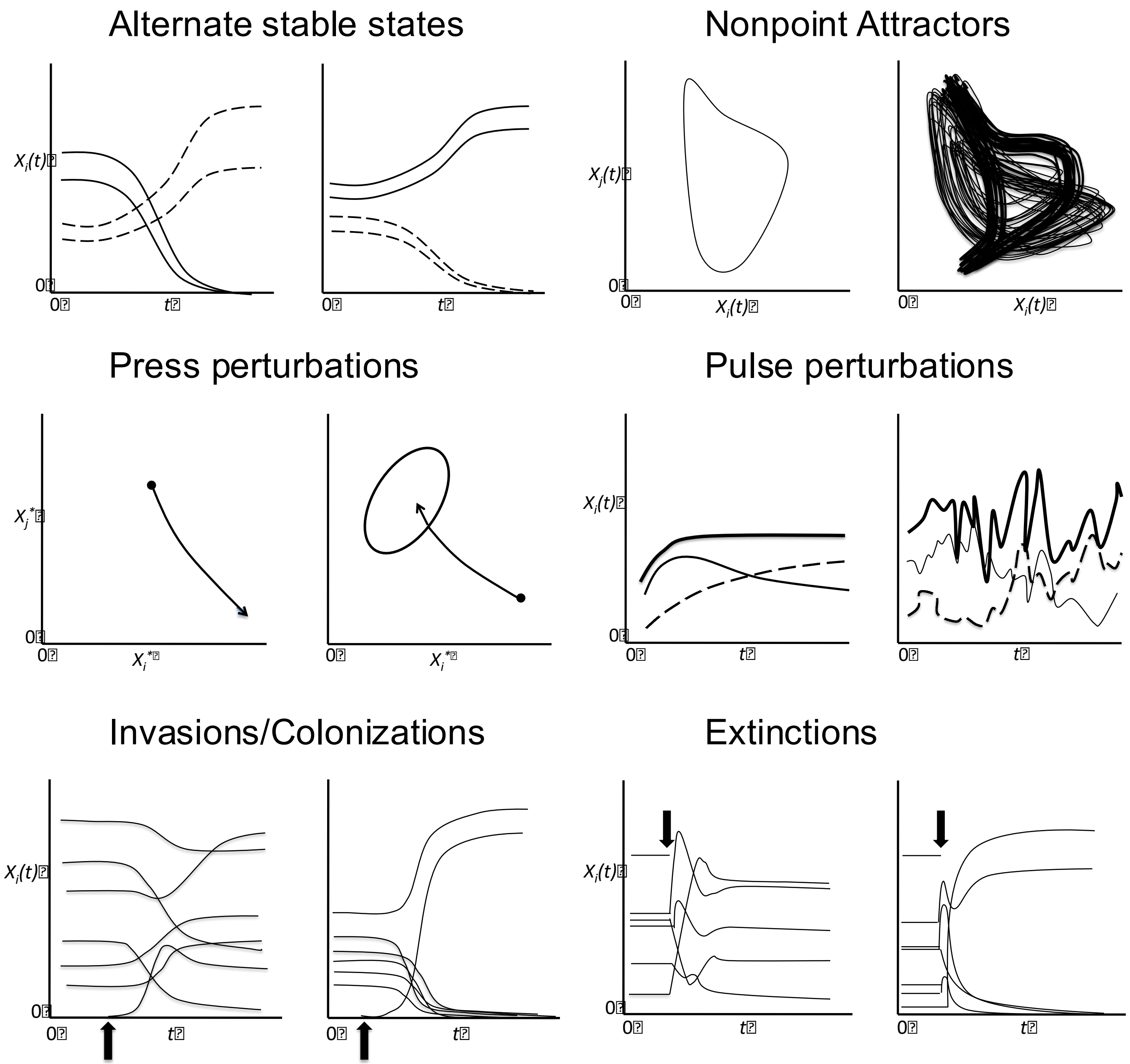


Reading Assignments

Predicting tipping points in complex environmental systems

Moore (2018)

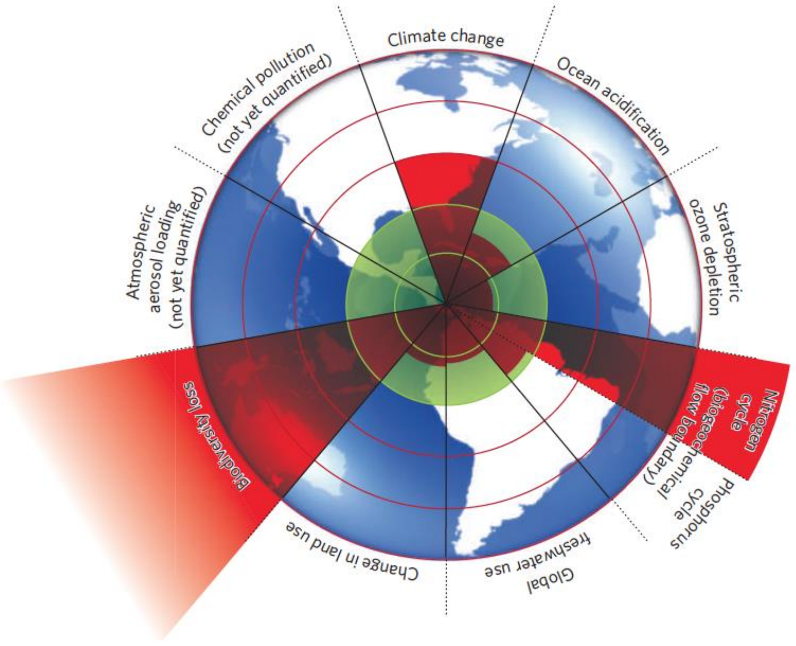




Alternate stable states
Nonpoint Attractors
Press perturbations
Pulse perturbations
Invasions/Colonizations
Extinctions
$X_i(t)$
$X_j(t)$
X_i^*
X_j^*
0
t

Core Questions of Sustainability Science

Can scientifically meaningful "limits" or "boundaries" be defined that would provide effective warning of conditions beyond which the nature-society systems incur a significantly increased risk of serious degradation?



PLANETARY BOUNDARIES

Earth-system process	Parameters	Proposed boundary	Current status	Pre-industrial value
Climate change	(i) Atmospheric carbon dioxide concentration (parts per million by volume)	350	387	280
	(ii) Change in radiative forcing (watts per metre squared)	1	1.5	0
Rate of biodiversity loss	Extinction rate (number of species per million species per year)	10	>100	0.1–1
Nitrogen cycle (part of a boundary with the phosphorus cycle)	Amount of N_2 removed from the atmosphere for human use (millions of tonnes per year)	35	121	0
Phosphorus cycle (part of a boundary with the nitrogen cycle)	Quantity of P flowing into the oceans (millions of tonnes per year)	11	8.5–9.5	~1
Stratospheric ozone depletion	Concentration of ozone (Dobson unit)	276	283	290
Ocean acidification	Global mean saturation state of aragonite in surface sea water	2.75	2.90	3.44
Global freshwater use	Consumption of freshwater by humans (km^3 per year)	4,000	2,600	415
Change in land use	Percentage of global land cover converted to cropland	15	11.7	Low
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis		To be determined	
Chemical pollution	For example, amount emitted to, or concentration of persistent organic pollutants, plastics, endocrine disrupters, heavy metals and nuclear waste in, the global environment, or the effects on ecosystem and functioning of Earth system thereof		To be determined	

Figure 1

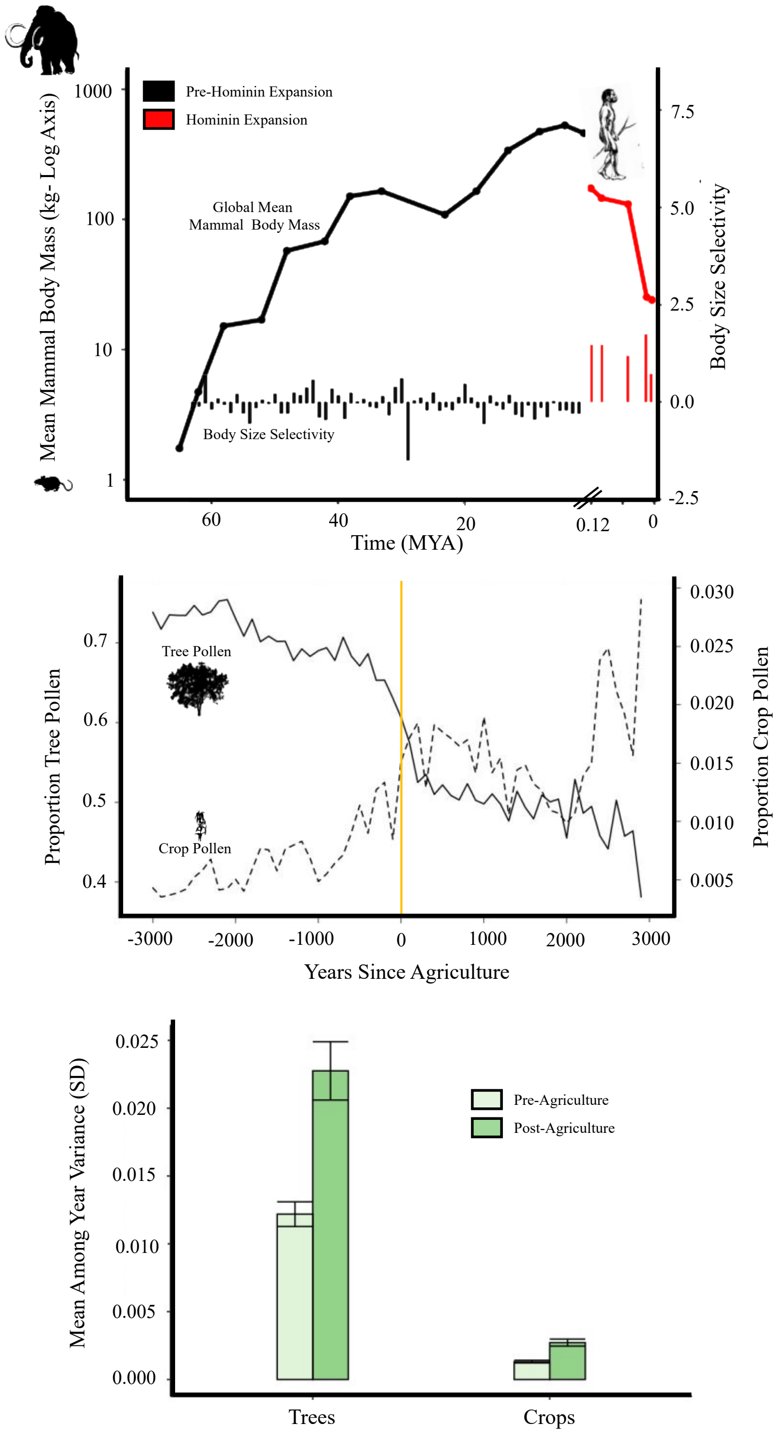
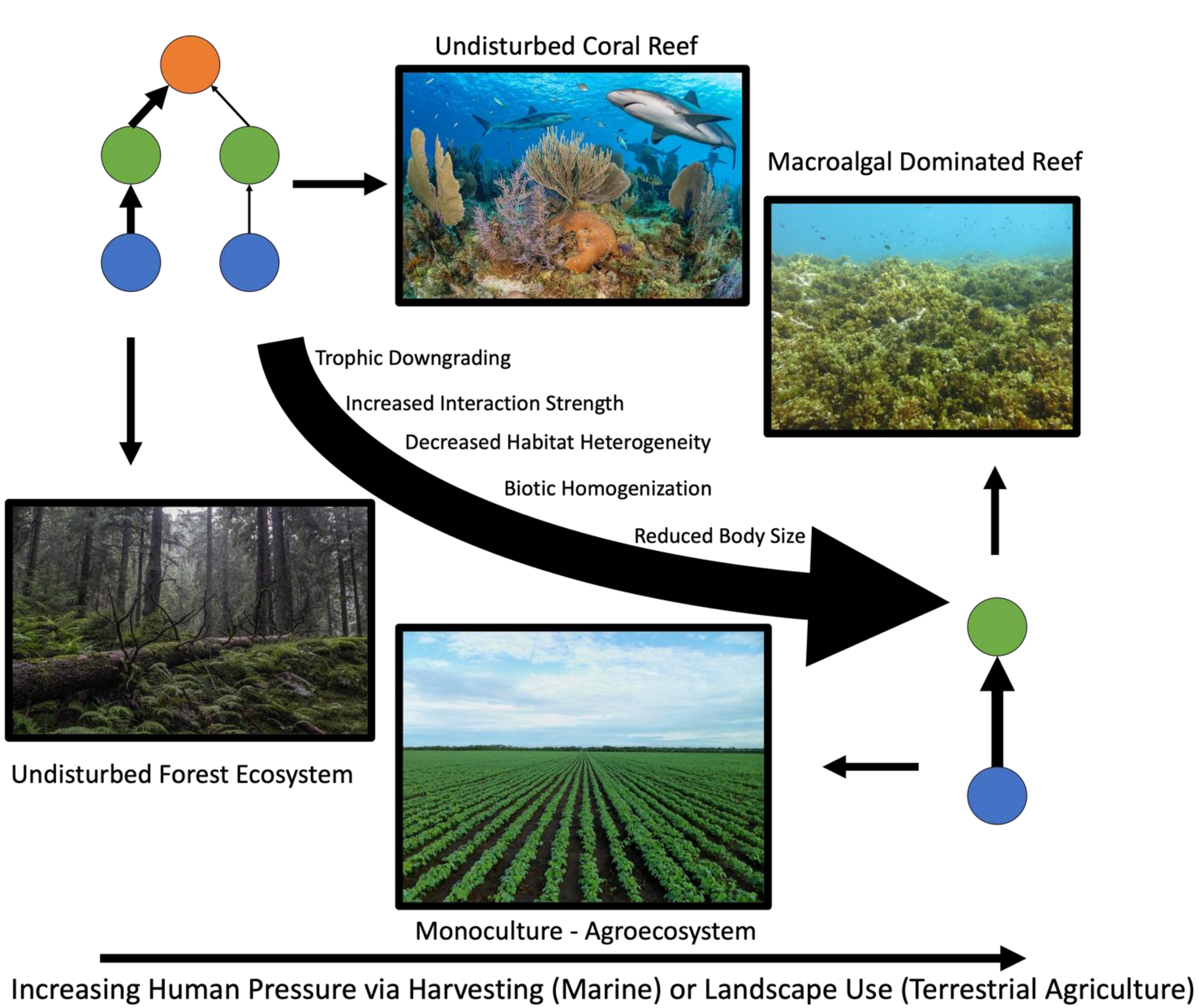


Figure 2



Gustgesell et al. (2024)

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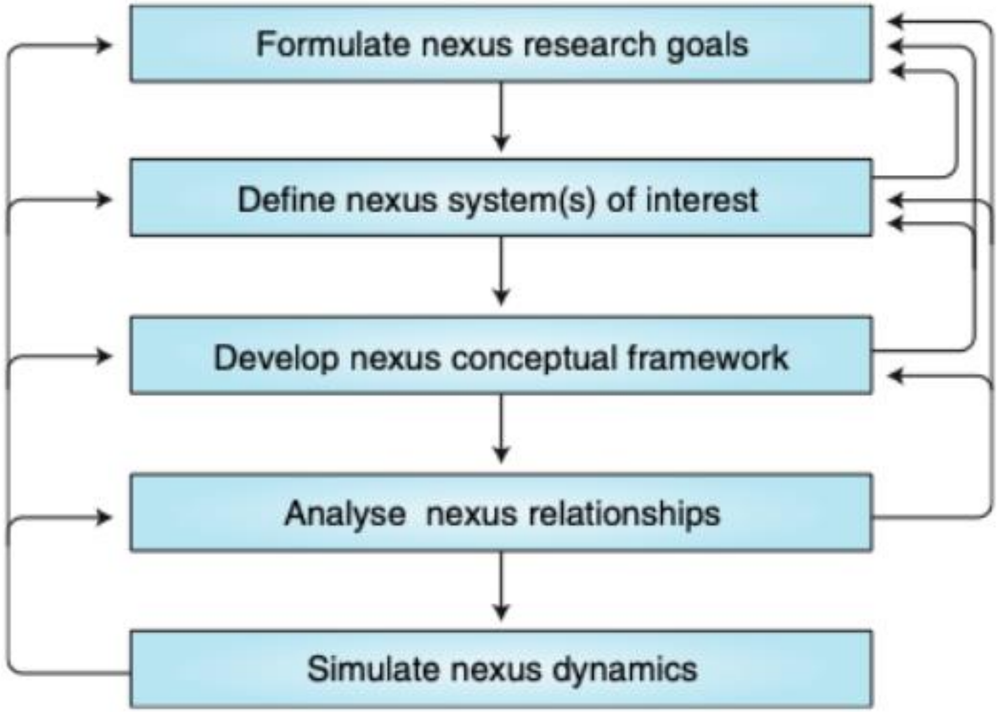

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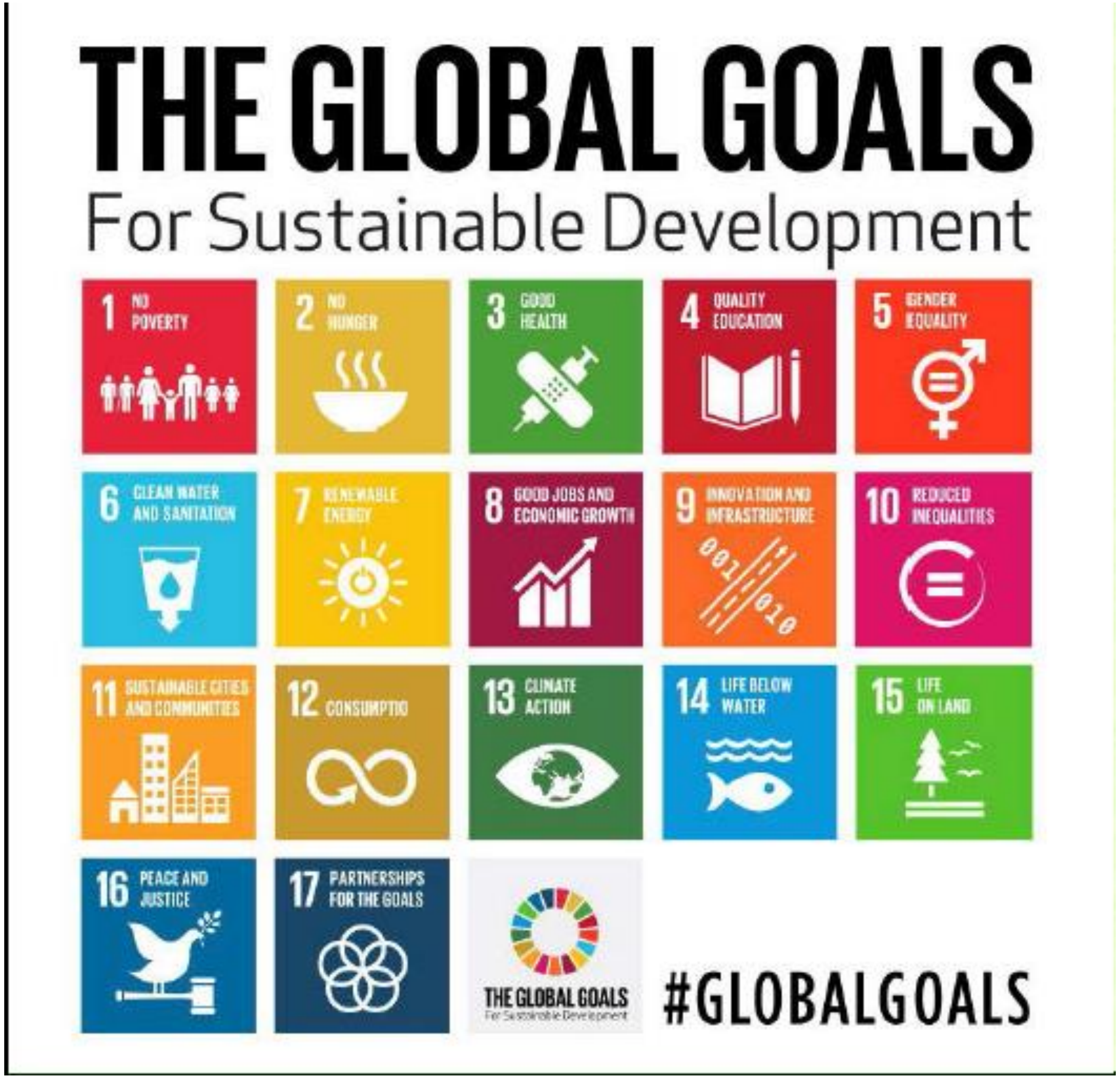
Liu et al. (2018) *Nature Sustainability*

Nutrient Dynamics
Urban Design
Watershed /Aquatic
Urban/Enviro Dat - VR/AR
Magnolia Tree Ecology
Snow Phenology - Vegetation
Carbon Offsets -Andes
Urban Ecology - Air Quality/Livelihoods
Wetland Ecology
Draoght and soil carbon -Tropics
Watershed /Aquatic Resilience
UAV/AI detection of large mammals
Invasive Species
Watershed Science - Stakeholder engagement
Snowpack, Dust, Water
Citizen Science - Stakeholder Engagement
Sustainable Timber Harvesting
Watershed Management Frameworks - Comparisions
Urban Greenspace Restoration
Alpine Ecosystem Restoration
Herbicide impacts - Microbes in Semi-arid shrublands
Public Education - Literacy - Human/Wildlife Interface Coastal Marine
Environmental Education - Literacy
Environmental Educaiton - Literacy
Urban Ecology - Air Quality/Livelihoods

Ecosystem Study	30%
Watershed Science	26%
ES Literacy	15%
Urban Ecology	15%
Policy/Engagement	2%
Restoration Ecology	2%


THE GLOBAL GOALS
For Sustainable Development
1 NO POVERTY
2 NO HUNGER
3 GOOD HEALTH
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 RENEWABLE ENERGY
8 GOOD JOBS AND ECONOMIC GROWTH
9 INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 CONSUMPTIO
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE AND JUSTICE
17 PARTNERSHIPS FOR THE GOALS
THE GLOBAL GOALS
For Sustainable Development
#GLOBALGOALS


Sustain Resource Availability
Strengthen Institutions and Collaborations
Preserve Terrestrial Biodiversity
Reduce Inequities
Build Partnerships
Preserve Aquatic Biodiversity
Reduce Poverty
Enhance Food Production and Security
Food
Water
Energy
Enhance Water Security
Innovations to Expand Industry and Jobs
Promote SMEB Innovations and Industry
Reduce Greenhouse Gas Emissions
Increase Energy Security
Expand SMEB Literacy
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